Skeena Salmon: Chum
Conservation Unit Snapshot
Lower Skeena

Version 1.0. December 19, 2013

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

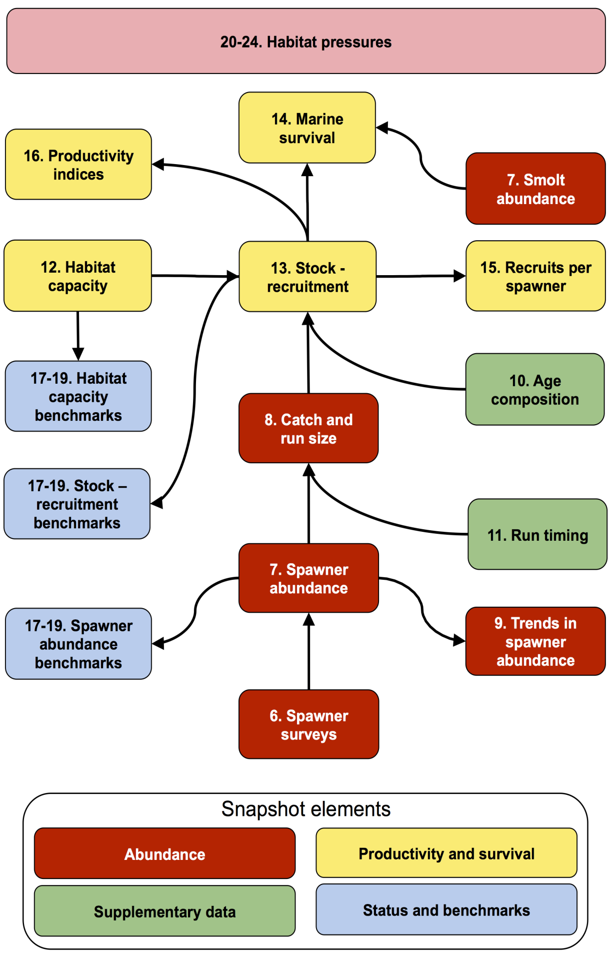


Figure 1. *This roadmap summarizes the types of information included in the following pages of the CU Snapshot. Arrows show the flow of information from raw data towards more complicated elements that are estimated based on one or more information inputs. For example, 'stock−recruitment' can't be estimated 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

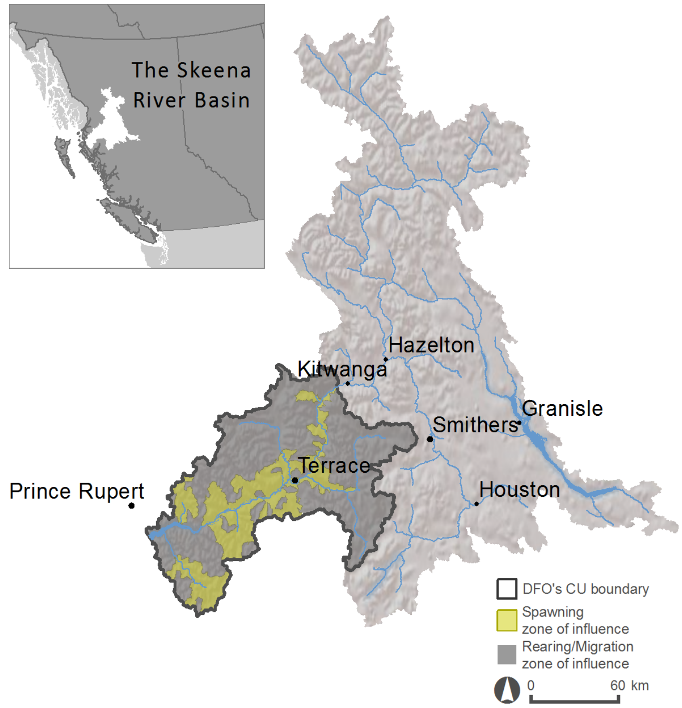


Figure 2. *Location of this CU within the Skeena watershed.*

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.

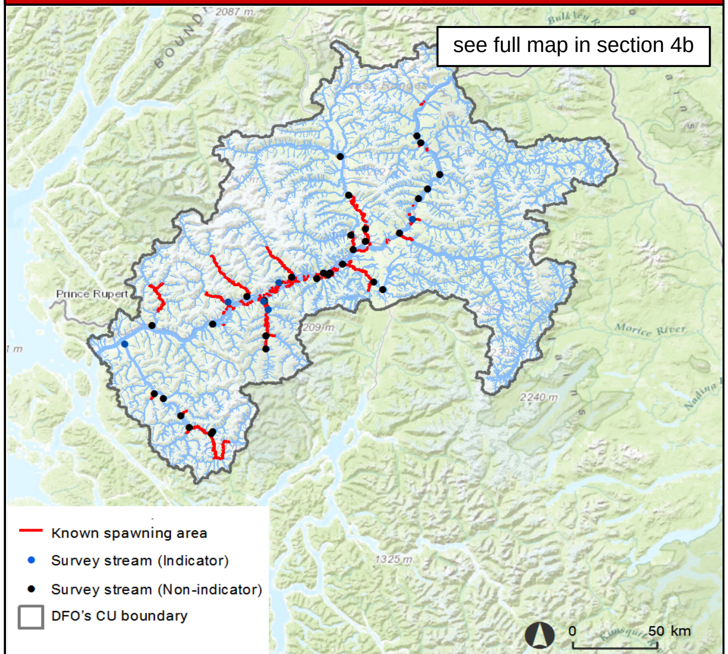
Status: Condition of a metric relative to a defined benchmark.

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.

3. Summary statistics

Number of survey streams	40
Number of indicator streams	6
Maximum estimated spawners (1988)	166,028
Minimum estimated spawners (1955)	498
Generation length	4 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

This CU encompasses all spawning in Skeena Watershed from the coast to just west of Kitwanga.

Earlier spawning survey records are available for this CU, but do not provide a reliable estimate of total spawner abundance. The somewhat ambiguous historic catch information indicates abundances up to the 1930s may have been 10 to 50 times larger than the recent decade.

The main chum spawning populations are located in the Ecstall and Skeena West areas, both of which are typically uncountable due to turbidity conditions. The majority of escapement observations are aerial counts. There has been an overall decline in enumeration effort for this CU.

