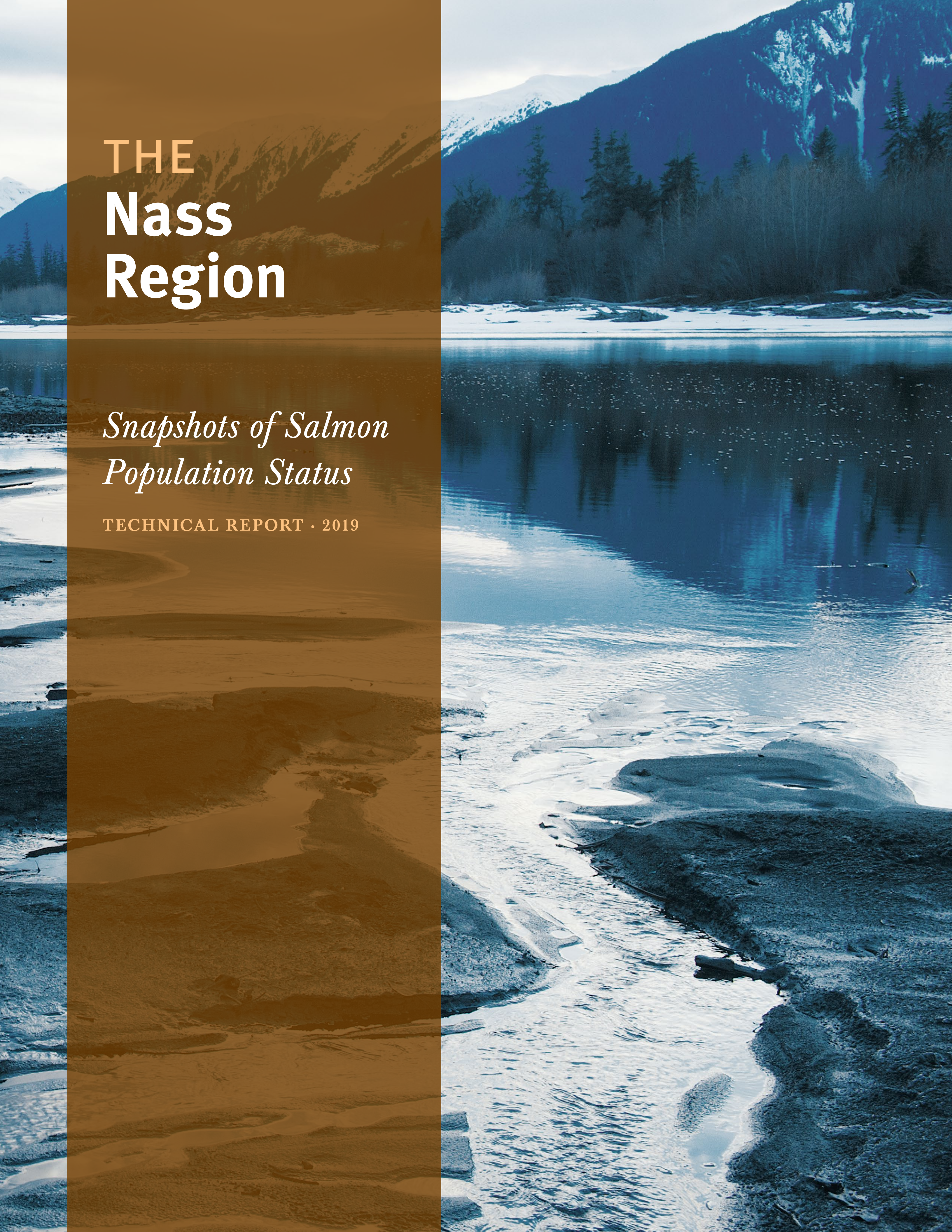

THE Nass Region

Snapshots of Salmon Population Status

TECHNICAL REPORT · 2019

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SALMON WATERSHEDS PROGRAM

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Snapshots of Salmon Population Status

TECHNICAL REPORT

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Executive Summary

Twenty-two ecologically, geographically, and genetically unique groups of wild salmon, known as Conservation Units (CUs) under Canada's Wild Salmon Policy[1], inhabit the Nass Region of British Columbia (BC). This rich salmon biodiversity has supported First Nations cultures and economies for millennia and, to this day, salmon remain central to the livelihoods of local communities.

While many salmon populations in the Nass Region are healthy and abundant, others are depressed, declining, or of conservation concern. Our ability to maintain healthy and thriving salmon populations depends, in part, on our ability to detect changes in salmon production over time, diagnose the drivers of salmon population dynamics, and identify where and when conservation and management measures may be required in order to support salmon recovery.

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1 Learn more at *https://salmonwatersheds.ca/wsp*

In an effort to assess the current status of salmon in the Nass Region, the Pacific Salmon Foundation (PSF) collaborated with First Nations, including the Nisga'a, Gitanyow, and Gitxsan, LGL Limited, and Fisheries and Oceans Canada, to assemble and summarize the best available data for describing the characteristics and dynamics of salmon CUs in the Nass Region. Much of the data used to assess the status of Nass salmon is the result of monitoring and assessment led by local First Nations. The Nisga'a Fisheries Program has been collecting data since 1992, with monitoring and assessment efforts over the past 19 years directly related to the implementation of the Nisga'a Treaty. In addition, the Gitanyow and Gitxsan First Nations contribute to monitoring and assessment in the Upper Nass River (e.g. Meziadin, Cranberry, Brown Bear, and Damdochax systems).

We quantified six different metrics for tracking and comparing status and trends across salmon CUs and generating snapshots of salmon status. Of the 13 CUs with sufficient data to assess their current biological status, pink salmon CUs tended to be of the lowest conservation concern and chum CUs of the greatest. In particular, two chum CUs were identified as a conservation concern based on their current biological status (Portland Canal – Observatory and Portland Inlet CUs). In recent years, chum salmon populations have fallen well below their long-term average, indicating the need for management and conservation intervention. Additionally, since 2009, Nass Chinook have experienced ongoing declines in spawner abundance. Although the current biological status assessments for both Chinook CUs is mixed based on data to 2014, more recent observations suggest a pattern of declining abundance.

While this project has produced snapshots of salmon status for the majority of Nass salmon CUs (13 of the 22), significant gaps in information remain for nine CUs. For instance, six of the 10 Nass sockeye CUs had insufficient information to assess their biological status. Our ability to make sound decisions about the conservation and management of salmon depends on the quality of data available, which in turn affects our ability to track long-term trends in salmon survival and productivity. Addressing these data gaps therefore remains an immediate priority. The capacity exists within local First Nations to expand their on-the-ground monitoring efforts and, with additional resources, First Nations could broaden the foundation of information that is needed to make informed, evidence-based fisheries management decisions.

The legacy of information assembled during the course of this project has been integrated into the Pacific Salmon Explorer (*salmonexplorer.ca*), an online data visualization tool that displays information on salmon populations and their habitats throughout BC, including the Central Coast. We have also made the source datasets broadly and freely available to the public via our Salmon Data Library (*data.salmonwatersheds.ca*). These centralized platforms for storing, distributing, and visualizing salmon-related datasets are critical for providing access to information, increasing the transparency of decision-making, and for identifying conservation and management strategies for supporting the recovery of at-risk CUs. Our hope is that these snapshots of salmon status provide a useful source of information for local and regional planning tables and for supporting systematic conservation planning efforts for Nass salmon CUs.

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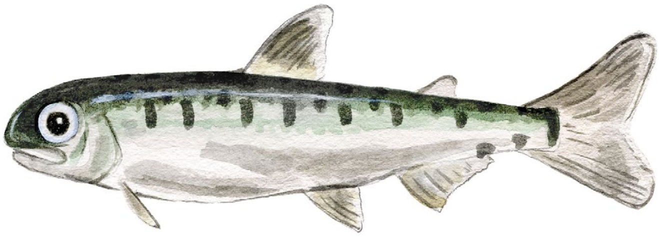

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FIGURE 1. Map of the Nass Region as defined by watershed boundaries for the purposes of this project.

1 Introduction

The Nass River watershed in northern British Columbia (BC), is the third largest watershed in BC, covering an area of 20,700 km² and flowing 380 km from the Coast Mountains to Portland Canal on the Pacific Coast. The watersheds draining into Portland Canal and Observatory Inlet comprise an additional 6,000 km² and, along with the Nass River watershed, make up the "Nass Region" (Figure 1). Some of the major tributaries of the Nass River include Bell-Irving, Cranberry, Meziadin, Kwinageese, and Damdochax rivers.

The Nass Region is the third-largest salmon producing region in BC, providing extensive spawning and rearing habitat for all five species of Pacific salmon (sockeye, coho, Chinook, chum, and pink), as well as steelhead. Since 1992, an average of approximately 1.5 million salmon have returned to the Nass Region each year with the majority of salmon being sockeye (43%), pink (39%), and coho (13%; Nisga'a Fisheries and Wildlife 2018). The Nass stock complex consists of an amalgamation of more than 250 separate spawning populations of salmon. These >250 spawning populations have been organized in 22 Conservation Units (CUs) under Canada's Wild Salmon Policy (Fisheries and Oceans Canada 2005; Table 1). A CU is defined as a group of wild salmon sufficiently isolated from other groups that, if lost, is very unlikely to re-colonize naturally within an acceptable timeframe, such as a human lifetime or a specified number of salmon generations (Holtby and Ciruna 2007). The 22 CUs in the Nass Region are comprised of two Chinook, three chum, three coho, four pink, and 10 sockeye CUs (Appendix 1). Collectively, these CUs reflect the geographic and genetic diversity of salmon in the Nass Region and, under the Wild Salmon Policy, represent the minimum level of salmon biodiversity that should be maintained in order to maintain adequate genetic diversity for Nass salmon and provide benefits to current and future generations.

The salmon biodiversity found in the Nass has supported First Nations cultures and economies since time immemorial. To this day, salmon remain central to the social, cultural, and economic fabric of communities throughout the region. While many salmon populations in the Nass are healthy, others are depressed, declining, or of conservation concern and the status of other populations is unknown (e.g. Fisheries and Oceans Canada 2018; Nisga'a Fisheries and Wildlife 2018). Declines have been attributed to a variety of human and environmental pressures, including overfishing (Wood 2008), habitat loss and degradation (Bradford and Irvine 2000), and reduced productivity (Fisheries and Oceans Canada 2018). On top of this, a growing body of evidence suggests that climate change is having and will have a major impact on Pacific salmon through changes in air temperature, precipitation, snowpack, stream flows, and water temperatures, as well as changes in predator and prey assemblages in both marine and freshwater environments (Nelitz et al. 2007; Beamish et al. 2009; Di Lorenzo and Mantua 2016). However, an understanding of how climate change and other freshwater and marine pressures influence salmon populations in the Nass Region is currently hampered by the limited amount of information on the productivity and the current biological status of Nass salmon CUs.

In an effort to assess the current status of Nass salmon CUs, the Pacific Salmon Foundation (PSF) collaborated with local partners including the Nisga'a, Gitanyow, and Gitxsan First Nations,

TABLE 1. List of Nass Conservation Units (CU) by species. The CU names are based on Holtby and Ciruna (2007).

Species	Conservation Unit
Chinook	Portland Sound – Observatory Inlet – Lower Nass
	Upper Nass
chum	Lower Nass
	Portland Canal – Observatory
	Portland Inlet
coho	Lower Nass
	Portland Sound – Observatory Inlet – Portland Canal
	Upper Nass
pink (even-year)	Nass – Skeena Estuary
	Upper Nass
pink (odd-year)	Nass – Portland Observatory
	Upper Nass
sockeye (lake-type)	Bowser
	Clements
	Damdochax
	Fred Wright
	Kwinageese
	Leverson
	Meziadin
	Oweegee
sockeye (river-type)	Lower Nass – Portland
	Upper Nass

LGL Limited, Fisheries and Oceans Canada (DFO), and the Nisga'a-Canada-BC Joint Technical Committee (a resource management working group of the Nisga'a Treaty with representatives from the Nisga'a, the Canadian government, and the Province of British Columbia) to develop snapshots of status for Nass salmon CUs. Specifically, this project aimed to compile the best available data for describing the characteristics and dynamics of salmon populations and quantify six different metrics for tracking and comparing status and trends across all 22 Nass salmon CUs. This project builds on almost three decades of work by Nisga'a Tribal Council and Nisga'a Lisims Government to monitor and assess returns of each salmon species to the Nass Region. The Nisga'a Fisheries Program has been monitoring salmon populations since 1992, with monitoring efforts since 2000 directly related to the implementation of the Nisga'a Treaty. In addition, the Gitanyow and Gitxsan First Nations contribute to Nass salmon monitoring and assessment, leading initiatives since 2000 in the Middle and Upper Nass River (e.g. Meziadin, Cranberry, Brown Bear, and Damdochax systems).

This project in the Nass Region is part of ongoing efforts by the PSF's Salmon Watersheds Program to work with First Nations, provincial and federal governments, local communities, and NGOs on BC's North and Central Coast to compile the best available data for Pacific salmon CUs and to use this information to develop snapshots of salmon status (Connors et al. 2013; Korman and English 2013; English et al. 2016; Connors et al. 2018). This project complements previous collaborations undertaken in 2015–2016 to assess pressures on freshwater habitats for Nass salmon CUs (Pacific Salmon Foundation 2016; Porter et al. 2016). The information compiled through this project, as well as the previous freshwater habitat assessments, have been made broadly, and freely, accessible to the public through the Pacific Salmon Explorer (*salmonexplorer.ca*), an online data visualization tool that displays information on salmon populations and their habitats throughout BC, including the Nass. We have also made the source datasets available to the public via our Salmon Data Library (*data.salmonwatersheds.ca*).

List of Acronyms

CU	Conservation Unit
DFO	Fisheries and Oceans Canada
PSF	Pacific Salmon Foundation

2 Methods

Given its central focus on maintaining and protecting salmon biodiversity, the Wild Salmon Policy was used as a framework for assessing the status of salmon CUs in the Nass Region. Specifically, we applied the approaches recommended by DFO for implementing of Strategy 1 of the Wild Salmon Policy (*salmonwatersheds.ca/wsp*), which calls for the standardized monitoring and assessment of wild salmon status (Fisheries and Oceans Canada 2005; Holt et al. 2009). Following the action steps laid out under Strategy 1, we worked to compile and synthesize data for all salmon CUs in the region. This involved sourcing the best available data from public databases, as well as identifying and acquiring supplementary datasets. With the available data, we summarized six population metrics that can be used to describe the dynamics and characteristics of salmon CUs. And finally, where sufficient data were available, we quantified the biological status for each CU using two different metrics. We describe each of these steps below.

2.1 Data Compilation & Synthesis

We compiled datasets that could be used to describe the dynamics and characteristics of salmon CUs in the Nass Region, including datasets on spawner abundance, catch, and exploitation rate. Our goal was to use the best available existing information to track and compare status among CUs in the Nass Region. Many of the datasets necessary to understand the dynamics of CUs in the Nass Region are available from DFO's New Salmon Escapement Database (NuSEDS), the Fisheries Operating System (FOS), and other DFO databases. Over the past decade many of these datasets for the Nass Region, including those from the Nisga'a-Canada-BC Joint Technical Committee, Nisga'a Fisheries and Wildlife, and the Gitanyow First Nation have been compiled and stored in the North and Central Coast (NCC) Database (English et al. 2016), a database produced and maintained by LGL Limited. This database synthesizes datasets on spawner surveys, catch, exploitation rate, and age structure, and also includes datasets for CU-level estimates of spawner abundance, run size, and exploitation rate from 1954–2014. In addition to data in the NCC database, we also identified and compiled additional data for six CUs through review of preliminary data with Nisga'a Lisims Government and LGL Limited staff (Lower Nass and Upper Nass coho CUs; Fred Wright, Damdochax, and Meziadin lake-type sockeye CUs; and Lower Nass-Portland river-type sockeye CU). We also used smolt abundance data from Nisga'a Fisheries and Wildlife.

