Skeena Salmon Conservation Unit Snapshots

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December 24, 2013

Acknowledgements

The Pacific Salmon Foundation and ESSA Technologies Ltd. would like to sincerely thank the numerous individuals who volunteered their time to provide feedback, data and insights into the salmon of the Skeena watershed. Without their contributions this project would not have been possible. A complete list of individuals who contributed to this project is provided in Appendix 2.

This project is funded by the Gordon and Betty Moore Foundation.

Citation: Connors B.M., D.C. Pickard, M. Porter, G. Farrell, K. Bryan, S. Casely and S. Huang**.** 2013. Skeena Salmon Conservation Unit Snapshots. Report prepared by ESSA Technologies Ltd. for the Pacific Salmon Foundation. v + 70p.

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Glossary

Anadromous	Fish that mature in seawater but migrate to fresh water to spawn.
Benchmark	A standard point of reference against which condition can be compared.
Brood year	The year that a cohort of salmon spawned.
Carrying capacity	The maximum population size that can be sustained indefinitely in the absence of harvest. Carrying capacity can refer to specific habitats (e.g., a sockeye nursery lake) or over the life of a species (e.g., integrated across all life stages).
Conservation Unit (CU)	A geographically, ecologically and genetically distinct population of wild Pacific salmon. A CU can contain one or more populations (see definition below).
Escapement	The number of mature salmon that pass through (or escape) fisheries and return to fresh water to spawn.
Exploitation rate	The proportion of a CU that is removed by harvest (e.g., commercial and recreational fishing).
Lake sockeye / river 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.
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.
Recruitment	The process where juvenile organisms survive and are added to a population of interest. In salmon management, recruitment usually refers to the pre-fishery abundance of adults. Thus recruitment is calculated based on the sum of all catches, estimates of pre-spawn mortality and post-release mortality (if fish are captured and then released), and the escapement.
Smolt	A juvenile salmon that has completed rearing in freshwater and migrates into the marine environment.
Status	Condition of a metric relative to a defined benchmark.
Zone of influence	Areas upstream or adjacent to habitats used by salmon during the various life stages (e.g., migration or spawning). ZOIs represent the geographic extent for measurement of habitat pressure indicators.

1 Summary

1.1 Project background

Salmon are of great ecological, cultural and economic importance in British Columbia (BC). While some salmon populations are healthy, other are depressed, declining and of conservation concern (e.g., Peterman and Dorner 2012; Riddell et al. 2013). Canada's Wild Salmon Policy (WSP; Fisheries and Oceans Canada 2005) provides a blueprint to monitor, manage and conserve salmon "to restore and maintain healthy and diverse salmon populations" in Canada. At the heart of the WSP is the management of salmon at the scale of individual Conservation Units (CUs), which are geographically, ecologically, and genetically distinct populations of wild salmon, and the assessment of CU status by comparing biological (i.e., population) and habitat metrics against benchmarks (e.g., Chaput et al. 2013; Grant et al. 2011; Grant and Pestal 2013; Holt et al. 2009; Stalberg et al. 2009).

The overall goal of this project is to develop a short standardized report, or 'snapshot', for each salmon Conservation Unit in the Skeena River basin, including: sockeye (both lake and river type), pink, chum, coho, and Chinook. These snapshots are intended to summarize in graphical form both habitat and biological information for each CU and to serve as a reference document to support discussions about the status of Skeena CUs, and approaches for the conservation and management of Skeena salmon and their habitat. More generally, the snapshots are intended to make key biological and habitat status information for Skeena salmon available and accessible to a broad audience. We supplemented the CU snapshots (Appendix 4) with a quick reference guide (Appendix 3) that provides data sources and supplemental information for each Section in the CU snapshots. This report provides further details on background, methodology and data sources to complement the CU snapshots and quick reference document.

The key considerations that went into generating the CU snapshots include:

- wherever possible, information is presented in a standardized format to facilitate updates and comparisons between CUs; however, equal emphasis is placed on including the best available data for each individual CU;
- snapshots should illustrate data gaps, variation in data quality, and key sources of uncertainty;
- though snapshot content is mainly graphical, important context and additional information that cannot be captured by the graphics is presented in a short text box for each CU;
- the snapshots themselves are intended to serve as a short 'stand-alone' document that is accessible to users with less technical knowledge, with more in-depth technical details provided in the accompanying 'Quick Reference' guide as well as this report;
- habitat-related information is drawn from a concurrent project being undertaken by ESSA for the Pacific Salmon Foundation (PSF) which summarizes habitat pressures and vulnerabilities for each Skeena CU (see Porter et al. 2013, 2014); and

- the snapshots are intended as “living documents” that can be updated in future years as new data becomes available; therefore, they are designed in a way that facilitates updates as new data becomes available.

1.2 Geographical scope and CU delineations

The CUs we considered in this report are based on delineations originally described in Holtby and Ciruna (2007) with provisional updates to delineations as described in English (2013). Population data was generally available in a format that was compatible with these delineations. In contrast, the habitat information used here was taken exclusively from Porter et al. (2013, 2014), which follows a slightly different delineation system, which more closely matches Holtby and Ciruna (2007) and excludes CUs confined to the Skeena Estuary. For this reason, some snapshots include habitat information that is split across multiple sets of maps, or covers a slightly different geographical area than the population data presented. In all cases, the geographical scope of population information presented within each snapshot can be gleaned from the ‘Location’ map (Section 4 within each snapshot), and the geographical scope of the habitat data should be clear as this information is presented in a map-based format (Sections 20-24 within each snapshot). A list of the CUs we considered and how they relate to those defined by Holtby and Ciruna (2007) is provided in Appendix 1.

1.3 Approach

The approach we took for developing the Skeena CU snapshots can be broken down into four stages:

1. summarize available data related to the biological status of salmon CUs for the region;
2. review the extent and quality of each data source identified in stage 1;
3. identify key population information to be summarized and habitat information to include; and
4. generate a series of figures to convey key information and data gaps across different CUs in a simple but comprehensive way.

We began stage 1 with a review of published and grey literature and discussions with regional salmon experts to identify information sources related to salmon populations in the Skeena Watershed. In stage 2, we organized the information identified in stage 1 in a data matrix to summarize the extent and quality of information related to each data source. Based on our review and synthesis of available data sources, an information roadmap emerged in Stage 3 that provided the backdrop against which further feedback on snapshot content was solicited from regional salmon experts. In stage 3, we also identified key habitat information to include, drawn from Porter et al. (2013, 2014) based on advice from that project’s Technical Advisory Committee. In stage 4 draft snapshots were created and reviewed by regional salmon experts and potential snapshot users who provided additional feedback before the final snapshots were created. A list of individuals who provided feedback at each stage is provided in Appendix 2. During the course of the project we noted some options which might be considered when creating future versions of the snapshots, but which were not achievable within the scope of the current project; these are summarized in Appendix 6.

1.4 Information roadmap

The picture that emerged from our review of information on salmon from the Skeena basin is represented schematically in Figure 1. The types of information available can be broadly categorized as those related to estimates of abundance; metrics and estimates of the productive capacity of the CU and salmon survival; supplementary information; the derivation of benchmarks and assessment of status; and habitat pressures.

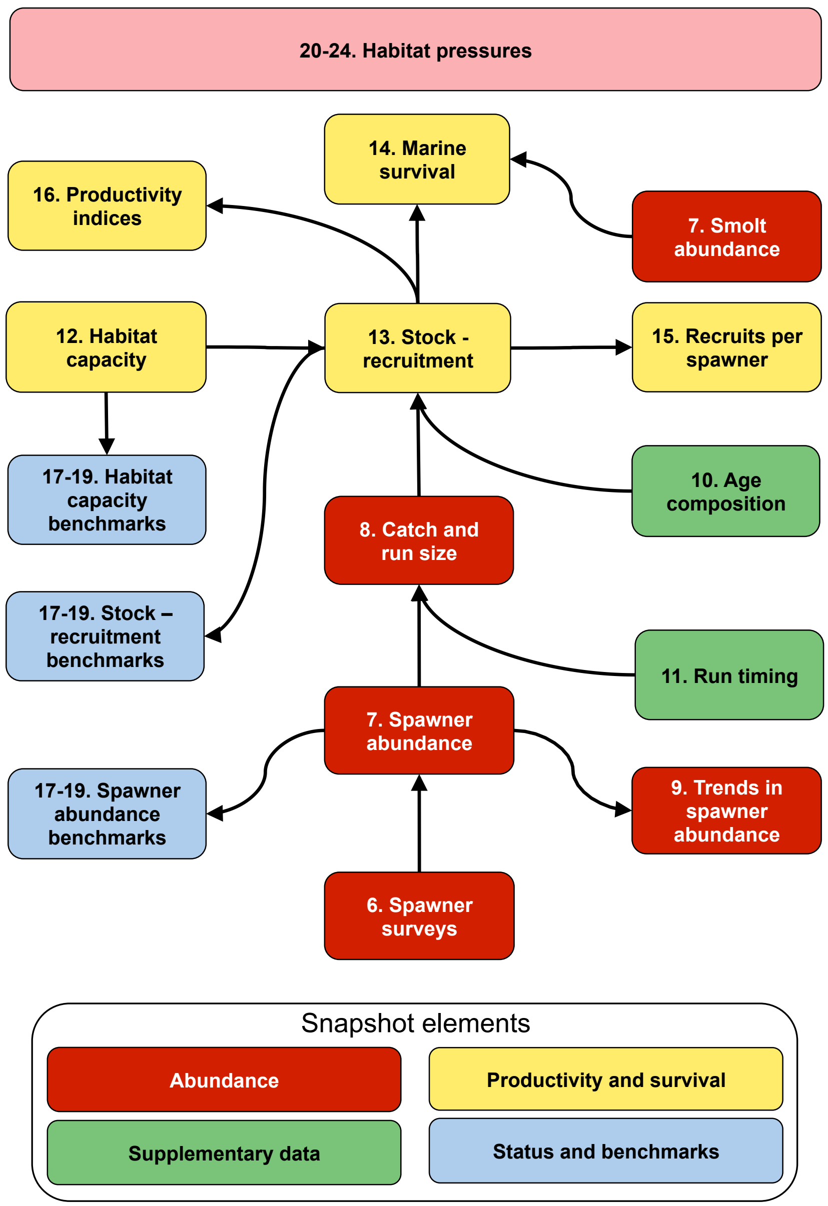

Figure 1: Roadmap of information available related to Skeena salmon CUs. Arrows show the flow of information from raw data towards more complicated elements that are estimated based on one or more information inputs. The colors and numbers correspond to the Section(s) in the CU snapshots that the information element pertains to.

Skeena salmon CU snapshots

Counts of returning adult fish on or just before the spawning grounds based on surveys are a core source of information on Skeena salmon populations. These spawner surveys form the basis of estimates of overall spawner abundance which together with estimates of catch (based in part on run-timing) provide an estimate of the total number of salmon that return to the coast from a given CU in a single year (run size). Estimates of spawner abundance can also provide insight into changes in the population through time. In addition to estimates of adult abundance, in some CUs estimates of the abundance of juvenile life stages (i.e., fry or smolts) are available.

When combined with the age at which individual fish return to spawn (age composition) run size can be used to estimate the total production of adult salmon from a given brood year, total life-cycle survival (productivity indices and recruits-per-spawner), and to understand the relationship between the abundance of spawners and the number of adult salmon they produce (stock-recruitment relationship). Stock-recruitment relationships can be refined when estimates of freshwater rearing habitat are available (e.g., the maximum number of juvenile sockeye a lake can produce).

Based on the sources of information described above it is possible to derive benchmarks against which the biological characteristics of a CU can be measured in order to evaluate its status. Four classes of indicators have been proposed for evaluating CU status: (1) current spawner abundance, (2) trends in spawner abundance, (3) geographic distribution of spawners, and (4) fishing mortality (Holt et al. 2009). Given the data availability for Skeena CUs, we present only a subset of the possible status metrics and benchmarks options from three of these indicator classes (all except geographic distribution). The first indicator that we present is current spawner abundance, which we assess in relation to several different types of benchmarks: two types of benchmarks based on historic abundance (percentiles and long term mean abundance); estimated freshwater rearing habitat capacity (for lake sockeye only); and the productive capacity of the CU (i.e., the shape of the stock-recruitment curve). In addition, we also assess trends in abundance based on benchmarks related to the rate of change in abundance over the past three generations, as well as fishing mortality based on the current fishing mortality experienced by the CU. The benchmarks we present are not intended to establish which benchmarks should be officially used for assessing the status of Skeena CUs as that is the responsibility of DFO in consultation with First Nations and other affected parties. In Appendix 5 we summarize CU status across the Skeena for each species and benchmark.

Lastly, habitat information can be synthesized to provide an overview of landscape-scale pressures within freshwater habitats used by Skeena salmon CUs for migration, spawning, incubation and rearing. Using GIS-based analyses the relative extent and intensity of key habitat pressure indicators (e.g. roads, logging, mines, etc.) can be quantified and compared to habitat indicator thresholds/benchmarks of concern so as to provide an indication of general habitat “status” in each Skeena watershed. GIS can also be used to quantify selected map-based habitat quantity and quality indicators to provide a measure of the relative vulnerability of CUs to watershed habitat stressors experienced during the freshwater migration, spawning, incubation and rearing life stages.

Sources of population information that were identified during the review of available information but not ultimately incorporated into this version of the CU snapshots included: data on spawner sex ratios; estimates of the number of juveniles produced per female spawner; time series of fry abundance for lake sockeye CUs; estimates of spawner abundance before 1950; and the age composition of juvenile lake sockeye from some CUs. These sources of additional insight into the characteristics and status of Skeena salmon CUs should be considered for inclusion in future CU snapshots.

1.5 Recommendations

Based on our review of the biological data and information roadmap related to wild salmon CUs in the Skeena across the 53 CUs considered in this report five recommendations emerge, and are outlined below (for recommendations related to habitat data for Skeena salmon CUs, please consult Porter et al. 2013, 2014).

1. **Life-stage-specific estimates of abundance**: Estimates of abundance broken down by key life stages can be critical to informing and identifying drivers of changes in salmon abundance. Without such datasets, research and management efforts may be misdirected at the wrong part of the salmon life cycle when abundance and survival declines. Current out-migrating smolt enumeration programs in CUs like the Babine, Gitnayow, Slamgeesh, and Kalum provide critical information related to life-stage-specific abundance and survival and are therefore important to continue supporting, as are the rotational hydroacoustic surveys of juvenile sockeye abundance in numerous lake sockeye CUs. Expansion of these types of monitoring programs to include additional CUs, species, and life histories could provide valuable insights into life-stage-specific survival for species or life histories not currently captured in ongoing monitoring.

2. **Spawner surveys and monitoring**: In the few CUs where there was not a single “indicator” stream being monitored. The identification and focused monitoring of at least one indicator stream should be considered both a priority and a minimum monitoring requirement moving forward. Without this information, it will be difficult to meaningfully assess CU status in the future. In addition, a full review of current monitoring practices should be completed. For example, probability-based sampling methods could be employed to select monitoring reaches within each CU to enable inference to the entire CU and estimates of precision. Additionally, though index sites may be a useful stratum to use within a probability design, some level of effort could be employed outside of index sites to ensure an unbiased estimate of the CU (Courbois et al. 2008). If the ratio of density within index sites and outside index sites is not constant, the current expansions used to estimate total spanner abundance at the level of the CU may not be adequate.

3. **Freshwater-rearing-habitat-based estimates of carrying capacity**: Estimates of the productive capacity of CUs based on rearing habitat that are derived independently of spawner abundance can provide important insight into the carrying capacity of a CU when estimates of recruitment and/or productivity are missing or uncertain. When stock-recruitment information is available, rearing-habitat-based

estimates of carrying capacity can improve benchmark estimates from stock-recruitment relationships (e.g., S_{MAX} and S_{gen1}). For Skeena sockeye lakes, data on juvenile abundance has been collected from rotational acoustic surveys for over a decade and incorporated into stock-recruitment analyses (Korman and English 2013) and habitat-based abundance benchmarks (Cox-Rogers 2012a). We recommend that these lake surveys continue.

Methods have been developed for the derivation of habitat-based estimates of carrying capacity for coho (Bocking and Peacock 2004) and Chinook (Parken et al. 2006) in other watersheds in BC. Applying these (or similar) approaches to Skeena coho and Chinook CUs would provide valuable additional insight into the current status of these CUs and would allow for a more direct link between the biological status of a CU and rearing habitat pressures, vulnerabilities, and changes than currently exists.

4. **Biological sampling of salmon across CUs**: A critical source of uncertainty for almost all CUs in the Skeena (excluding pink salmon CUs) is age composition and the extent to which it varies through time. Lack of age-composition information or the assumption that it does not vary from year to year (i.e., using an average) can result in biased stock-recruitment relationships where the estimated productive capacity of a CU is inflated. Because of the importance of, and reliance upon, stock-recruitment relationships to derive benchmarks and assess status, increased efforts to sample returning adult fish to determine age composition would be very useful. Because this information can only be generated moving forward, sensitivity analyses that explore the importance of assumptions around age composition may provide valuable insight into the robustness or sensitivity of benchmarks and status to age composition assumptions based on historical data (e.g., Korman and English 2013).

   The collection of biological samples of returning salmon could also help to improve estimates of run-timing for Skeena salmon CUs. This information can help improve estimates of exploitation rates, the conditions experienced by returning spawners and the extent to which run timing varies from year to year.

5. **Finalizing CU boundaries:** This project worked from an evolving set of CU boundaries and delineations which at times made it difficult to compare the biological information available with the habitat information that has been summarized. Given that CUs are the foundational building blocks of the WSP, a focus on finalizing CU boundaries and delineations would ensure that future work to assess status is done at an appropriate scale and in a consistent manner.

2 Information elements in CU snapshots

This section contains supplementary details for many of the types of information in the CU snapshots including: a general description of the data and its source; methodology and coverage within the Skeena watershed; rationale for inclusion of the information in the CU snapshots; key uncertainties; and additional details as necessary. The number(s) in square brackets following the title for each information type correspond to the Section(s) in the CU snapshots in which the information is shown. The supplementary information provided in this section complements the information provided in the quick reference document (Appendix 3).

2.1 Spawner surveys and observed spawner abundance [6-7]

Data description
Spawner surveys consist of counts of the number of salmon in a specific stream section in a given year. Counts of salmon from the surveys within a CU can be summed to generate an estimate of the observed abundance of salmon that have returned to spawn within a CU in a given year. Surveyed streams that are considered by North Coast DFO biologists to provide the most reliable set of escapement data within a given CU are classified as indicator streams.
Data source
Fisheries and Oceans Canada salmon escapement database (nuSEDs), with additional information (e.g., indicator streams) as reported in English (2013) and updated to include spawner surveys through 2012. File: " NCCC_Streams1950-2012_7Oct2013.xls”
Data coverage
All pink, chum, coho and Chinook CUs have some record of spawner abundance between 1950 and 2012, while two sockeye CUs have no record of surveyed spawner abundance and six of the 28 sockeye CUs have less than 10 years of spawner survey data.
Methodology
The methodology used to estimate spawner abundance varies considerably by species, CU, and stream section ranging from a single visual survey of a stream section on foot under poor visibility conditions to counts of fish passing through an unbreached counting fence. Survey methodology can also change through time when, for example, surveys change from foot counts to aerial surveys. Recent indicator survey quality is denoted by a qualitative five-point survey quality code as reported in English et al. (2012).
Rationale
Spawner surveys are the foundation upon which estimates of abundance are derived and thus are a fundamental source of information for assessing and tracking the status of CUs through time. Examining the spatial and temporal coverage of spawner surveys within a CU allows one to evaluate whether there are important gaps in coverage. This also allows one to

visualize the degree to which individual spawning locations tend to co-vary in their abundance. Variation in abundance that is largely asynchronous across surveyed streams suggests that spawning-location-specific factors are important in driving variation in abundance, while variation that is largely shared suggests that shared environments (e.g., the marine environment or common rearing lake) are more important.
Uncertainties
Survey quality is a critical source of uncertainty in estimates of spawner abundance. While expansion and correction factors are often applied to account for this, surveys that are inherently less precise in their estimates of spawner abundance will always lead to some amount of uncertainty. Changes in survey methodology over time can make these uncertainties even more pronounced. For some CUs, the location at which spawner abundance is enumerated does not allow for independent estimates of spawner abundance to be made across the distinct habitats (e.g., sockeye lakes) that make up spawning and rearing areas (e.g., the Babine/Onerka lake sockeye CU).
Other
Individuals conducting stream surveys initially record estimates of spawner abundance on BC16 forms. These forms are then submitted to the North Coast DFO office, which incorporates spawner abundance estimates from the surveys into a North Coast salmon escapement database, which is then incorporated into the nuSEDS database. Estimates of spawner abundance are available within North Coast salmon escapement database as far back as the early 1900s, however, because enumeration methods for most CUs varied to an unknown extent in these early years, spawner surveys prior to 1950 were not included in the CU snapshots.

2.2 Conservation Unit estimated spawner abundance [7]

Data description
Reconstructed estimates of total spawner abundance at the scale of individual CUs.
Data source
Reconstructed spawner abundance estimates were generated by LGL Ltd. as described in English et al. (2012) and English (2013) and updated to include 2011 and 2012 spawner estimates. Files: "TRTCEstimates_Output_[SX/PKo/PKe/CO/CN/ CM]_20130827.xlsx"
Data coverage
Spawner abundance can only be reconstructed for CUs that have indicator streams. As a result, CU-level reconstructions of total spawner abundance were not generated for 14 CUs without indicator streams and for one sockeye CU without any estimates of spawner abundance at all. Of these 14 CUs, four are Chinook CUs and 10 are lake sockeye CUs.
Methodology
A series of expansions are used to convert observed spawner abundance for frequently monitored streams into a series of annual spawner abundance estimates for a given CU. This methodology is described in detail in English et al. (2012). Briefly, the four steps to the methodology are: 1. trends in escapement from indicator streams are calculated and used to infer trends for all streams in the CU (with and without spawner estimates); 2. correction for missing estimates from indicator streams; 3. expansion of spawner estimates to account for all streams in the CU; and 4. expansion for observer efficiency (i.e., to account for the extent to which the methodology used to estimate spawner abundance may underestimate true abundance).
Rationale
Not all spawning locations are surveyed in a given year within a CU and so in order to estimate the number of spawners in the entire CU in a given year one needs to estimate the number of spawners in streams that were not surveyed. Reconstructing the total abundance of spawning fish in a given year allows for comparable estimates of total abundance to be derived. In principle, these reconstructed estimates are the ones that should be used to assess status and trends in abundance because variation from year to year is not an artefact of survey effort and instead reflects true variation in abundance.
Uncertainties
Key uncertainties in reconstructed estimates of abundance include the extent to which estimates of abundance should be expanded to account for observer efficiency; the relative contribution each stream to total CU abundance; the assumption that the proportion of spawners occurring in index reaches and non-index reaches is constant from year to year; and the extent to which the selection of stream reaches represents the CU. A detailed description of all uncertainties and assumptions underlying these data are provided in Appendix D of English et al. (2012).