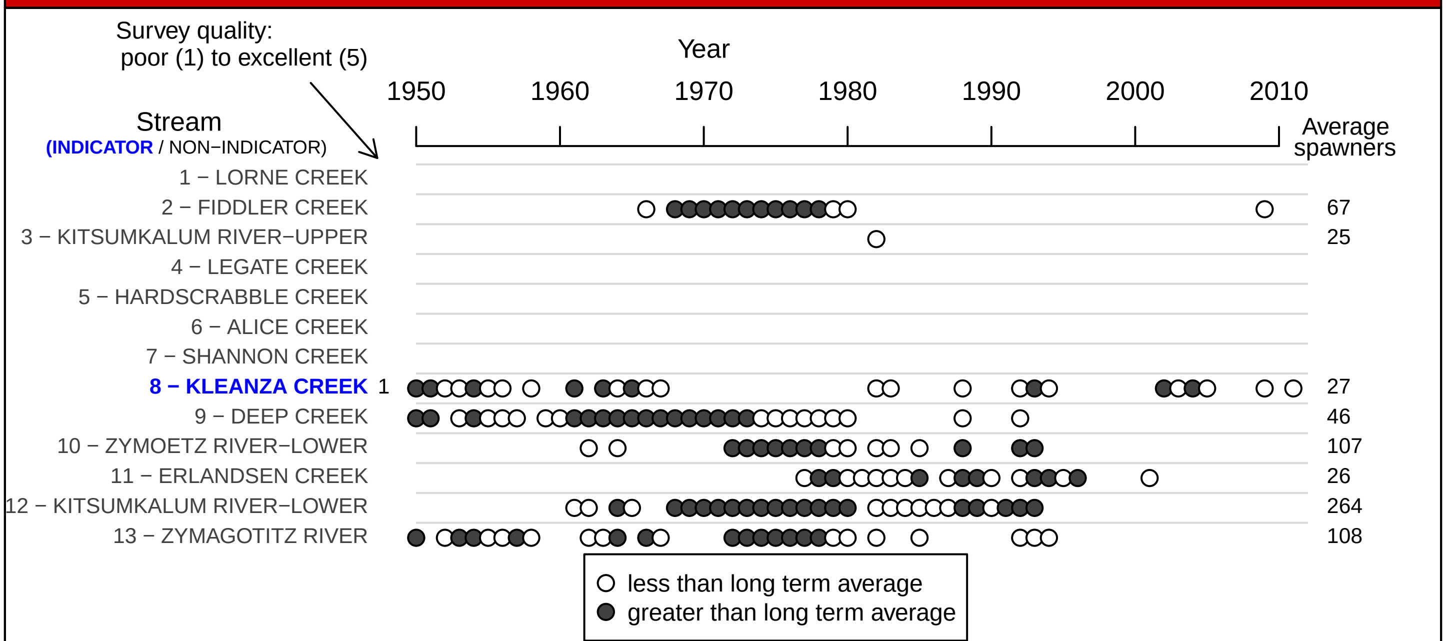
Impacts to chum habitat in this CU include encroachment and loss of some side−channel habitat due to linear development (Highway 16 and CN Rail line). Some tributary spawning habitat has also been impacted by dyke construction and subsequent scouring of suitable gravels.

A consequence of limited management activities and research is an inadequate understanding of Skeena chum biology, population structure, presence, and abundance. Why, where, and how Skeena chum declines are occurring is currently not understood. DFO is currently in the process of developing a rebuilding plan for Skeena chum salmon.

Coastal Canadian commercial net fisheries in Fisheries Management Area 4 were substantially reduced in August for most years since 1997 due to conservation concerns for Skeena coho from 1997−2000, concerns for Skeena chum after 2000, and low abundance of pink salmon from 2005−2010.

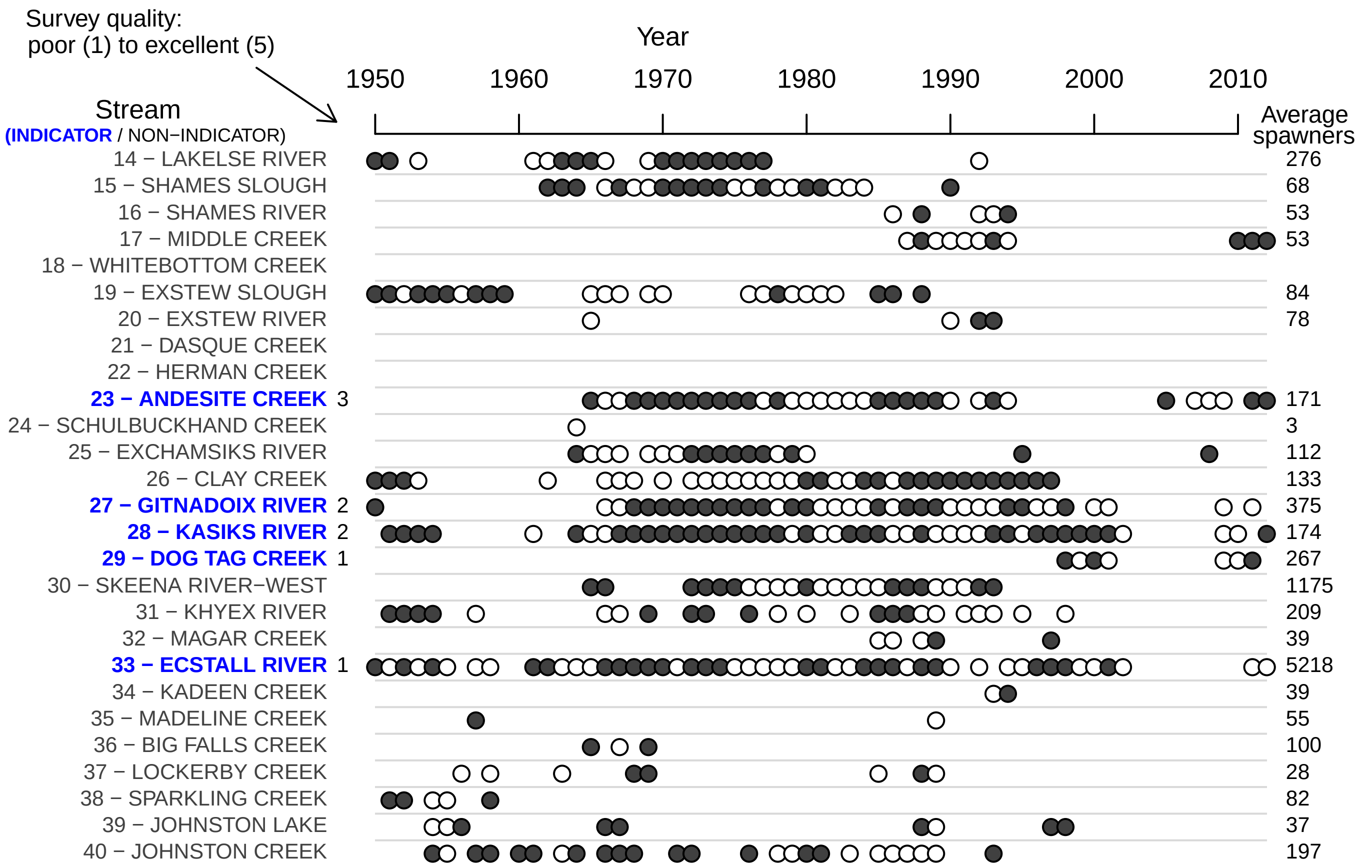
Additional information for this CU provided by Skeena salmon experts and compiled by ESSA Technologies Ltd.