We used six metrics to characterize the dynamics and status of each CU. These metrics provide a detailed snapshot of the best available data and an overview of temporal trends in salmon CUs over time.

Spawner Surveys

Spawner surveys consist of counts or observations of the number of salmon spawning in a specific stream in a given year. Spawner surveys are a fundamental source of information for assessing and tracking the status of salmon populations through time. We used data from NuSEDS compiled in the NCC Database to illustrate the spatial and temporal coverage of spawner counts by stream for each Nass CU.

All surveyed streams in the Nass Region have been classified as indicator and non-indicator streams (see English et al. 2006 for details). Indicator streams are those streams that have been identified by regional experts as providing more reliable indices of abundance. These indicator streams tend to be more intensively surveyed using methodologies that provide relatively accurate estimates of annual abundance. Spawner counts from indicator streams are also assumed to be representative of the number of spawners returning to other streams in the CU. A number of other streams within the CU that are classified as non-indicator may also be surveyed in a given year. These streams typically have less consistent survey coverage, variable methods applied, or may simply be difficult to survey (e.g. poor water clarity, remote location).

The methods used to survey spawners in both indicator and non-indicator streams vary considerably by stream, CU, and species. Methodology ranges from estimates based on a single visual survey of a stream section on foot, to counts of fish passing through an unbreached counting fence. Survey methodology can also change through time. For example, some streams that were previously surveyed by visual surveys on foot are now enumerated using a counting fence, with some including video documentation of fish passage.

Estimated Spawner Abundance

Estimated spawner abundance represents the estimated total number of spawners that return to spawn each year for a given CU. This CU-level estimate of abundance is based on spawner survey data from NuSEDS, and also accounts for streams that are not surveyed in a given year.

The quantity and quality of the spawner abundance estimates in NuSEDS varies by time period, region, and stream. As such, the stream-level data are not always representative of actual changes in abundance through time for a CU. This is because a CU may be comprised of more than one spawning population, and the monitoring coverage of spawning populations has varied greatly over time. Sockeye CUs typically have only one indicator stream to enumerate. For other species, there are very few CUs where all of the salmon spawning populations that comprise a CU are actually enumerated in a given year (English et al. 2016). As such, an “expansion procedure” is needed so that any changes in abundance through time are not confounded with changes in monitoring effort.

From 2008 to present, the PSF has worked with LGL Limited and Nisga’a Fisheries and Wildlife to generate Nass CU-level estimates of abundance, or run reconstructions, in collaboration with DFO North Coast stock assessment staff (English et al. 2006; 2012; 2016). The expansion procedures, by necessity, make a number of simplifying assumptions. The first expansion factor assumes that the proportion of the overall CU that each indicator stream represents is constant through time. The second expansion factor assumes that indicator and non-indicator streams make up a constant contribution to the overall abundance of a CU. The final expansion factor assumes that observer efficiency is constant between years, CUs, methodologies (except for fences), and hydrological systems. These, and other assumptions, are described in detail in Appendix E of English et al. 2016.

Separate from the expansion procedures, in the Nass, CU-level estimates of spawner abundance for five CUs are derived from additional enumeration methods. Three CUs have mark-recapture programs initiated at lower Nass River fishwheels that have been operated by Nisga’a Fisheries and Wildlife as part of the Nisga’a Treaty fisheries projects since 1992. As a result, for the Upper Nass coho and Upper Nass Chinook CUs, spawner abundance was estimated via mark-recapture and expansion procedures were not used. For the Lower Nass coho CU, the mark-recapture program is for only one indicator stream, Zolzap Creek (Ksi Ts’oohl Ts’ap), so expansion procedures were used in addition to mark-recapture data. The Meziadin and Fred Wright lake-type sockeye CUs are directly enumerated with a fishway and weir, respectively, and expansion procedures were not used for these CUs.

We used the CU-level **spawner abundance** estimates to illustrate estimated spawner abundance for each Nass CU over time. These values were also used as inputs for the Trends in Spawner Abundance, Catch and Run Size, and Recruits-per-Spawner metrics described below, and were used in the assessments of biological status (see Section 2.2).

Smolt Surveys

Smolt abundance is an estimate of the number of outmigrating smolts that are counted in a given system in a given year. For each CU, we plotted smolt abundance data for each stream, where available. We also calculated average smolt counts using the geometric mean because, unlike the arithmetic mean, it is insensitive to less frequent, higher abundance years.

In this project, all smolt abundance data were provided by the Nisga'a Fisheries and Wildlife Department, who have been running a smolt monitoring program in Ksi Ts'oohl Ts'ap (Zolzap Creek) since 1992. This monitoring program uses a weir to monitor outmigrating coho smolts. Counts of smolts occur daily throughout the sampling season, typically from mid-April through mid-June. Due to differential effort between years, and issues with sampling under high-flow events, the smolt abundance estimates shown on the Pacific Salmon Explorer (*salmonexplorer.ca*) should be considered an index of abundance rather than an estimate of the total number of smolts that migrated to the ocean in a given year.

Catch & Run Size

Catch refers to adult salmon that are caught in commercial (US and Canadian), recreational, and First Nations fisheries. Total **run size** refers to the total number of adult salmon returning in a given year, including those that reach the spawning grounds (i.e. estimated spawner abundance) and those that are caught in all fisheries (US and Canadian). **Exploitation rate** refers to the proportion of the total run size that is caught in all fisheries. The large and variable exploitation rates that a CU encounters in various fisheries has a significant influence on the number of fish that return to the spawning streams.

For each CU, annual estimates of catch and estimated exploitation rates were sourced from the NCC Database, which primarily sources data from DFO's Fisheries Operating System database and other external models (English et al. 2016). To determine a CU's exploitation rate, a variety of approaches are used depending on the quality and quantity of data available (English et al. 2016). For Nass sockeye CUs, exploitation rates are calculated from the Northern Boundary Sockeye Run Reconstruction Model (Alexander et al. 2010), which is the product of over three decades of monitoring and assessing stock composition and migration timing data for Nass and Skeena sockeye in northern BC and Alaskan fisheries. Exploitation rates for pink and chum are derived from various effort-harvest rate and other reconstruction models (see Table 1 in English et al. 2016). For coho, recoveries of coded-wire tags applied to Ksi Ts'oohl Ts'ap (Zolzap Creek) coho are used to derive exploitation rate estimates and CU-specific harvests. For Nass Chinook, exploitation rates estimates are derived from Nisga'a-Canada-BC Joint Technical Committee tables which combine estimates of escapement with in-river catch and the Nass component of marine harvests derived using coded-wire tag data (prior to 2009) and DNA sampling (English et al. 2016; Beveridge et al. 2018).

Recruits-per-Spawner

Recruits-per-spawner is an estimate of the number of adult salmon produced per spawner in the parental generation. Recruits-per-spawner provides 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 and will decline in abundance until the recruits-per-spawner again exceeds one.

Recruits-per-spawner was calculated as the number of recruits (the sum of all fish that return to spawn from a given brood year) divided by the number of spawners for each brood year (based on CU-level estimates of spawner abundance). The number of recruits is determined from estimates of the total run size for each CU along with estimates of age structure (i.e. the proportions of recruits that returned to spawn for each age at maturity). Age structure data for each CU, or indicator stream therein, was sourced from the NCC Database, which were based on datasets derived from the Pacific Region Salmon Age Dataset (English et al. 2016). For most CUs, there are no annual estimates of age composition, so average age composition estimates were used for all years, which creates uncertainty in the derivation of recruits-per-spawner.

Assuming a fixed age structure can lead to uncertainty and bias in estimates of recruits-per-spawner, and corresponding stock-recruitment benchmarks. The assumption of a fixed age structure for a CU creates less variation in the time series of recruits, and thus can result in an underestimation of the lower stock-recruitment benchmark, and an overestimation of the upper stock-recruitment benchmark (Zabel and Levin 2002; Korman and English 2013). However, previous studies on salmon CUs in BC have shown that the overall influence of age structure on estimating stock-recruitment benchmarks is relatively small (Korman and English 2013; Holt et al. 2018).

Trends in Spawner Abundance

Trends in spawner abundance refers to an estimate of the trend in abundance for an individual CU for the full time-series of information. These trends highlight long-term shifts in abundance that may otherwise be obscured by the high variability in abundance common in most salmon populations. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) uses trends in abundance over the last three generations (or 10 years, whichever is longer) as an indicator of the risk of extinction. However, consideration of trends in abundance over even longer time periods has been shown to be more likely to detect true declines in abundance (Porszt et al. 2012; d'Eon-Eggerston et al. 2015).

For each CU, trends in abundance were based on the geometric mean for each generation as estimated from a sliding window of the CU generation length. For example, pink CUs had a generation length (and thus a sliding window) of two years, while coho had a four-year generation length. The window was right-aligned so that the data displayed for a given year is for the most recent year in a given time period. For this analysis, the data was natural-log-transformed so that a linear relationship could be fit to the data to estimate the rate of change.

2.2 Assessing Biological Status

Under Strategy 1 of the Wild Salmon Policy (*salmonwatersheds.ca/wsp*), the status of salmon CUs is to be assessed using standard points of reference (i.e. benchmarks) against which condition can be compared. These benchmarks can be based on various metrics to quantify the biological status of a CU as being in one of three status zones: red, amber, or green. As the given status metric declines for a CU, the biological status of the CU moves from green to amber to red, and the extent of management intervention required increases. However, the Wild Salmon Policy is not prescriptive with regards to management actions applied to red and amber CUs; rather, the type and extent of intervention is determined for CUs on a case-by-case basis.

Holt et al. 2009 proposed candidate benchmarks for evaluating CU status, grouped into four classes: current spawner abundance, trends in abundance over time, distribution of spawners, and fishing mortality related to stock productivity. For the Nass, we used one class of indicator to quantify biological status, spawner abundance, and two different metrics within that class: those based on (1) historic spawners and (2) the stock-recruitment relationship. The addition of the historic spawner benchmark was suggested by the Nisga'a-Canada-BC Joint Technical Committee as a way to address concerns around applying stock-recruitment benchmarks to data-limited CUs. The methods we used to assess biological status for Nass CUs build off our work in the Skeena River watershed (Connors et al. 2013) and Central Coast (Connors et al. 2018), and recommendations by Holt et al. 2009 and Holt et al. 2018.

Each of the status metrics that we considered have their own advantages and drawbacks. The stock-recruitment approach has the advantage of being more biologically-based than the historic spawners approach, as it considers the productivity

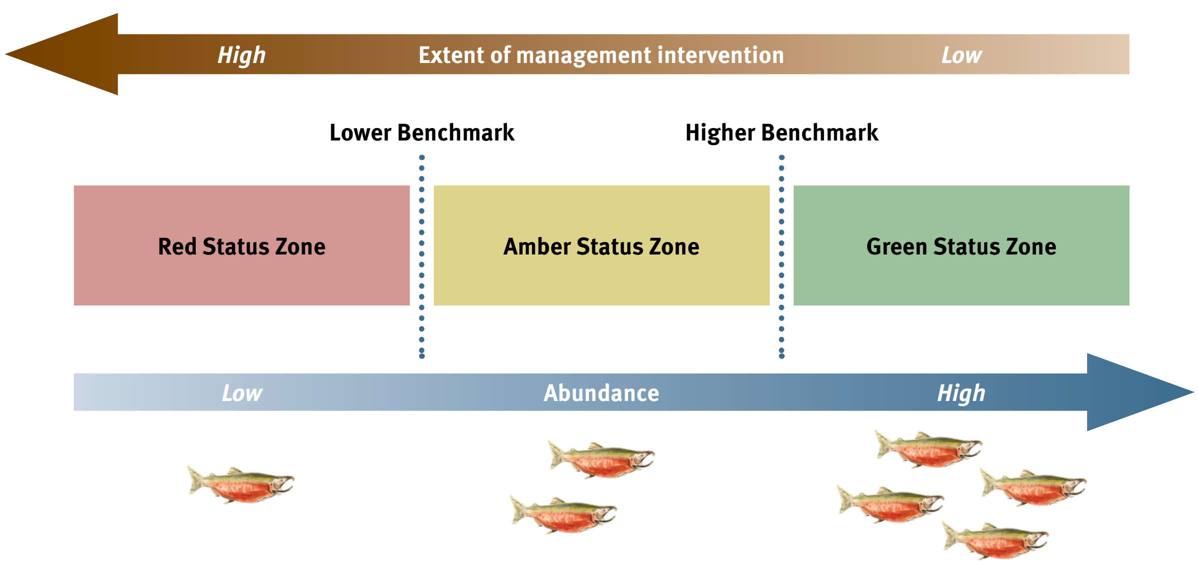


FIGURE 2. Benchmarks and biological status zones to be determined for each Conservation Unit, adapted from the Wild Salmon Policy (Fisheries and Oceans Canada 2005).

and carrying capacity of each CU. However, this approach is also more data-intensive, requiring estimates of age structure, exploitation rates, and CU-level spawner abundance. The historic spawners approach requires less data, so is more suited to data-limited situations, but is also less representative of population dynamics. Historic spawner approaches have previously been used in Canada (Holt et al. 2009; 2018) and Alaska (Clark et al. 2014; 2017). Previous research has found that historic spawner approaches are generally more precautionary for assessing the status of data-limited salmon populations than other approaches (Hilborn et al. 2012; Holt and Folkes 2015; Holt et al. 2018).

Neither metric is intended to provide a definitive assessment of biological status. *Additionally, these status assessments are not intended to represent management targets, escapement goals, or reference points used in the management of salmon fisheries* (Box 1). Rather, the estimates presented in this report are intended to provide a synoptic overview of CU status based on a suite of metrics and an overall indication of the dynamics and characteristics of salmon CUs over the available time series. In addition, while the biological benchmarks used in this project may or may not align with management reference points that have been developed for specific Nass CUs, they can provide important inputs for developing management reference points, undertaking integrated status assessments, or supporting other expert-driven processes that integrate socioeconomic information in the future.

Historic Spawners

For the historic spawners metric, we use the 25th and 75th percentile of historic spawner abundance as the lower and upper benchmarks, respectively (Hilborn et al. 2012; Connors et al. 2018). The status of each CU was determined by comparing

Box 1. Biological Benchmarks & Management Reference Points

In the management of salmon fisheries, multiple, competing objectives can make it difficult to define reference points for decision-making (Holt and Irvine 2013). Biological benchmarks and management reference points are distinct concepts that help to disentangle the trade-offs between long-term biological and shorter-term socioeconomic considerations.

Biological benchmarks, which are used in this project, delineate zones of biological status (i.e. good/green, fair/amber, or poor/red) based on population dynamics and conservation considerations. They are scientifically derived. In contrast, *management reference points* typically integrate biological information with shorter-term socioeconomic considerations that may be obtained through stakeholder engagement.