2.3 Smolt abundance [7]

Data description
The estimated number of out-migrating juvenile salmon leaving freshwater rearing habitat en route to the marine environment.
Data source
Estimates of smolt abundance are based on those reported in Fernando (2012), Kingston (2012) and Cox-Rogers and Spilsted (2012).
Data coverage
Estimates of out-migrating smolt abundance are available for the Gitanyow, Slamgeesh, Tahlo/Morrison, Babine and Nilkitkwa lake sockeye CUs. Smolt abundance estimates from the Babine system (Tahlo/Morrison, Babine and Nilkitkwa) are available from 1951-2002 while those from the Gitanyow and Slamgeesh CUs are available from 2001-2011 (except 2006-2008 in the Slamgeesh CU).
Methodology
Smolt abundance estimates are generated based on smolt trap and mark-recapture programs in the Babine (Tahlo/Morrison, Babine and Nilkitkwa CUs, smolt trap located below Nilkitkwa lake) and the Slamgeesh CUs and by summing the daily catch of smolts across the sampling season in the Gitanyow CU (below Gitanyow Lake on Kitwanga River).
Rationale
Estimates of the abundance of salmonids at juvenile life stages can provide important insight into life-stage-specific influences on survival. For example, estimates of smolt abundance allow the calculation of smolt-to-adult survival, which provides information on the relative influence of conditions in freshwater vs. the marine environment on overall survival.
Uncertainties
Within the Babine complex it is not possible to break apart smolt abundance by CU (i.e., run-timing group); however, smolt abundance is broken down by early- and late-timed migrants. Early migrant smolts are thought to originate from Nilkitkwa sockeye and late migrant smolts are thought to primarily originate from early- and mid-timed adults (i.e., Tahlo/Morrison and Babine CUs, and the enhanced Babine "CU").

2.4 Catch and run size [8]

Data description
Estimates of the number of mature salmon captured in US and Canadian fisheries (catch), corresponding exploitation rate (proportion of total run caught in fisheries), and the sum of estimated spawner abundance and total catch (run size) for each CU.
Data source
US and Canadian catch, exploitation rates and run size were estimated by LGL Ltd. as described in English et al. (2012) and English (2013). Files: "TRTCEstimates_Output_[SX/PKo/PKe/CO/CN/ CM]_20130827.xlsx"
Data coverage
Catch and run size estimates are available for all CUs where it was possible to generate estimates of spawner abundance at the CU level (39 of 53 CUs). Time series of catch and exploitation rates extend as far back as 1960 for sockeye; 1954 for coho, pink and chum; and 1985 for Chinook.
Methodology
The methodology used to estimate catch varies by species and is described in detail in English et al. (2012) and English (2013). Briefly, sockeye catch is estimated based on a run-reconstruction model that uses information about when salmon from each CU are thought to be migrating through areas where fisheries are occurring including fisheries within the Skeena River. Pink and chum catch is estimated based on known and estimated harvest rates and the relationship between harvest and effort in fisheries. Chinook and coho catch is based on exploitation rates derived from coded-wire tag recoveries from a few tagged CUs.
Rationale
Catch information is central to understanding the extent to which fish are removed from a CU by fisheries. Run size provides an indication of the total number of fish that would return to spawn from a given spawning cohort in the absence of fisheries. Run size information is critical to building brood tables and understanding stock-recruitment dynamics.
Uncertainties
A detailed description of the uncertainties and assumptions underlying catch and run size estimates are provided in Appendix D of English et al. (2012). Key sources of uncertainty include: run-timing estimates for run-reconstruction in sockeye where small changes in assumed run-timing (see next section) can produce large differences in the estimated catch; and the assumption that “indicator” stocks that are used to derive estimates of exploitation based on coded-wire tags accurately represent exploitation in other CUs.

2.5 Age composition [10]

Data description
The number of salmon of a given age that return to spawn in a given CU and year.
Data source
Average age composition information for Skeena CUs is reported in English et al. (2012) and English (2013) and is based on the Pacific Region Age Dataset. Annual age composition for Babine sockeye CUs and the Kalum Chinook CU is also as reported in English (2013). File: “Age data summary 5Jan2012 Peacock Input+WD.xls” Additional information on age composition for Gitanyow (Kitwanga/Kitwancool) lake sockeye were provided by D. Kingston (Gitanyow Fisheries Authority).
Data coverage
At least one year of age composition information was available for 7 of 11 Chinook CUs, 2 of 3 chum CUs, 2 of 3 coho CUs, 11 of 28 lake sockeye CUs and 0 of 2 river sockeye CUs. Pink salmon have fixed age at maturity (two years of age). In order to construct brood tables for CUs without any age composition data, CUs were assigned an age composition based on data for neighboring CUs thought to have similar age composition (English et al. 2012, English 2013).
Methodology
Age composition is based on “reading” scales sampled from returning adult salmon whose rings (or circuli) can be interpreted to determine the number of years the sampled fish spent in marine and freshwater habitats.
Rationale
Estimates of age composition are a critical piece of information because they are necessary to calculate the total number of fish that are produced from a given brood year (i.e., brood tables), which are in turn necessary to estimate stock-recruitment relationships.
Uncertainties
Age composition estimates are often based on a relatively small number of individuals. This can result in inaccurate estimates of the proportion of fish in a given age class, including overestimates of the occurrence of the most common age classes and underestimates of the least common age classes.
Other
The age composition data we summarise and include in the CU snapshots is based exclusively on the Pacific Region Age Dataset. However, age composition information likely exists for some CUs in other formats that we were unable to compile for this version of the CU snapshots.

2.6 Run-timing [11]

Data description
Average peak timing of the entry of returning spawners into the Skeena river.
Data source
Run-timing information for sockeye as reported in Table 3 in English et al. (2013). For other species, North Coast DFO provided estimates of peak run-timing and variation in peak run-timing.
Data coverage
Average run-timing estimates were available for all CUs.
Methodology
Run-timing estimates are based on genetic samples collected from the Tyee Test Fishery or best estimates of peak run-timing by North Coast DFO.
Rationale
The timing of migration into the Skeena river provides insight into the river conditions migrating fish from a given CU are likely to experience. These conditions can include water temperature and flow as well as fisheries that specifically or incidentally target the migrating fish.
Uncertainties
Run-timing is assumed to be uni-modal (i.e., one peak). In some instances there may be evidence of bi-modal (two peaks) run-timing but, given the small number of DNA samples actually analyzed for most CUs, it is currently not possible to determine whether there is truly bi-modal run-timing or if it is an artefact of the limited sampling to date. All run-timing estimates that are based on DNA sampling are averages of all years of available information. In some instances, peak run-timing may vary from year to year (2012b); however sufficient samples are not available to derive year-specific run-timing estimates. The width of the peak run-timing curve may be greater than reality because it is includes variation across years. Estimates of run-timing based on DNA collected in fish caught in the Tyee test fishery are constrained to the period of operation of the test fishery (typically mid-June to early-September). As a result, fish migrating before or after the operation of the test fishery will not be captured in estimates of peak run-timing.

2.7 Habitat capacity [12]

Data description
Rearing-habitat-based estimates of the capacity of freshwater habitat to support juvenile life-history stages within a CU. These estimates can be expressed as either the maximum number / biomass of juveniles or the equivalent number of adults and can be compared, for example, to estimates of the number / biomass of juvenile salmon observed in a given CU.
Data source
Lake sockeye rearing habitat information is provided in Cox-Rogers (2012a) along with a summary of hydroacoustic-survey-based estimates of juvenile sockeye biomass.
Data coverage
Estimates of the carrying capacity of sockeye lakes in the Skeena are available for 16 CUs but are not currently available for other species and CUs.
Methodology
A habitat-based photosynthetic rate (PR) model is used to convert estimates of the photosynthetic rate of a lake into the predicted number of juvenile sockeye the lake can support. Details of the PR model and its application in the Skeena are provided in Cox-Rogers et al. (2010) and Cox-Rogers (2012a).
Rationale
Estimates of the productive capacity of CUs based on rearing habitat that are derived independently of spawner abundance can provide important insight into the carrying capacity of a CU when estimates of recruitment and/or productivity are missing or uncertain. When stock-recruitment information is available, habitat-based estimates of carrying capacity can improve parameter estimates in the stock-recruitment relationship, such as the intrinsic rate of growth and strength of density dependence. In addition, habitat-based estimates of carrying capacity can be used to derive habitat-based abundance benchmarks (Cox-Rogers 2012a).
Uncertainties
Of the 16 lakes for which there are photosynthetic rate estimates, at 10 lakes data were collected once monthly from approximately May to October. In the remaining six lakes photosynthetic rate estimates are based on a single sampling event in late August or early September. At those lakes where sampling only occurred once, random variation in lake conditions (e.g., sunlight, temperature, turbidity, etc.) may result in biased overall estimates of lake characteristics (whereas the variability of these conditions may be captured at lakes with multiple sampling events). A detailed description of the uncertainties and assumptions underlying the photosynthetic rate model used to estimate rearing capacity for lake sockeye is provided in Cox-Rogers et al. (2010).
Other
When data on spawner abundance are not available or are of poor quality, juvenile abundance may provide an indication of spawning status (Holt et al. 2009). Juvenile abundance estimates for lake sockeye has been collected from rotational acoustic surveys for over a decade and can be compared against juvenile rearing capacity estimates for general status assessment (Cox-Rogers 2012a).

2.8 Stock-recruitment relationship [13]

Data description
Estimated relationship describing how the number of fish in one generation (i.e., recruits: adult fish that returned to the coast, including those captured in fisheries, summed across all age classes) varies with the number of fish in the parental generation (i.e., stock: the number of spawners).
Data source
The brood tables and R-code used to estimate stock-recruitment relationships are described in Korman and English (2013).
Data coverage
Stock-recruitment data were available for 17 of 28 lake sockeye CUs, 0 of 2 river sockeye CUs, 7 of 11 Chinook CUs, 2 of 3 chum CUs, and all coho and pink CUs. Stock-recruitment relationships were only estimated for CUs with more than three data points. As a result, one additional lake sockeye CU was excluded (Asitika).
Methodology
Ricker stock-recruitment relationships were fit to the stock-recruitment data by species using a Hierarchical Bayesian model. The modeling is described in detail in Korman and English (2003). Briefly, a hierarchical approach was used because: (a) it allows for estimates of stock-recruitment relationships to be derived simultaneously which enables the relationship for each CU to be estimated more reliably than if they were independently estimated; and (b) it can incorporate prior information on the carrying capacity of a CU (e.g., carrying capacity of sockeye lakes) which reduces uncertainty in the estimated stock-recruitment relationship.
Rationale
By fitting a stock-recruitment model to data from each CU, one can estimate the average number of adult salmon that are expected to return to the coast for a given number of spawners. Using this information, a variety of metrics that are commonly used as status benchmarks can then be estimated. Numerous relationships have been proposed to describe stock-recruitment relationships. The most commonly used relationship for Pacific salmon is the Ricker relationship (Ricker 1975), which assumes a hump-shaped relationship between spawners and recruitment, where above a certain spawner abundance the number of recruits declines as spawner abundance increases. Alternatives include the Beverton-Holt relationship, which assumes that as spawners increase the number of recruits produced asymptotes, and the Larkin model (Larkin 1971), which is an extension of the Ricker relationship that allows for negative interactions between brood years.
Uncertainties
All the uncertainties that underlie the spawner and recruitment data that are described in previous sections apply in this case. See Korman and English (2013) for a thorough discussion of uncertainties and potential biases in the stock-recruitment analysis. Important potential sources of uncertainty and bias include those introduced from over- or under-estimating recruitment and/or spawners in a given year because of a lack of year-specific age composition information, incorrect estimates of catch, incorrect stock-recruitment relationship, or inaccurate counts of the number of fish returning to spawn.

2.9 Marine survival [14]

Data description
Estimates of the percent of smolts that survive residence in the marine environment to return to the coast as adult fish prior to fisheries.
Data source
Estimates of marine survival are based on those provided by North Coast DFO (Late-timing Kalum Chinook and Middle Skeena coho), the Gitanyow Fisheries Authority (Gitanyow/Kitwanga and Slamgeesh sockeye), or as reported in Cox-Rogers and Spilsted (2012) for Babine sockeye.
Data coverage
Estimates of marine survival are available for the Tahlo/Morrison, Babine, Nilkitkwa, Gitanyow and Slamgeesh lake sockeye CUs; the late-timing Kalum Chinook CU; and the Middle Skeena coho CU. These marine survival estimates range in duration from 42 years in the Babine complex CUs (i.e., Tahlo/Morrison, Babine and Nilkitkwa), to 25-30 years in the Middle Skeena coho and Kalum Chinook CUs, and 6-7 years in the Slamgeesh and Gitanyow CUs.
Methodology
Marine survival can be estimated in CUs where estimates of out-migrating smolt abundance and adult returns from smolt traps and counting fences are available, or in CUs where coded-wire tags are placed in out-migrating smolts and recovered for returning adults either in fisheries or on the spawning grounds.
Rationale
Estimates of survival by life stages can provide important insight in to life-stage-specific influences on survival. For example, estimates of smolt-to-adult survival can provide insight into the extent to which variability in marine conditions is responsible for year-to-year changes in the productivity of a CU.
Uncertainties
Estimates of marine survival based on either smolt and adult enumeration programs or tagging studies will always result in some degree of uncertainty resulting from imperfect estimates of abundance. Uncertainties may arise due to: insufficient number of tagged fish or tagging events; tag loss; tags affecting the recapture probability; inaccurate reporting of tags; unaccounted for variability in trap efficiency (Johnson et al. 2007). Within the Babine complex of sockeye CUs, it is not possible to separate smolt abundance by CU (i.e., run-timing group); however, smolt abundance is broken into early- and late-timed migrants. Early migrant smolts are thought to originate from Nilkitkwa sockeye and late migrant smolts are thought to primarily originate from early- and mid-timed adults (i.e., Tahlo/Morrison, enhanced and Babine CUs).
Other
While smolt-to-adult survival is often thought of as being synonymous with marine survival, smolt-to-adult survival includes a short period spent in fresh water following when estimates of juvenile abundance are made, as well as a much longer period spent in the ocean.

2.10 Productivity indices [15-16]

Data description
Three different measures of the productivity of a CU were generated: 1. Recruits-per-spawner: number of adult returns per spawner. 2. Ricker index: an index that accounts for the influence of spawner abundance on returns per spawner thereby representing productivity changes that are attributable to causes other than spawner abundance, such as environmental factors. 3. Kalman index: an extension of the second index that uses a Kalman filter to remove high-frequency year-to-year variation ("noise") in productivity, thereby bringing out any long-term trends in the time series (Peterman et al. 2003; Dorner et al. 2008).
Data source
The three productivity indices were derived from the brood tables generated by English (2013), which are the same as were used in Korman and English (2013).
Data coverage
Productivity indices were generated for all CUs for which stock-recruitment analyses were conducted. This included 16 of 28 lake sockeye CUs, 0 of 2 river sockeye CUs, 7 of 11 Chinook CUs, 2 of 3 chum CUs, and all coho and pink CUs. Stock-recruitment relationships were only estimated for CUs with more than three data points.
Methodology
Recruits-per-spawner were calculated as the number of recruits divided by the number of spawners for each brood year for which there was information. We generated the Ricker index by calculating observed deviations from predicted recruitment in a given year (points above and below the stock-recruitment relationship). We generated the Kalman index by fitting a modified version of the Ricker stock-recruitment relationship, which allows for time-varying productivity. Additional details are provided in the Quick Reference guide (Appendix 3) that accompanies this report. The mathematical details of the Kalman filter estimation method are described in the appendices of Peterman et al. (2003) and Dorner et al. (2008).
Rationale
Productivity indices provide important information on the survival of salmon from a CU over time, which can help to inform questions about drivers of variation in survival within and among CUs. When the total number of recruits produced per spawner is below one, the CU is no longer replacing itself from one generation to the next and will decline in abundance until the recruits-per-spawner exceeds one. Instances where the Ricker and Kalman indices largely agree suggest there is little evidence of long-term persistent changes in productivity in the CU. When they do not agree it suggests that there may be persistent changes in the productivity of a CU over time. Note that the Kalman index is scaled (subtracted from the mean and divided by its standard deviation). This scaling allows for the two indices to be more easily compared, but also means that the magnitude of increases or decreases in productivity are not shown.
Uncertainties
All the uncertainties underlying the spawner and recruitment data (described in previous sections) apply in this case.

2.11 Migration period pressures (lake sockeye); rearing/migration pressures (other species) [20]

Data description
Summation of seven derived habitat Impact Category ratings within each 1:20K Freshwater Atlas (FWA) watershed within the CU migration corridor zone of influence (ZOI) (for lake sockeye) or the CU combined rearing/migration ZOI (for all other salmon species). ZOIs represent areas delineated adjacent to and upstream/upslope of habitats used by the different life stages of salmon CUs and represent the geographic extent for capture and measurement of the extent and intensity of human pressures/stressors that could potentially impact these habitats. Habitat Impact Categories scored were (1) Hydrologic Processes, (2) Surface Erosion, (3) Fish Passage/Habitat Connectivity, (4) Vegetation Quality, (5) Water Quantity, (6) Water Quality, and (7) Human Development Footprint. A score of 2 was applied for each individual red-rated (higher risk) Impact Category, score of 1 for an amber-rated (moderate risk) Impact Category, and score of 0 for a green-rated (lower risk) Impact Category in each watershed. The total potential cumulative pressure score for each watershed in the ZOI therefore ranges from 0 to 14 (lower to higher risk), with a grey colour gradation visually indicating this range of cumulative pressure ratings across the mapped watersheds in the ZOI. Darker shades represent areas within the ZOI where relatively higher risk habitat impacts may be occurring.
Data source
Data sources across the 13 habitat pressure indicators that are used to derive the watershed habitat Impact Category ratings are described in Porter et al. (2013, 2014; generally in Table 2 of Porter et al. (2013) and in greater detail in Appendix 3 of that report). Information was assembled and quantified for the habitat pressure indicators: (1) % forest disturbance, (2) Equivalent Clear Cut Area, (3) road density, (4) stream crossing density, (5) % forest defoliated, (6) % riparian disturbance, (7) # licensed water permits, (8) # permitted wastewater discharges, (9) # of mines (general), (10) # of acid-generating mines, (11) % total land cover alteration, (12) density of linear development, and (13) % impervious surfaces.
Data coverage
Habitat pressure indicators were quantified in all 1:20K Freshwater Atlas (FWA) watersheds within the Skeena Basin. Temporal and spatial coverage of the data sources that inform the indicators is variable: temporal coverage of data sources ranges from 1992 to the time of data access for habitat analyses (December 2012), and spatial coverage ranges from the whole Skeena basin to subset areas of the basin. Data coverage for each data source is provided in Porter et al. (2013, 2014; Appendix 5 in Porter et al. 2013).
Methodology
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). Roll-up rule sets were developed within and across Impact Categories so as to provide a single, overall assessment of the cumulative risk of habitat degradation (lower, moderate, higher)

within each watershed. Habitat indicators embedded within the seven derived Impact Categories were rated as lower, moderate, or higher risk based on indicator risk threshold criteria developed for each indicator. Individual habitat indicator risk ratings were then “rolled up” within each Impact Category based on defined rule sets to define a risk rating (lower, moderate, higher) for each Impact Category (see Table 1 in Porter et al. 2013 for the specific rule sets used for risk roll-ups within each Impact Category). A score of 2 was applied for each individual red-rated (higher risk) Impact Category, a score of 1 for amber-rated (moderate risk) Impact Categories, and a score of 0 for green rated (lower risk) Impact Categories within each watershed. The total potential cumulative pressure score for each watershed in the migration ZOI (for lake sockeye only) or the combined rearing/migration ZOI (for all other salmon species) therefore ranged from 0 to 14 (lower to higher risk) (i.e. seven Impact Categories, each with a value range of 0-2).
Rationale
This provides a synthesis and visual representation at the broad scale of the CU migration ZOI (lake sockeye) or rearing/migration ZOI (all other salmon species) of the relative extent/intensity (based on a gradated risk scale) of cumulative human activities (stressors) that could directly or indirectly induce qualitative or quantitative changes in habitat condition that could affect salmon.
Uncertainties
The habitat pressure indicators used for this analysis were quantified from a broad suite of information derived using currently available local, provincial, and federal agency models and GIS layers. Each GIS layer used has some level of uncertainty in terms of spatial accuracy, temporal currency and overall completeness (e.g. secondary roads may exist in reality that aren’t captured in current GIS layers, stream crossings on smaller streams may not be captured in existing GIS, Vegetation Resource Inventory (VRI) data is lacking for some areas of the Skeena, etc.). General risk thresholds (i.e., lower, moderate, or higher risk of habitat degradation) defined for each of the habitat pressure indicators and used for watershed analyses, while based on the best available science and expert-based information, are highly uncertain. Actual habitat responses when the defined thresholds are exceeded are likely to be highly variable across Skeena drainages dependent on localized terrain conditions and underlying watershed processes.
Other
The approach taken for aggregating (rolling up) habitat pressure indicators into cumulative risk scores for watersheds in the ZOI should be considered only when a broad first-cut attempt at quantifying and representing cumulative stress across suites of habitat pressure indicators in the Skeena region. Further work is needed to better calibrate and adjust “roll-up” rule sets for assessing cumulative risk based on aggregated habitat indicator information.

2.12 Summary of pressure indicators – rearing (lake sockeye); spawning (other species) [21]

Data description
Risks to watersheds within a CU's rearing lake zone of influence (ZOI) (lake sockeye) or spawning ZOI (other salmon species) are summarized for each of 13 habitat pressure indicators: (1) % forest disturbance, (2) Equivalent Clear Cut Area, (3) road density, (4) stream crossing density, (5) % forest defoliated, (6) % riparian disturbance, (7) # licensed water permits, (8) # permitted wastewater discharges, (9) # of mines (general), (10) # of acid generating mines, (11) % total land cover alteration, (12) density of linear development, and (13) % impervious surfaces. Relative risk for each habitat pressure indicator is indicated by risk placement on a normalized slider scale (with risk increasing on a score from 0 to 1). Lower risk (green) is defined as a normalized risk score below 0.33, moderate risk (amber) is scored as 0.33 to 0.66, and higher risk (red) is defined as scores above 0.66.
Data source
Data sources across the 13 habitat pressure indicators illustrated in the slider scale are described in Porter et al. (2013, 2014; generally in Table 2 of Porter et al. 2013 and in greater detail in Appendix 3 of that report). Information was assembled and quantified for the habitat pressure indicators: (1) % forest disturbance, (2) Equivalent Clear Cut Area, (3) road density, (4) stream crossing density, (5) % forest defoliated, (6) % riparian disturbance, (7) # licensed water permits, (8) # permitted wastewater discharges, (9) # of mines (general), (10) # of acid generating mines, (11) % total land cover alteration, (12) density of linear development, and (13) % impervious surfaces.
Data coverage
Habitat pressure indicators were quantified in all 1:20K Freshwater Atlas (FWA) watersheds within the Skeena Basin. Temporal and spatial coverage of the data sources to inform the indicators is variable: temporal coverage of data sources ranges from 1992 to the time of data access for the habitat analyses (current as of December 2012), and spatial coverage ranges from whole Skeena basin to subset areas of the basin. Data coverage for each data source is provided in Porter et al. (2013, 2014; Appendix 5 of Porter et al. 2013).
Methodology
The "average" risk scores for the pressure indicators across all watersheds within the CU's rearing lake ZOI (lake sockeye) or spawning ZOI (all other salmon species) was determined based on the area-weighted averages of all watershed habitat pressure indicator risk scores within the ZOI, for all Freshwater Atlas (FWA) watersheds that overlapped the CU's ZOI boundary. Risk scores were calculated and weighted using entire areas of FWA watersheds that overlapped the ZOI boundary, even when only a portion of the FWA watershed was within the CU's ZOI (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 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.