6. Spawner surveys

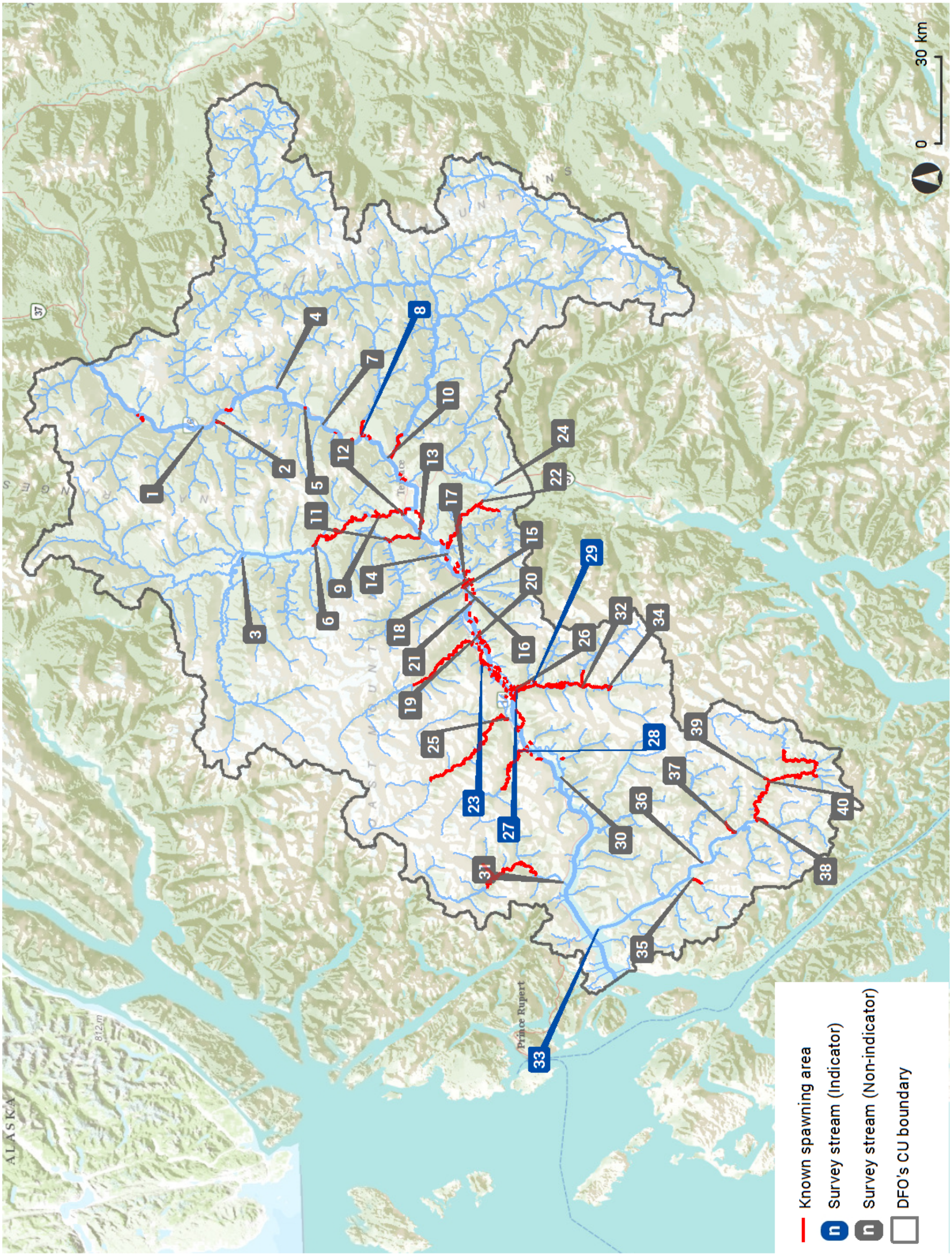


Past spawner surveys for this CU. Circles represent a survey for a given stream and year. The more complete the spawner surveys are across streams and years, the more reliable the estimated spawner abundance for the entire CU will be.