In this project, our approach to developing biological benchmarks is consistent with the methodologies put forward by DFO for assessing status under the Wild Salmon Policy (Fisheries and Oceans Canada 2005; Holt et. al 2009). While the biological benchmarks used in this project may not align with management reference points that have been developed for specific CUs, they can provide important inputs for developing management reference points, undertaking integrated status assessments, or supporting other expert-driven processes that integrate socioeconomic information.

the geometric mean spawner abundance over the most recent generation to the upper and lower benchmarks. A CU was assigned a “red” status if the average spawner abundance over the most recent generation was at or below the 25th percentile of historic spawner abundance. An “amber” status was assigned if average spawner abundance over the most recent generation was between the 25th and 75th percentiles of historic abundance, and a “green” status was assigned if it was at or over the 75th percentile.

Stock-Recruitment

The shape of the stock-recruitment relationship can also be used to define benchmarks for evaluating biological status (Holt et al. 2009; Korman and English 2013). For the stock-recruitment approach, the upper benchmark corresponds to S_{MSY} (the spawner abundance predicted to achieve Maximum Sustainable Yield over the long-term), and the lower benchmark corresponds to S_{GEN1} (the spawner abundance predicted to return the population to S_{MSY} in one generation under equilibrium conditions in the absence of fishing). This approach has previously been used to inform biological status for CUs in the Skeena River watershed (Korman and English 2013) and has been used in integrated status assessments for Fraser sockeye (Grant and Pestal 2012).

Stock-recruitment benchmarks are estimated in a hierarchical Bayesian framework by species. A hierarchical approach was chosen because estimates of stock-recruitment relationships within a species that are derived simultaneously are more reliable than those estimated independently. Hierarchical modeling approaches, which borrow information from data-rich populations to potentially improve assessments for data poor ones, are being increasingly applied in stock assessments (see Jiao et al. 2011; Korman and English 2013; Malick et al. 2017).

We generated brood tables for Nass CUs based on estimates of age-specific recruitment from the NCC Database (English et al. 2016). For Nass salmon, 13 CUs were deemed to have sufficient data (>3 stock-recruit pairs) to fit a species-specific hierarchical Ricker model:

$$
\begin{aligned}
&log_e\left(\frac{R_{i,t}}{S_{i,t}}\right) = \alpha_{i,t} - \beta_i S_{i,t} + \varepsilon_{i,t},\\
&\alpha_i \sim N(\mu_\alpha, \sigma_\alpha),\\
&\varepsilon_{i,t} \sim N(0, \sigma_{i,t})
\end{aligned}
$$

EQUATION 1.

where R is total recruitment from spawners S from CU i in brood year t, α is intrinsic productivity, β is the strength of within CU density dependence and ε is residual variation. Parameters for each CU within a species were estimated in a hierarchical framework with CU-specific intrinsic productivity values from a normal distribution. For each species, the model in Equation 1 was fit to all Nass CUs with more than three stock-recruit pairs.

We used diffuse prior distributions for the hyper-parameters of α (hyper-priors) and σ_α, and informative priors for CU-specific estimates of β_i based on its reciprocal S_{MAX} with a mean equal to the average spawner abundance for the CU and a coefficient of variation set to a diffuse (10) or minimally informative (1) value if there were problems with convergence.

Posterior probability distributions were generated for the parameters in equation 1 using a Markov chain Monte Carlo procedure in the r2JAGS package in R (Su and Yajima 2012). We ran six chains for 100,000 iterations with a burn-in of 5,000 iterations and thinned every tenth iteration. Convergence was assessed by examining the potential scale reduction factor ($\hat{R}$); convergence was assumed to have occurred if $\hat{R}$ was less than 1.1 (Gelman and Rubin 1992).

S_{GEN1} was calculated by nonlinear estimation using the 'L-BFGS- B' algorithm from the 'optim' library in R and S_{MSY} was calculated based on the explicit solution proposed by Scheuerell 2016. We then compared the geometric mean spawner abundance over the most recent generation to the upper (S_{MSY}) and lower (S_{GEN1}) benchmarks to determine biological status. To account for uncertainty in the benchmarks, we also calculated the probability of the current spawner abundance value for each CU being below, between, and above the lower and upper benchmarks.

Data Deficient Conservation Units

Assessments of biological status were contingent on the availability and quality of time series data on spawner abundance. For a number of CUs, limitations in the available data meant that the status of CUs could not be assessed and these CUs were categorized as 'data deficient.'

We considered four types of data deficiencies in this project. The first type includes CUs with *no run reconstruction* (i.e. no CU-level estimates of abundance). This could be for one of two reasons: (1) These CUs do not have any data in NuSEDS. This means that there have been no spawner surveys conducted for these CUs since 1954. Or (2) these CUs do not have an identified indicator stream. Without an indicator stream, CU-level estimates of spawner abundance cannot be generated, which are necessary for estimating biological status.

The second type of data deficient CUs are those with a run reconstruction, but *have a significant gap in the run reconstruction time series*. For example, a CU with no monitoring for a period of 20 years or greater — in the most recent 30 years of the time series — would be considered data deficient. These CUs are considered data deficient because there is insufficient recent data to assess their current biological status.

The third type of data deficient CUs are those for which there is *no data on spawner abundance for the most recent generation*. This means that we cannot generate an estimate of current abundance to compare against the different benchmarks.

The fourth type of data deficient pertains specifically to the stock-recruitment benchmark. Some CUs *lack any data on age structure*, and thus brood tables cannot be generated. This means that the stock-recruitment benchmark cannot be calculated for these CUs.

3 Results

This section provides a high-level overview of the project results for all 22 salmon CUs in the Nass Region. Full results are available online through the Pacific Salmon Explorer (*salmonexplorer.ca*), where individual figures, maps, data, and summary statistics are provided for each Nass CU. Please note that the results of this assessment reflect the data in-hand as of October 2018 and data that are current to 2014. As new data become available, we will update the analyses and visualize the updated results in the Pacific Salmon Explorer. Consequently, in the future, the results described and summarized in this report will not match the results presented online.

3.1 Biological Status

Of the 22 CUs examined in this project, we were able to assess biological status using at least one metric for 13 CUs (Table 2, Figures 3–9, Appendix 2). The remaining nine CUs had insufficient information for evaluating their biological status (see Section 2.2 for a discussion of the criteria used to define data deficient CUs). Of the CUs for which we were able to assess biological status, the majority were in the green or amber status zones: for the historic spawners metric, five CUs were in the green zone and four were in the amber zone; for the stock-recruitment metric, five CUs were in the green zone and five were in the amber zone. Four CUs were in the red status zone for the historic spawners metric, while two CUs were in the red status zone based on the stock-recruitment metric.

Chinook

We were able to assess status for both Nass Chinook CUs (Table 2, Figure 3). The Portland Sound – Observatory Inlet – Lower Nass CU was in the green status using the stock-recruitment metric, but the amber status zone using the historic spawner approach. These results highlight the tendency of the historic spawners metric to produce more precautionary results (i.e. more likely to assign CUs to a red or amber status zone), which is consistent with previous studies (Holt et al. 2018). The Portland Sound – Observatory Inlet – Lower Nass CU could therefore be considered of low to moderate conservation concern based on the metrics considered. One note to highlight for this CU is that Ksi Gingolx (Kincolith River), an indicator stream, was hatchery-enhanced for a period from the 1990s through early 2000s. This would have resulted in an unquantified increase in the number of spawners in this indicator stream over the time period of hatchery operations.

The other Chinook CU, Upper Nass, was in the green status zone according to the stock-recruitment metric, but in the red status zone according to the historic spawner metric. The lack of concordance between the two status metrics was likely due to the differences in the way that the benchmarks are applied: the stock-recruitment approach considers the productivity and carrying capacity of the CU, while the historic spawner approach only considers the variation in spawner abundance over the time series. A closer examination of the other metrics, such as trends in spawner abundance, can help to support a more in-depth understanding of status for this CU. Notably, this CU shows a decline in spawner abundance of 34% over the time series, and has had recruits-per-spawner below replacement level for the last three years, suggesting that the red status zone classification (historic spawner metric) may be more accurate. In addition, as noted previously, the biological status assessments reflect data that are current to 2014. Based on the limited monitoring data that is available, especially for coastal Chinook systems, both Chinook CUs have experienced declines in spawner abundance since 2009.

Chum

We were able to quantify the biological status of two out of the three Nass Chum CUs (Table 2, Figure 4). The status of chum CUs in the Nass Region was poor, with status ranging from the red to amber zone depending on the metric and CU. The Portland Inlet CU was in the red status zone according to the historic spawner metric and in the amber status zone according to the stock-recruitment metric, suggesting that this CU is of moderate to high conservation concern. The Portland Canal – Observatory CU was in the red status zone according to both metrics, suggesting a critcal need for conservation and management intervention to promote long-term recovery.

The poor status of Nass chum is also recognized in the 2018 DFO Integrated Fisheries Management Plan (Fisheries and Oceans Canada 2018), where a number of management measures were taken to ensure that the exploitation rate for Nass chum remains below 10%. These management actions include non-retention of chum in most fisheries, area closures where chum are abundant, and gill net mesh restrictions to limit bycatch. The Nisga'a Nation has also limited harvest of chum salmon in the Nisga'a Treaty fisheries by foregoing harvest of 41,000 Nass chum that were allocated from 2000 to 2018.

Coho

We were able to assess status for all three Nass coho CUs (Table 2, Figure 5). The coho CUs were in the green or amber status zones, depending on the metric and CU. This suggests that coho CUs are of low to moderate conservation concern. The Upper Nass CU was in the green status zone according to both metrics, suggesting low conservation concern for this CU. The Lower Nass CU was in the amber status zone according to the historic spawner metric and in the green status zone according to the stock-recruitment metric, suggesting low to moderate conservation concern. The Portland Sound – Observatory Inlet – Portland Canal CU was in the amber status zone according to both metrics, suggesting moderate conservation concern. The relatively good status of these CUs occurs despite an exploitation rate that generally exceeds 50%, primarily from US commercial fisheries.

Pink

We were only able to assess status for two out of the four Nass pink CUs (Table 2, Figures 6–7). Both the Nass – Portland – Observatory (odd-year) and Nass – Skeena Estuary (even-year) CUs were in the green status zone for both metrics and were of low conservation concern. The status of these CUs was improved by the high number of returning spawners in 2013 and 2014, and both also show an increasing trend in spawner abundance over the entire time series.

Sockeye

Of the 10 sockeye CUs in the Nass Region, we were able to assess status for four CUs (Table 2, Figures 8–9). Two lake-type populations (Meziadin and Damdochax) were in the amber status zone, suggesting moderate conservation concern. Meziadin sockeye, the primary sockeye-producing system in the Nass Region, is monitored through a fishway, which allows for the enumeration of returning spawners. This enumeration method means that expansion procedures are not required to generate a CU-level estimate of spawner abundance. As a result, there tends to be less uncertainty in the spawner abundance data and resulting biological status assessments for Meziadin sockeye than for CUs that are only monitored through stream surveys. However, in recent years, Meziadin sockeye have returned later than average, and some fish have passed through the Meziadin fishway after operations have ceased for the season.

The Fred Wright CU was in the red status zone according to both metrics. This CU is recovering from a blockage that greatly reduced fish passage beginning in 2008 or 2009. In 2011, the Nisga'a Lisims Government, Province of BC, and Government of Canada worked together to address this blockage, and by the fall of 2011, the Fred Wright CU was again able to reach their spawning grounds. This CU is still rebuilding in response to the impacts of this blockage.

The Lower Nass – Portland river-type CU was in the green status zone according to the historic spawner metric, and data deficient according to the stock-recruitment metric (due to a lack of age-structure data). Since 2000, enumeration assessments on Gingit Creek by the Nisga'a Fisheries and Wildlife Department and LGL Limited contribute to better knowledge of this CU (Beveridge et al. 2017).

3.2 Data Deficient Conservation Units

Biological status could not be assessed for nine CUs using either metric and they were classified as "data deficient." Seven of these CUs did *not have run reconstructions* which are required to derive biological status. Two CUs did not have any data in NuSEDS (Kwinageese and Leverson lake-type sockeye CUs). The remaining five CUs (Bowser, Clements, and Oweegee lake-type sockeye, Upper Nass pink (odd-year), and Upper Nass pink (even-year)) CUs had some spawner survey data in NuSEDS, but a CU-level estimate of spawner abundance could not be generated for these CUs because they did not have any identified indicator streams. (At least one indicator stream is required in order to generate a CU-level estimate of abundance.)

The remaining two data deficient CUs, Upper Nass River river-type sockeye and Lower Nass chum CUs, were data deficient based on *a significant gap in the run reconstruction time series*. Both CUs have a run reconstruction, but the Nisga'a-Canada-BC Joint Technical Committee identified a significant gap in monitoring for both these CUs. The Upper Nass River river-type sockeye CU had a complete gap in monitoring of nearly 20 years, from 1986–2004. The Lower Nass chum CU had a gap in continuous monitoring during a 40+ year period. For this CU, there were consistent spawner counts for the identified indicator stream from 1954–1968 and again from 2009–2014, but in the 42 years from 1968–2009 there were only 10 years of monitoring. As such, we did not assess the biological status of these two CUs.

TABLE 2. Summary statistics, biological status designation, and benchmark values for 22 Nass Region Conservation Units. Current abundance is expressed as the geometric mean over the most recent generation, shown in parentheses. CUs followed by a * have CU-level estimates of spawner abundance generated (at least in part) from mark-recapture programs or fishway or weir counts. Years of Data shows the number of years with a CU-level estimate of spawner abundance. For the stock-recruitment metric, the percentage in each column is the probability (%) of a given status based on the benchmarks (S_{GEN1} and S_{MSY} values) estimated from a Hierarchical Bayesian Model. (Note: probabilities may not sum to 100% due to rounding.) For the stock–recruitment benchmark values, 95% credible intervals (CI) are shown in parentheses.