Rationale
This provides a simple, easily interpretable synthesis of the “average” status of habitat stressors across all watersheds within a CU’s ZOI (rearing lake ZOI for lake sockeye, spawning ZOI for all other species). As such, it allows the reader to quickly identify the particular habitat pressures that seem to be most problematic across ZOIs for any particular CU and where targeted habitat monitoring and management efforts might be directed most productively.
Uncertainties
The habitat pressure indicators used for this analysis were quantified from a broad suite of information derived using currently available local, provincial, and federal agency models and GIS layers. Each GIS layer used has some level of uncertainty in terms of spatial accuracy, temporal currency and overall completeness (e.g. secondary roads may exist in reality that aren’t captured in current GIS layers, stream crossings on smaller streams may not be captured in existing GIS, Vegetation Resource Inventory (VRI) data is lacking for some areas of the Skeena, etc.). General risk thresholds (i.e., lower, moderate, or higher risk of habitat degradation) defined for each of the habitat pressure indicators and used for watershed analyses, while based on the best available science and expert-based information, are highly uncertain. Actual habitat responses when the defined thresholds are exceeded are likely to be highly variable across Skeena drainages, dependent on localized terrain conditions and underlying watershed processes.

2.13 Rearing and spawning pressures (lake sockeye); spawning habitat pressures (other species) [22]

Data description
Cumulative risk ratings from habitat pressures for each watershed within CU rearing lake and spawning zones of influence (ZOIs) (lake sockeye) or spawning ZOIs solely (other salmon species). The cumulative risk rating is based on the individual risk ratings of seven habitat pressure Impact Categories: (1) Hydrologic Processes, (2) Surface Erosion, (3) Fish Passage/Habitat Connectivity, (4) Vegetation Quality, (5) Water Quantity, (6) Water Quality, and (7) Human Development Footprint. A roll-up rule set across these individual Impact Category risk ratings was then used to assign cumulative risk classifications for each watershed in the ZOI: if $\geq$ 3 Impact Categories are rated as higher risk, then the watershed's cumulative risk classification = higher risk (red), else if $\geq$ 5 of the Impact Categories are rated as lower risk, then the watershed's cumulative risk classification = lower risk (green), else the watershed's cumulative risk classification = moderate risk (amber).
Data source
Data sources across the 13 habitat pressure indicators that are used to derive the watershed Habitat Impact Category ratings are described in Porter et al. (2013, 2014; generally in Table 2 of Porter et al. 2013 and in greater detail in Appendix 3 of that report). Information was assembled and quantified for the habitat pressure indicators: (1) % forest disturbance, (2) Equivalent Clear Cut Area, (3) road density, (4) Stream crossing density, (5) % forest defoliated, (6) % riparian disturbance, (7) # licensed water permits, (8) # permitted wastewater discharges, (9) # of mines (general), (10) # of acid generating mines, (11) % total land cover alteration, (12) density of linear development, and (13) % impervious surfaces.
Data coverage
Habitat pressure indicators were quantified in all 1:20K Freshwater Atlas (FWA) watersheds within the Skeena Basin. Temporal and spatial coverage of the data sources to inform the indicators is variable: temporal coverage of data sources ranges from 1992 to the time of data access for PSF habitat analyses (current as of December 2012), and spatial coverage ranges from the whole Skeena basin to subset areas of the basin. Data coverage for each data source is provided in Porter et al. (2013; Appendix 5).
Methodology
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). Roll-up rule sets were developed within and across Impact Categories so as to provide a single, overall assessment of the cumulative risk of habitat degradation (lower, moderate, higher) within each watershed. For watersheds in CU ZOIs a cumulative risk rule set was developed based on roll-ups of both habitat pressure indicator risk ratings within the 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 – see Table 1 in Porter et al. (2013) for Impact-Category-specific roll-up rule sets), and then a roll-up of risk ratings across the Impact Categories to assign a final cumulative habitat risk classification for each watershed (2nd level roll-up: see Table 2 in Porter et al. (2013, 2014) for cumulative risk classification roll-up rules across Impact Categories).
Rationale
This provides a synthesis and visual representation at a CU zone of influence scale of the relative extent and intensity (categorical: lower, moderate, or higher risk) of cumulative human activities (stressors) that could directly or indirectly induce qualitative or quantitative changes in habitat condition that could affect salmon.
Uncertainties
The habitat pressure indicators used for this analysis were quantified from a broad suite of information derived using currently available local, provincial, and federal agency models and GIS layers. Each GIS layer used has some level of uncertainty in terms of spatial accuracy, temporal currency and overall completeness (e.g. secondary roads may exist in reality that aren't captured in current GIS layers, stream crossings on smaller streams may not be captured in existing GIS, Vegetation Resource Inventory (VRI) data is lacking for some areas of the Skeena, etc.). General risk thresholds (i.e., lower, moderate, or higher risk of habitat degradation) defined for each of the habitat pressure indicators and used for watershed analyses, while based on the best available science and expert-based information, are highly uncertain. Actual habitat responses when the defined thresholds are exceeded are likely to be highly variable across Skeena drainages, and dependent on localized terrain conditions and underlying watershed processes. Reporting out on the large number of habitat indicators presents a challenge in providing a general, overall assessment of habitat risks. Aggregating information into a single overall cumulative risk rating as has been done here can make interpretation of multiple stressors easier, but information on individual components can be lost and there may be multiple approaches to aggregating indicators without certainty about which is best.
Other
A Skeena Technical Advisory Committee assisted Porter et al. (2013, 2014) in defining the seven Impact Categories to be used for the cumulative risk analyses and in assignment of the different pressure indicators to each of the Impact Categories. The seven Impact Categories selected for the cumulative risk roll-ups were considered to represent relatively independent processes driving potential change in environmental conditions within salmon habitats.

2.14 Integrated vulnerability/habitat pressures – migration, spawning and rearing (lake sockeye); spawning, incubation, rearing/migration (other salmon species) [23]

Data description
Bivariate indices of the relative rankings across CUs for scored cumulative habitat pressures and scored vulnerability to these pressures within CU migration, spawning and rearing zones of influence (ZOIs) (lake sockeye), or spawning, incubation, migration/rearing (other salmon species).
Data source
Data sources for indicators used within these sections to assess relative CU cumulative habitat pressures across life-stage-specific ZOIs are described in Porter et al. (2013, 2014; generally in Table 2 of Porter et al. 2013 and in greater detail in Appendix 3 of that report). For lake sockeye, information on cumulative pressure indicators was assembled and quantified for the life stages: **Migration**: (1) total number of water licenses, (2) total number of identified obstructions, (3) cumulative area-weighted risk classifications of all watersheds in the migration ZOI; **Spawning**: percentage of all watersheds in the spawning ZOI with higher or moderate cumulative risk classifications; **Rearing**: total combined score of all area-weighted average CU scores for the 13 individual habitat pressures indicators within the rearing lake ZOI (index score ranges from 0-13 based on normalized 0-1 scores for each of the 13 habitat pressure indicators). For all other salmon species, information on cumulative pressure indicators was assembled and quantified for the life stages: **Spawning and Incubation**: % of watersheds within the spawning ZOI that are rated as being either moderate or high cumulative risk (amber, red) of habitat impairment; **Rearing/migration**: cumulative pressure score (area-weighted average score) across all watersheds within the rearing/migration ZOI. Data sources for indicators used within these sections to assess relative CU vulnerabilities across specific life stages are described in Porter et al. (2013, 2014; generally in Table 2 of Porter et al. 2013 and in greater detail in Appendix 3 of that report). Information was assembled and quantified for the life stage vulnerability indicators as indicated below: Lake sockeye: **Migration:** (1) total migration distance, (2) length of migration distance that is summer flow sensitive; **Spawning:** (1) total length of known spawning habitat spawning length, (2) ratio of lake influenced spawning to total spawning length; **Rearing:** (1) size of nursery lake, (2) nursery lake productivity. Other salmon species: **Spawning: (**1) total spawning length, (2) percentage of total spawning length within summer flow sensitive areas; **Incubation: (**1) percentage of total spawning length within winter flow sensitive areas; **Rearing/migration:** (1) Total accessible stream length; (2) percentage of total accessible stream length within flow sensitive areas (all seasons).

Data coverage
Habitat pressure and habitat vulnerability indicators were quantified in all 1:20K FWA-defined watersheds within the Skeena Basin. Temporal and spatial coverage of the data sources that inform the indicators is variable: temporal coverage of data sources ranges from 1992 to the time of data access for habitat analyses (current as of December 2012), and spatial coverage ranges from the whole Skeena basin to subset areas of the basin. Data coverage for each data source is provided in Porter et al (2013, 2014).
Methodology
Methods for calculation of the integrated habitat pressures and vulnerabilities rankings across Skeena CU ZOIs are described in Porter et al. (2013, 2014; Section 2.8 of Porter et al. 2013).
Rationale
Given a general lack of comprehensive information that could be used to reliably assess differences in habitat condition across all spawning, incubation, rearing, and migratory habitats for Skeena CUs, Porter et al. (2013, 2014) instead defined relative CU habitat status as a combination of: (1) the intrinsic habitat vulnerability to potential impacts (based on quantified measures of habitat quantity and/or quality), and (2) the cumulative intensity of various human stresses on those habitats. In this approach, a CU that was considered more highly vulnerable (relatively more sensitive to potential habitat impacts compared to other CUs), while also exposed to relatively high levels of composite human development pressures within its spawning, incubation, 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 that are rated as having relatively high habitat pressures and relatively high vulnerability may not in reality demonstrate any detectable negative effects on freshwater survival from the impacts of human stressors. In the future, with continued research into the effects of landscape habitat pressures on salmon habitat responses and salmon population resilience, it may be possible to better define benchmarks of concern for combined pressures/vulnerability scoring (i.e., instead of basing scoring for CU habitat status simply on relative CU rankings across the defined indicators).
Uncertainties
The habitat pressure indicators used for this analysis were quantified from a broad suite of information derived using currently available local, provincial, and federal agency models and GIS layers. Each GIS layer used has some level of uncertainty in terms of spatial accuracy, temporal currency and overall completeness (e.g. secondary roads may exist in reality that aren't captured in current GIS layers, stream crossings on smaller streams may not be captured in existing GIS, Vegetation Resource Inventory (VRI) data is lacking for some areas of the Skeena, etc.). General risk thresholds (i.e., lower, moderate, or higher risk of habitat degradation) defined for each of the habitat pressure indicators and used for watershed analyses, while based on the best available science and expert-based information, are highly uncertain. Actual habitat responses when the defined thresholds are exceeded are

likely to be highly variable across Skeena drainages, dependent on localized terrain conditions and underlying watershed processes.

The habitat vulnerability indicators used for this analysis were quantified from a broad suite of information derived using currently available local, provincial, and federal agency models and GIS layers. Each GIS layer used has some level of uncertainty in terms of spatial accuracy, temporal currency, and overall completeness (e.g. spawning distribution mapping may be incomplete, flow sensitivity modeling is spatially coarse, etc.).

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Appendix 1. CUs considered in this project

Table1: List of CUs considered in this report and their correspondence to DFO's original CU delineations reported in Holtby and Ciruna (2007). Note that the habitat-related information contained in the snapshots is taken from Porter et al. (2013, 2014), who based their habitat delineations on Holtby and Ciruna (2007) and did not include CUs that are restricted to the Skeena Estuary.

Species	CUs in this report	Holtby and Ciruna (2007)
Chinook	Ecstall	Ecstall
Chinook	Early Kalum	Kalum-Early
Chinook	Kalum-late timing	Kalum-Late
Chinook	Lakelse	Lakelse
Chinook	Lower Skeena	Lower Skeena; Gitnadoix (2 CUs)
Chinook	Middle Skeena Large Lakes	Middle Skeena-Large Lakes
Chinook	Middle Skeena Mainstem Tributaries	Middle Skeena Mainstem Tributaries; Middle Skeena (2 CUs)
Chinook	Skeena Estuary	Skeena Estuary
Chinook	Upper Bulkley	Upper Bulkley River
Chinook	Upper Skeena	Upper Skeena
Chinook	Zymoetz	n/a
Chum	Lower Skeena	Lower Skeena
Chum	Middle Skeena	Middle Skeena
Chum	Upper Skeena	Upper Skeena
Chum	Skeena Estuary	Skeena Estuary
Coho	Lower Skeena	Lower Skeena
Coho	Middle Skeena	Middle Skeena
Coho	Upper Skeena	Upper Skeena
Coho	Skeena Estuary	Skeena Estuary
Pink	Lower Skeena (odd)	Lower Skeena River
Pink	Middle and Upper Skeena (even)	Middle-Upper Skeena (Even)
Pink	Middle and Upper Skeena (odd)	Middle-Upper Skeena (Odd)
Pink	Nass and Skeena Estuary (even)	Nass-Skeena Estuary (Even)
Pink	Nass and Skeena Estuary (odd)	Nass-Skeena Estuary (Odd)
Sockeye-Lake	Alastair	Alastair
Sockeye-Lake	Asitika	Asitika
Sockeye-Lake	Azuklotz	Azuklotz
Sockeye-Lake	Babine/Onerka	Babine
Sockeye-Lake	Babine (Enhanced)	n/a
Sockeye-Lake	Bear	Bear
Sockeye-Lake	Bulkley/Maxan	Bulkley; Maxan (2 CUs)
Sockeye-Lake	Damshilgwit	Damshilgwit
Sockeye-Lake	Ecstall/Lower	Ecstall/Lower
Sockeye-Lake	Footsore/Hodder	n/a
Sockeye-Lake	Gitanyow (Kitwanga/Kitwancool)	Kitwancool

Sockeye-Lake	Johanson	Johanson
Sockeye-Lake	Johnston	Johnston
Sockeye-Lake	Kitsumkalum	Kitsumkalum
Sockeye-Lake	Kluatantan	Kluatantan
Sockeye-Lake	Kluayaz	Kluayaz
Sockeye-Lake	Lakelse	Lakelse
Sockeye-Lake	Mcdonell/Dennis/Aldrich	Mcdonell; Aldrich; Dennis (3 CUs)
Sockeye-Lake	Morice/Atna	Morice; Atna (2 CUs)
Sockeye-Lake	Motase	Motase
Sockeye-Lake	Nilkitkwa	Nilkitkwa
Sockeye-Lake	Sicintine	Sicintine
Sockeye-Lake	Slamgeesh	Slamgeesh
Sockeye-Lake	Spawning	Spawning
Sockeye-Lake	Stephens	Stephens
Sockeye-Lake	Sustut	Sustut
Sockeye-Lake	Swan/Club	Swan; Club (2 CUs)
Sockeye-Lake	Tahlo/Morrison	Tahlo/Morrison
Sockeye-River	Skeena River	Skeena River
Sockeye-River	Skeena River-High Interior	Skeena River-High Interior

Appendix 2. Individuals who provided feedback for this project

Table 1: Individuals who provided feedback during stages 1, 3, and 4 of this project as described on page 7.

Project stage(s)	Name	Affiliation
1	Alana Dickson	Lake Babine Nation
1, 3	Alicia Fernando	Gitxsan Watershed Authority
1	Charmaine Carr-Harris	SFU/Skeena Fisheries Commission
1, 3	Dave Peacock	Fisheries and Oceans Canada
1	Davide Latremouille	Skeena Fisheries Commission
4	Derek Kingston	Gitanyow Fisheries Authority
3	Don Morgan	BC Ministry of Environment and Bulkley Valley Research Centre
1, 3, 4	Greg Knox	SkeenaWild Conservation Trust
3, 4	Greg Taylor	Fish First Consulting
1	Ivan Withler	Fisheries and Oceans Canada
1, 3	Jessica Hawryshyn	North Coast Skeena First Nations Stewardship Society
3	Johanna Pfalz	Eclipse GIS
1, 4	Karl English	LGL Ltd.
1, 3, 4	Ken Rabnett	Suskwa Research
3, 4	Lana Miller	Fisheries and Oceans Canada
1	Mark Cleveland	Gitanyow Fisheries Authority
1	Mike Price	SkeenaWild Conservation Trust
3	Sandra Devcic	Fisheries and Oceans Canada
1	Siegi Kriegl	Kitsumkalum Fish and Wildlife
1	Steve Cox-Rogers	Fisheries and Oceans Canada
4	Walter Joseph	Wet'suwet'en Fisheries

Appendix 3. CU snapshot quick reference guide

Skeena Salmon
Conservation Unit Snapshot Quick

Version 1.0, December 19, 2013

These Conservation Unit (CU) Snapshots summarize key population and habitat information for Skeena salmon CUs. CU Snapshots are intended to serve as a reference document to assist discussions about the state of salmon and their habitats. The approach for developing the Snapshots was to: 1) summarize all of the available data for the region, 2) review the extent and quality of each data source, 3) identify key population and habitat summaries, and 4) generate a series of figures to convey key information and data gaps across different CUs in a simple but comprehensive way. Various external experts and potential users were solicited to provide feedback throughout the process. This 'Quick Reference' provides data sources and supplemental information for each section. Full methods and results can be found in the main report, (Skeena Salmon Conservation Unit Snapshots, Connors et al. 2013) available from PSF at: www.skeenasalmonprogram.ca.

In general, this project uses CU names and delineations as provided by B. Holtby (DFO) in 2011 and described in English 2013, which represent a provisional update to CU delineations identified by Holtby and Ciruna in 2007. However, the information on habitat pressures in the final pages of the CU Snapshot is based on the 2007 Holtby and Ciruna system. In cases where these two CU systems differ we have included all relevant habitat pressure information and used a joint name to identify the CU more clearly (e.g., Bulkley/Maxan).

Cover Page

1. CU Snapshot information roadmap. In addition to providing a road map to the information contained in the CU Snapshot, this figure indicates the linkages among data types and consequences of data gaps. Very few CUs have all possible types of information (e.g., Babine lake sockeye). Many of the CUs are missing everything except spawner abundance. In the latter case, many of the figures within the Snapshot will be blank and only spawner abundance based benchmarks will be available. Habitat pressures are shown as a stand-alone element because, while they influence the status of the populations, they are not directly used to generate the population estimates.

2. Location of this CU. Lake Sockeye: Map showing location of the CU rearing lake within the Skeena drainage, and the location of the Skeena drainage within BC. The rearing lake is shaded blue and its defined 'zone of influence' (ZOI) is indicated in black outline. The ZOI for the rearing lake is defined as the 1:20K Fresh Water Atlas (FWA) upstream watersheds that directly flow into or intersect the CU rearing lake. The migration route between the mouth of the Skeena River and the CU rearing lake outlet is indicated by the blue river line (see Figure 2 for the migration corridor's ZOI). **Data sources:** Porter et al. 2013 (based on: DFO_BC_Sockeye_Lake_CU_V2 [2010], FWA Stream Network [2008])

Other Salmon Species: Map showing location of the CU within the Skeena drainage, and the location of the Skeena drainage within BC. **Data sources:** Porter et al. 2014 (based on: FWA Stream Network [2008], spawning locations compiled by SkeenaWild Conservation Trust based on FISS and refined with information provided by regional experts).

Abundance (3-9)

3. Summary statistics. The **number of survey streams** refers to the number of streams identified within the nuSEDS database since 1950. **Indicator streams** are those that DFO North Coast biologists have identified as providing the most reliable set of escapement data for each CU. The **maximum** and **minimum** estimates refer to the maximum and minimum of the annual total number of spawners estimated for the CU (i.e., the estimates derived from the monitored indicator streams expanded to represent the entire CU). **Generation length** refers to the maximum age for those ages that comprise 90% of the spawners for a given CU; for CUs without age information generation length is the most common generation length for the species. **Data sources:** nuSEDs, as reported in "NCCC_Streams1950-2012_7Oct2013.xls" (see English et al. 2012 and English 2013 for details).

4. Location. Lake Sockeye: A more detailed map of the CU's spawning streams, indicator streams, spawning areas, and the defined 'zone of influence' (ZOI) capturing the drainage area upstream from the CU's rearing lake outlet (dark grey outline). **Other Salmon Species:** A more detailed map of the streams within the CU, indicator streams, spawning areas and the defined 'zone of influence' (ZOI) capturing the full drainage area directly influencing CU spawning habitat (dark grey outline). **Known spawning areas** reflect current state of knowledge provided by local experts. Not all known spawning areas are captured in the nuSEDS database. Survey streams listed in nuSEDS are identified by numbers consistent with Section 6 allowing comparison of survey effort across space and time. **Data sources:** ZOIs and known spawning areas from Porter et al. 2013 and Porter et al. 2014 (based on: DFO_BC_Sockeye_Lake_CU_V2 [2010], FWA Stream Network [2008], spawning locations compiled by SkeenaWild

Conservation Trust based on FISS and refined with information provided by regional experts). Survey streams from nuSEDs, as reported in "NCCC_Streams1950-2012_7Oct2013.xls" (see English et al. 2012 and English 2013 for details.

5. Additional Information. Short bulleted descriptions of additional information about the CU. This may include:

- a description of the information quality regarding escapement, catch, age composition, and productivity estimates for this CU;
- historical events that likely affected abundance or productivity;
- current level of enhancement or enhancement related issues;
- the most likely limiting factors and/or habitat concerns;
- references to any recovery plans in place or under development; and
- recent exploitation rates (ERs) and any management measures taken to reduce ERs.

The intent of this section is to capture any relevant information or insights, which are not captured within the Snapshot. This additional information was compiled by ESSA Technologies Ltd. and has not undergone a formal review process. **Data sources:** Narrative content provided by Skeena regional experts for this project.

6. Spawner surveys. All spawning streams within the CU which are identified in the nuSEDS database. Streams are roughly ordered from west to east and correspond to the numbers shown on the detailed location map (Section 4). Black and white circles represent those years which are greater than or less than the stream's geometric mean for all years. The geometric mean is used here because, unlike the arithmetic mean, it is not inflated by the less frequent, higher abundance years, a characteristic of many salmon time series. **Indicator streams** that are highlighted in blue have a corresponding **survey quality code** which provides a qualitative ranking of the quality of spawner estimates within the stream in recent years:

INDICATOR Stream Survey Quality Code:

1 - Poor: an estimate with poor accuracy due to poor counting conditions, few surveys (one or two in a given year), incomplete time series, etc.;
2 - Fair: an estimate using two or more visual inspections that occur during peak spawning where fish visibility is reasonable; methodology and data quality varies across the time series in terms of good to poor quality;
3 - Good: four or more visual inspections with good visibility;
4 - Very Good: an estimate of high reliability using mark recapture methods, DIDSON methods, or near-complete fence counts that have relatively high accuracy and precision. Visual surveys that have been calibrated with local fence programs;
5 - Excellent: an unbreached fence estimate with extremely high accuracy given an almost complete census of counts.