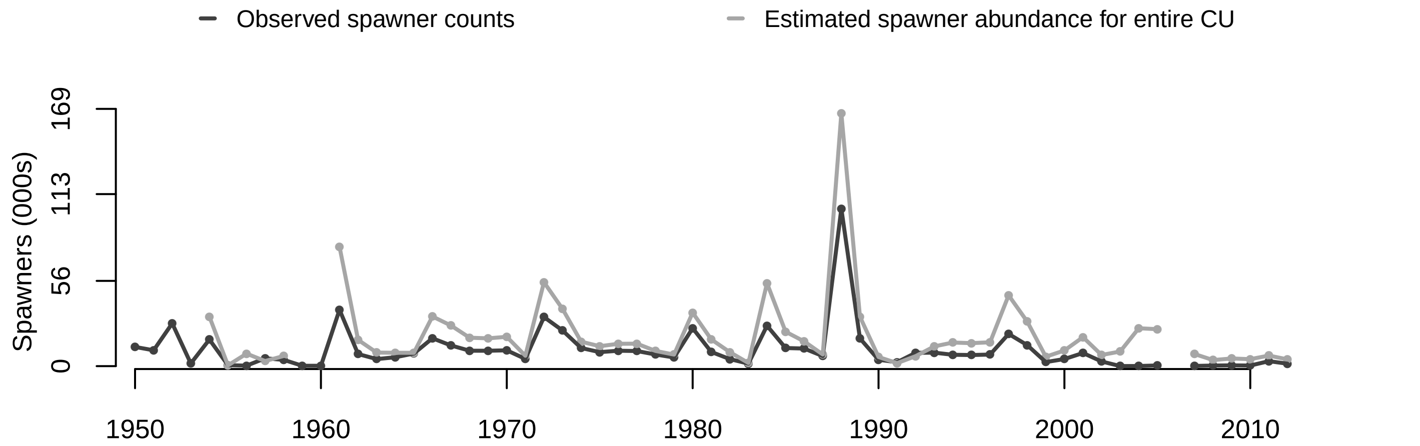
6b. Spawner surveys continued



4b. Location continued

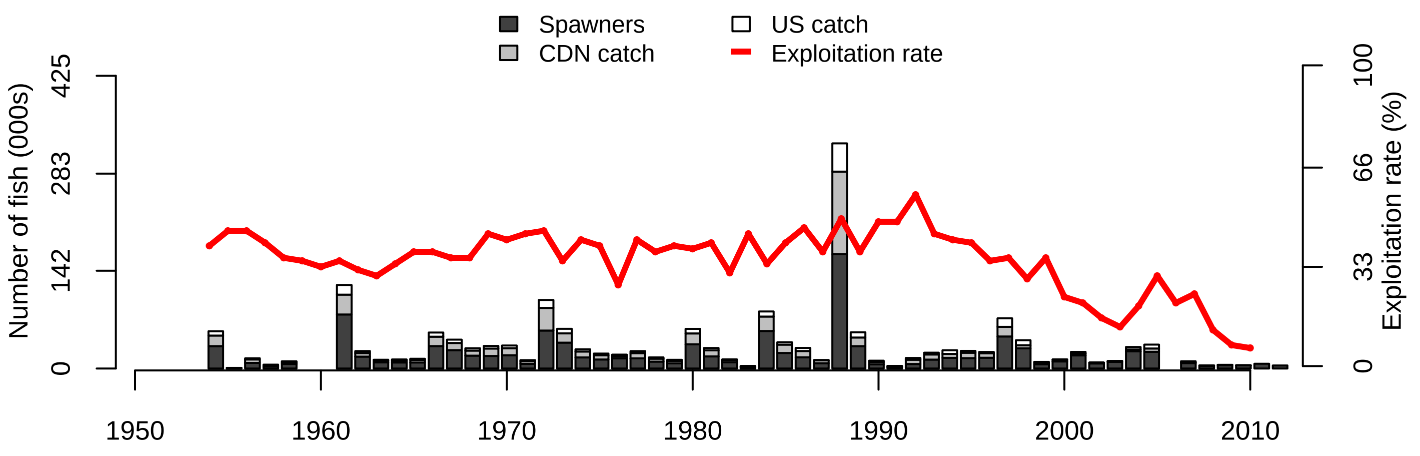


7. Spawner and smolt abundance



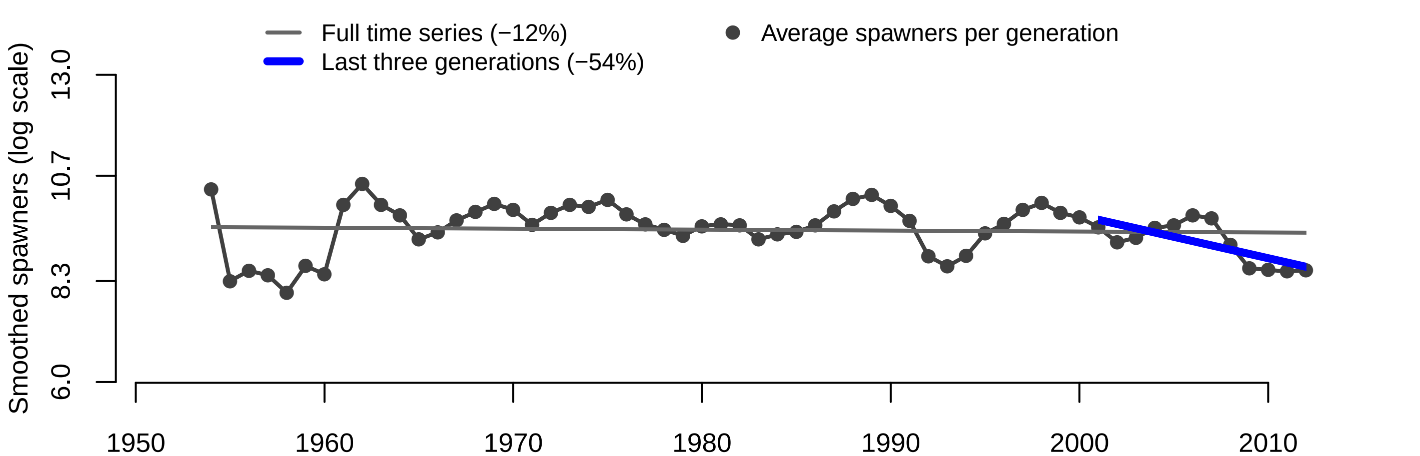
Observed counts represent the number of spawners recorded by stream surveys each year. The estimate for the entire CU is usually higher than the observed count since it accounts for streams that aren't surveyed that year. The greater the difference between the two lines, the more caution should be used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

8. Catch and run size



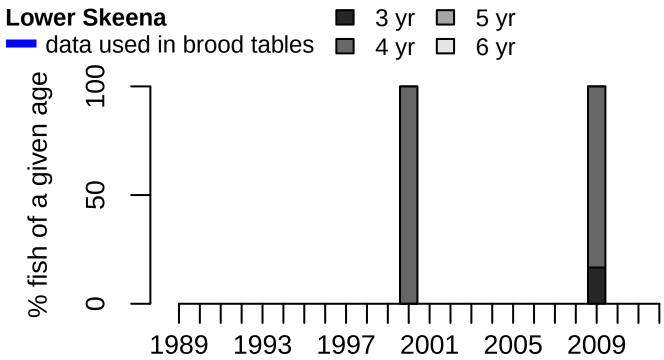
Run size is the total number of adult fish returning from the ocean in a given year, including those that reach the spawning grounds as well as fish captured in US and Canadian fisheries. The exploitation rate is the percent of the run that is captured in fisheries.

9. Trends in spawner abundance

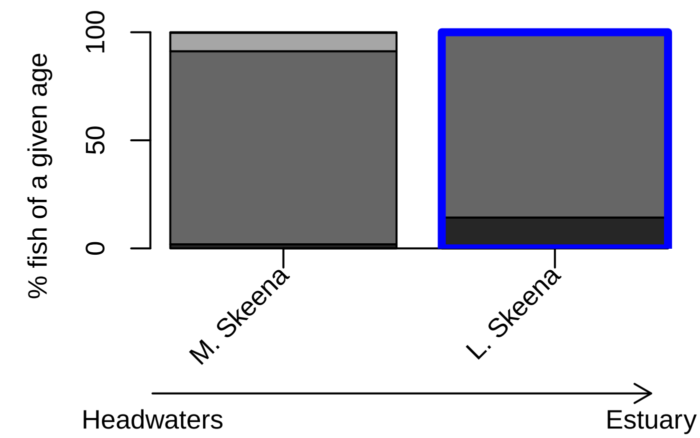


Plotting the running average of spawner abundance removes excess year−to−year variability making it easier to see whether or not there are any notable long−term or recent trends. The trend in abundance over the past 3 generations (or 10 years) is used as a measure of conservation status by some organizations,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

10. Age composition

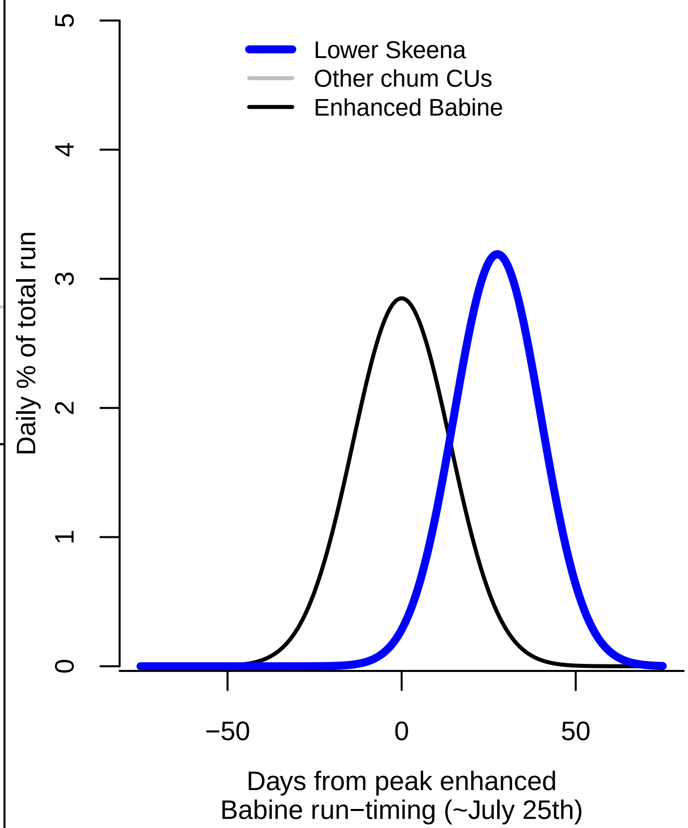


Estimated age composition of this CU's spawning fish shown for all years with data. Salmon vary in the age at which they mature and return to spawn, so that each year's spawners can be a mixture of fish of varying age.