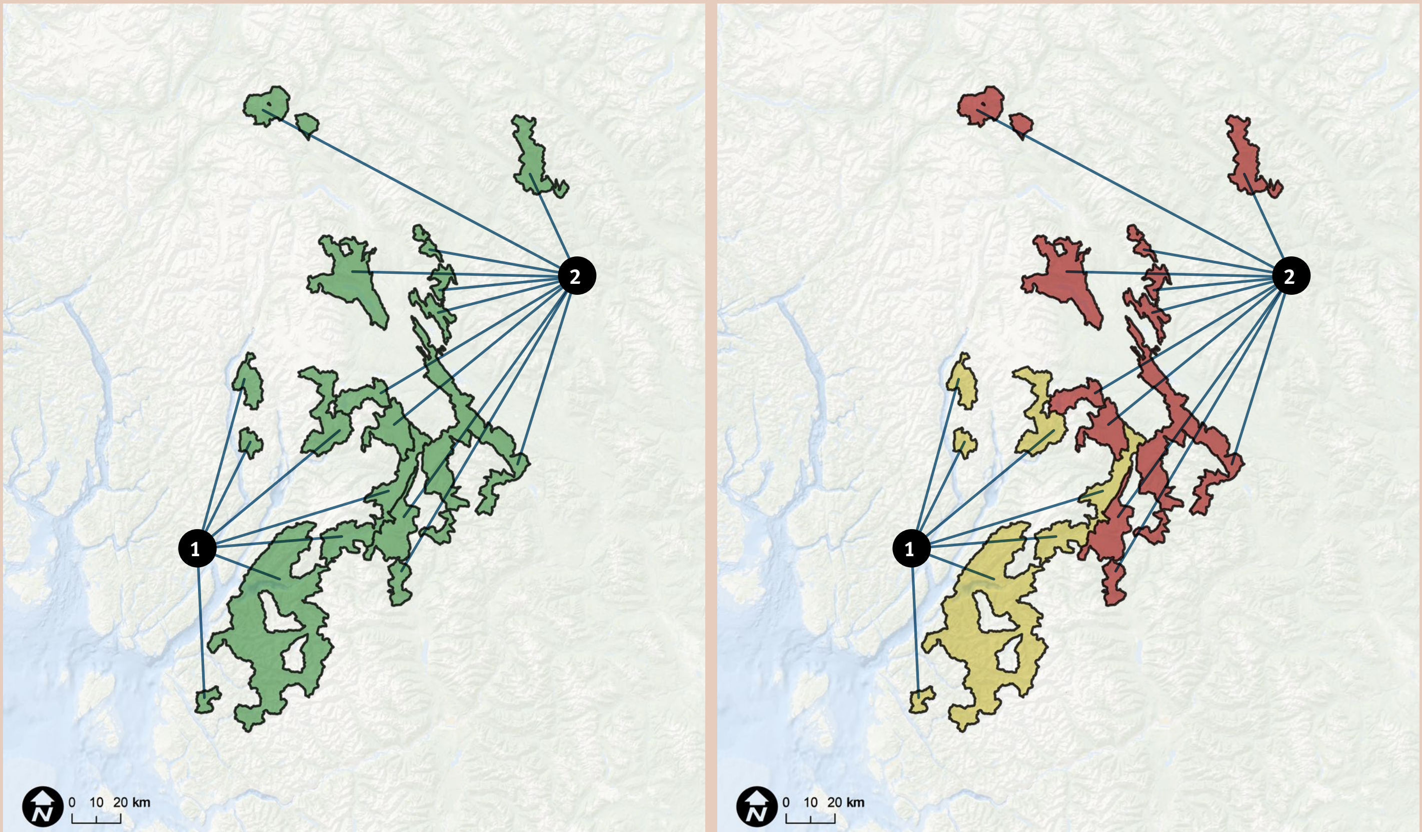
Conservation Unit	Current Abundance	Years of Data	Biological Status				Status Metrics			
			Historic Spawners	Stock–Recruitment			Historic Spawners		Stock–Recruitment	
				% Chance of Red Status	% Chance of Amber Status	% Chance of Green Status	Lower Benchmark: 25th percentile	Upper Benchmark: 75th percentile	Lower Benchmark: S_{GEN1} (95% CI)	Upper Benchmark: S_{MSY} (95% CI)
Chinook										
Portland Sound – Observatory Inlet – Lower Nass	1,372 (2010–2014)	29		0%	14%	86%	1,108	2,425	356 (188–747)	1,168 (945–1,672)
Upper Nass *	10,738 (2010–2014)	29		1%	49%	51%	13,352	23,594	2,466 (1,008–8,082)	10,712 (8,519–16,679)
Chum										
Portland Inlet	11,626 (2011–2014)	61		7%	93%	0%	13,184	33,194	9,041 (4,312–12,864)	18,752 (15,365–25,740)
Lower Nass	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Portland Canal – Observatory	12,975 (2011–2014)	61		90%	10%	0%	16,992	51,635	15,496 (7,059–21,762)	31,030 (24,888–43,524)
Coho										
Lower Nass *	38,070 (2011–2014)	23		3%	24%	73%	12,496	50,784	7,959 (2,624–40,947)	30,384 (18,464–81,893)
Upper Nass *	88,969 (2011–2014)	23		0%	3%	97%	47,046	85,629	26,738 (5,378–45,351)	53,476 (40,128–90,701)
Portland Sound – Observatory Inlet – Portland Canal	28,034 (2011–2014)	49		36%	64%	0%	21,136	63,407	25,459 (5,053–114,232)	51,287 (35,673–1,177,694)

(continued on next page)

Conservation Unit	Current Abundance	Years of Data	Biological Status				Status Metrics			
			Historic Spawners	Stock–Recruitment			Historic Spawners		Stock–Recruitment	
				% Chance of Red Status	% Chance of Amber Status	% Chance of Green Status	Lower Benchmark: 25th percentile	Upper Benchmark: 75th percentile	Lower Benchmark: S_{GEN1} (95% CI)	Upper Benchmark: S_{MSY} (95% CI)
Pink (even-year)										
Upper Nass	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nass – Skeena Estuary	4,854,184 (2014)	30		0%	0%	100%	643,283	2,732,887	561,863 (412,443–868,672)	1,123,726 (824,886–1,737,345)
Pink (odd-year)										
Nass – Portland – Observatory	1,447,856 (2013)	29		21%	22%	57%	252,973	917,823	442,342 (0–24,126,711)	1,122,696 (437,527–2,501,976,379)
Upper Nass	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sockeye (lake-type)										
Clements	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Leverson	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bowser	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Damdochax	3,270 (2010–2014)	29		1%	96%	4%	1,985	5,500	815 (380–2,387)	4,737 (3,181–9,933)
Fred Wright *	794 (2010–2014)	26		97%	3%	0%	2,550	8,625	2,643 (769–28,251)	13,416 (6,782–56,502)
Kwinageese	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Meziadin *	157,096 (2010–2014)	33		3%	73%	24%	116,588	186,757	89,605 (64,872–165,372)	179,210 (129,745–330,744)
Oweegee	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sockeye (river-type)										
Lower Nass – Portland	26,224 (2011–2014)	33		NA	NA	NA	2,890	11,350	NA	NA
Upper Nass River	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Chinook
Biological Status

Good
Fair
Poor
Data Deficient

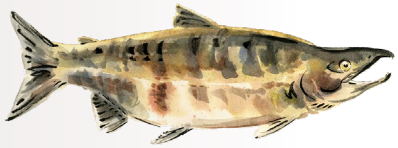


Stock-Recruitment
Historic Spawners

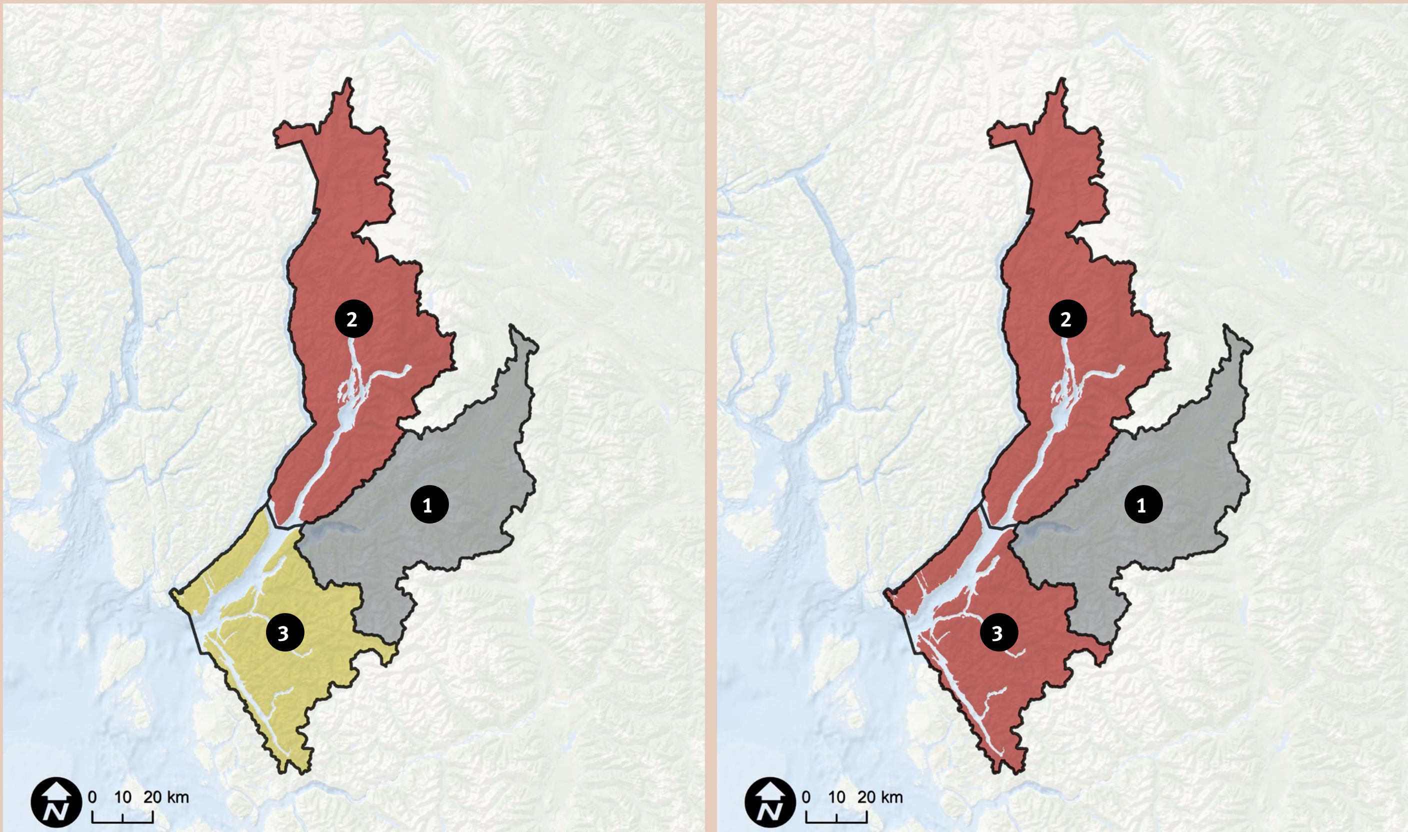
Stock-Recruitment	Historic Spawners		Conservation Unit
		1	Portland Sound – Observatory Inlet – Lower Nass
		2	Upper Nass

FIGURE 3. Maps showing the biological status of Nass Chinook salmon Conservation Units, using stock-recruitment and historic spawners metrics.

Chum
Biological Status



Good		Fair	
Poor		Data Deficient	



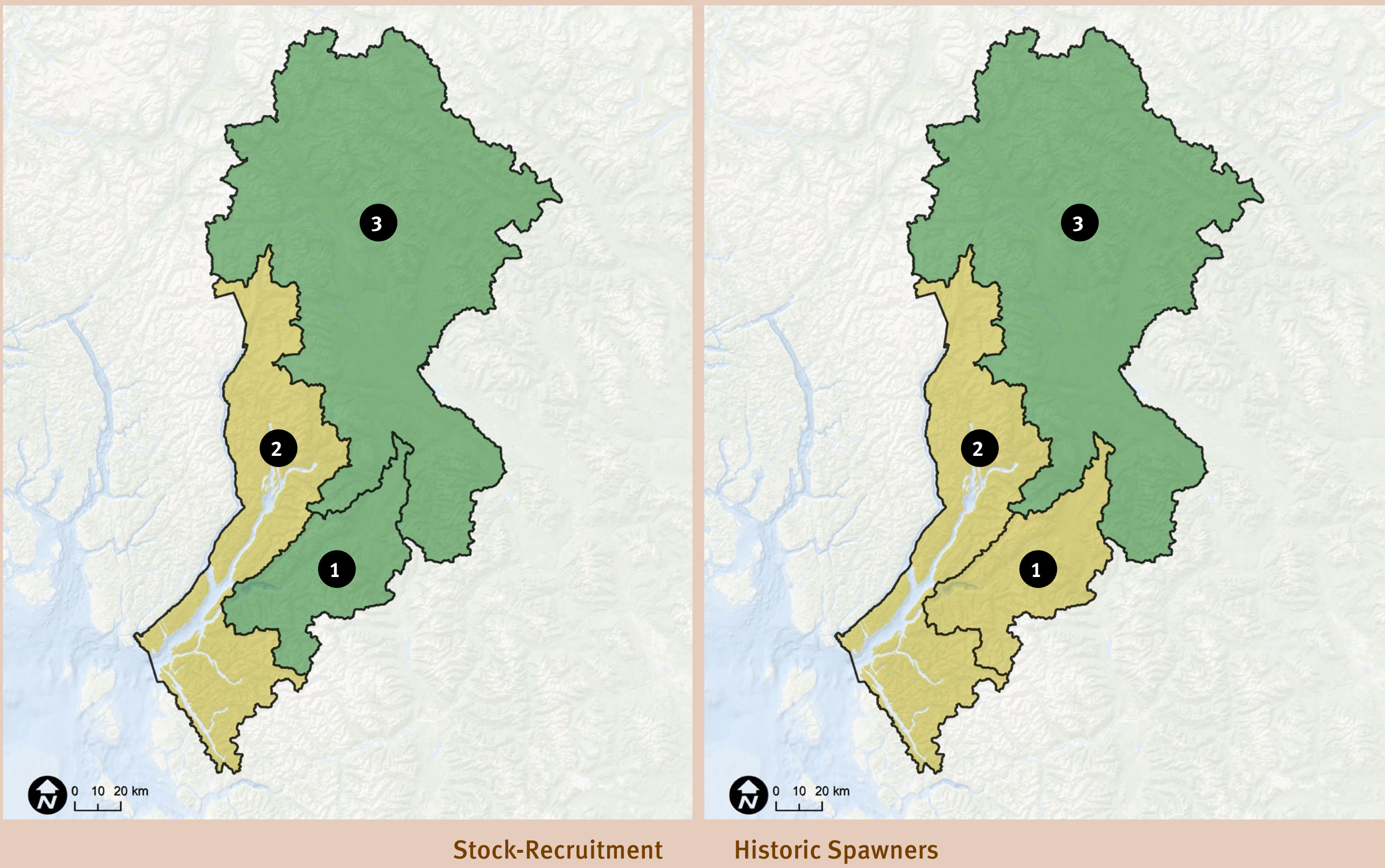
Stock-Recruitment   Historic Spawners

Stock-Recruitment	Historic Spawners		Conservation Unit
Data Deficient	Data Deficient	1	Lower Nass
Poor	Poor	2	Portland Canal – Observatory
Fair	Poor	3	Portland Inlet

FIGURE 4. Maps showing the biological status of Nass chum salmon Conservation Units, using stock-recruitment and historic spawners metrics.