Though the quality of spawner estimates may have changed through time only a single data quality estimate is available. In a few cases the number of survey streams is too great to illustrate on a single page. In these cases the figure is continued on subsequent pages. **Data sources:** nuSEDs, as reported in "NCCC_Streams1950-2012_7Oct2013.xls" (see English et al. 2012 and English 2013 for details). The CU to which a few survey streams were assigned was adjusted based on the advice from regional salmon experts.

7. Spawner and smolt abundance. Observed spawner counts represent the total number of spawners recorded in the nuSEDS database each year for most CUs. These are calculated by summing all spawners from all survey streams by year. A portion of the variability in these records results from the variability in survey effort. These observed counts are presented here to illustrate the raw data and extent to which expansion occurs, but are not used throughout the remainder of the CU Snapshot. **Estimated spawner abundance for the entire CU** represents a CU-level reconstruction of total spawner abundance. The reconstruction is based on (1) trends in escapement from indicators stream to infer trends for non-indicator streams of a CU (with at least one spawner estimate), (2) a correction for missing estimates from indicator streams, (3) an expansion to account for all streams of a CU and (4) a final expansion for observer efficiency (i.e., to account for the extent to which the methodology used to estimate spawner abundance may underestimate true abundance). This estimate of spawner abundance is used throughout the rest of the CU Snapshot. Estimated spawner abundance for the three wild Babine sockeye CUs (run timing groups) including Babine/Onerka (early), Nilkitwa (mid) and Tahlo/Morrison (late), and the Babine coho component of the Mid-Skeena coho CU are based on Babine fence counts not included in the nuSEDS database. **Smolt abundance** represents available data on smolt abundance for the CU. For CUs where smolt counts are available, it may be possible to estimate marine survival.

Pre-1985 Chinook records: The estimates of the total spawner abundance for a CU require: consistent monitoring of the indicator streams, an estimate of the portion that the indicator stream spawners represent of the total for all streams in that CU, and an adjustment for the observer efficiency for the indicator streams. For Skeena Chinook, the methods used to derive spawner abundance estimates for Chinook indicator streams (e.g., Kalum, Morice, and Bear) and coverage of Chinook spawning areas improved in the mid-1980's with additional funding provided through the Pacific Salmon Treaty. For most Skeena Chinook indicator streams, there is no basis for defining observer efficiencies prior to 1985.

Pre-1960 sockeye records: In contrast to Chinook, there has been more consistency in the distribution and quantity of monitoring effort for Skeena sockeye CUs back to 1960. The time series for Skeena sockeye CUs starts in 1960 because this was the first year of pre-1982 run reconstruction analysis (Les Jantz, DFO, pers.comm.). The fact that a large portion of Skeena sockeye have been enumerated at the Babine fence since 1949 provides greater confidence in the annual escapement estimates for sockeye than for Skeena Chinook in the 1960-1984 period. **Data sources:** Observed spawner counts: nuSEDs, as reported in “NCCC_Streams1950-2012_7Oct2013.xls” (see English et al. 2012 and English 2013 for details). Estimated spawner abundance for entire CU: updated from English et al. 2012 ("TRTCEstimates_Output_[SX/PKo/PKe/CO/CN/ CM]_20130827.xlsx"). Smolt abundance: based on estimates reported in Fernando 2012, Kingston 2012 and Cox-Rogers and Spilsted 2012.

8. Catch and run size. Run size refers to the total number of recruits (i.e., estimated spawner abundance plus estimated catch from marine US and Canadian commercial fisheries as well as in-river fisheries). **Exploitation rates** and catch are estimated in different ways depending on the species but generally consists of some combination of estimates of catch, harvest rate-effort relationships, species and CU specific run-timing, and coded wire tag recoveries from indicator stocks. When exploitation rates are low and run size remains low, it suggests that exploitation is not maintaining abundance at low level, instead either freshwater or marine factors may be suppressing the population. **Data sources:** Estimates of CU-level catch and exploitation updated from English 2013 ("TRTCEstimates_Output_[SX/PKo/PKe/CO/CN/CM]_20130827.xlsx").

9. Trends in spawner abundance. A smoothed time series of estimated spawner abundance is plotted by calculating the generational average based on a sliding window the length of one generation (as specified in Section 3). A logarithmic scale is used to enable a linear trend in smoothed abundance to be estimated. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) uses trends in abundance over the last 3 generations (or 10 years, whichever is longer) as an indicator of risk category. Change in abundance over the entire time series provides a longer-term perspective of the trajectory of the CU and provides context for observed shorter term trends. Estimates of % change indicated in parentheses in the legend are raw estimates after being back transformed from the logarithmic scale. **Data sources:** Calculated for this project from estimates of CU-level spawner abundance updated from English 2013 ("TRTCEstimates_Output_[SX/PKo/PKe/CO/CN/CM]_20130827.xlsx").

Age Composition and Run Timing (10-11)

10. Age composition. Estimates of age composition are required to generate brood tables (i.e., to determine how to assign recruits to different brood years), which are required for stock-recruitment analyses. The most accurate brood tables are generated by using year- and CU-specific age composition. However in most cases year-specific data are not available and some approximation of age composition is necessary. **Approximations** are listed here from best to worst case scenarios:

- no approximation needed, use year and CU specific data;
- use an average of all years’ data from the CU of interest;
- use an average of all years’ data from nearby or similar CUs;
- use an average of all years’ data from all CUs with data; and
- no reasonable approximation possible, do not generate a brood table.

Which of these approximations was used for the profiled CU is indicated in the figure by the placement of the blue box. (The absence of a blue box indicates that no reasonable approximation was possible and a brood table was not generated.) It is important to note that the practice of using a single average age composition in stock recruitment analyses could result in biases in the recruitment estimates. In most cases, these biases are expected to lead to evaluating abundance and exploitation rate status as being better than they actually are. These biases are a concern for all Skeena Salmon CUs except for pink salmon (which all spawn at two years of age), the Babine system sockeye CUs (for which annual age data are available for every year), and possibly the Kalum-late Chinook CU (for which annual age data is available for returns from 1988 onwards). Wide variation in the extent of age-related bias among populations does not allow the computation of a reliable correction factor. See Korman and English 2013 for more information on potential bias in Skeena salmon status assessments due to lack of year-specific age composition data. **Data sources:** PADS database, as reported by LGL in "Age data summary 5Jan2012 Peacock Input+WD.xls" (see Korman and English 2013 for details) with additional information on age composition for Gitanyow (Kitwanga/Kitwancool) lake sockeye were provided by the Gitanyow Fisheries Authority.

11. Run timing. Estimates of peak timing of river entry for the different sockeye CUs were estimated from DNA sampled from fish caught in the Tyee test fishery near the mouth of the Skeena River between 2000-2010 (Cox-Rogers 2012a). The duration of the timing of river entry is assumed to have a bell-shaped curve (i.e., normal distribution) and so shape of the curves are defined by the mean and standard deviation of the available run timing data. However, in most instances there is insufficient data to determine if the shape of the curve would be better described by a different distribution. This is likely a reasonable approximation in most cases if the run timing is uni-modal (i.e., if there is a single peak in run timing). If the run timing is bi-modal (i.e., if there are two run timing groups) the assumption of spread is likely reasonable but the peak may be misleading.

Note that these run timing curves were only used to estimate exploitation rates for Skeena sockeye CUs and a conservative assumption of relatively broad run timing (80-110 days) for each sockeye CU was used so that exploitation rates would not be sensitive to small shifts in fishery timing. For some CUs run timing information is not available and for some species run timing is assumed to be the same for all CUs. **Data sources:** Table 3 in English et al. 2013 for sockeye and North Coast DFO for other species.

Productivity and Survival (12-16)

12. Rearing habitat capacity. For Skeena salmon, currently there are only habitat-based estimates of freshwater carrying capacity for a subset of lake sockeye CUs. Efforts are underway to develop estimates for Chinook and coho CUs. For **lake sockeye CUs** in the Skeena, a habitat-based photosynthetic rate model predicts the maximum number of smolts a given rearing lake should be able to produce (i.e., the **rearing capacity**). Independent estimates of sockeye smolt biomass from hydroacoustic surveys over the past decade can then be compared to the modeled rearing capacity to evaluate the extent to which the productive capacity of the lake is being realized. Note that estimates of rearing habitat capacity are not presented for wild Babine CUs because of the extent to which multiple CUs share Babine lake for rearing. For some CUs rearing habitat capacity information is not available. **Data sources:** Hydroacoustic surveys as reported in table 2 of Cox-Rogers 2012b.

13. Stock-recruitment relationship. The number of adult salmon (recruits) produced for a given spawner abundance is a fundamental relationship in fisheries ecology. In salmon, the stock-recruit relationship is typically assumed to be best described by the **Ricker model**, which allows for a density dependent relationship.

Ricker model:

$$R_{i,t} = S_{i,t} exp(\alpha_i - \beta_i S_{i,t})$$

- R_t is the number of recruits for brood year t
- S_t is the number of Spawners in brood year t
- α is the log of the initial slope or the recruitment in absence of density dependence
- β is the density dependent term
- i indicates the CU, and therefore α and β are CU-specific parameters

Data source and analytical approach: A hierarchical Bayesian approach was used to simultaneously fit the Ricker model for all Skeena CUs within a species (Korman and English 2013). This approach assumes the α_is are not independent and are derived from a common distribution $\alpha_i \sim lognormal(\mu_\alpha, \sigma_\alpha)$ and allows information from other CUs to be shared particularly when there are limited data or high uncertainty. For lake sockeye, CU-specific informative priors based on rearing capacity estimates were used for β_i. Where brood tables could not be generated, this analysis could not be completed.

14. Marine survival. Marine survival can be estimated in CUs where: a) estimates of smolt abundance (e.g., from smolt traps) and adult recruits are available, or b) in CUs where coded wire tags are placed in out-migrating smolts and recovered from returning spawners. Estimates of survival broken down by life stage through time can provide valuable insight into the mechanisms influencing the overall productivity of a CU. For example, if overall productivity is declining but marine survival is stable or increasing, it is likely that pressures during the freshwater rearing phase are driving the decline in productivity. **Data sources:** Marine survival estimates were provided by North Coast DFO (Late-timing Kalum Chinook and Middle Skeena coho), the Gitanyow Fisheries Authority (Gitanyow/Kitwanga and Slamgeesh sockeye) or as reported in Cox-Rogers and Spilsted 2012 for Babine sockeye (aggregate of Nilkitkwa, Tahlo/Morrison and Babine CUs).

15. Recruits per spawner. The number of recruits (adult fish produced per spawner in the previous generation) plotted by brood year. Recruits, like spawner abundance, tend to have skewed distributions so it is not unexpected to find that deviations above the replacement line (1:1) are greater in magnitude than deviations below the replacement line. For some CUs extreme values lie beyond the range of the y-axis and so are not shown.

16. Productivity indices. Derived from two-different stock-recruitment approaches. As described for Section 13 (above), the **Ricker model** uses a single estimate of α for all years for a given CU. The second index illustrated in this figure (**Kalman**) is an extension of the Ricker index that incorporates a second time-dependent parameter for α. The form of this time dependence is an auto-regressive, order 1 (AR-1), in other words it assumes that the value of alpha in year t is related to the value of alpha in year t+1. The new form of the model is:

Time-varying Ricker model:

$$R_{i,t} = S_{i,t} exp\left(\alpha_{i,t} - \beta_i S_{i,t}\right)$$

$$\alpha_{i,t} = \alpha_{i,t+1} + w_{i,t}$$

- R_t is the number of recruits for brood year t
- S_t is the number of spawners in brood year t
- $\alpha_{i,t}$ is the recruitment in the absence of density dependence in each year, which is composed of the previous years estimate plus random variation (w_t) which is assumed to be normally distributed with a mean of 0.
- β is the density dependent term
- i indicates the CU, and therefore α, β and *w* are CU specific parameter

When the time-varying Ricker model was fit to the stock-recruitment data, a **Kalman filter** (Peterman 2003) was applied to remove high-frequency year-to-year variation in productivity (i.e., to smooth the time series) thereby making any long-term trends that may exist in the time series easier to see.

The points labeled '**Ricker**' were derived by taking the difference between the points shown in the stock-recruitment curve (Figure 13) and subtracting the predicted value (solid line) for the corresponding x-value (note that this occurs on the log scale). The points labeled '**Kalman'** are standardized estimates of $\alpha_{i,t}$ derived by fitting the revised model on the log scale using Maximum Likelihood methods with independent estimates of α_t and w_i for each CU (i.e., not a hierarchical Bayesian approach). The mathematical details of the Kalman filter estimation method are described in the appendices of Peterman et al. 2003 and Dorner et al. 2008. For some CUs extreme values lie beyond the range of the y-axis and so are not shown.

Status and Benchmarks (17-19)

17. Status metrics and benchmarks. Canada's Wild Salmon Policy (FOC 2005) states that CUs will be assessed against specific reference points, or benchmarks, for indicators such as spawning abundance or fishing harvest rate. For each CU, a higher and a lower benchmark are to be defined so as to delimit 'green', 'amber', and 'red' status zones. As numbers of spawning salmon decrease, a CU moves towards the lower status zones and the extent of management actions directed at conservation should increase. The status of an indicator does not dictate that any specific action must be taken, but instead serves to guide management decisions in conjunction with other information on habitat, ecology, and socioeconomic factors. Four classes of indicators have been recommended for evaluating status: current spawner abundance, trends in spawner abundance, geographic distribution of spawners, and fishing mortality (Holt et al. 2009). Given the data availability for Skeena CUs, we present only a subset of the possible status metrics and benchmarks options from three of these indicator classes. Note that the benchmark options presented do not determine which benchmarks should be used for assessing Skeena CUs as that is the responsibility of DFO in consultation with First Nations and other affected parties. The benchmark options included here are:

- **Stock-recruitment:** As shown in Figure 1, the shape of the stock-recruitment relationship can be used to derive benchmarks, including S_{msy} and S_{gen1}. $\mathbf{S_{msy}}$ is the spawner abundance corresponding to the maximum sustainable yield (MSY), where MSY is defined as the largest long-term average catch or yield that can be taken from a stock under constant environmental conditions (Korman and English 2013). $\mathbf{S_{gen1}}$ is the spawner abundance that will result in recovery to Smsy in one generation in the absence of fishing under equilibrium conditions (Korman and English 2013, Holt et al. 2009). See Korman and English 2013 for a discussion of uncertainty and possible biases in benchmarks and status assessments derived from stock-recruit models.
- **Historic spawners:** 25% and 75% historic spawners correspond to the 25^{th} and 75^{th} percentile of historic spawner abundance (i.e., the abundance which 25% and 75% of the historic spawner abundance observations fall below, respectively) (Spilsted and Pestel 2009).
- **Habitat capacity:** Benchmarks are based on 15% and 55% of S_{max}, where $\mathbf{S_{max}}$ is the spawner abundance that is expected to produce the maximum number of juveniles that the rearing habitat can support, based on models of rearing habitat capacity (Cox-Rogers 2012b). These benchmarks have been suggested by Cox-Rogers 2012b to be roughly equivalent to S_{gen1} and S_{msy}. S_{max} has been estimated for many Skeena sockeye CUs based on a photosynthetic rate (PR) model of sockeye rearing lakes (Table 1 in Cox-Rogers 2012b).

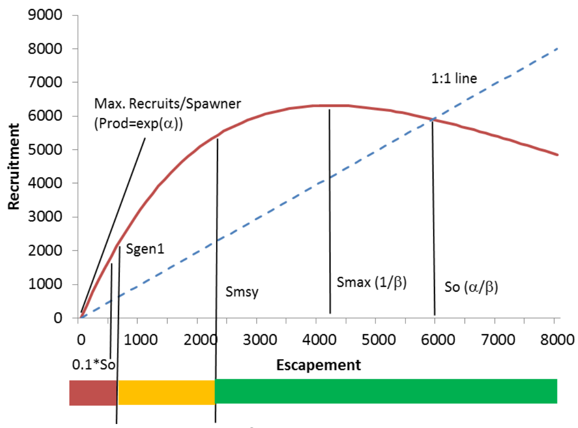

Figure 1. Reproduced from Korman and English 2013.

- **Spawner ratio:** Ratio is calculated from current spawner abundance (geometric mean escapement for the four most recent years of data) vs. geometric mean long-term spawner abundance calculated from all available data (Pestal and Cass 2009).
- **Trends in spawners:** 15% and 25% decline over 3 generations (Holt et al. 2009). A smoothed time series of estimated spawner abundance (log scale) is plotted by calculating the generational average based on a sliding window the length of one generation. A logarithmic scale is used to enable a linear trend in smoothed abundance to be estimated by Bayesian linear regression. Estimate of % change and 95% credible intervals are back transformed from the logarithmic scale.
- **Exploitation rate:** U_{opt} is the exploitation rate that maximizes long-term fishing yield, as estimated from the stock-recruitment model. See Korman and English 2013 for a discussion of uncertainty and possible biases in benchmarks and status assessments derived from stock-recruit models.

18. Current status summary. For **stock-recruitment** status, the percentage in each coloured box is the probability (%) of a given status based on the benchmarks (S_{gen1} and S_{msy} values) estimated from a Hierarchical Bayesian Model (HBM). For **trends in spawners**, the percentage in each coloured box is the probability of a given status where the 2008-2012 average spawner abundance is compared to 50% and 75% of the long-term average spawner abundance. For **exploitation** status, the probability that the average exploitation rate falls above U_{opt} (red status) or below U_{opt} (green) was generated by comparing the average exploitation rate for 2006-2010 to the U_{opt} values from a Hierarchical Bayesian Model (Korman and English 2013). For CUs where the status is not available for most metrics, additional caution should be used making any conclusions about status.

19. Spawner abundance in relation to benchmarks. Upper and lower benchmarks for three status metrics are superimposed over a time series of spawner abundance estimated for the entire CU, providing a general picture of how the status of these metrics has varied over the long term.

Habitat: Overview of CU Vulnerabilities and Pressures (20-24)

20. Migration habitat pressures (lake sockeye); Rearing/migration habitat pressures (other species). Detailed map of the CU's migration 'zone of influence' (ZOI) (lake sockeye) or rearing/migration zones of influence (ZOI) (other species) showing cumulative risk scoring. The location of water licenses occurring within migration corridor ZOI watersheds, and the locations of identified obstructions along the CU migration route are also shown for lake sockeye CUs.

- **Impact Categories:** hydrologic processes, vegetation quality, surface erosion, fish passage/habitat connectivity, water quantity, human development footprint, and water quality. **Data sources:** cumulative risk scoring (Porter et al. 2013).
- **Obstructions.** Obstructions can directly impede, delay, or even block passage of adult migrating salmon. **Data sources:** Provincial Obstacles to Fish Passage [updated daily – Downloaded Dec 2012].

- **Licensed water allocations.** 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. **Data sources:** BC POD with Water License Information [updated daily – Downloaded Dec 2012].

21. Summary of pressure indicators

Rearing (lake sockeye). 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[1]. The greyed areas within the figure represent the separation of the individual indicators into the seven Impact Category groupings. **Data sources:** Porter et al. 2013.

Spawning (other species). Area weighted average of all watershed pressure indicator scores for 1:20K FWA assessment watersheds within or intersecting the CU's spawning 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[2]. The greyed areas within the figure represent the separation of the individual indicators into the seven Impact Category groupings. **Data sources:** Porter et al. 2014.

22. Cumulative pressure

Spawning and rearing (lake sockeye). Map of cumulative risk from habitat pressures for each watershed found with the zones of influence (ZOI) for CU rearing lakes and tributary spawning areas[3]. 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 and spawning ZOIs: 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). **Data sources:** Porter et al. 2013.

Spawning (other species). Map of cumulative risk from habitat pressures for each watershed found with CU spawning ZOIs[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 spawning ZOIs: 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). **Data sources:** Porter et al. 2014.

23. Integrated vulnerability and habitat pressures

Rearing, migration, and spawning (lake sockeye). 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 assessing CU cumulative habitat pressures and vulnerabilities are different for each life stage evaluated (see Porter et al. 2013). 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. **Data sources:** Porter et al. 2013.

Incubation, rearing/migration, and spawning (other species). Figures representing bivariate indices of the relative rankings across CUs of this species for scored cumulative habitat pressures and scored vulnerability to these pressures within CU ZOIs for incubation, rearing/migration, and spawning. Methods used for assessing scored CU cumulative habitat pressures and vulnerabilities are described in Porter et al. 2013. The larger solid blue circle in each figure represents the ranking of the particular CU relative to the other Skeena CUs of this species and identifies its ranked position relative to a coloured gradation representing both increasing cumulative habitat pressure and

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

[3] 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.

7

increasing vulnerability to those pressures. **Data sources:** Porter et al. 2014.

24. Proposed development projects (as of 2010). Skeena overview map of the locations of new resource development projects proposed within the Skeena drainage (across a range of activities). The table shows the total number or extent of resource development related projects that are known to be proposed for future development within watersheds affecting the CU, and the potential percentage increase in these pressures (if any) over the current baselines. **Data sources:** Porter et al. 2013, extracted from multiple sources.

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Acknowledgements

The Pacific Salmon Foundation and ESSA Technologies Ltd. would like to sincerely thank the numerous individuals who volunteered their time to provide feedback, data and insights into the salmon of the Skeena watershed. Without their contributions this project would not have been possible. A complete list of individuals who contributed to this project is provided in the main report (Skeena Salmon Conservation Unit Snapshots, Connors et al. 2013).

This project is funded by the Gordon and Betty Moore Foundation

Appendix 4. Example CU snapshot for the Lakelse lake sockeye CU

SKEENA SALMON PROGRAM

Version 1.0. December 19, 2013

Skeena Salmon: Lake Sockeye
Conservation Unit Snapshot
Lakelse

PACIFIC SALMON FOUNDATION

Introduction

This Conservation Unit Snapshot ('CU Snapshot') is part of a 2013 project that summarizes key population and habitat information for Skeena salmon CUs. These Snapshots are intended to serve as a reference document to assist discussions about the state of salmon and their habitats. For data sources and a more detailed explanation of each figure, please see the accompanying 'CU Snapshot Quick Reference' booklet. Full methods can be found in the main report, 'Skeena Salmon Conservation Unit Snapshots'.