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



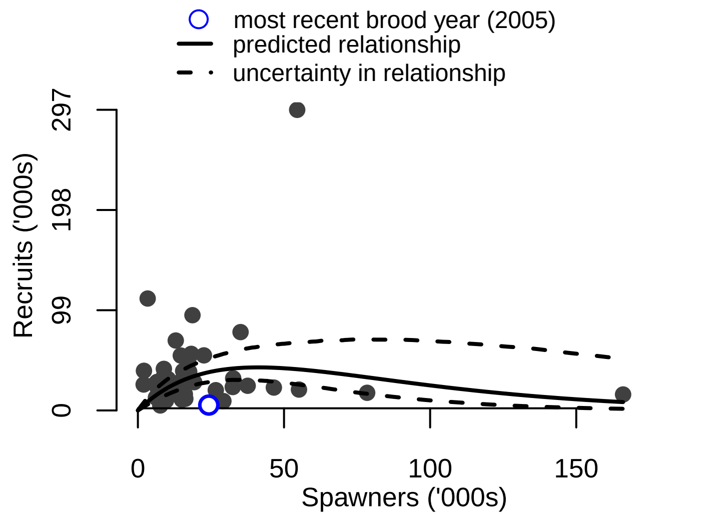
The curves show the average time of year at which fish from each CU enter the Skeena river as they return to spawn. The main target of commercial marine fisheries is the enhanced Babine sockeye CU. Spawners from other CUs whose river entry timing is most similar to that of enhanced Babine sockeye may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

12. Rearing habitat capacity

Not available

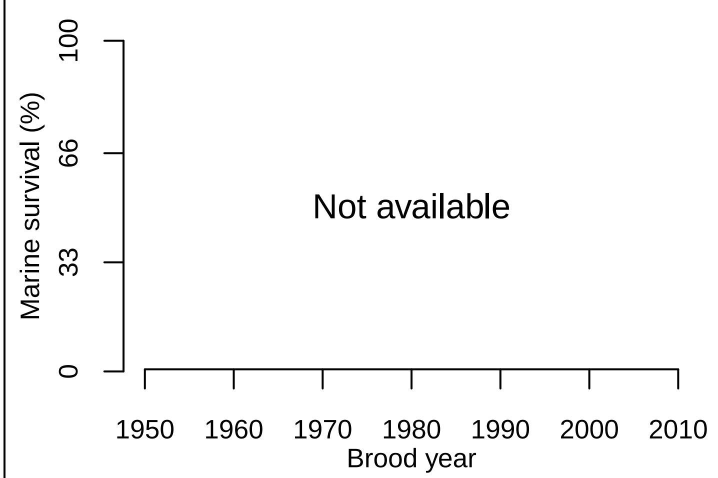
Comparing the capacity of the rearing habitat to the actual number of smolts present shows whether the rearing habitat is limiting the size of the CU's population. For CUs where less than 100% of the rearing capacity is being used, this suggests that the rearing habitat capacity is not limiting the population.

13. Stock−recruitment relationship



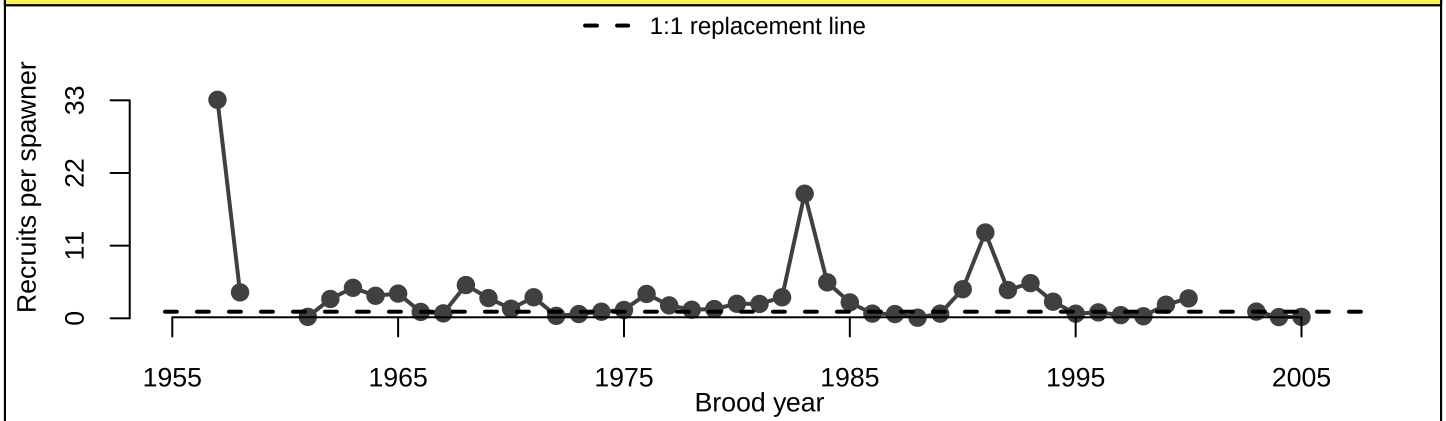
The curve shows the number of individuals in one generation ("recruits") that are expected to be produced by a given number of spawners in the previous generation. The farther apart that the dashed lines are from the solid line, the less certain the relationship is, and the more caution should be used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

14. Marine survival



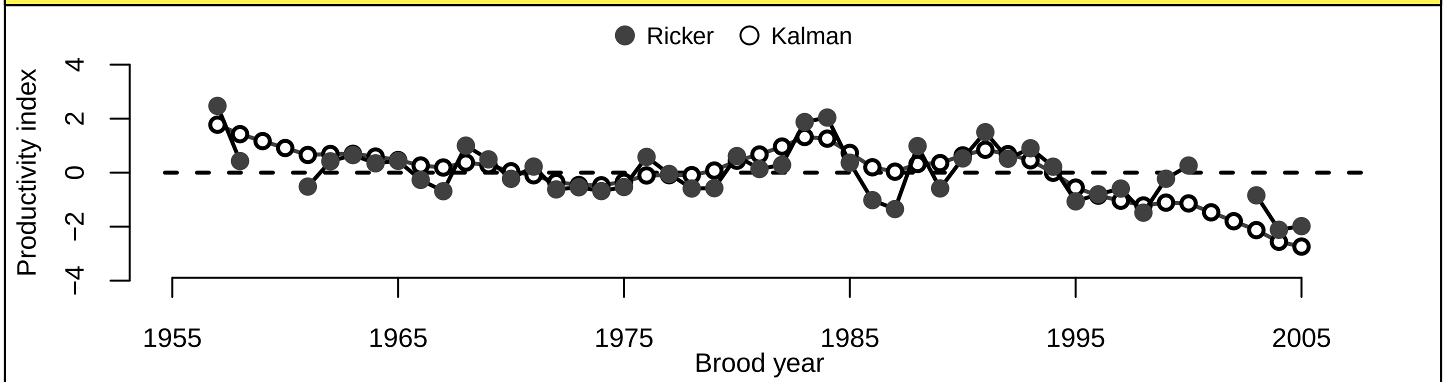
The number of returning adult fish can be compared to the number of smolts that migrate out to the ocean to determine what percentage survive from smolts to adult in the marine environment. Declining marine survival suggests that conditions in the marine environment are reducing survival.