Coho
Biological Status

Good
Fair
Poor
Data Deficient

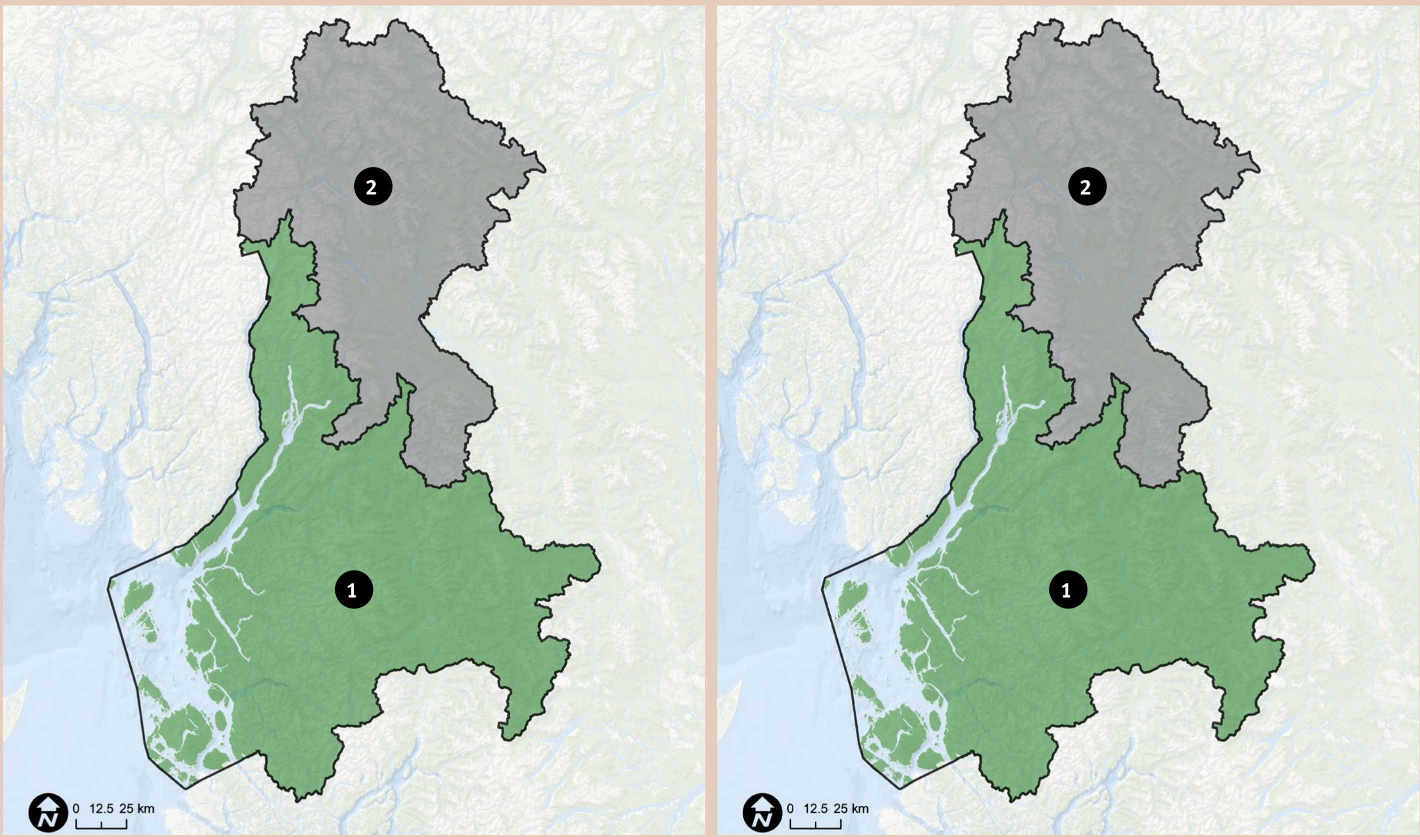


Stock-Recruitment	Historic Spawners		Conservation Unit
		1	Lower Nass
		2	Portland Sound – Observatory Inlet – Portland Canal
		3	Upper Nass

FIGURE 5. Maps showing the biological status of Nass coho salmon Conservation Units, using stock-recruitment and historic spawners metrics.

Pink (even-year)
Biological Status

Good | Fair | Poor | Data Deficient



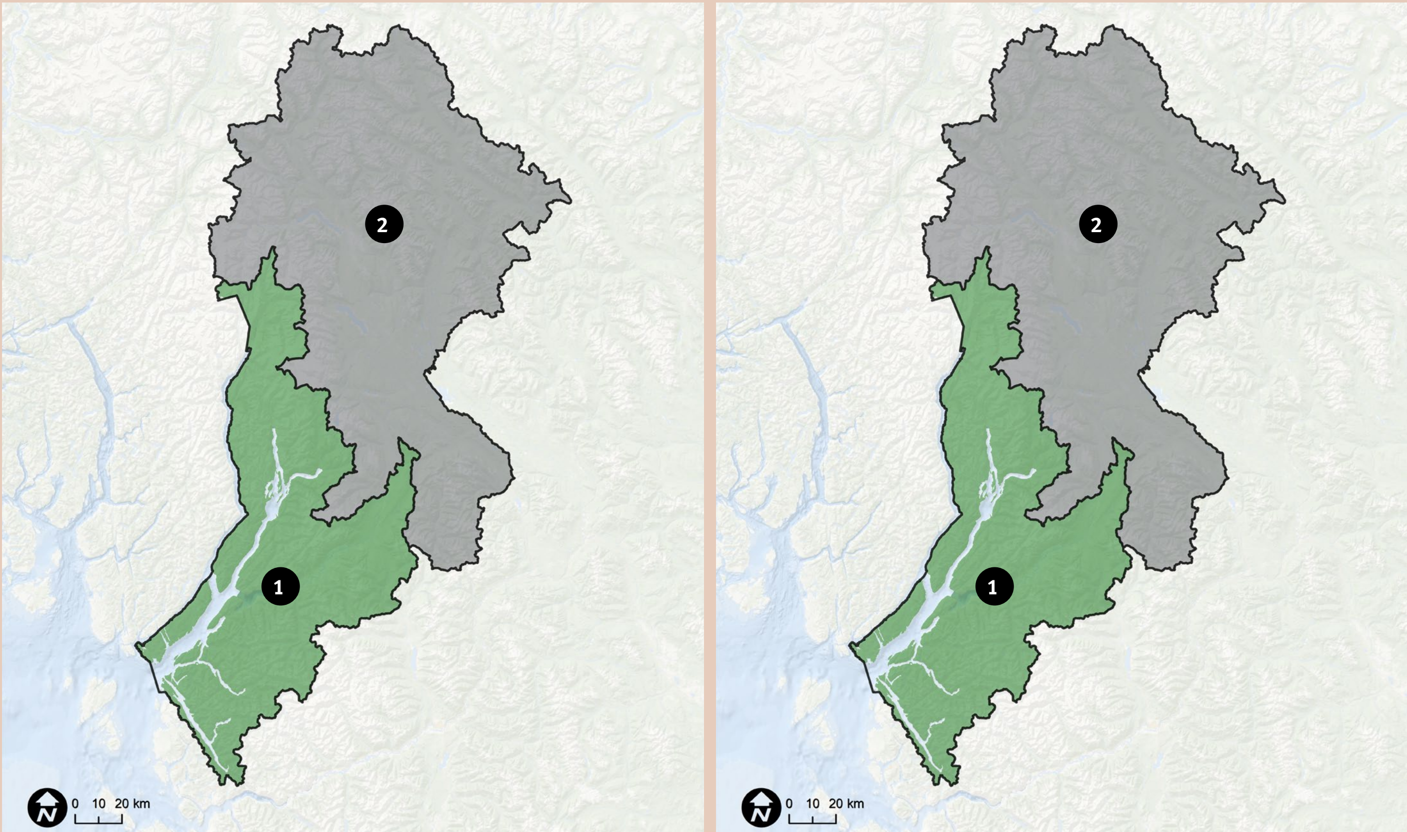
Stock-Recruitment | Historic Spawners

Stock-Recruitment	Historic Spawners		Conservation Unit
		1	Nass – Skeena Estuary
		2	Upper Nass

FIGURE 6. Maps showing the biological status of Nass pink (even-year) salmon Conservation Units, using stock-recruitment and historic spawners metrics.

Pink (odd-year)
Biological Status

Good | Fair | Poor | Data Deficient



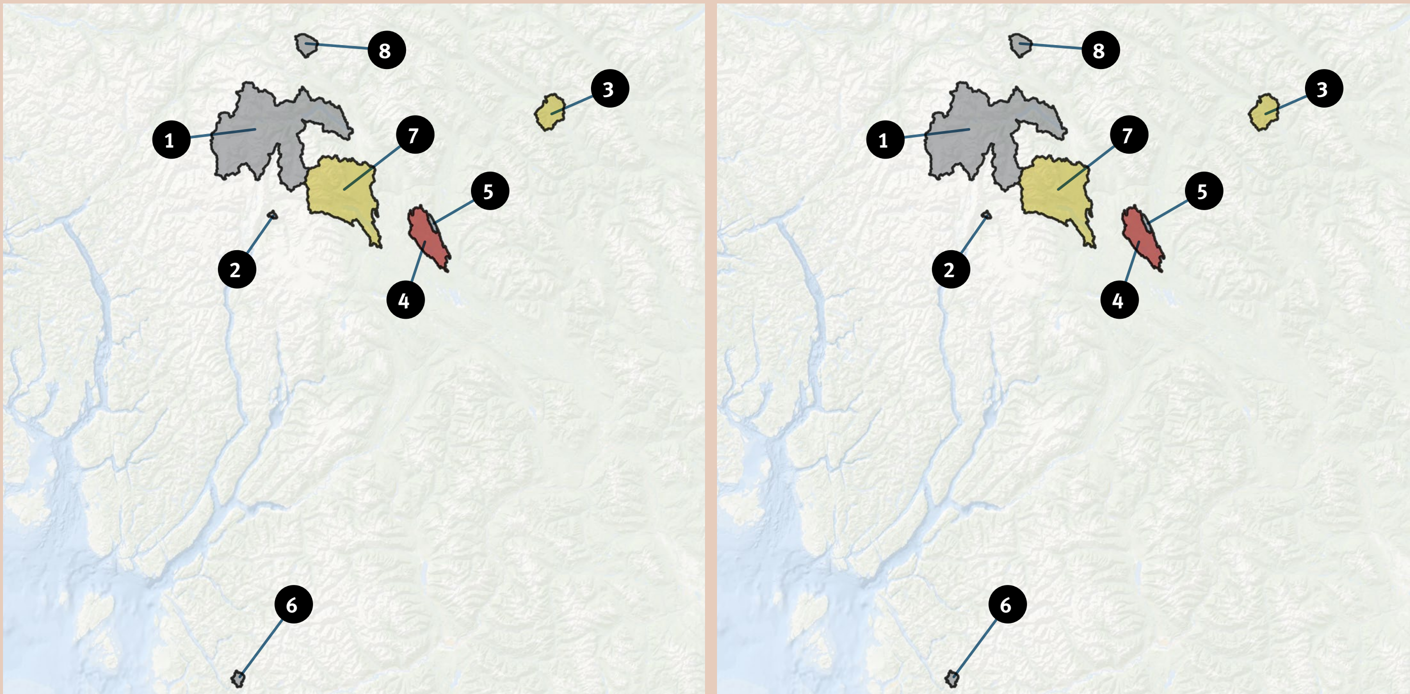
Stock-Recruitment Historic Spawners

Stock-Recruitment	Historic Spawners		Conservation Unit
		1	Nass – Portland – Observatory
		2	Upper Nass

FIGURE 7. Maps showing the biological status of Nass pink (odd-year) salmon Conservation Units, using stock-recruitment and historic spawners metrics.

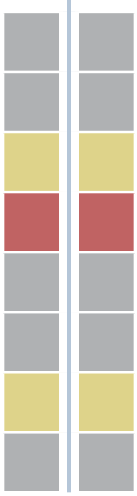
Sockeye (lake-type)
Biological Status

Good | Fair | Poor | Data Deficient



Stock-Recruitment | Historic Spawners

Stock-Recruitment	Historic Spawners	Conservation Unit

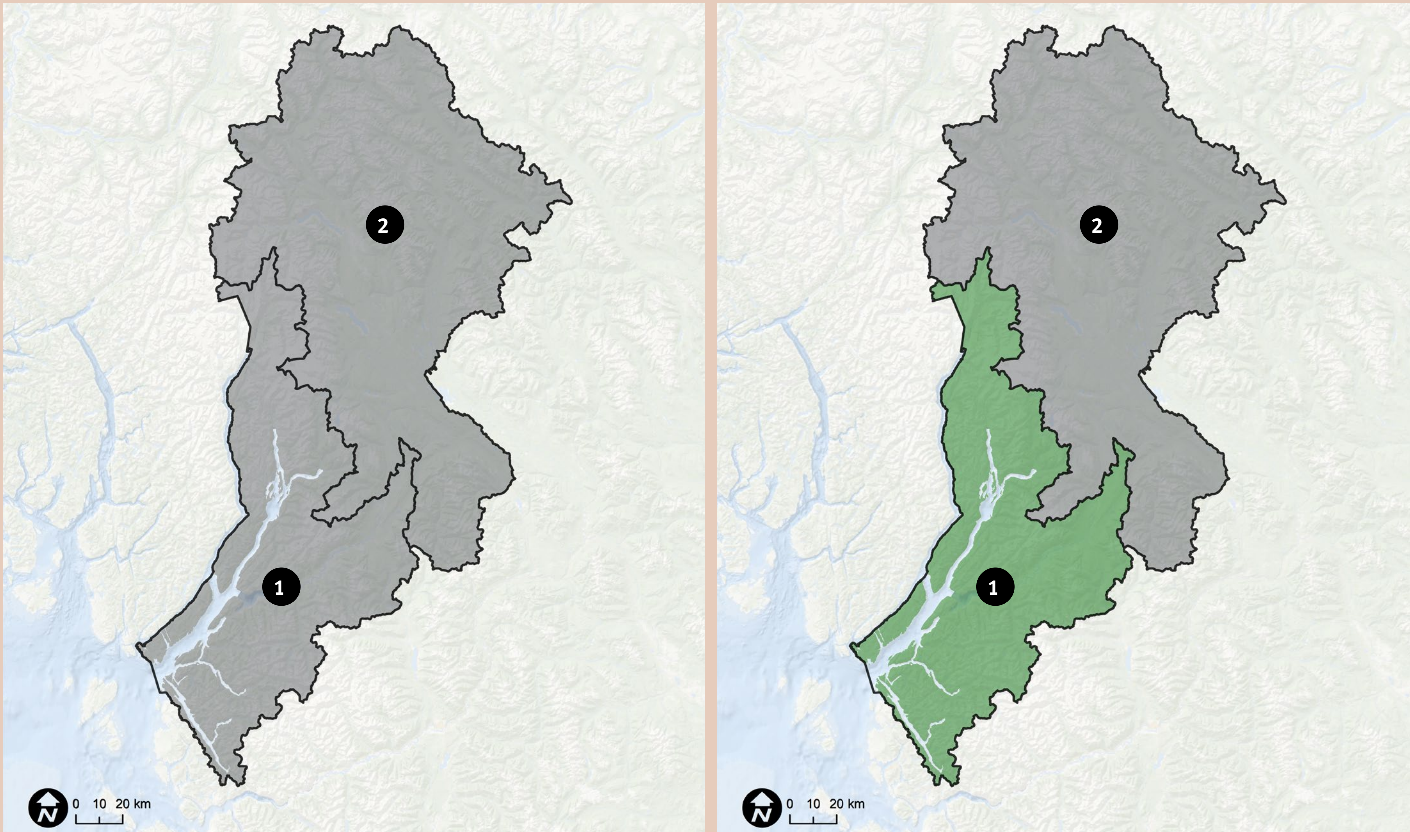


1 Bowser
2 Clements
3 Damdochax
4 Fred Wright
5 Kwinageese
6 Leverson
7 Meziadin
8 Oweegee

FIGURE 8. Maps showing the biological status of Nass lake-type sockeye salmon Conservation Units, using stock-recruitment and historic spawners metrics.

Sockeye (river-type)
Biological Status

Good	Fair
Poor	Data Deficient



Stock-Recruitment   Historic Spawners

Stock-Recruitment	Historic Spawners		Conservation Unit
Data Deficient	Good	1	Lower Nass – Portland
Data Deficient	Data Deficient	2	Upper Nass River

FIGURE 9. Maps showing the biological status of Nass river-type sockeye salmon Conservation Units, using stock-recruitment and historic spawners metrics.