CU snapshot information roadmap

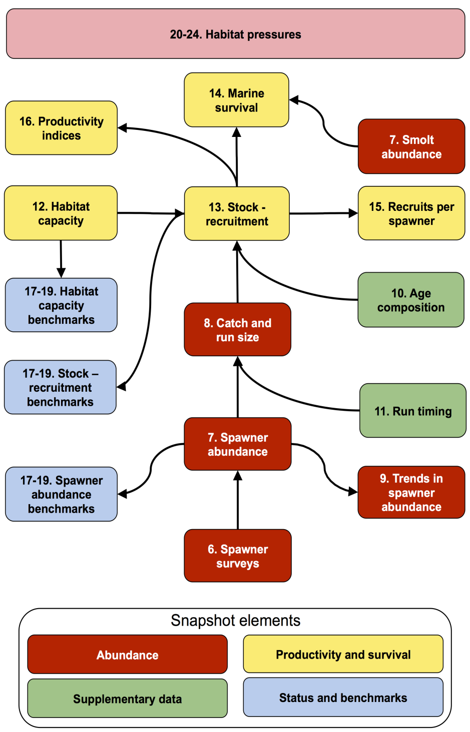


Figure 1. *This roadmap summarizes the types of information included in the following pages of the CU Snapshot. Arrows show the flow of information from raw data towards more complicated elements that are estimated based on one or more information inputs. For example, 'stock–recruitment' can't be estimated without information about 'age composition' and 'catch and run size', and also all of the information that flows into 'catch and run size'. Estimates such as 'stock–recruitment' that require many inputs are less likely to be available for all CUs and may be more uncertain as they incorporate uncertainty from multiple sources.*

Location of this CU

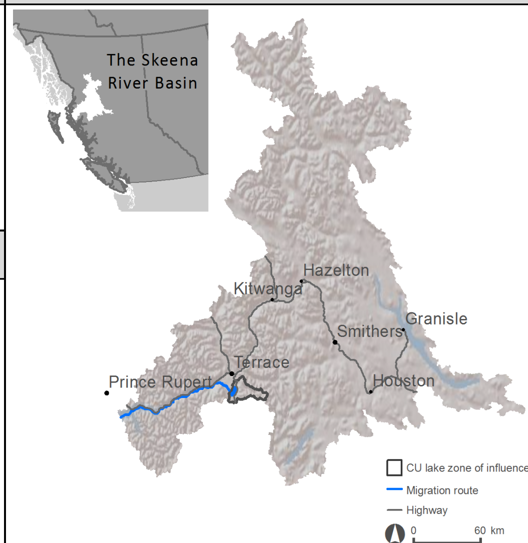


Figure 2. *Location of this CU within the Skeena watershed.*

Glossary

Benchmark: A standard or point of reference against which condition can be compared.

Brood Year: Information in this report is often organized by 'Brood Year', the year in which each individual fish was spawned.

Conservation Unit (CU): A geographically, ecologically and genetically distinct population of wild Pacific salmon.

Productivity: The ability of a salmon population to sustain itself, often defined as the number of adult fish produced per spawner.

Recruit: A salmon that survives to maturity is considered a 'recruit' from its parent generation, or 'Brood Year'. Fish harvested as adults are still considered recruits.

Smolt: A young salmon which has survived the early stages of development: incubation as an egg, emergence as an alevin and freshwater rearing as a fry. It undergoes the necessary changes to transition from freshwater to the ocean, and will migrate to the ocean during this life–stage.

Spawner: Adult salmon that successfully migrate from marine to freshwater spawning grounds and have the opportunity to reproduce, avoiding natural mortality and harvest.

Status: Condition of a metric relative to a defined benchmark.

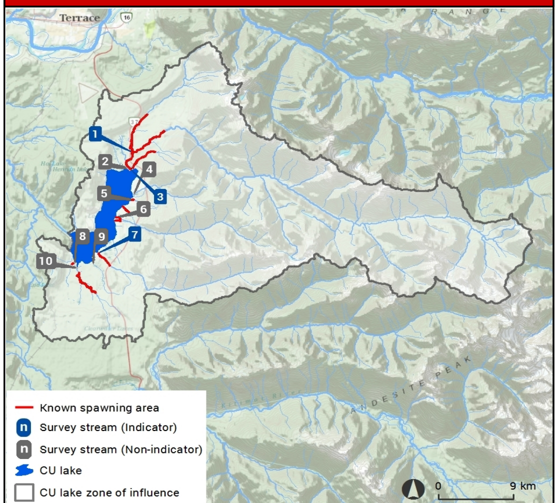
Zone of Influence (ZOI): Areas upstream or adjacent to habitats used by salmon during the various life stages (e.g., migration or spawning). ZOIs represent the geographic extent for measurement of habitat pressure indicators.

Sockeye – Lakelse

3. Summary statistics

Number of survey streams	10
Number of indicator streams	3
Maximum estimated spawners (1965)	87,341
Minimum estimated spawners (1990)	2,677
Generation length	5 years

4. Location



Location of spawning areas and spawner surveys. Indicator streams have relatively consistent survey effort over time and often represent streams with more spawners. Non–indicator streams have been surveyed less frequently and often represent a smaller portion of the population. The remaining streams have no survey data.

5. Additional information

Information quality is generally good. Multiple historic sockeye counting fences have operated periodically on Williams, Scully, and Sockeye creeks; DNA data from Tyee Test fishery have been used to estimate run timing and derive annual estimates of catch and exploitation rate.

Records of observed spawners date back to the mid–1930s. It has been suggested that spawner levels crashed in the mid–1940s, and since then, have been low relative to historic levels.

The Lakelse Lake Sockeye Recovery Plan has been active and functioning since 2003 with both habitat rehabilitation and stock rebuilding components.

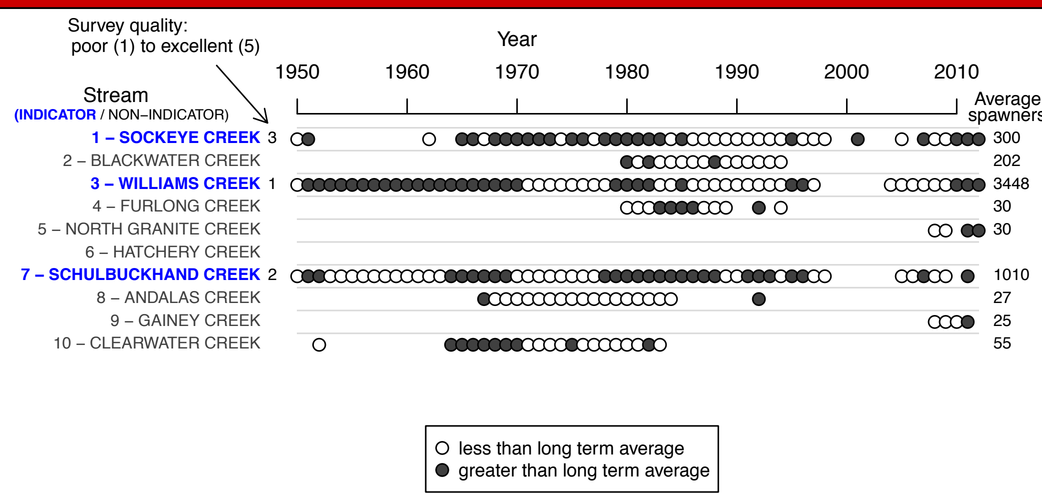
Hatchery enhancement occurred at: Coldwater Creek from 1901–1920, Hatchery Creek from 1921–1936, and Scully Creek from 1960–1966. From 2006 to 2014, Williams Creek sockeye have been enhanced with approximately 300,000 fry released annually in Williams Creek using Snootli hatchery for incubation and rearing.

Significant migration habitat issues to the spawning tributaries for Lakelse CU (e.g., barriers, low water conditions, beaver activity).

This CU's run timing is one of the earliest of the Skeena sockeye CUs; fishing pressure on early timed stocks has been consistently lower than for middle and late timed stocks to minimize catch of the Morice (Nanika) sockeye CU.

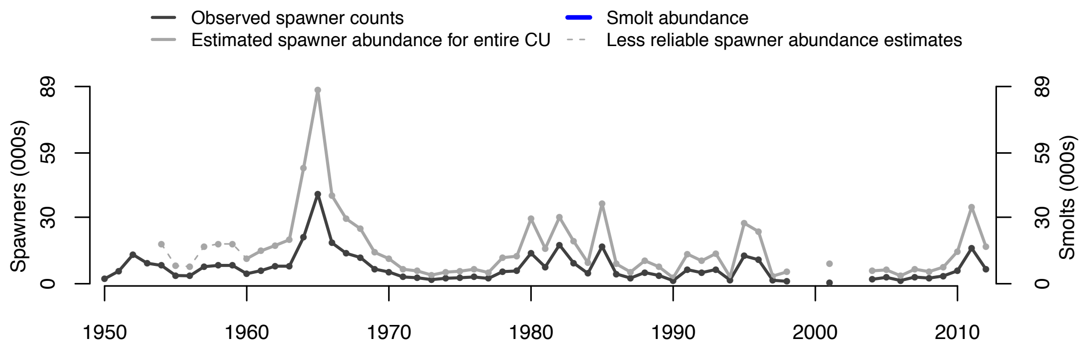
Additional information for this CU provided by Skeena salmon experts and compiled by ESSA Technologies Ltd.

6. Spawner surveys



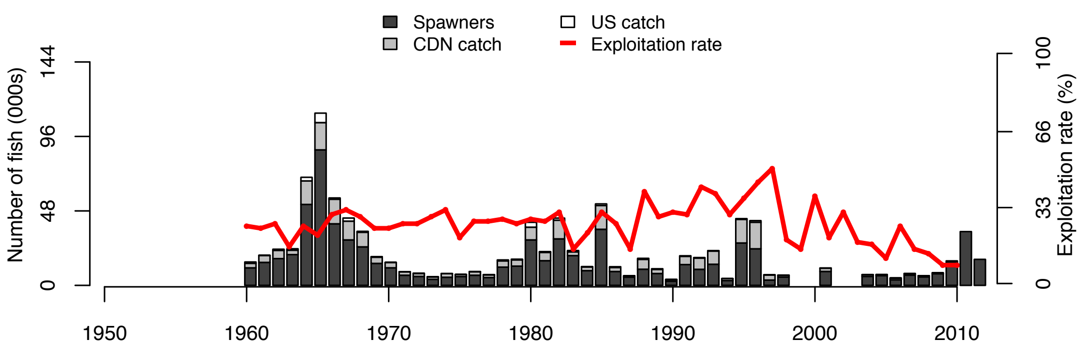
Past spawner surveys for this CU. Circles represent a survey for a given stream and year. The more complete the spawner surveys are across streams and years, the more reliable the estimated spawner abundance for the entire CU will be.

7. Spawner and smolt abundance



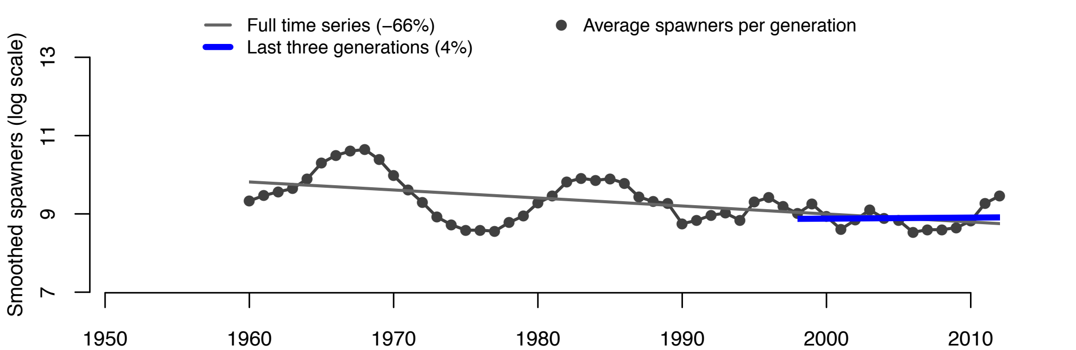
Observed counts represent the number of spawners recorded by stream surveys each year. The estimate for the entire CU is usually higher than the observed count since it accounts for streams that aren't surveyed that year, any estimates prior to 1960 are considered less reliable. The greater the difference between the two lines, the more caution should be used in interpreting results shown below, such as metrics of the CU's status. Smolt abundance is plotted when available.

8. Catch and run size



Run size is the total number of adult fish returning from the ocean in a given year, including those that reach the spawning grounds as well as fish captured in US and Canadian fisheries. The exploitation rate is the percent of the run that is captured in fisheries.

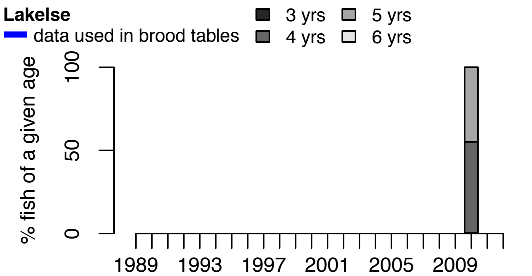
9. Trends in spawner abundance



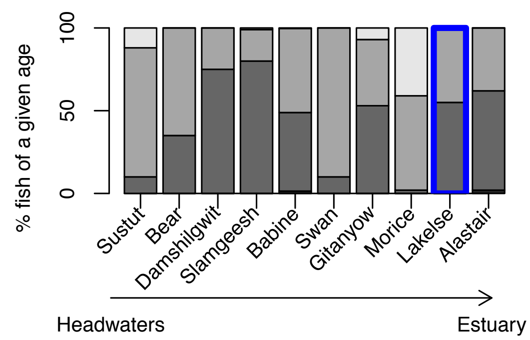
Plotting the running average of spawner abundance removes excess year–to–year variability making it easier to see whether or not there are any notable long–term or recent trends. The trend in abundance over the past 3 generations (or 10 years) is used as a measure of conservation status by some organizations, including the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Sockeye – Lakelse

10. Age composition

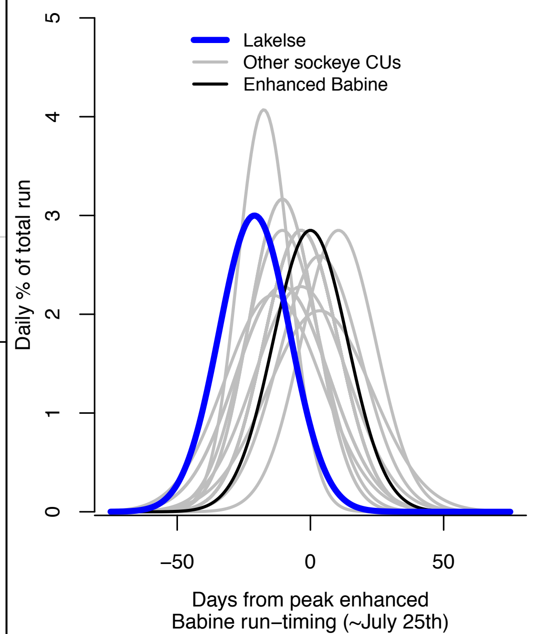


Estimated age composition of this CU's spawning fish shown for all years with data. Salmon vary in the age at which they mature and return to spawn, so that each year's spawners can be a mixture of fish of varying age.



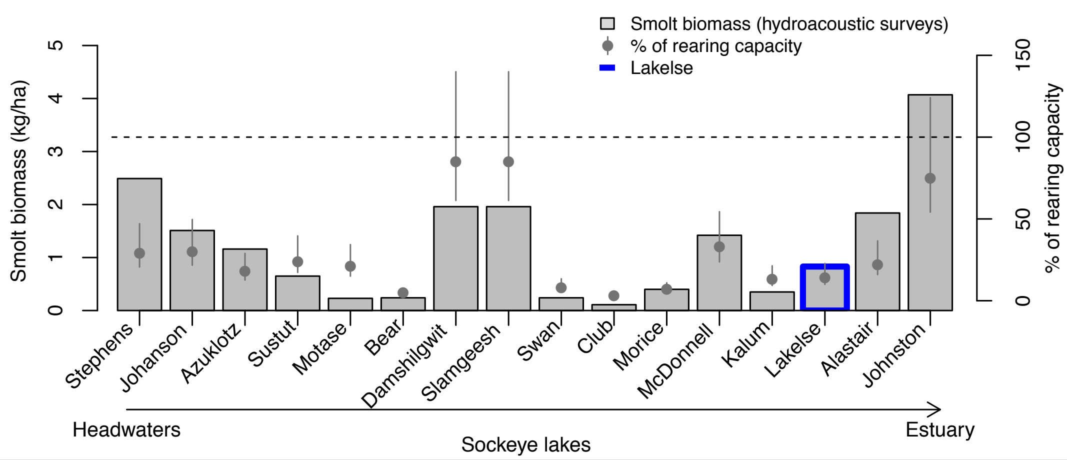
Variation between CUs in average age composition across all years with data. Yearly age composition is a key input for stock–recruitment analyses. Lack of data often requires using average age composition or data from other CUs; this can lead to biased stock–recruitment analyses and status assessments.

11. Run timing



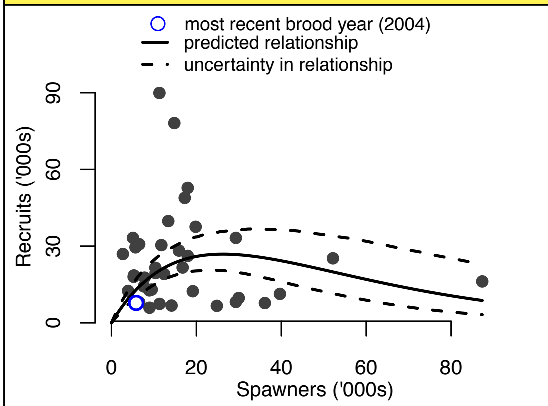
The curves show the average time of year at which fish from each CU enter the Skeena river as they return to spawn. The main target of commercial marine fisheries is the enhanced Babine sockeye CU. Spawners from other CUs whose river entry timing is most similar to that of enhanced Babine sockeye may be more vulnerable to incidental capture in these fisheries.

12. Rearing habitat capacity



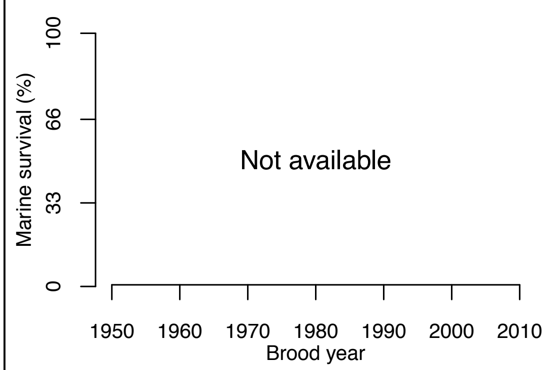
Comparing the capacity of the rearing habitat to the actual number of smolts present shows whether the rearing habitat is limiting the size of the CU's population. For CUs where less than 100% of the rearing capacity is being used, this suggests that the rearing habitat capacity is not limiting the population.

13. Stock–recruitment relationship



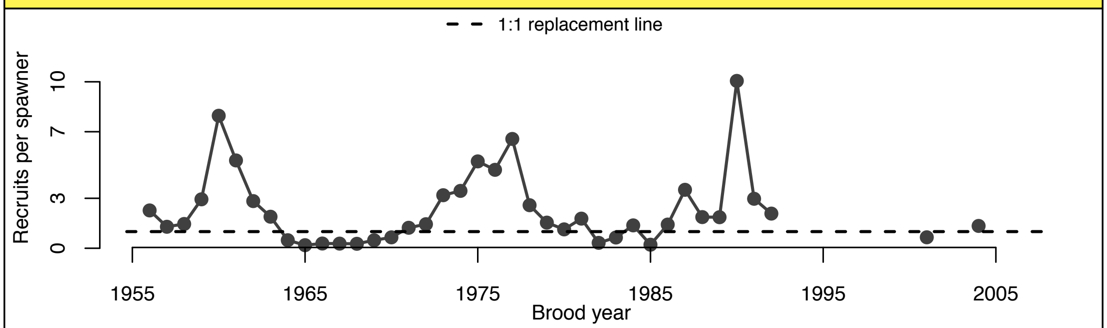
The curve shows the number of individuals in one generation ("recruits") that are expected to be produced by a given number of spawners in the previous generation. The farther apart that the dashed lines are from the solid line, the less certain the relationship is, and the more caution should be used in interpreting results that rely on this information, such as productivity indices and status metrics.

14. Marine survival



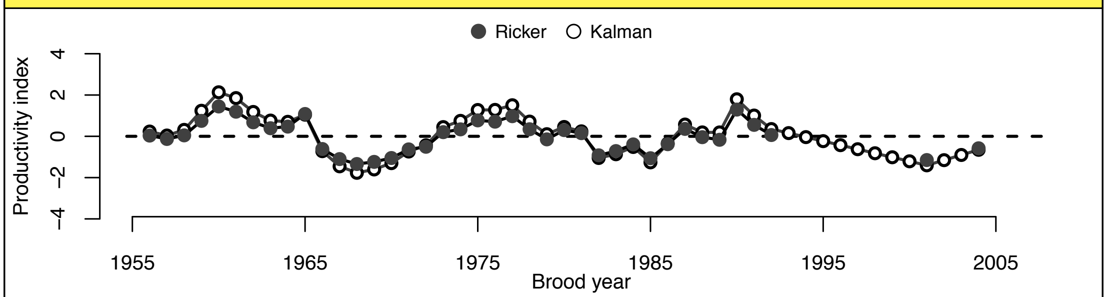
The number of returning adult fish can be compared to the number of smolts that migrate out to the ocean to determine what percentage survive from smolts to adult in the marine environment. Declining marine survival suggests that conditions in the marine environment are reducing survival.

15. Recruits per spawner



Changes in the number of recruits per spawner reflect changes in overall survival from egg to mature adult. Declining recruits–per–spawner show that survival is decreasing but cannot show whether the change is taking place in either freshwater, the ocean, or both. Values less than one (below the dashed line) indicate the population did not replace itself in that year.

16. Productivity indices



Two indices of productivity are shown. Values less (or greater) than zero in the first index of productivity (Ricker) are years when the CU has produced fewer (or more) adult fish than expected based on the stock–recruitment relationship. A second index of productivity (Kalman), which allows the stock–recruitment relationship to change over time, can be compared to the first. If the two lines are different it may mean that productivity is changing over time. A smoothing technique (Kalman filter) was also applied to the second index to make it easier to detect any persistent changes over time.

Sockeye – Lakelse

17. Status metrics and benchmarks

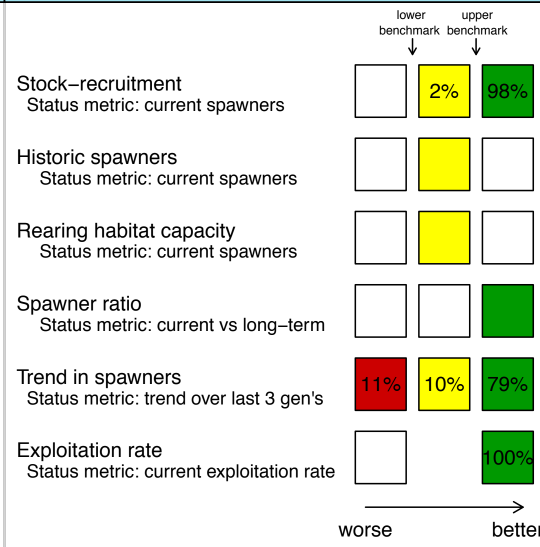
Status metrics: current values (95% C.I.)

Current spawner abundance (2008–2012)	15,787
Current vs. long–term spawners	1.4
Trend in spawners (past 3 gen's)	4% (−39%, 80%)
Exploitation (2006–2010)	9%

Benchmark values (95% C.I.)