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.

17. Status metrics and benchmarks

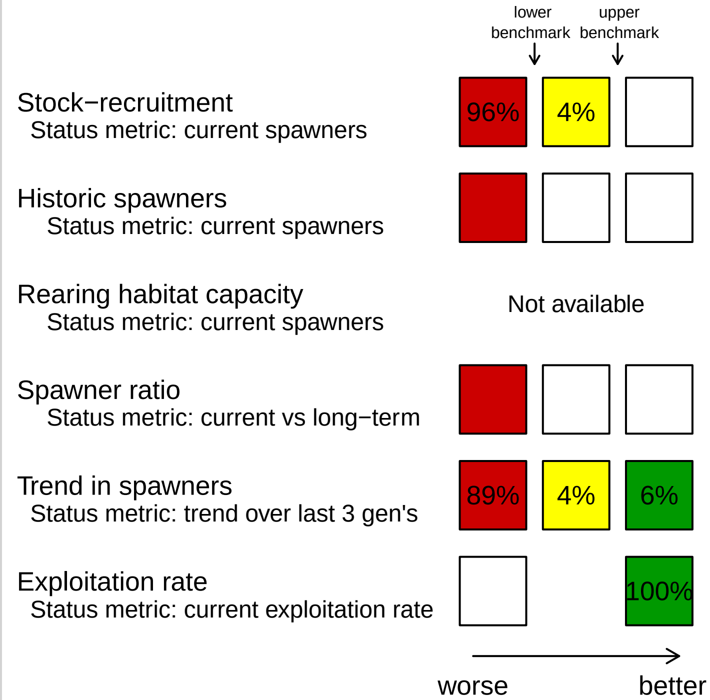
Status metrics: current values (95% C.I.)

Current spawner abundance (2008−2012)	4,982
Current vs. long−term spawners	0.4
Trend in spawners (past 3 gen's)	−54% (−76%, 5%)
Exploitation (2006−2010)	8%

Benchmark values (95% C.I.)

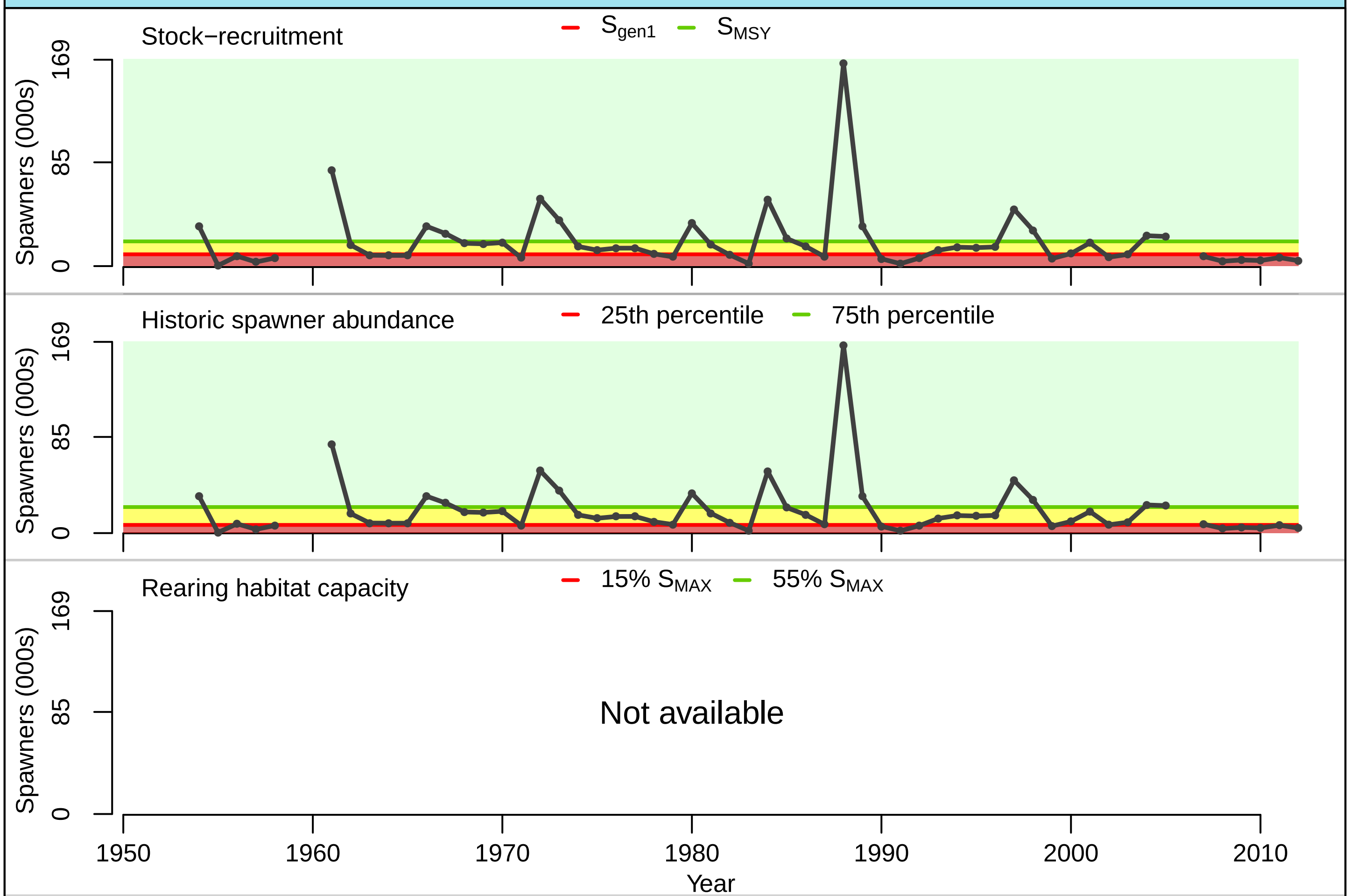
Stock−recruitment	
Lower: S_{gen1}	9,671 (4,775, 14,661)
Upper: S_{MSY}	20,238 (12,950, 28,883)
Historic Spawners	
Lower: 25% historic spawners	7,219
Upper: 75% historic spawners	23,014
Rearing habitat capacity	
Lower: 15% Habitat S_{MAX}	Not available
Upper: 55% Habitat S_{MAX}	Not available
Spawner 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% (28%, 57%)

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.