4 Discussion

The goal of this project was to provide snapshots of salmon status for all CUs in the Nass Region. Using Canada's Wild Salmon Policy (*salmonwatersheds.ca/wsp*) as a framework, we synthesized the best available data for describing the characteristics and dynamics of salmon CUs in the region, and assessed their current biological status using two sets of biological benchmarks. We found that there were stark differences in status by species. For example, pink CUs tended to be of low conservation concern with the two assessed CUs having had record or near-record numbers of returning spawners. In contrast, both assessed chum CUs showed strong declines in spawner abundance since 2007 and fall either in the red or amber status zones. As such, chum CUs in the Nass Region have an imminent need for further conservation and management intervention.

Our analyses also showed distinct differences in the monitoring and availability of data by species. We were able to assess status for all of the Chinook and coho CUs, but were able to assess status for fewer than half of the sockeye CUs. Among the CUs that had enough data to assess status, there also were significant differences in the monitoring effort and quality of data for the CUs. Overall, we found that many CUs in Nass Region have experienced a general decline in monitoring effort through time. These declines in monitoring coverage were especially evident for coastal CUs. For example, for the Portland Canal – Observatory chum CU, only three out of the six indicator streams were monitored in 2014. These declines in monitoring result in greater uncertainty in the status assessments for these CUs. Declines in monitoring means that there is less spawner survey data to use in analyses and inferences must be drawn from neighbouring streams in order to generate CU-level estimates of abundance.

This project has helped to identify data gaps that currently hinder our understanding of the status of of Nass salmon CUs; the next step is to identify how First Nations and others can work to address those gaps through on-the-ground monitoring programs. The capacity exists within local First Nations to expand their monitoring efforts and, with additional resources, First Nations could broaden the foundation of information that is needed to make informed, evidence-based fisheries management decisions. Obvious opportunities include reinstating the monitoring programs for Bowser and Clements lake-type sockeye CUs, establishing monitoring programs for Upper Nass pink CUs (odd- and even-year), and identifying indicator streams for the Kwinageese and Leverson sockeye CUs.

Our ability to make sound decisions about the conservation and management of salmon depends on our ability to track long-term trends in salmon survival and productivity. This begins with on-the-ground monitoring programs that allow us to detect changes in salmon production over time and determine where and when conservation and management measures may be required to recover declining salmon populations. Addressing the data gaps identified in this project and sustaining current monitoring programs are therefore critical and immediate priorities.

5 Conclusion

This project developed snapshots of salmon status for 22 CUs using the baseline of information that is currently available for the Nass Region.

The data summaries and analyses developed through the course of this project have been integrated into the Pacific Salmon Explorer (*salmonexplorer.ca*), an online data visualization tool that displays information on salmon populations and their habitats in the Nass, and in other regions throughout BC. We have also made the source datasets broadly and freely available to the public via our Salmon Data Library (*data.salmonwatersheds.ca*). These centralized platforms for storing, distributing, and visualizing salmon-related datasets are critical for providing access to information, increasing the transparency of decision-making, and for helping to identify conservation and management strategies for at-risk CUs. Our hope is that these snapshots of salmon status provide a useful starting point for supporting discussions at local and regional planning tables. Examples of how the outputs of this project can be applied to support local planning, fisheries management, and conservation initiatives include:

- identifying data gaps and where monitoring efforts are lacking or non-existent;
- establishing a baseline of current status that can be used to track future changes in status; and
- identifying which CUs may be good candidates for recovery planning exercises and management and conservation intervention.

Over the long-term, the PSF intends to work with the project collaborators to regularly update the population assessments. This will ensure the Pacific Salmon Explorer remains a timely and relevant source of information on salmon CUs in the Nass Region.

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APPENDIX 1

Conservation Unit Maps by Species

Chinook

Conservation Units

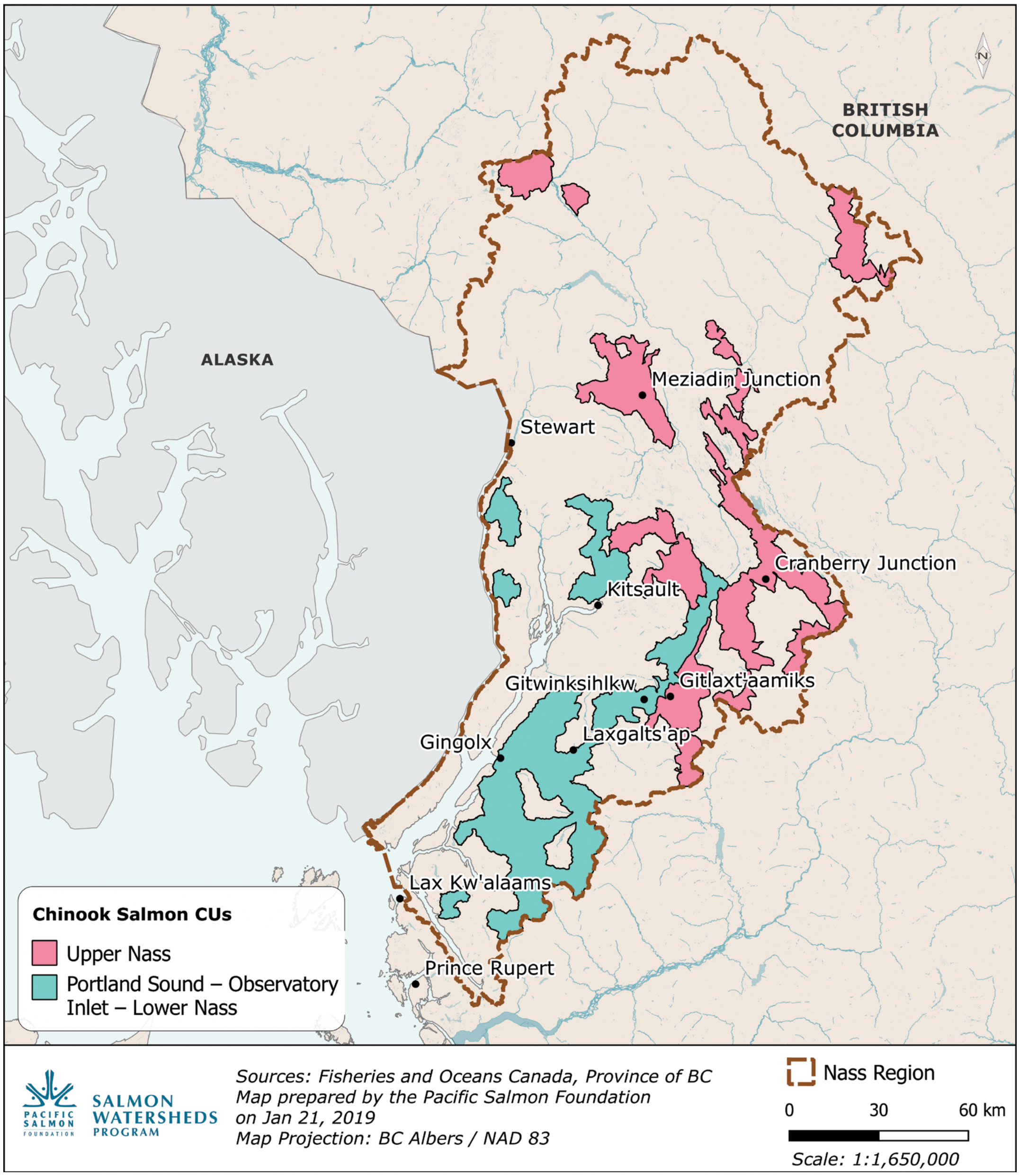

FIGURE A.1. This map shows the two Chinook Conservation Units (CUs) in the Nass Region, as defined by Holtby and Ciruna 2007.

Chum
Conservation Units

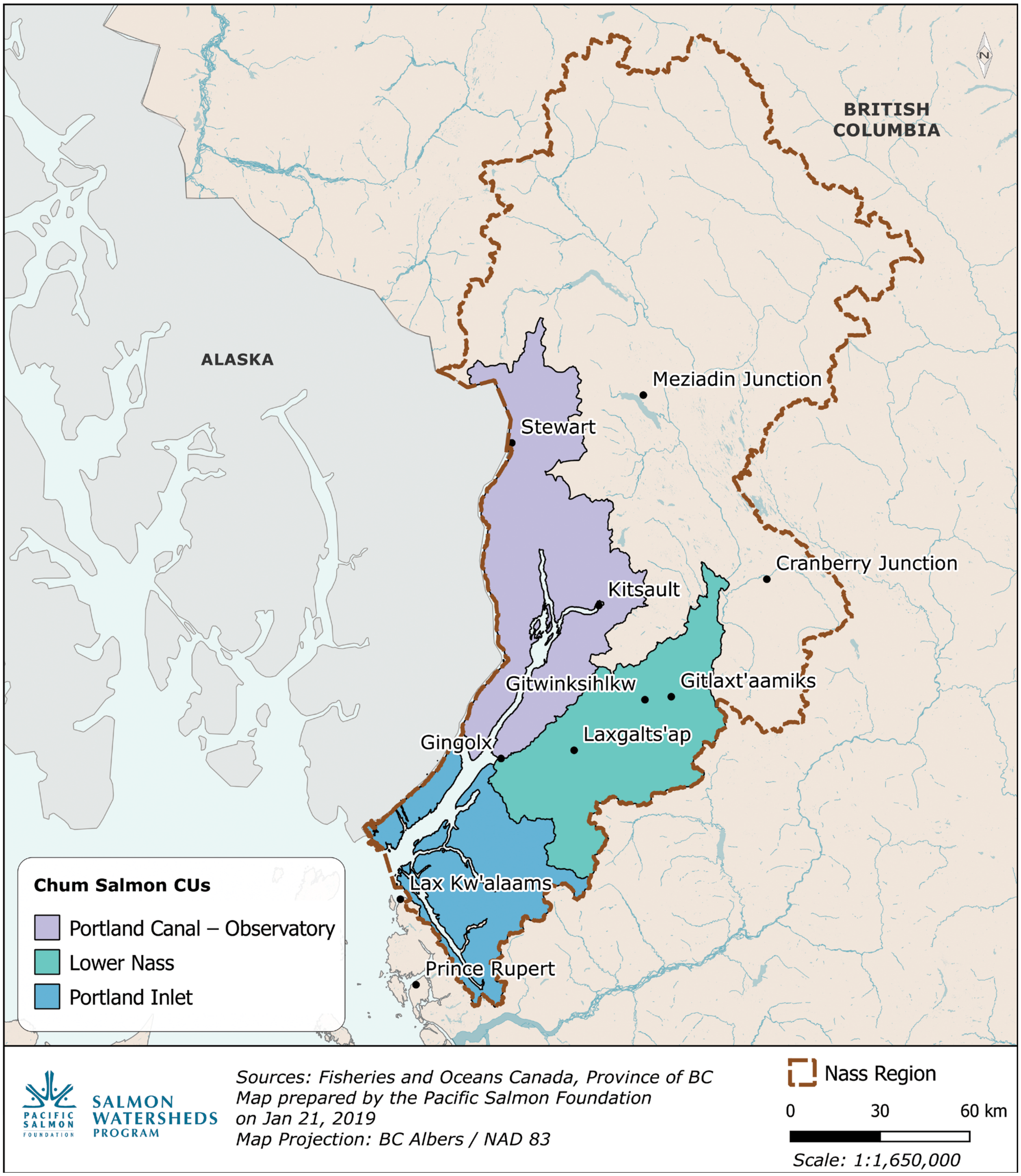

FIGURE A.2. This map shows the three chum Conservation Units (CUs) in the Nass Region, as defined by Holtby and Ciruna 2007.

Coho
Conservation Units

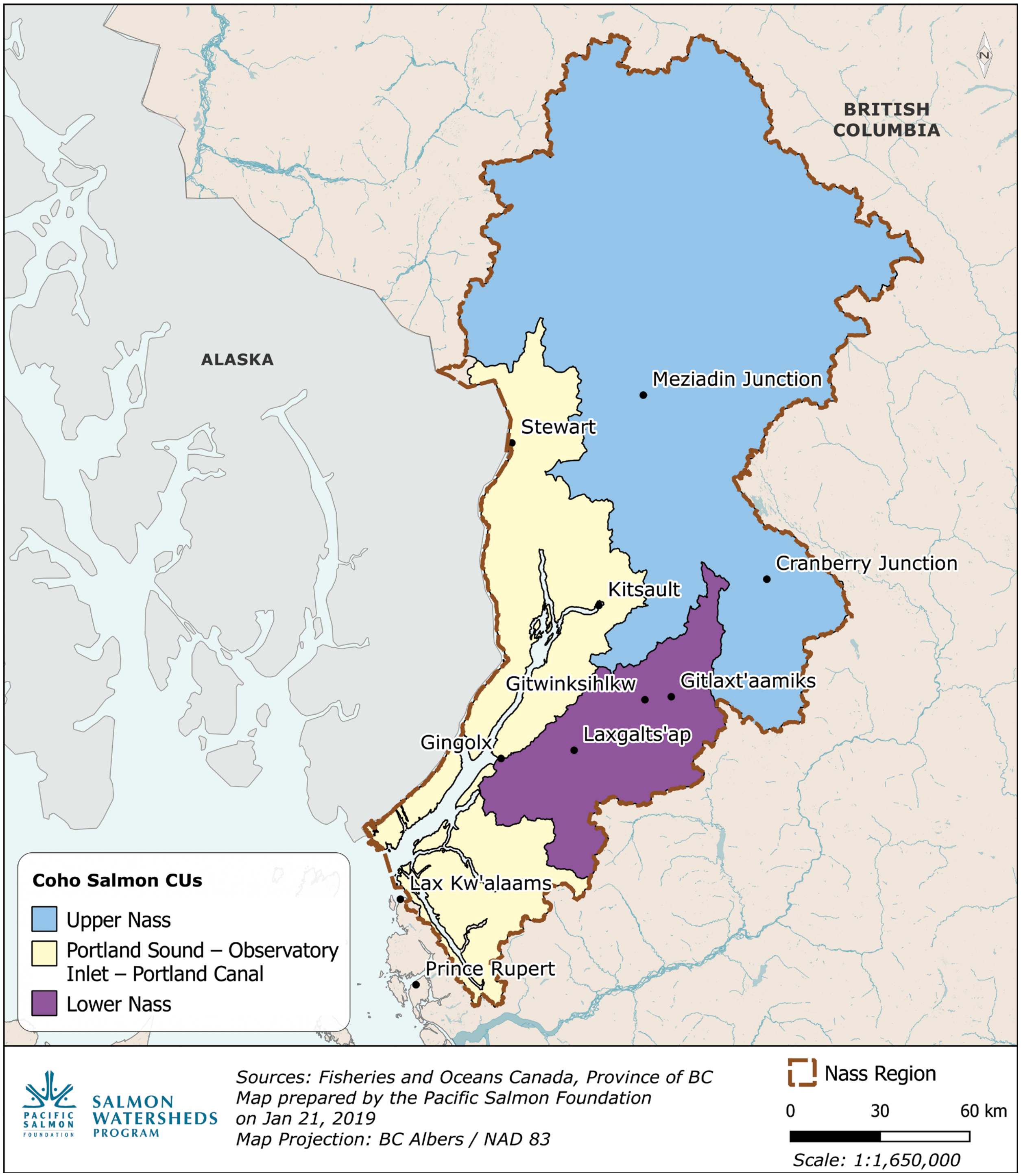

FIGURE A.3. This map shows the three coho Conservation Units (CUs) in the Nass Region, as defined by Holtby and Ciruna 2007.