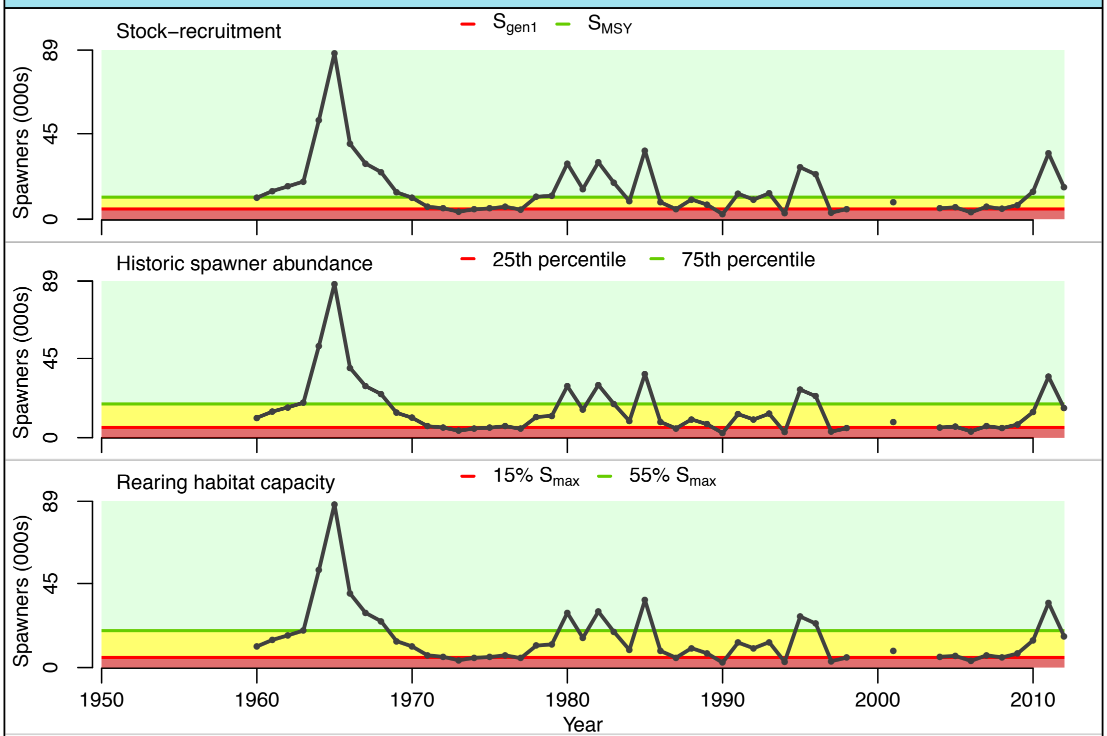
Stock–recruitment	
Lower: S_{gen1}	5,355 (3,382, 7,702)
Upper: S_{MSY}	11,602 (8,798, 15,380)
Historic Spawners	
Lower: 25% historic spawners	5,811
Upper: 75% historic spawners	19,154
Rearing habitat capacity	
Lower: 15% Habitat S_{MAX}	5,387
Upper: 55% Habitat S_{MAX}	19,754
Spawner ratio	
Lower: current vs. long–term spawners	50%
Upper: current vs. long–term spawners	75%
Trend in spawners	
Lower: decline over 3 generations	25%
Upper: decline over 3 generations	15%
Exploitation rate	
Single benchmark: U_{opt}	44% (32%, 55%)

18. Current status summary



Current values for a range status metrics (left top) compared to possible benchmarks (left bottom) with results summarized in a colour–coded display (right). When the status is available for most metrics and is consistent across metrics, there is greater certainty in interpreting integrated CU status. When there are conflicting results (e.g., different colours across the metrics) the interpretation of CU status is more complicated. Numbers within the squares show the % chance of being a given status, when this information is available.

19. Spawner abundance in relation to benchmarks

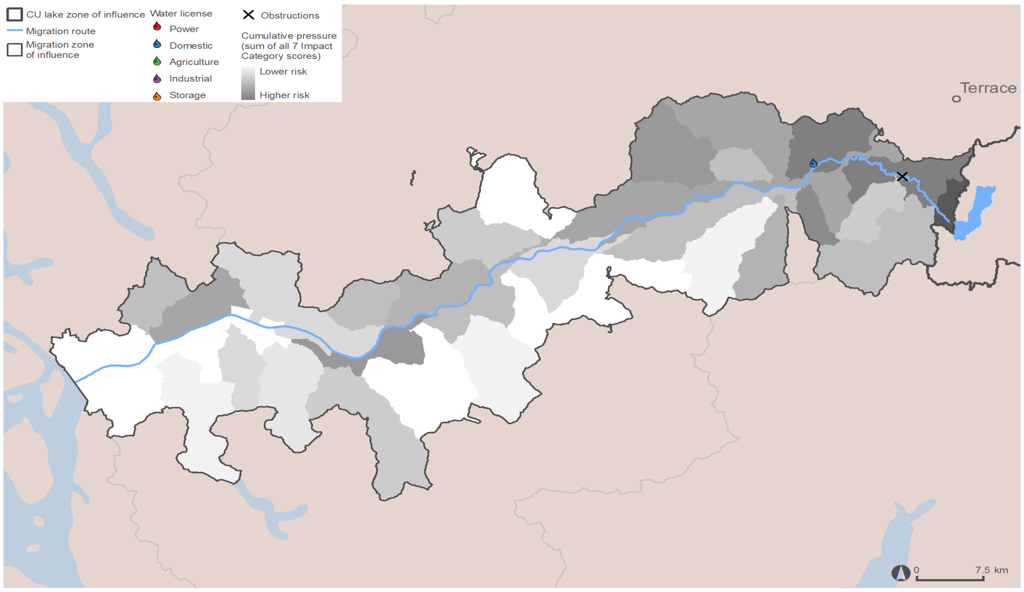


Spawner abundance over time in comparison to upper and lower benchmarks for three status metrics.

Sockeye – Lakelse

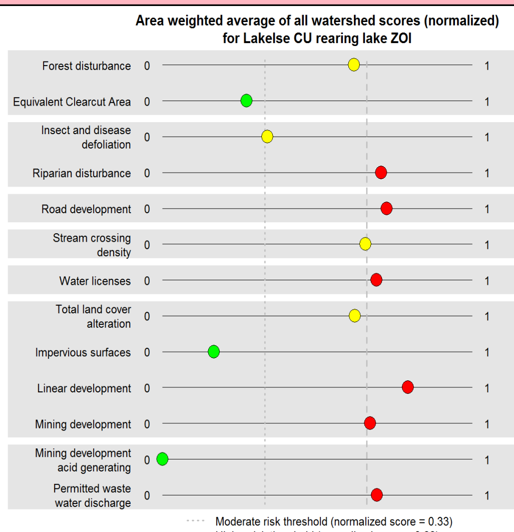
HABITAT: Overview of Sockeye – Lakelse CU Vulnerabilities and Pressures

20. Migration habitat pressures



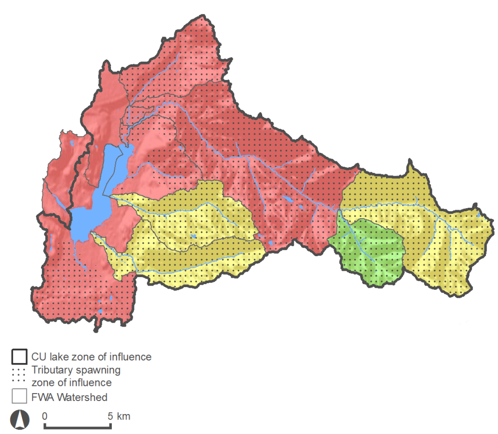
Map of cumulative habitat pressures for watersheds located along the CU's migration corridor zone of influence. Darker–shaded watersheds represent areas where relatively higher risk habitat impacts may be occurring. Location of water licenses and known obstructions are also shown.

21. Summary of pressure indicators: rearing



Risks to watersheds influencing this CU's rearing lake summarized for 13 pressure indicators. Risk is shown by slider position (risk increasing from left to right) and colour (green=lower, amber=moderate, red=higher). Grey boxes group the indicators into related categories.

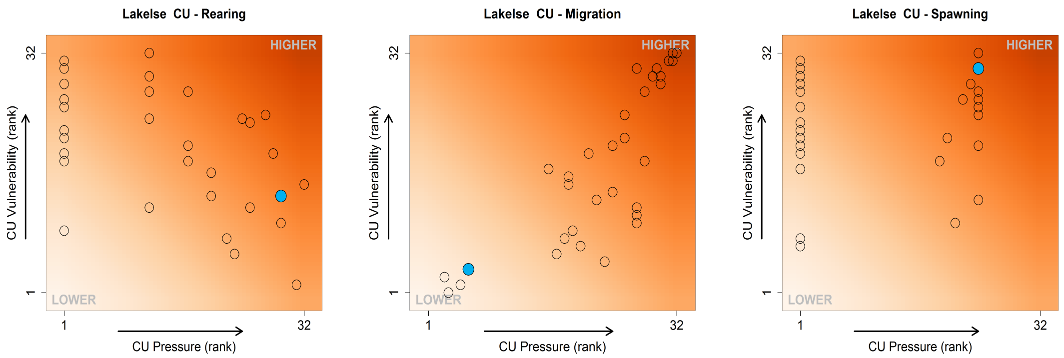
22. Cumulative pressure: spawning and rearing



Map of cumulative risk from habitat pressures for each watershed within the CU's spawning and rearing habitat zones of influence. Cumulative risk is categorized as relatively lower (green), moderate (amber), or higher (red).

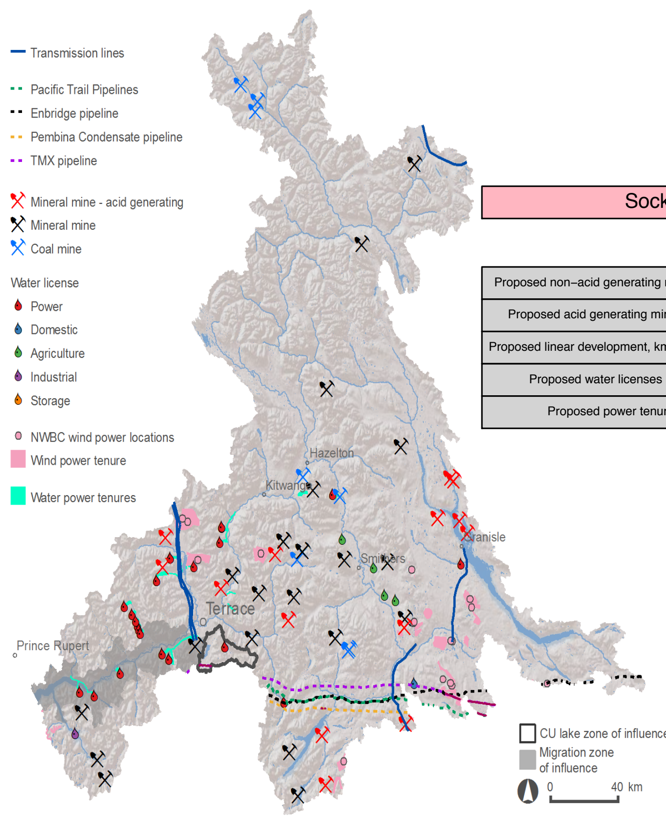
Sockeye – Lakelse

23. Integrated vulnerability and habitat pressures



The solid blue circle in each figure represents the ranking of the particular CU relative to all other Skeena lake sockeye CUs. Darker colour gradation represents increasing cumulative habitat pressure and increasing vulnerability to those pressures for the rearing, migration, and spawning life stages.

24. Major proposed development projects (as of 2010)



Sockeye – Lakelse CU summary

	Rearing	Migration	Spawning
Proposed non–acid generating mines (% increase)	0 (0%)	1 (10%)	0 (0%)
Proposed acid generating mines (% increase)	0 (0%)	0 (0%)	0 (0%)
Proposed linear development, km^2/km (% increase)	0.02 (1.13%)	0.01 (0.59%)	0.02 (1.13%)
Proposed water licenses (% increase)	2 (3.77%)	7 (19.44%)	2 (3.77%)
Proposed power tenures, km^2	0.00	38.25	0.00

Negligible values are rounded to zero

The map shows the locations of proposed new resource development projects across the entire Skeena River Basin as of 2010. The table summarizes the number or extent of these proposed developments within watersheds influencing this CU, and the potential increase over current baselines.

Sockeye – Lakelse

Appendix 5. Biological status summaries

Biological status metrics compared against six types of benchmark can be summarized using maps of the CUs in the Skeena watershed. For each CU, maps are colour coded to reflect the status zone of the metrics relative to their benchmarks (Figures 2-14). Color is based on the most likely status zone. For example, if there is a 20% chance that the status is red, a 20% chance that the status is amber and a 40% chance that the status is green, then a status of green is assigned. Each status figure is followed by a map which provides the names of the CUs shown in the preceding status figure.

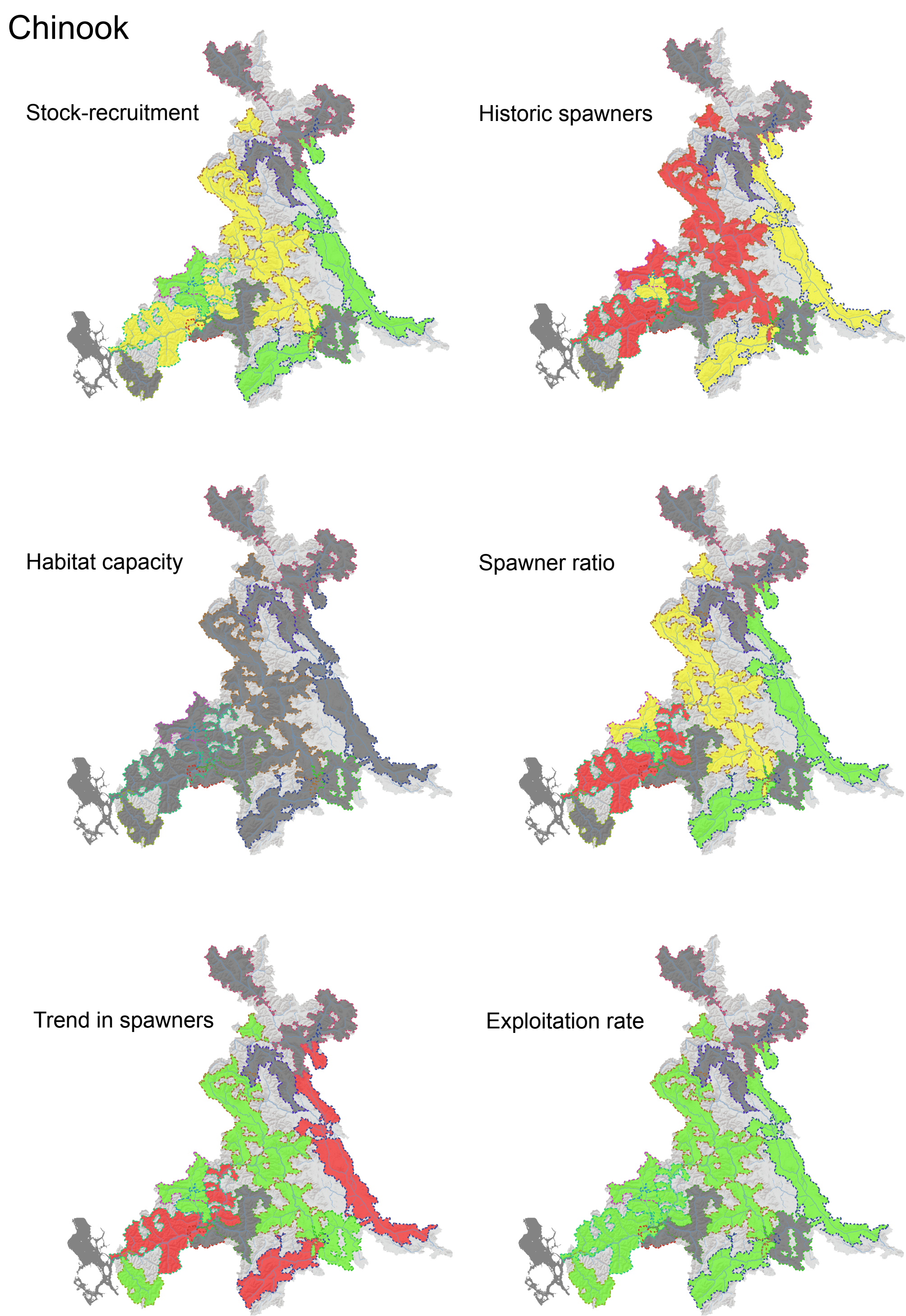


Figure 2: Chinook CU biological status metrics relative to benchmark values (denoted in top left of each map and described in Section 1.4 and the Quick Reference). Colors correspond to red, amber and green status zones, while grey indicates that the status for a given status metric-benchmark combination could not be assessed due to a lack of data. CU names are shown in Figure 3. These maps should be viewed together with the CU Snapshots, which contain important information about uncertainty and the time period assessed.

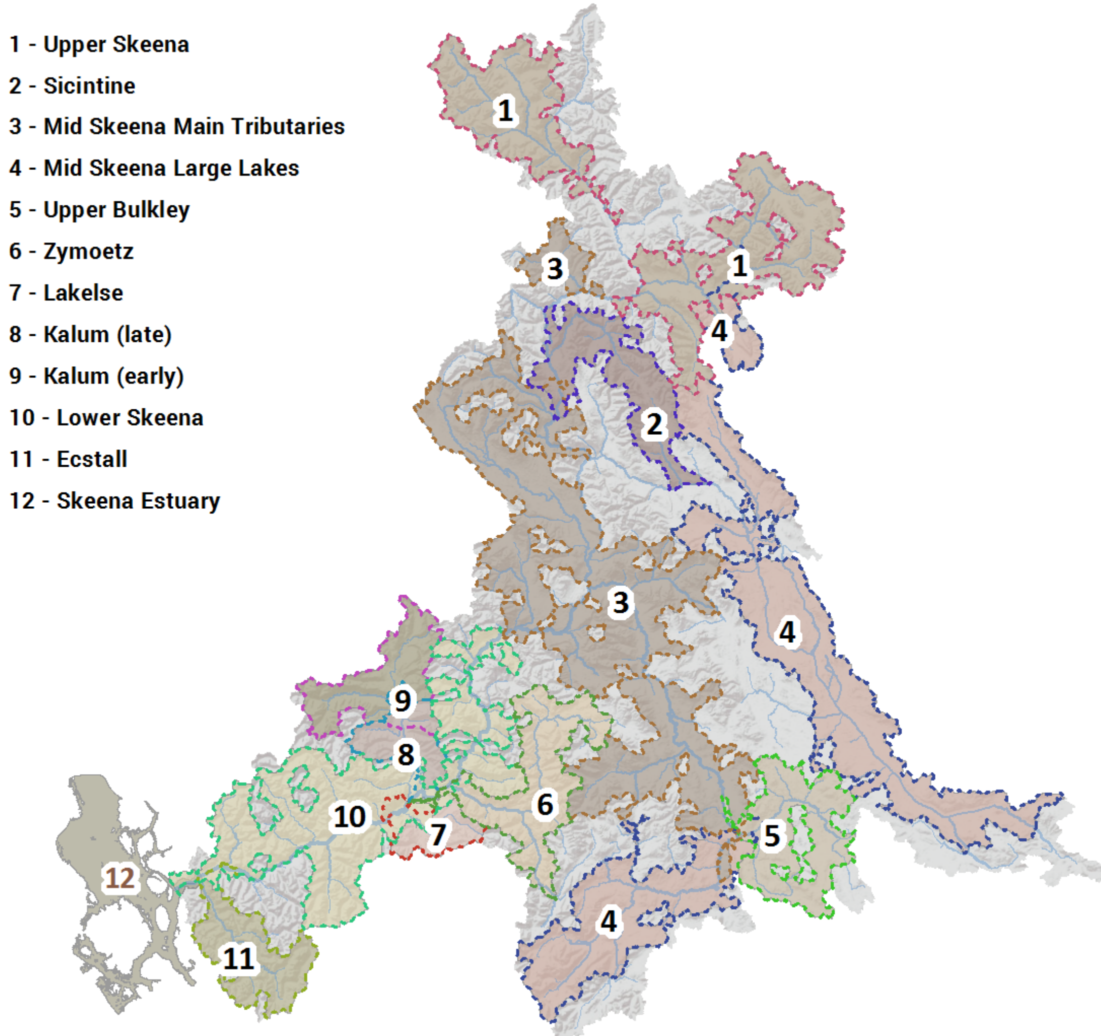


Figure 3: Location and names of Chinook CUs considered in this report.

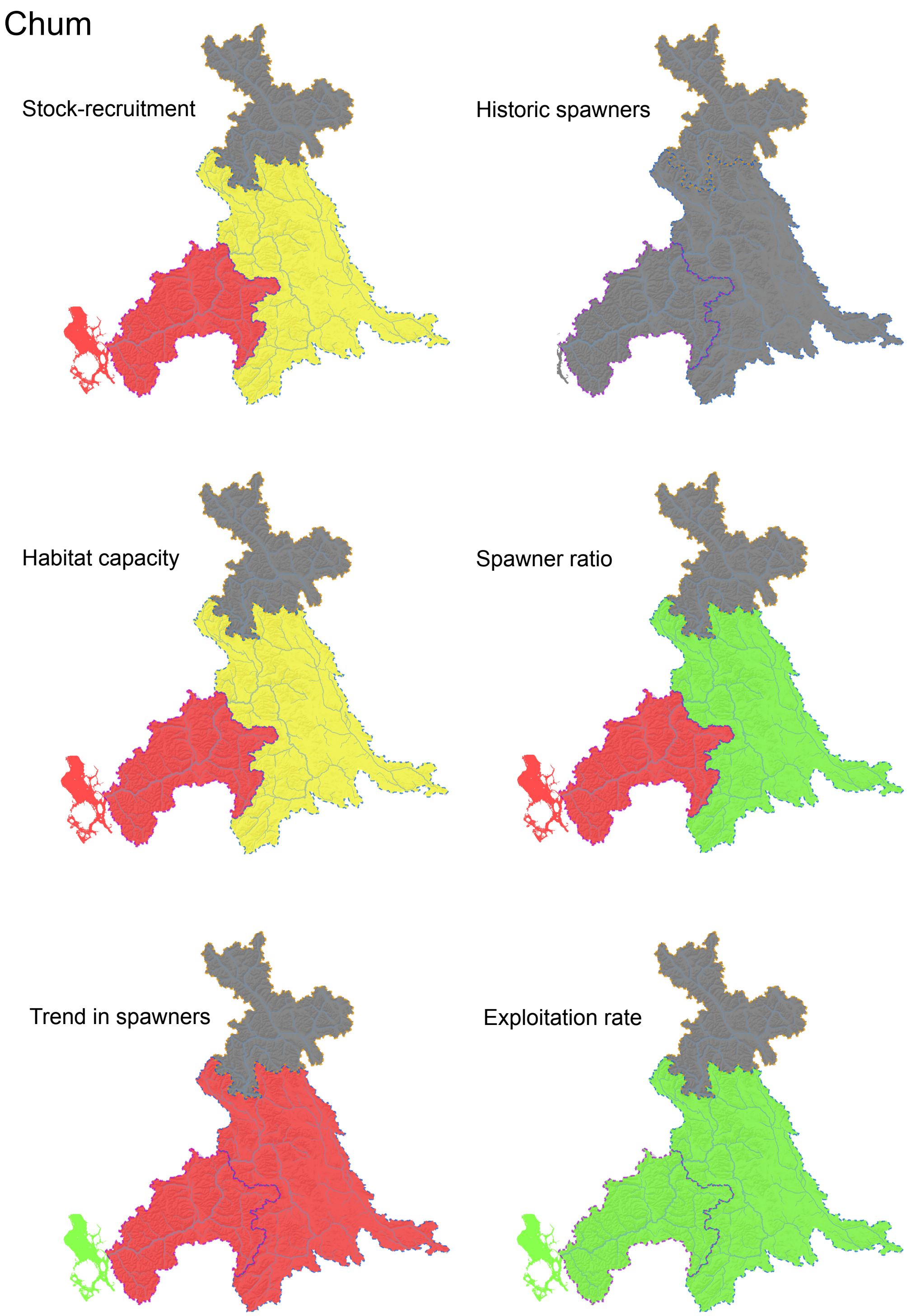


Figure 4: Chum CU biological status metrics relative to benchmark values (denoted in top left of each map and described in Section 1.4 and the Quick Reference). Colors correspond to red, amber and green status zones, while grey indicates that the status for a given status metric-benchmark combination could not be assessed due to a lack of data. CU names are shown in Figure 5. These maps should be viewed together with the CU Snapshots, which contain important information about uncertainty and the time period assessed.