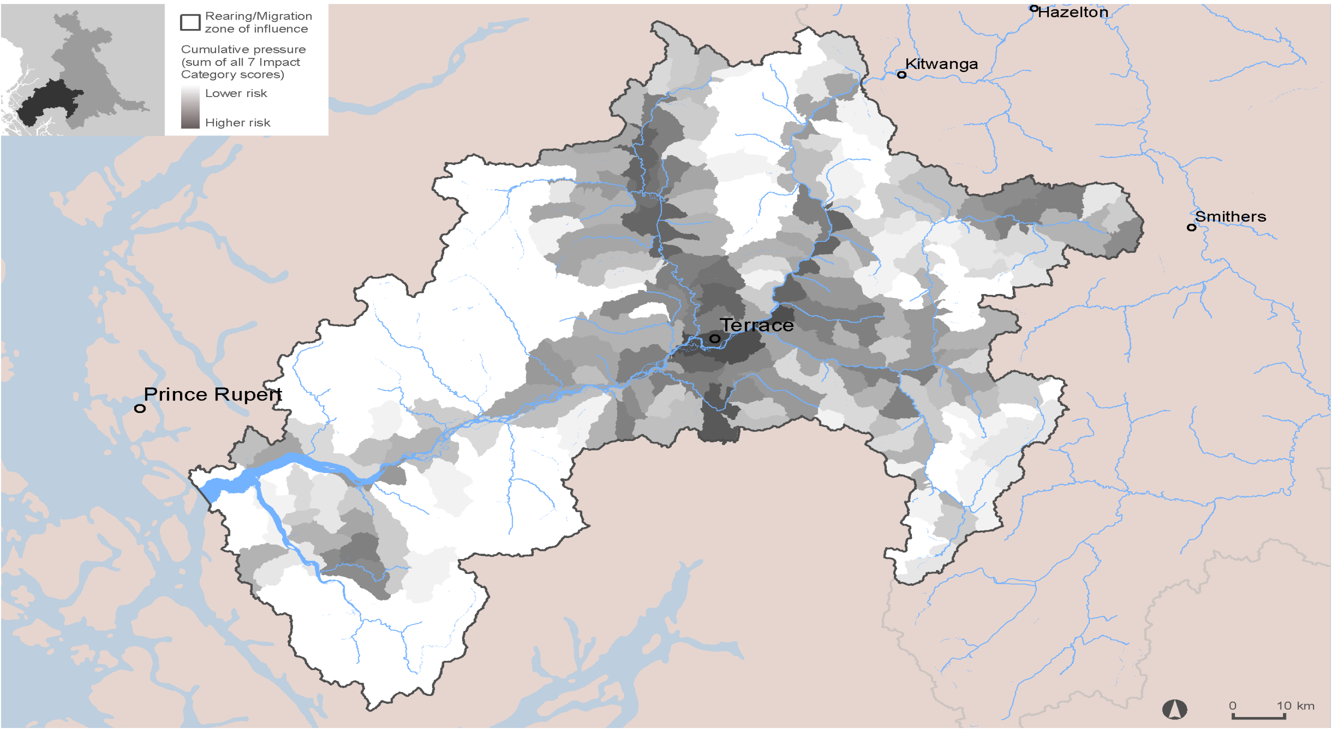
19. Spawner abundance in relation to benchmarks



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

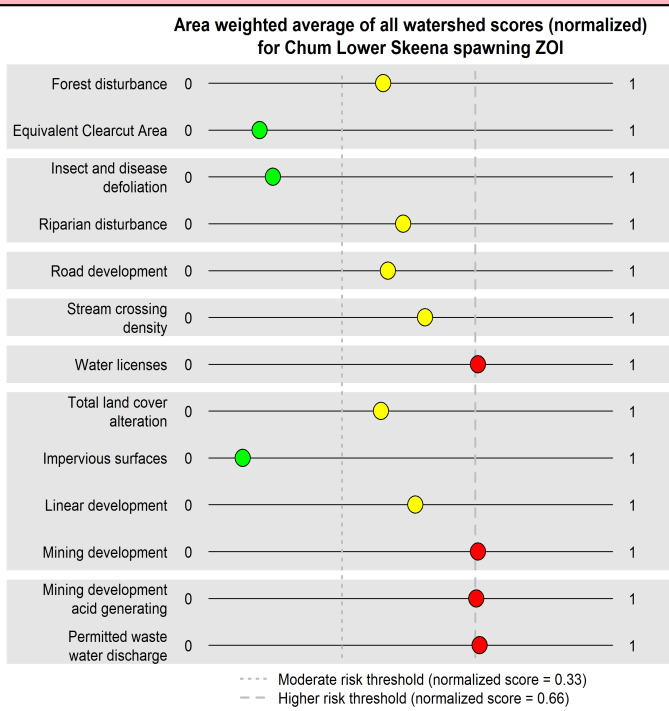
HABITAT: Overview of Chum − Lower Skeena CU Vulnerabilities and Pressures

20. Rearing/migration habitat pressures



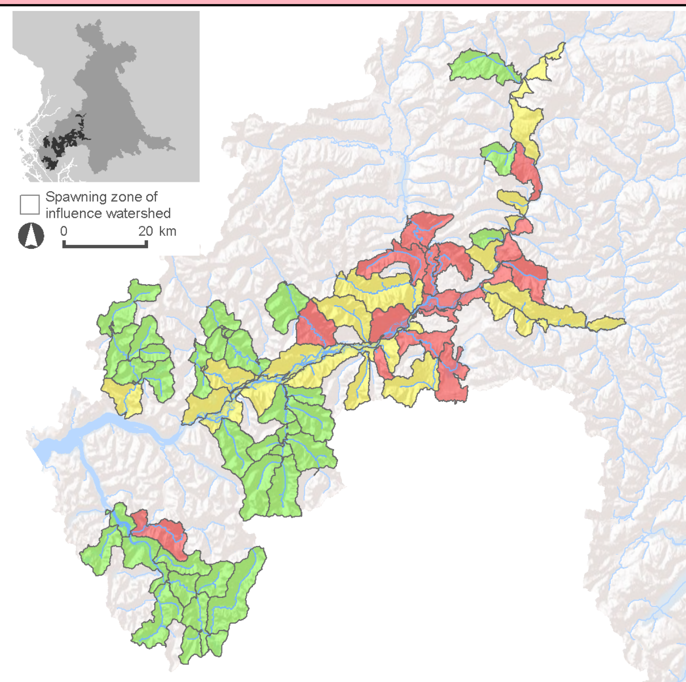
Map of cumulative habitat pressures for watersheds located within the CU's rearing/migration zone of influence. Darker−shaded watersheds represent areas where relatively higher risk habitat impacts may be occuring.

21. Summary of pressure indicators: spawning



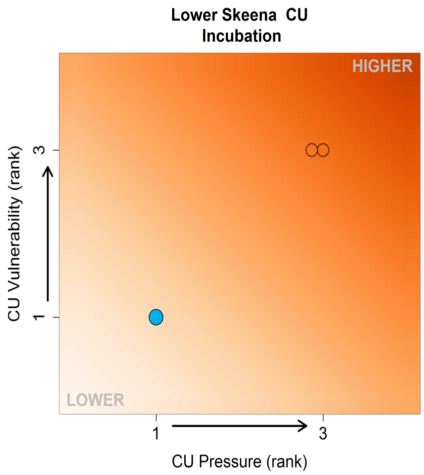
Risks to watersheds influencing this CU's spawning habitat summarized for 13 pressure indicators. Risk is shown by slider position (risk increasing from left to right) and colour (green=lower, amber=moderate, red=higher). Grey boxes group the indicators into related categories.