Pink (even-year)
Conservation Units

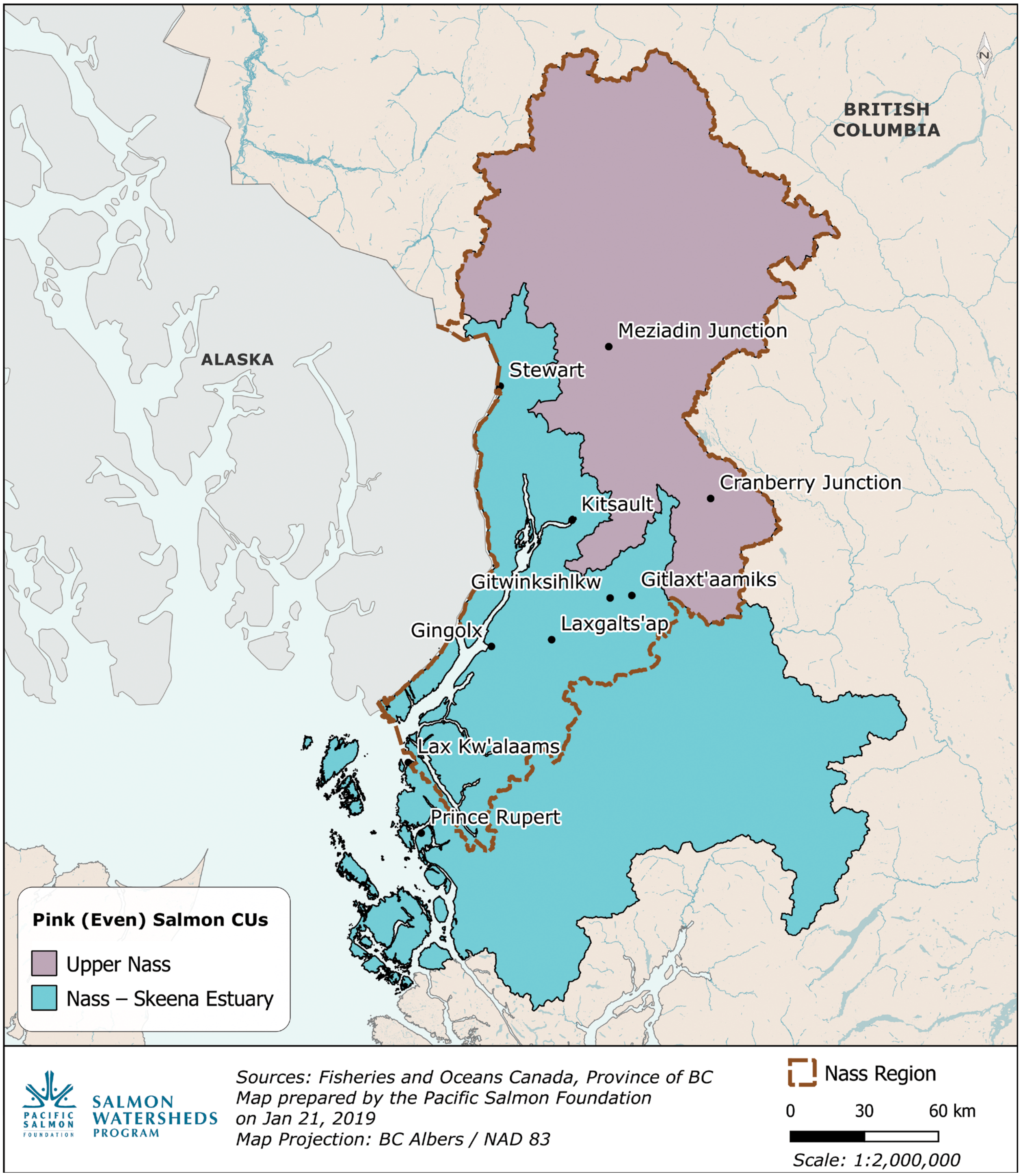

FIGURE A.4. This map shows the two pink (even-year) Conservation Units (CUs) in the Nass Region, as defined by Holtby and Ciruna 2007. Note that the boundary for the Nass-Skeena Estuary CU extends beyond the Nass Region.

Pink (odd-year)
Conservation Units

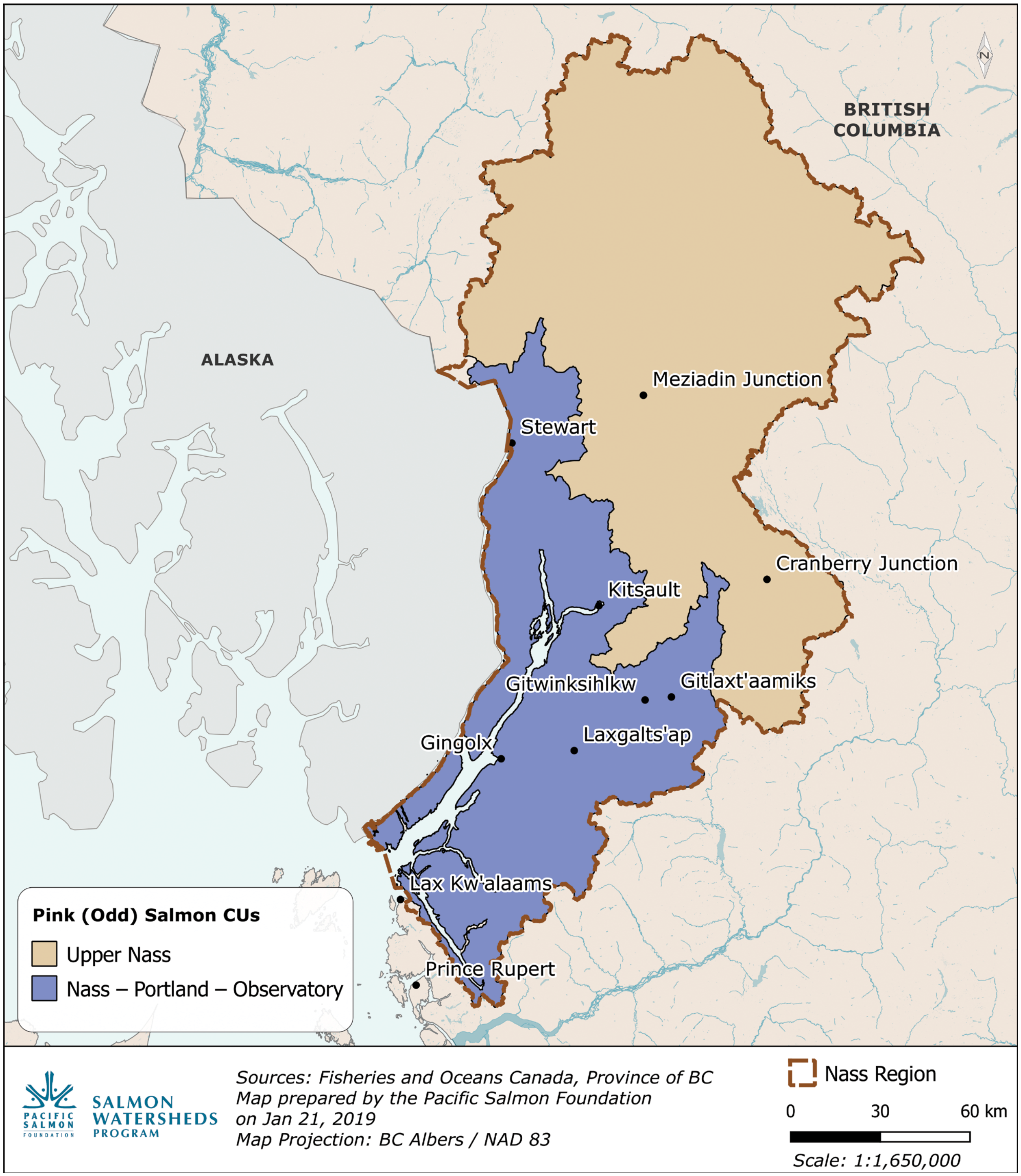

FIGURE A.5. This map shows the two pink (odd-year) Conservation Units (CUs) in the Nass Region, as defined by Holtby and Ciruna 2007.

Sockeye (lake-type)
Conservation Units

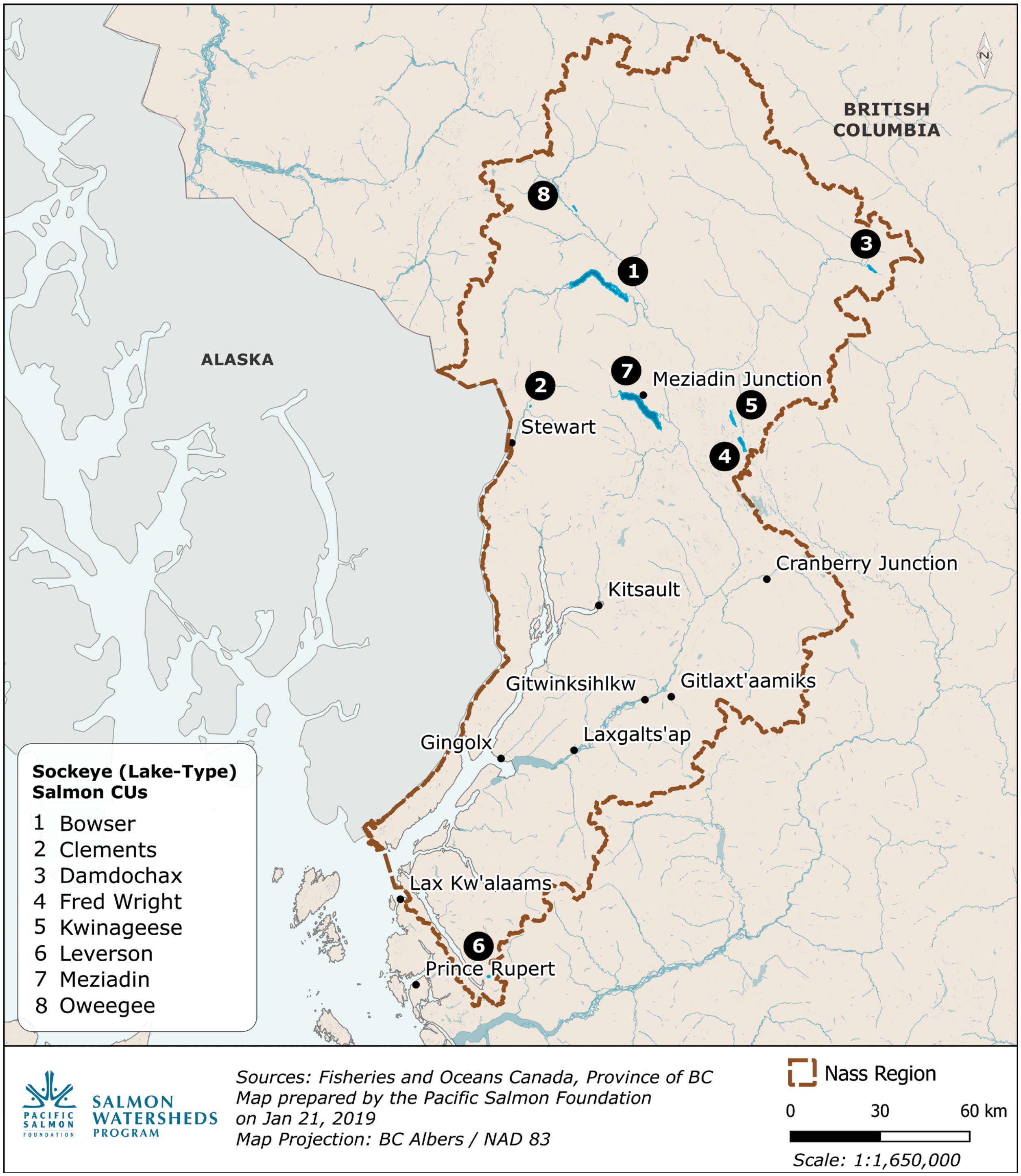

FIGURE A.6. This map shows the eight lake-type sockeye Conservation Units (CUs) in the Nass Region, as defined by Holtby and Ciruna 2007.

Sockeye (river-type)
Conservation Units

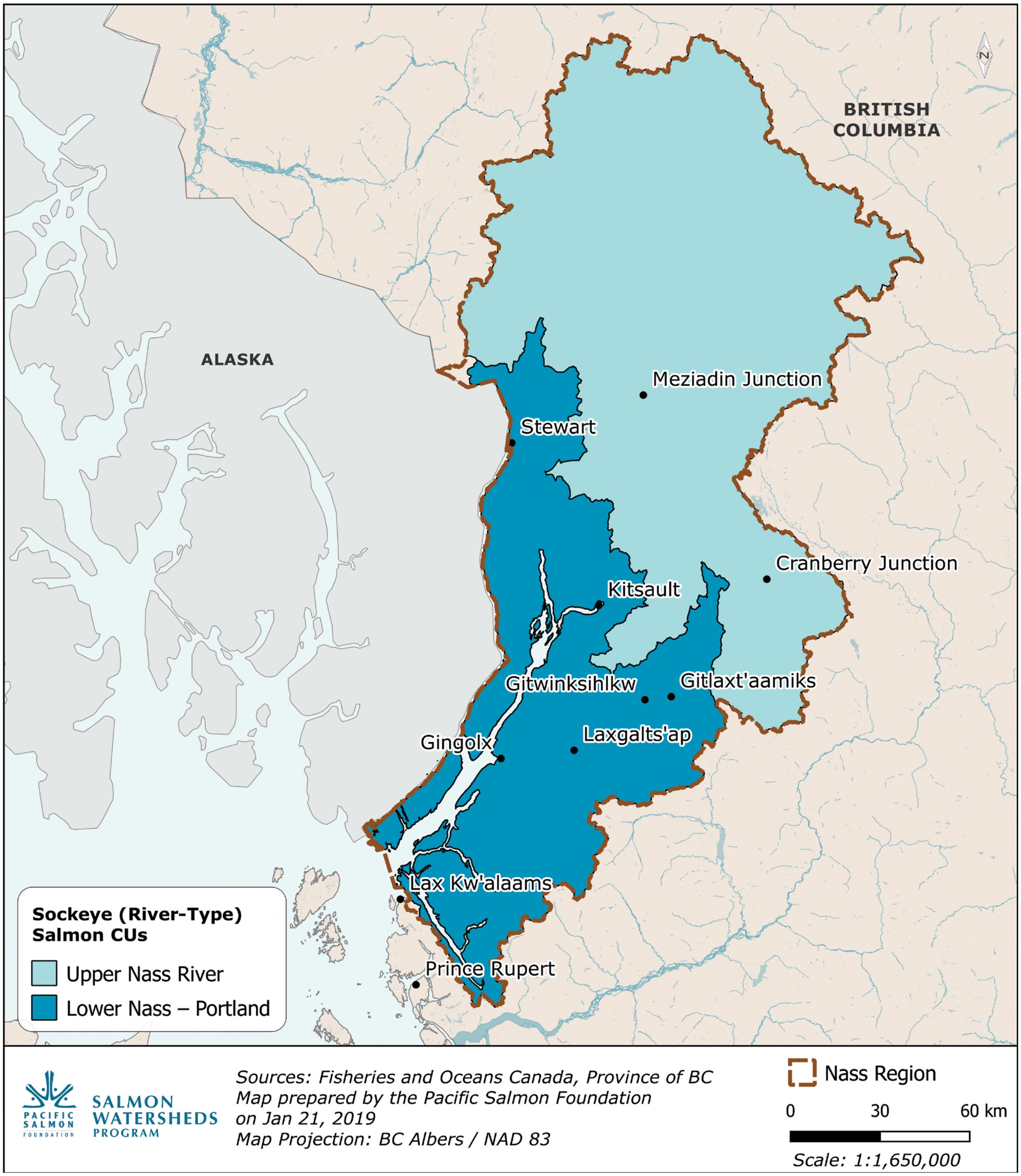

FIGURE A.7. This map shows the two river-type sockeye Conservation Units (CUs) in the Nass Region, as defined by Holtby and Ciruna 2007.