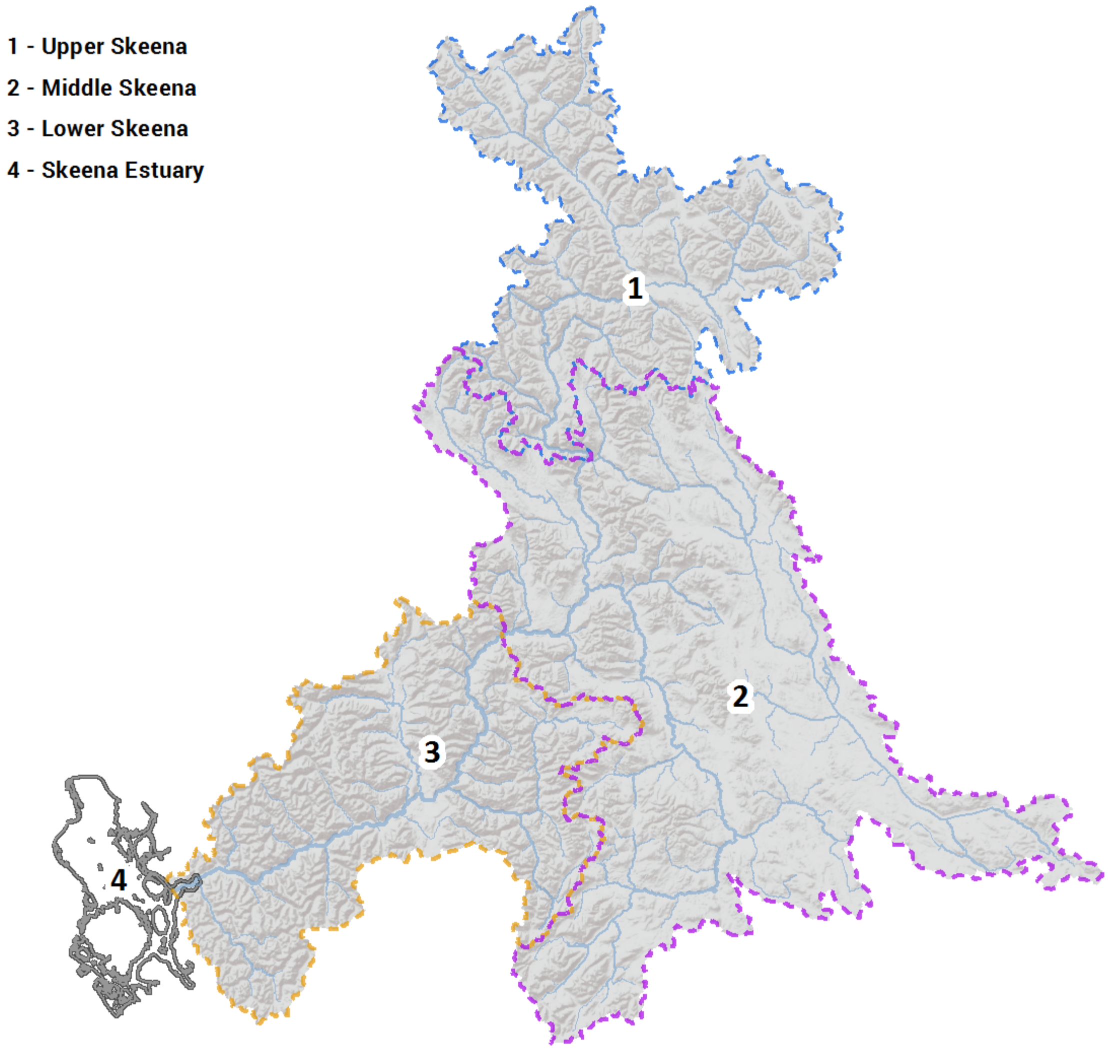


Figure 5: Location and names of chum CUs considered in this report.

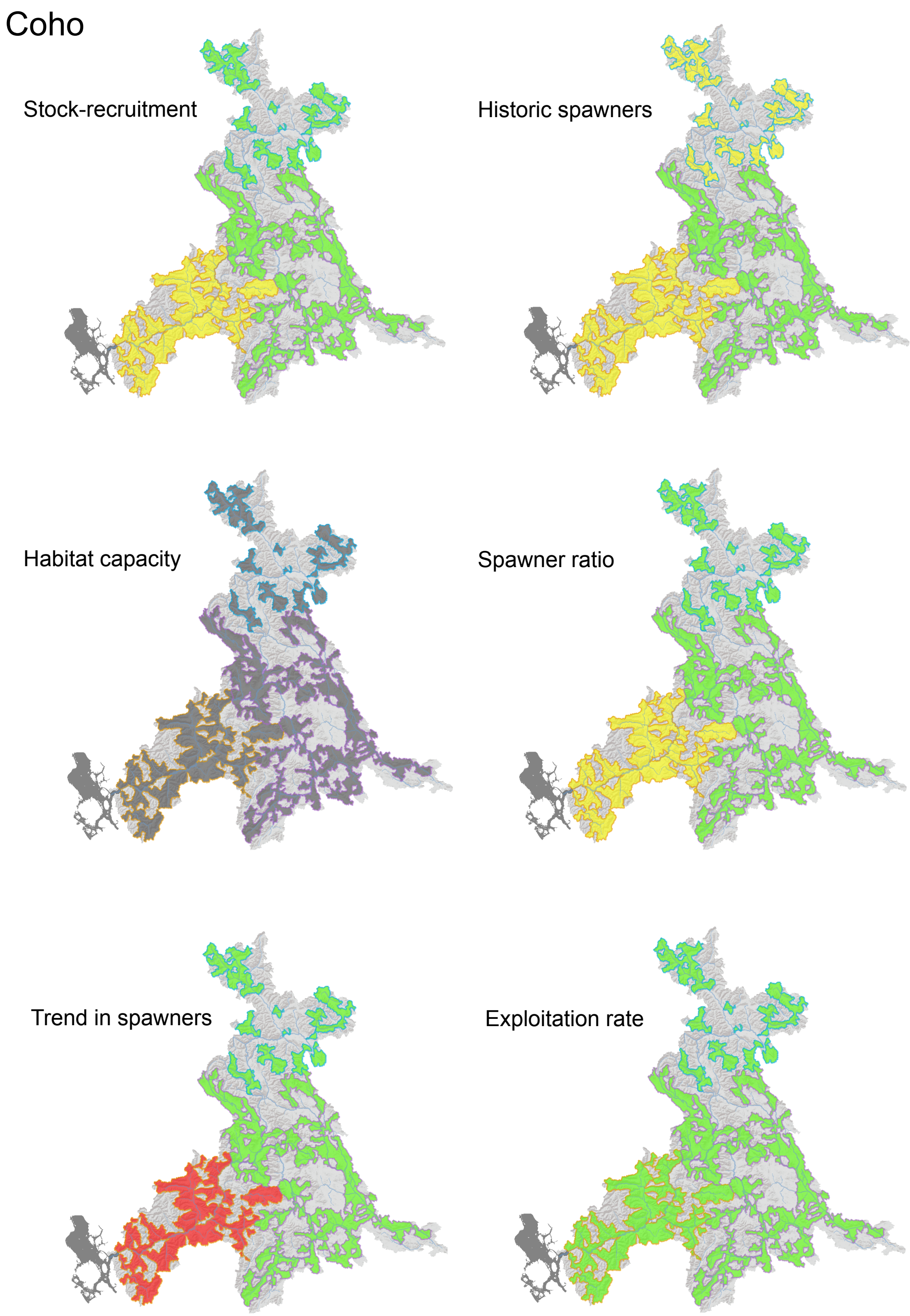


Figure 6: Coho CU biological status metrics relative to benchmark values (denoted in top left of each map and described in Section 1.4 and the Quick Reference). Colors correspond to red, amber and green status zones, while grey indicates that the status for a given status metric-benchmark combination could not be assessed due to a lack of data. CU names are shown in Figure 7. These maps should be viewed together with the CU Snapshots, which contain important information about uncertainty and the time period assessed.

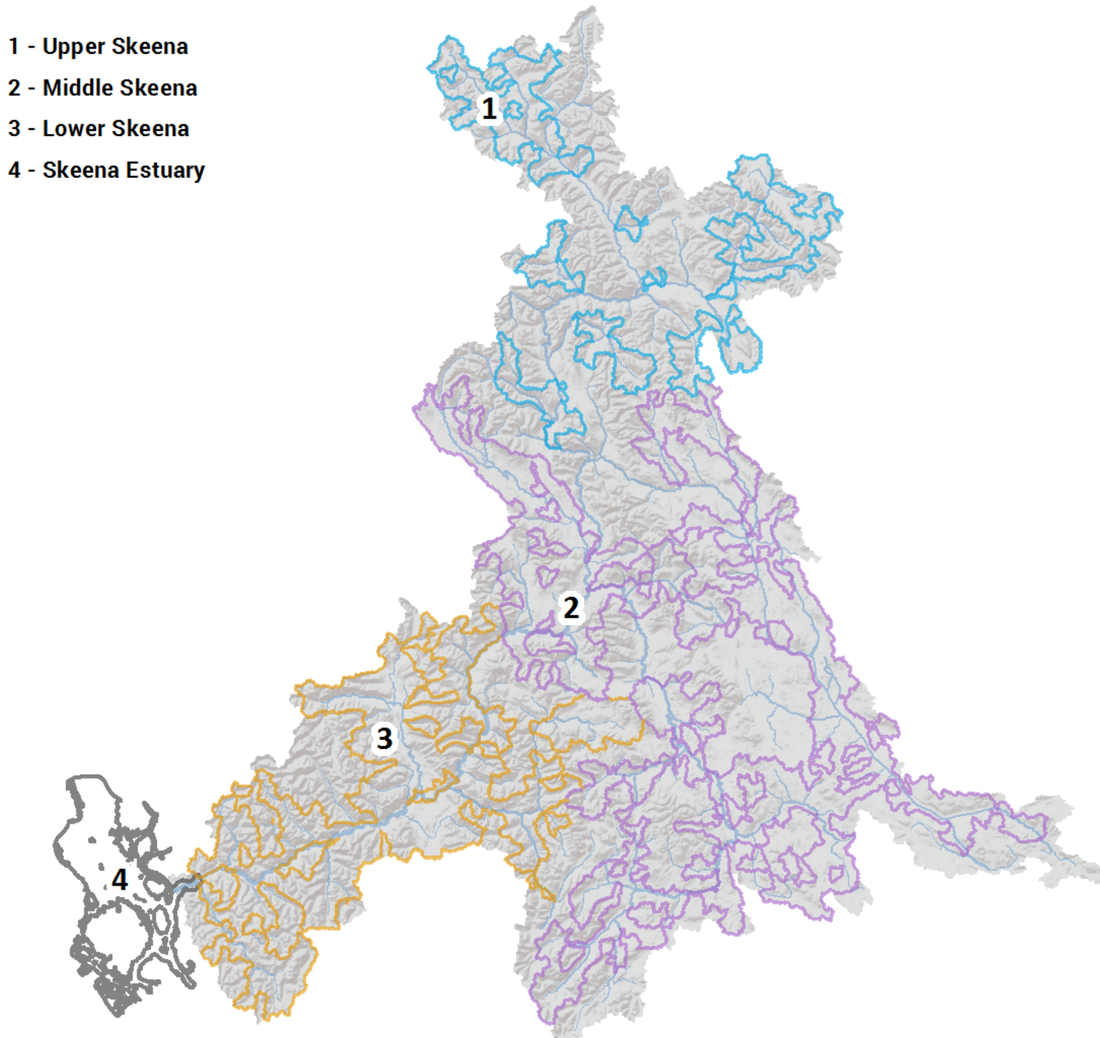


Figure 7: Location and names of coho CUs considered in this report.

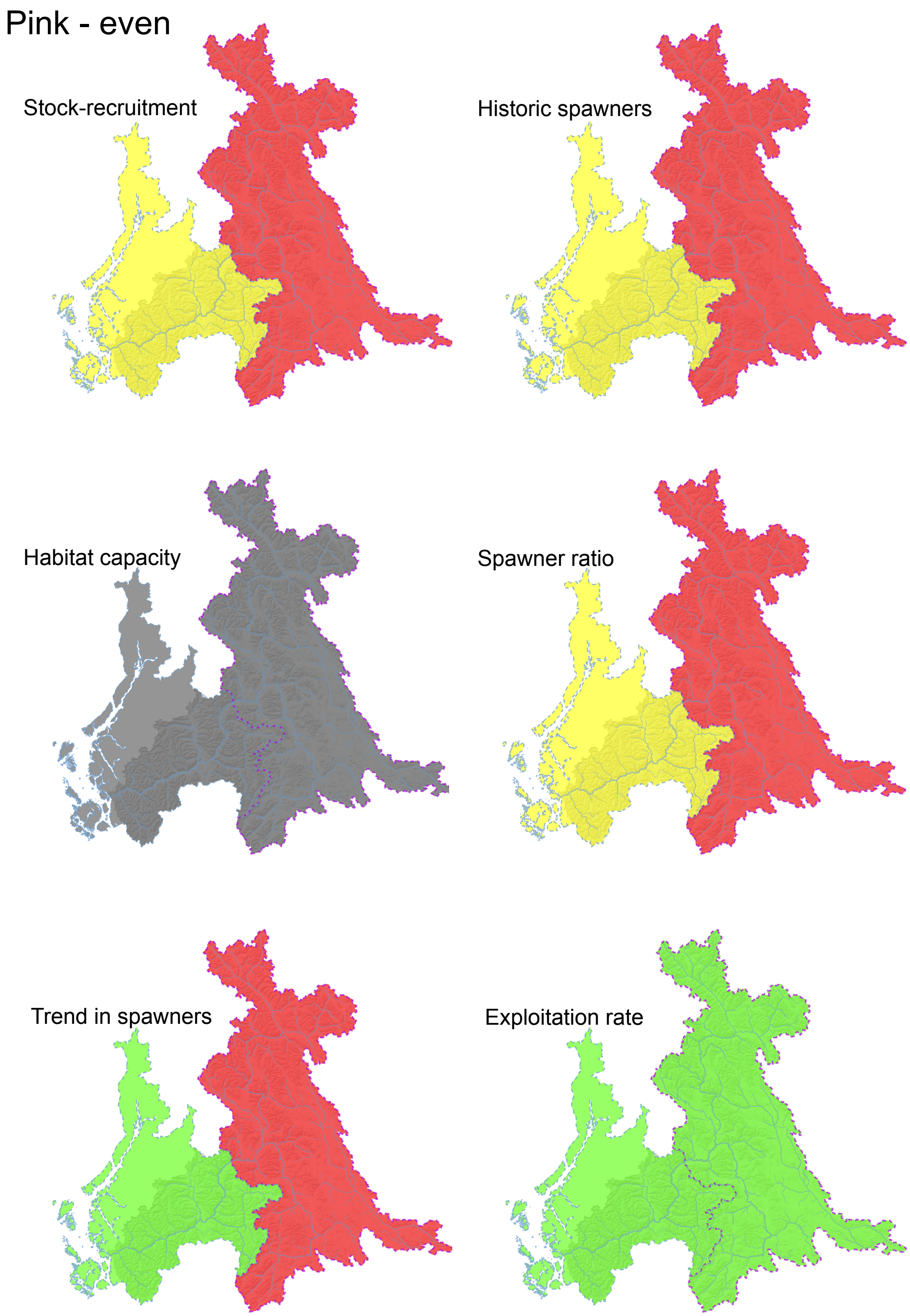


Figure 8: Even-year pink CU biological status metrics relative to benchmark values (denoted in top left of each map and described in Section 1.4 and the Quick Reference). Colors correspond to red, amber and green status zones, while grey indicates that the status for a given status metric-benchmark combination could not be assessed due to a lack of data. CU names are shown in Figure 9. These maps should be viewed together with the CU Snapshots, which contain important information about uncertainty and the time period assessed.

Skeena salmon CU snapshots

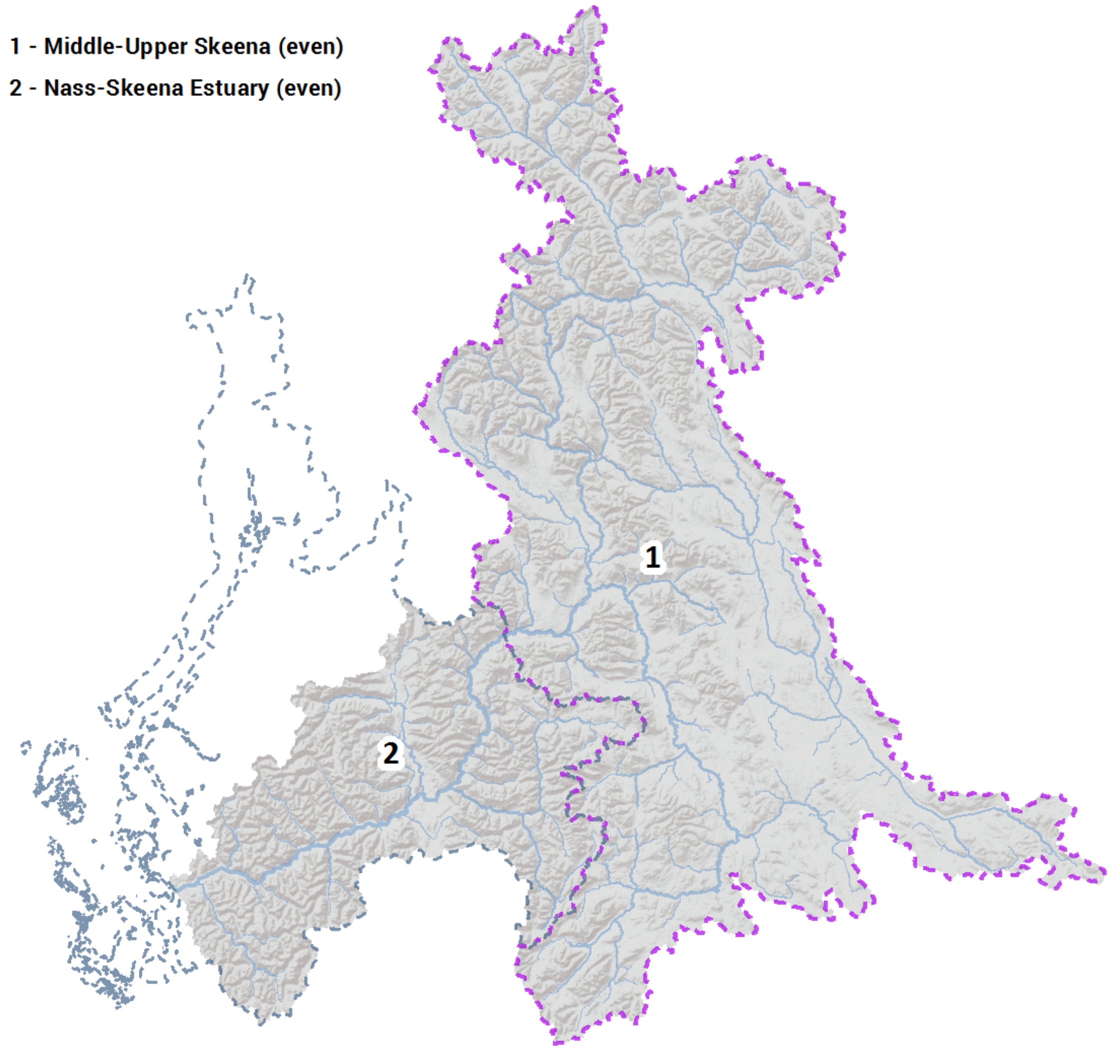


Figure 9: Location and names of even-year pink CUs considered in this report.