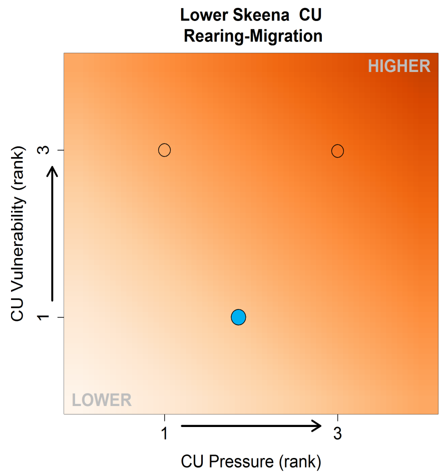
22. Cumulative pressure: spawning

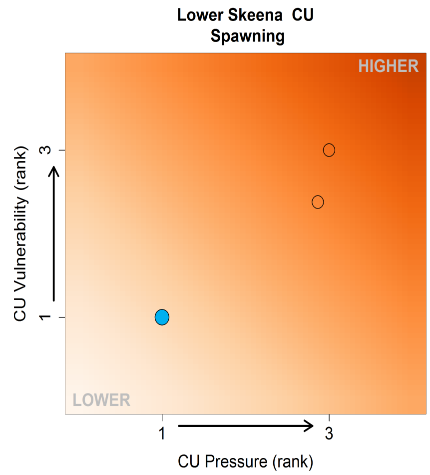


Map of cumulative risk from habitat pressures for each watershed within the CU's spawning zone of influence. Cumulative risk is categorized as relatively lower (green), moderate (amber), or higher (red).

23. Integrated vulnerability and habitat pressures

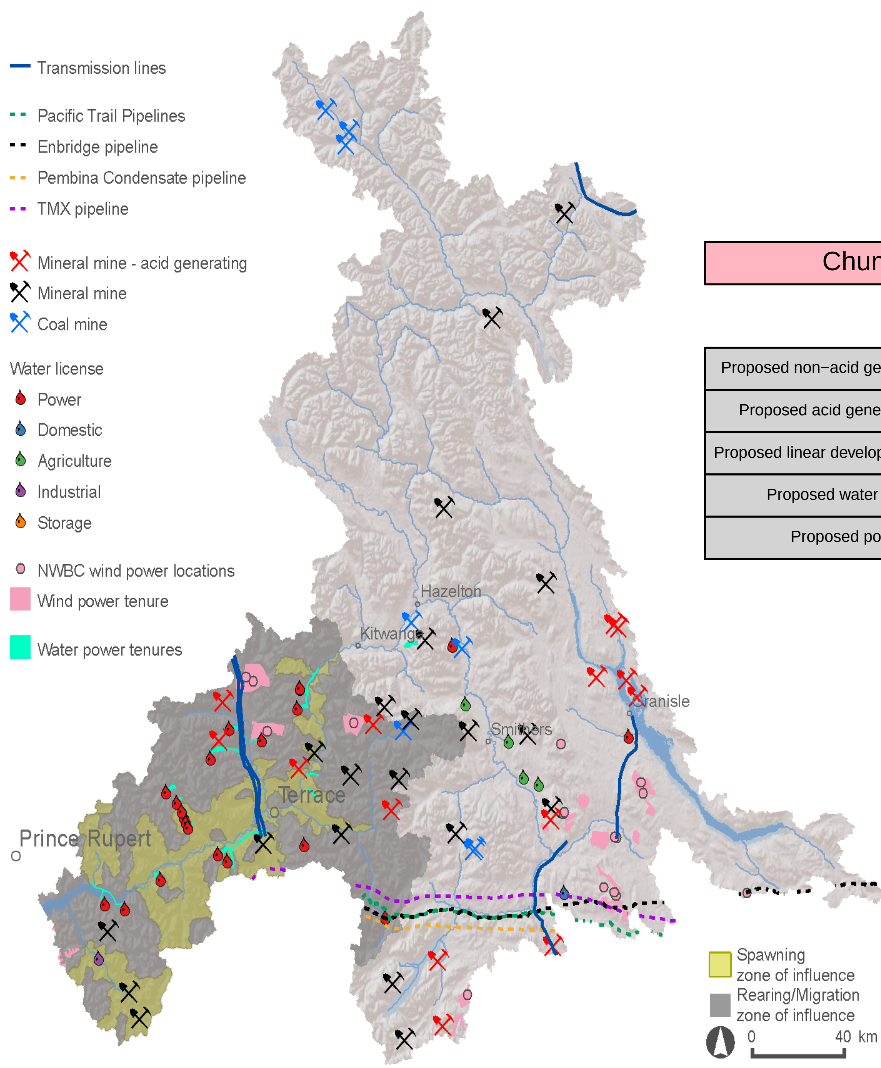






The solid blue circle in each figure represents the ranking of the particular CU relative to all other Skeena chum CUs. Darker colour gradation represents increasing cumulative habitat pressure and increasing vulnerability to those pressures for the egg incubation, rearing/migration, and spawning life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

24. Major proposed development projects (as of 2010)



Chum − Lower Skeena CU summary

	Rearing/migration	Spawning
Proposed non−acid generating mines (% increase)	9 (12.33%)	4 (20%)
Proposed acid generating mines (% increase)	5 (250%)	0 (0%)
Proposed linear development, km^2/km (% increase)	0.02 (2.5%)	0.01 (1.45%)
Proposed water licenses (% increase)	27 (13.17%)	7 (5.69%)
Proposed power tenures, km^2	314.51	31.53

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.

Skeena Salmon Program

Skeena Salmon

Conservation Unit Snapshot Quick Reference

Version 1.0, December 19, 2013

Pacific Salmon Foundation

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:

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

- 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:

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

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

- 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 25th and 75th 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).

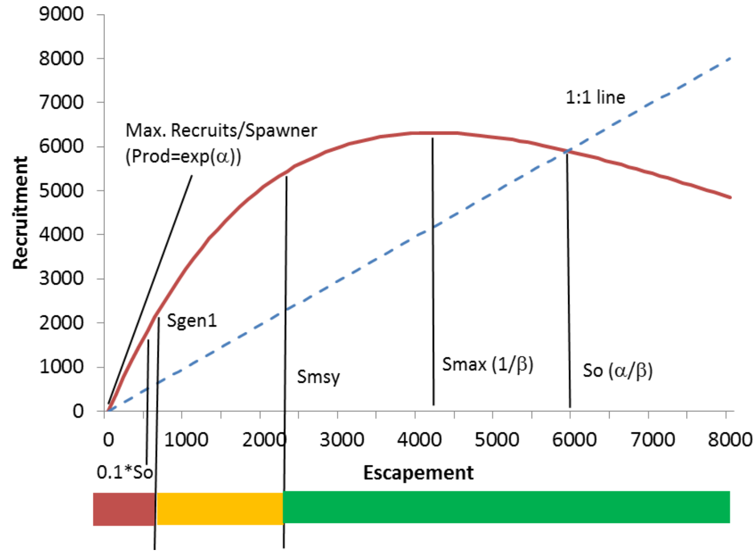


Figure 1. Reproduced from Korman and English 2013.

- **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.

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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