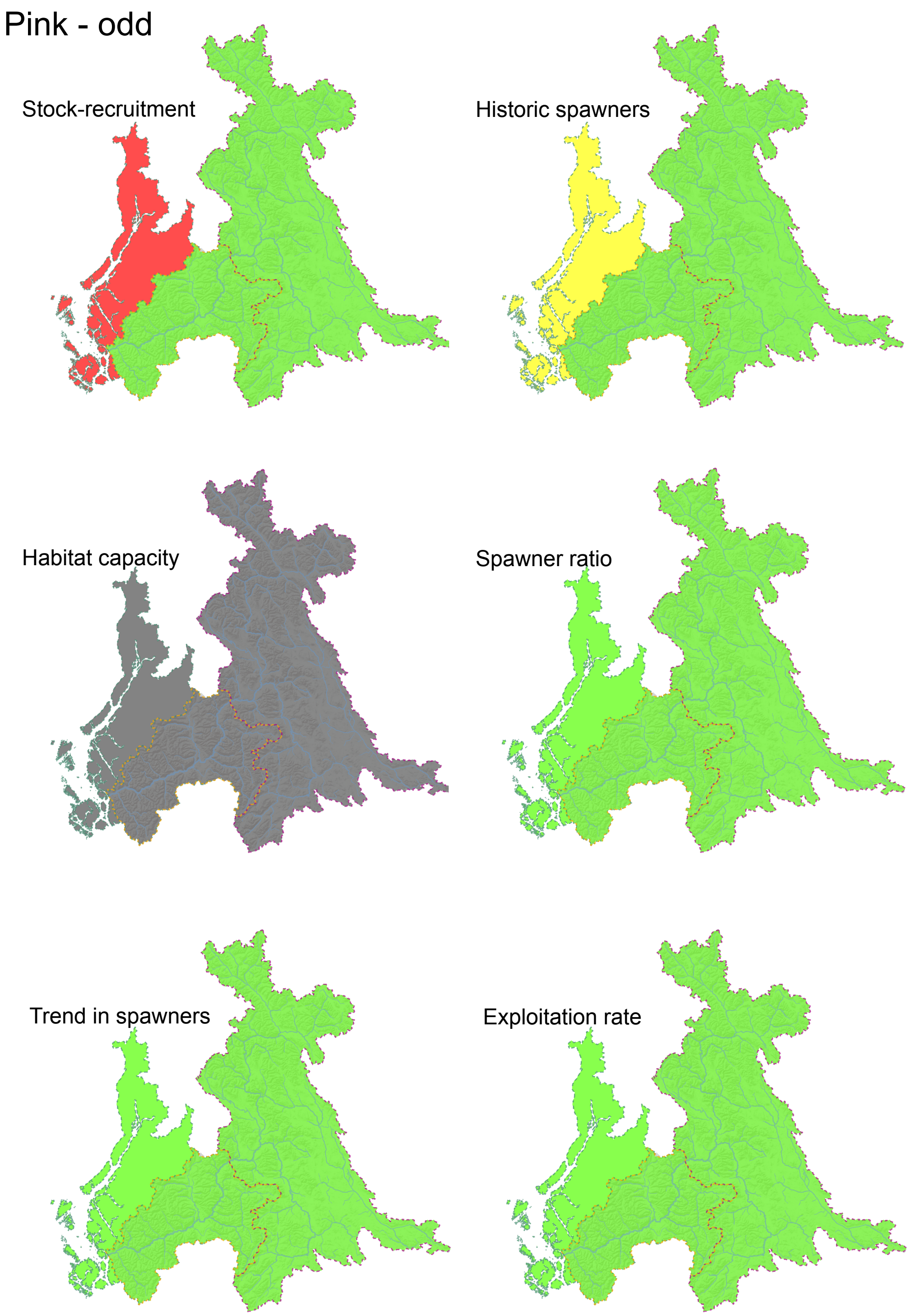


Figure 10: Odd-year pink CU biological status metrics relative to benchmark values (denoted in top left of each map and described in Section 1.4 and the Quick Reference). Colors correspond to red, amber and green status zones, while grey indicates that the status for a given status metric-benchmark combination could not be assessed due to a lack of data. CU names are shown in Figure 11. These maps should be viewed together with the CU Snapshots, which contain important information about uncertainty and the time period assessed.

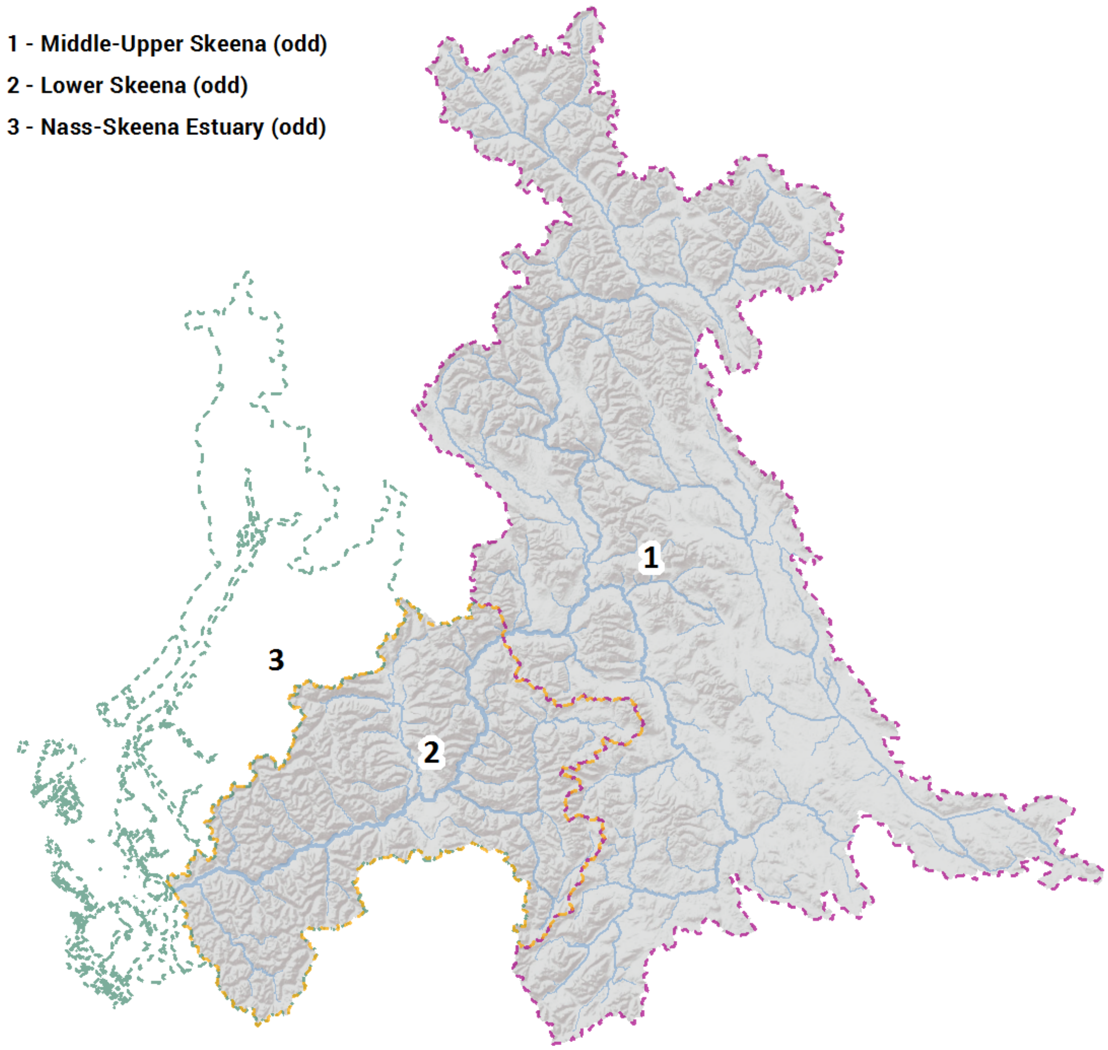


Figure 11: Location and names of odd-year pink CUs considered in this report.

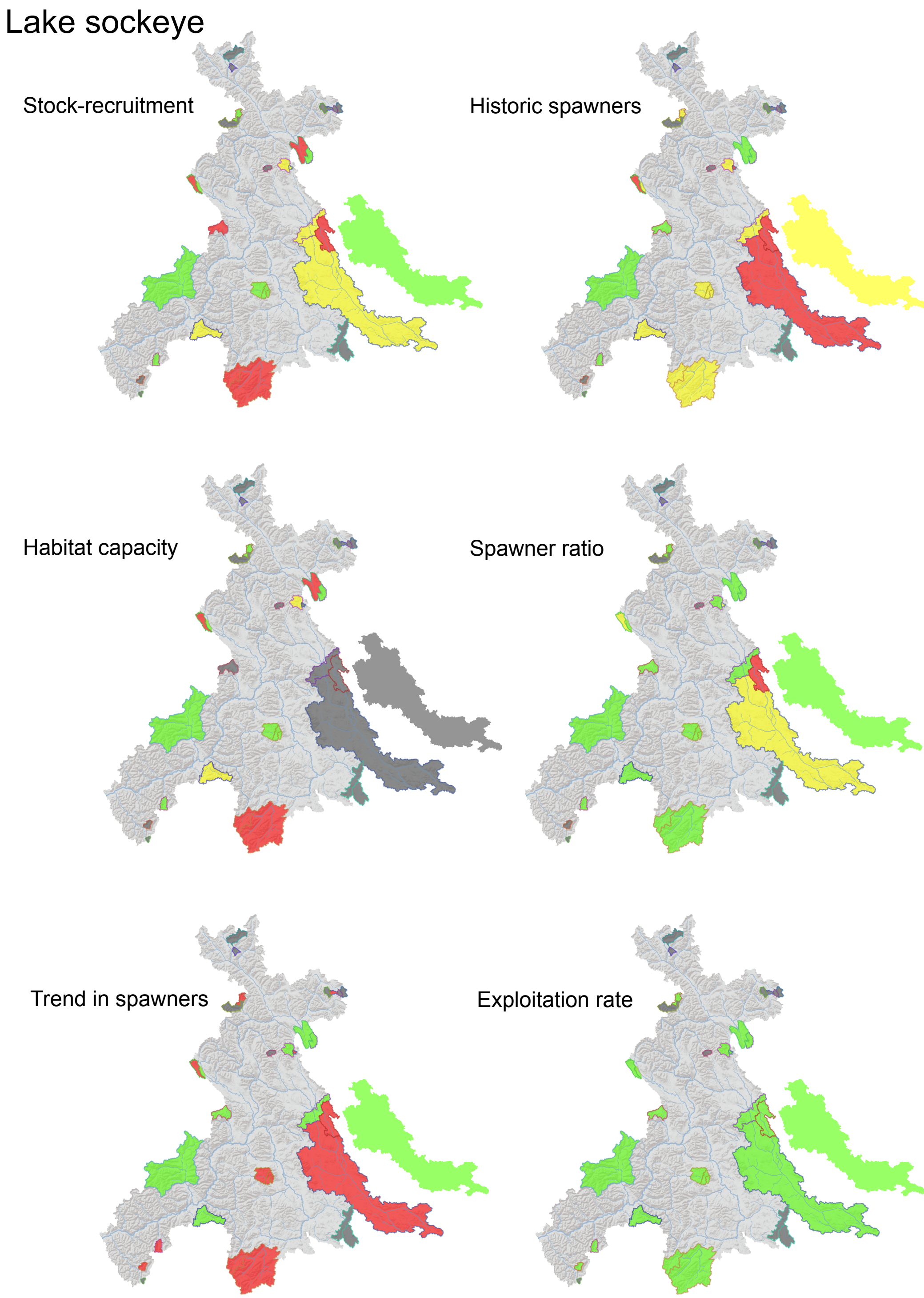


Figure 12: Lake sockeye CU biological status metrics relative to benchmark values (denoted in top left of each map and described in Section 1.4 and the Quick Reference). Colors correspond to red, amber and green status zones, while grey indicates that the status for a given status metric-benchmark combination could not be assessed due to a lack of data. CU names are shown in Figure 13. Babine (enhanced) is presented separately in the bottom right. These maps should be viewed together with the CU Snapshots, which contain important information about uncertainty and the time period assessed.

Skeena salmon CU snapshots

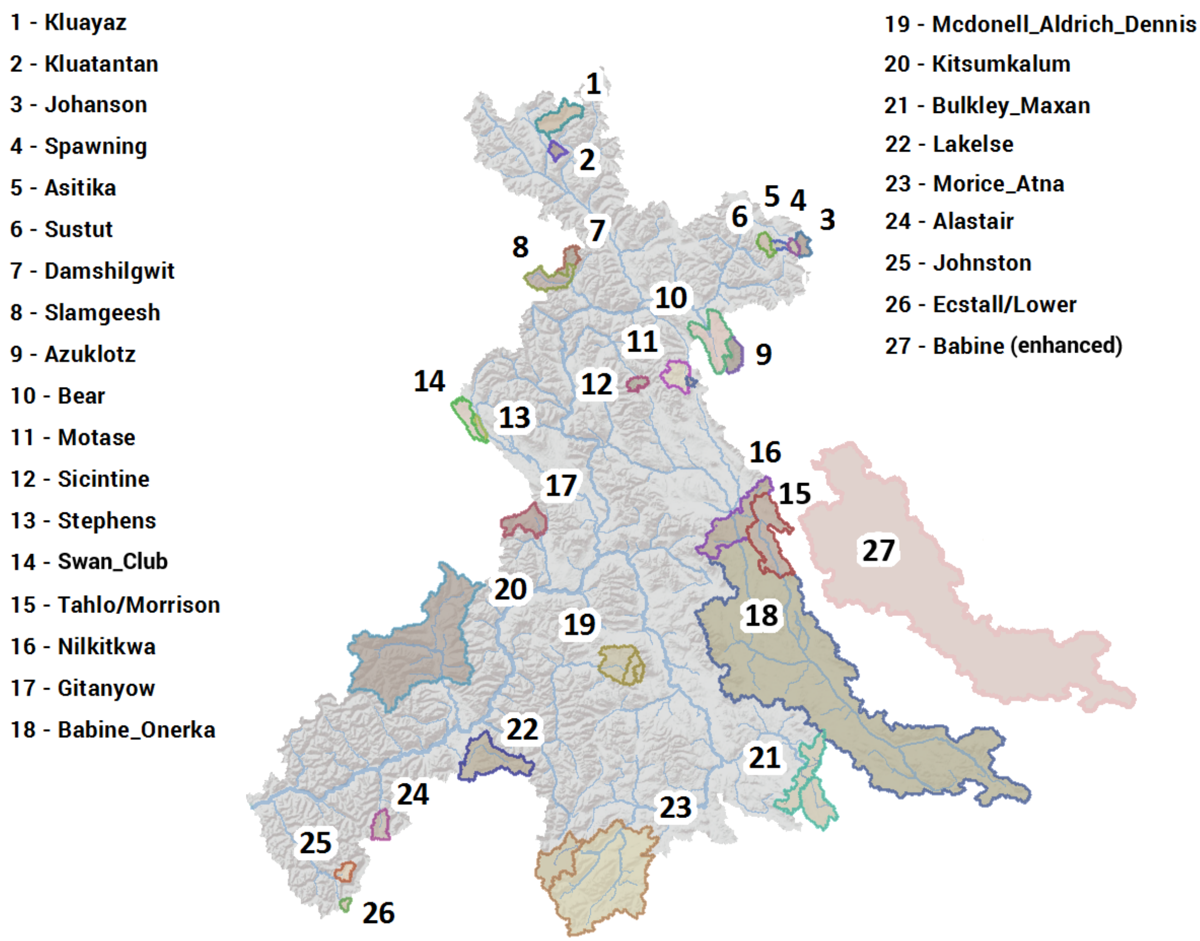


Figure 13: Location and names of lake sockeye CUs considered in this report.

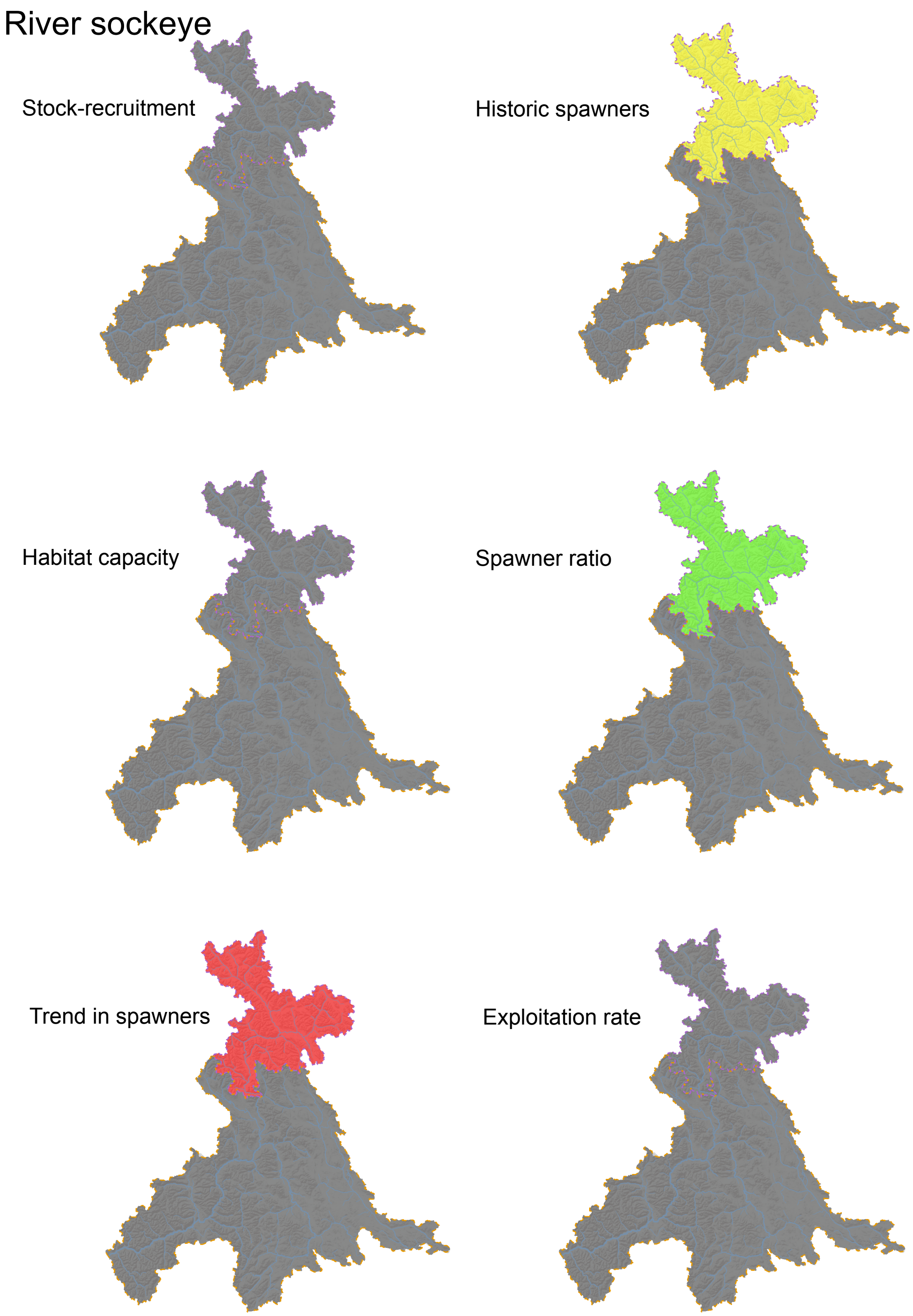


Figure 14: River sockeye CU biological status metrics relative to benchmark values (denoted in top left of each map and described in Section 1.4 and the Quick Reference). Colors correspond to red, amber and green status zones, while grey indicates that the status for a given status metric-benchmark combination could not be assessed due to a lack of data. CU names are shown in Figure 13. These maps should be viewed together with the CU Snapshots, which contain important information about uncertainty and the time period assessed.

Skeena salmon CU snapshots

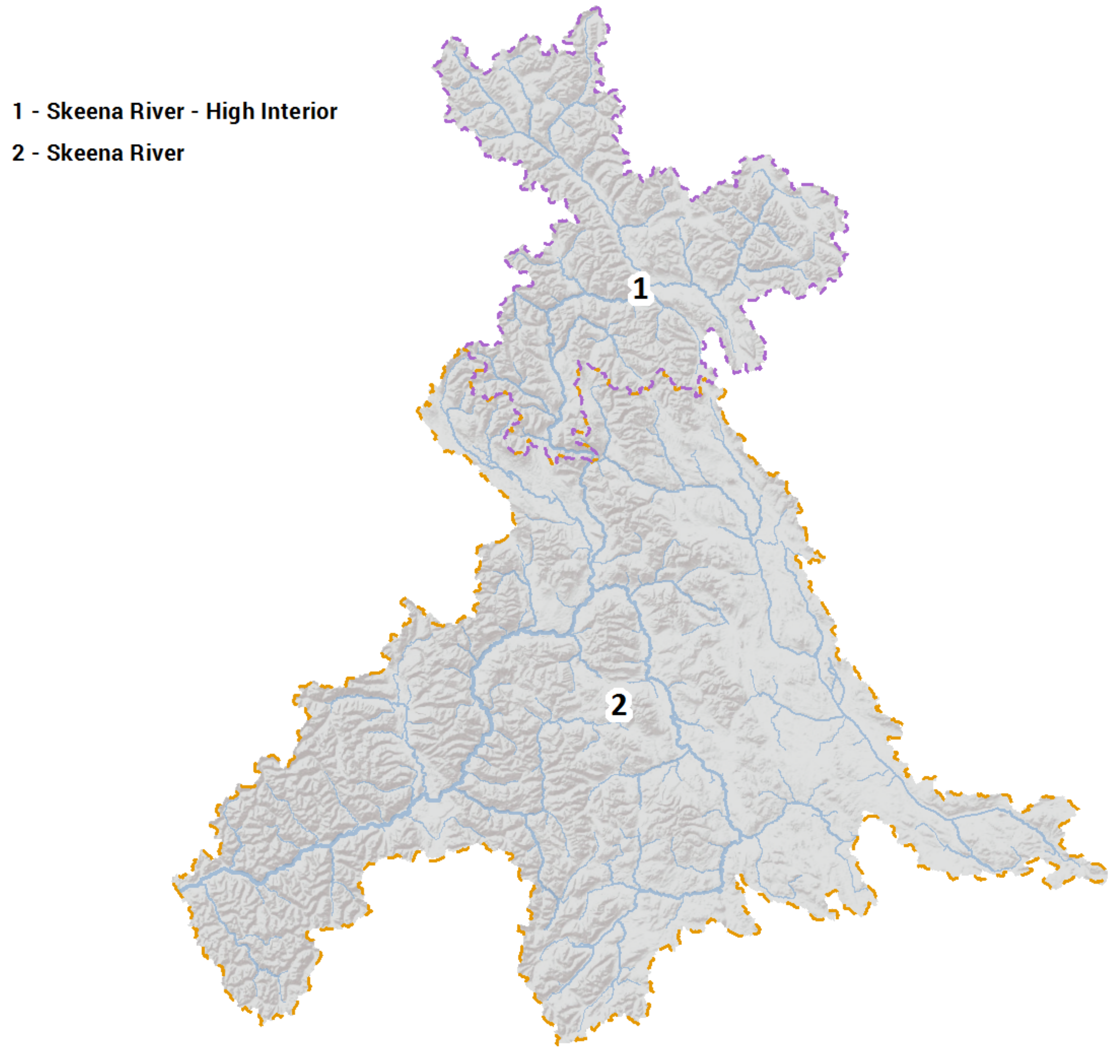


Figure 15: Location and names of river sockeye CUs considered in this report.

Appendix 6. Considerations for future versions of Skeena CU snapshots

Below is a list of possible considerations for future Skeena salmon CU snapshots:

- Update age composition information presented in snapshots to include historical data for CUs such as Lakelse lake sockeye and age composition information from sources other than the Pacific Age Database System.
- Consider compiling and presenting information on hydroacoustic surveys for juvenile lake sockeye, and presenting status based on comparison of estimates of current juvenile sockeye abundance to estimates of rearing habitat capacity.
- Explore convening a workshop(s) with technical and regional experts to generate an integrated status assessment for each CU. Such a workshop could be based upon the approach used to derive an integrated status assessment for Fraser sockeye (Grant and Pestal 2013).
- Revisit the best placement of the status information within the CU snapshots (currently Sections 17-19). Feedback received drafts of the snapshots was split between presenting status first or last.
- Consider revising the migration ZOI for migration route to include the rearing lake and spawning tributaries for lake sockeye.
- Consider revising the run-timing information presented in Version 1.0 based on feedback from additional Skeena salmon experts and updating it to include year-specific estimates of peak run-timing for lake sockeye.
- Consider a formal process for soliciting and compiling additional information on each CU to be presented in Section 5 of the CU snapshots ("Additional Information"). If this process was combined with the integrated status assessment workshop(s) suggested above then Section 5 could also include a brief summary of expert opinion on CU status including potential drivers and limiting factors.