APPENDIX 2

Stock-Recruitment Figures

Portland Sound – Observatory Inlet – Lower Nass Chinook CU

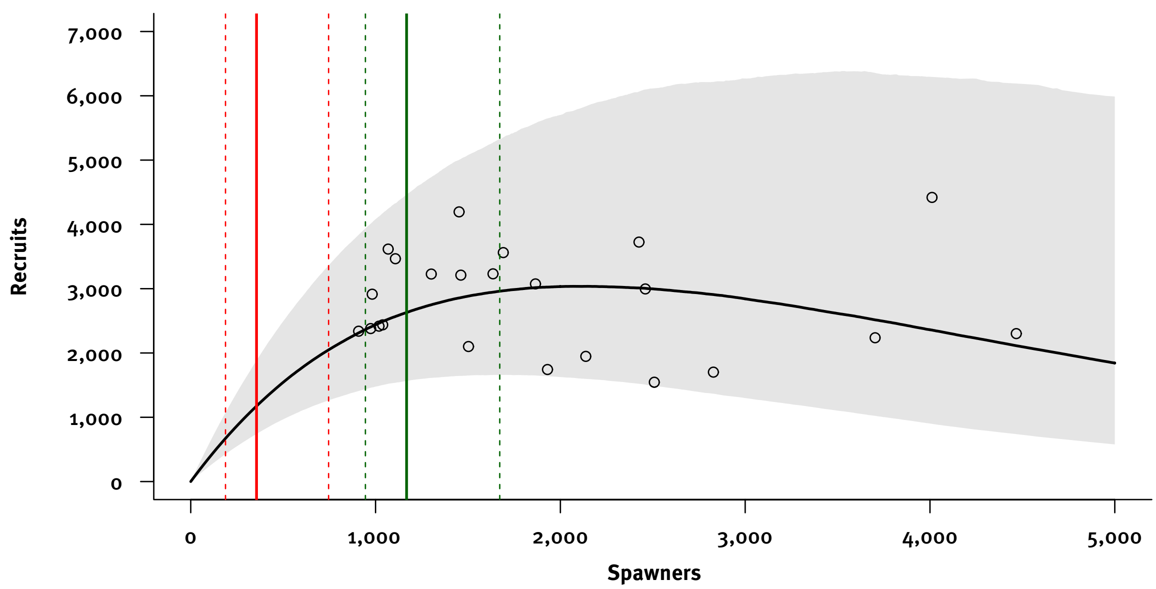

FIGURE A.8. Observed spawner-recruit data for the Portland Sound – Observatory Inlet – Lower Nass Chinook CU with fitted Ricker curve and associated benchmarks using a Bayesian hierarchical Ricker model. The shaded grey area shows the uncertainty associated with the fit of the Ricker curve to these spawner-recruit data. The solid green line denotes the upper stock-recruitment benchmark and the solid red line denotes the lower stock-recruitment benchmark. Dashed green and red lines indicate 95% credible intervals (CIs) for the upper and lower benchmarks respectively, delineated by 2.5th and 97.5th posterior densities.

Upper Nass Chinook CU

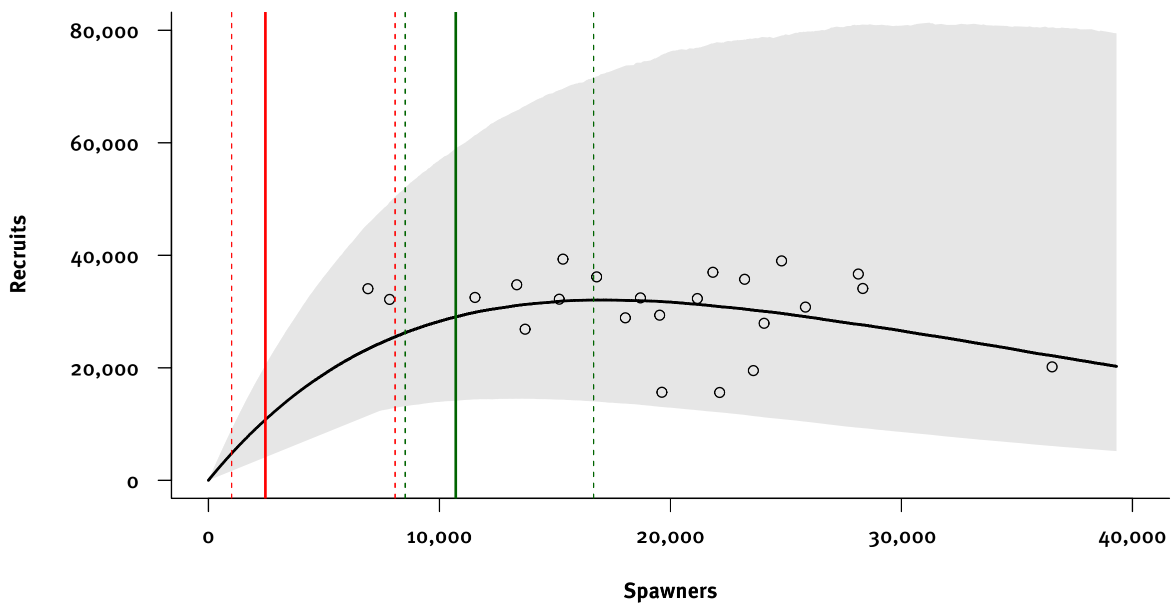

FIGURE A.9. Observed spawner-recruit data for the Upper Nass Chinook CU with fitted Ricker curve and associated benchmarks using a Bayesian hierarchical Ricker model. The shaded grey area shows the uncertainty associated with the fit of the Ricker curve to these spawner-recruit data. The solid green line denotes the upper stock-recruitment benchmark and the solid red line denotes the lower stock-recruitment benchmark. Dashed green and red lines indicate 95% credible intervals (CIs) for the upper and lower benchmarks respectively, delineated by 2.5th and 97.5th posterior densities.

Portland Canal – Observatory Chum CU

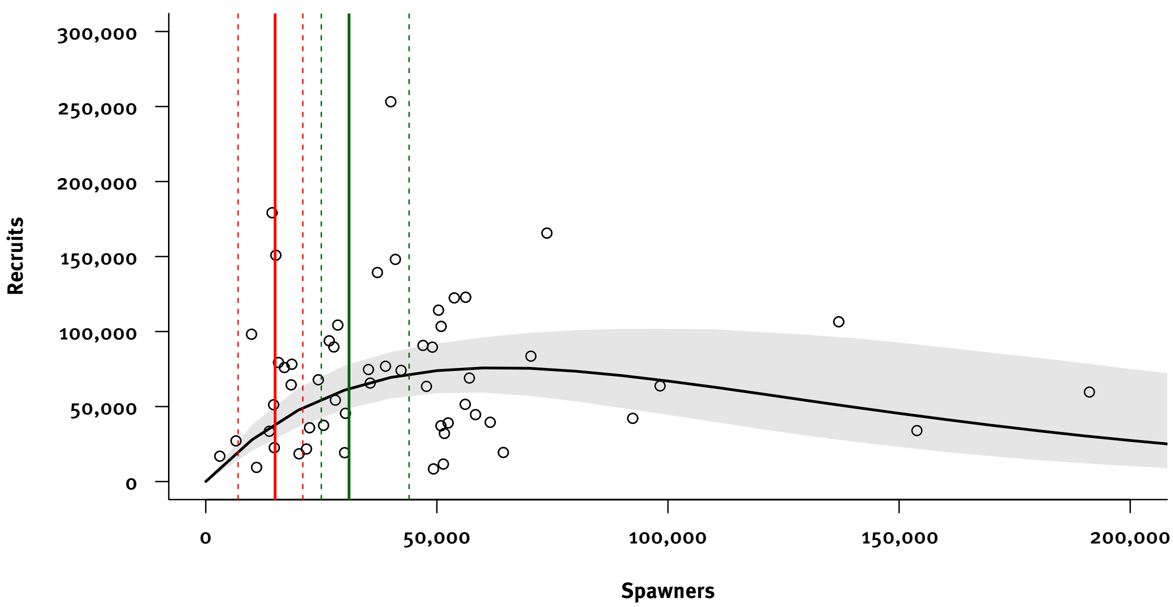

FIGURE A.10. Observed spawner-recruit data for the Portland Canal – Observatory chum CU with fitted Ricker curve and associated benchmarks using a Bayesian hierarchical Ricker model. The shaded grey area shows the uncertainty associated with the fit of the Ricker curve to these spawner-recruit data. The solid green line denotes the upper stock-recruitment benchmark and the solid red line denotes the lower stock-recruitment benchmark. Dashed green and red lines indicate 95% credible intervals (CIs) for the upper and lower benchmarks respectively, delineated by 2.5th and 97.5th posterior densities.

Portland Inlet Chum CU

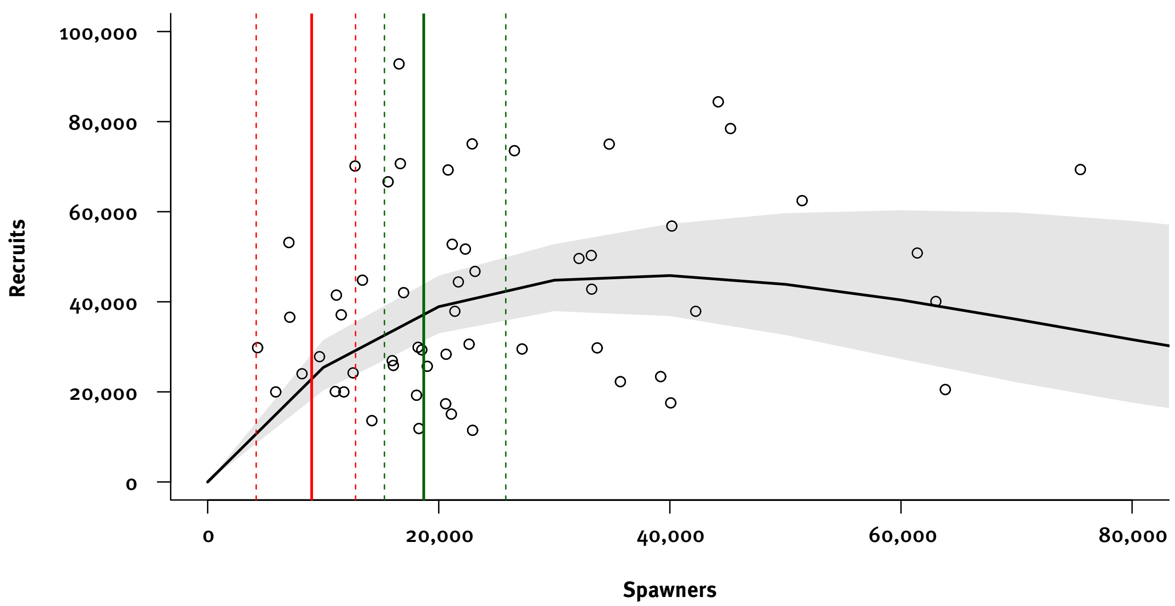

FIGURE A.11. Observed spawner-recruit data for the Portland Inlet chum CU with fitted Ricker curve and associated benchmarks using a Bayesian hierarchical Ricker model. The shaded grey area shows the uncertainty associated with the fit of the Ricker curve to these spawner-recruit data. The solid green line denotes the upper stock-recruitment benchmark and the solid red line denotes the lower stock-recruitment benchmark. Dashed green and red lines indicate 95% credible intervals (CIs) for the upper and lower benchmarks respectively, delineated by 2.5th and 97.5th posterior densities.

Lower Nass Coho CU

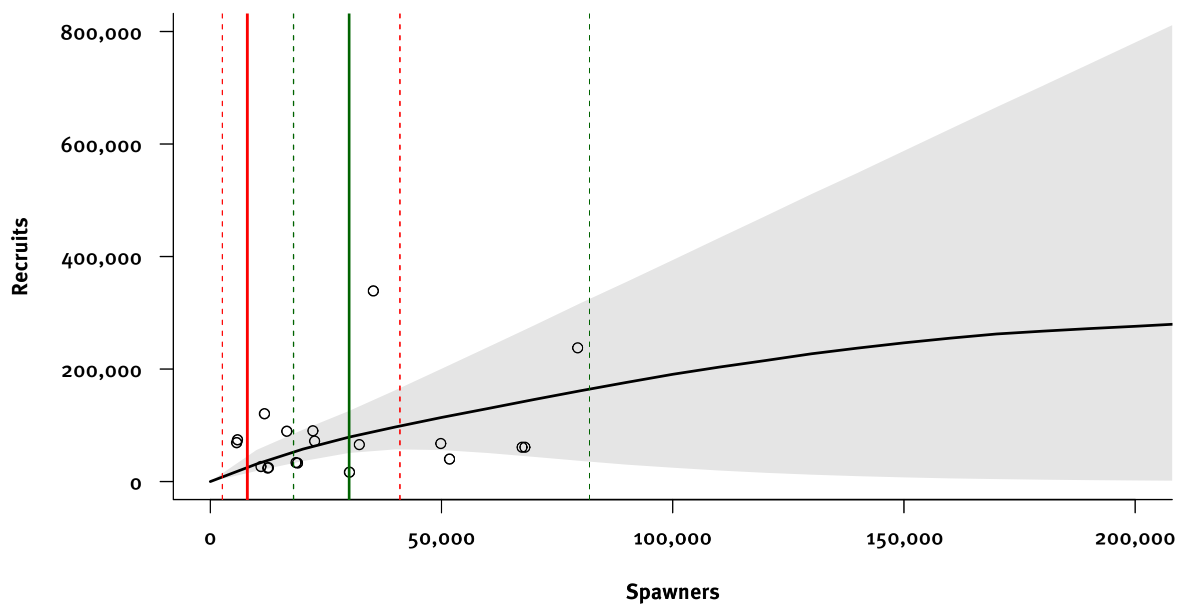

FIGURE A.12. Observed spawner-recruit data for the Lower Nass coho CU with fitted Ricker curve and associated benchmarks using a Bayesian hierarchical Ricker model. The shaded grey area shows the uncertainty associated with the fit of the Ricker curve to these spawner-recruit data. The solid green line denotes the upper stock-recruitment benchmark and the solid red line denotes the lower stock-recruitment benchmark. Dashed green and red lines indicate 95% credible intervals (CIs) for the upper and lower benchmarks respectively, delineated by 2.5th and 97.5th posterior densities.

Portland Sound – Observatory Inlet – Portland Canal Coho CU

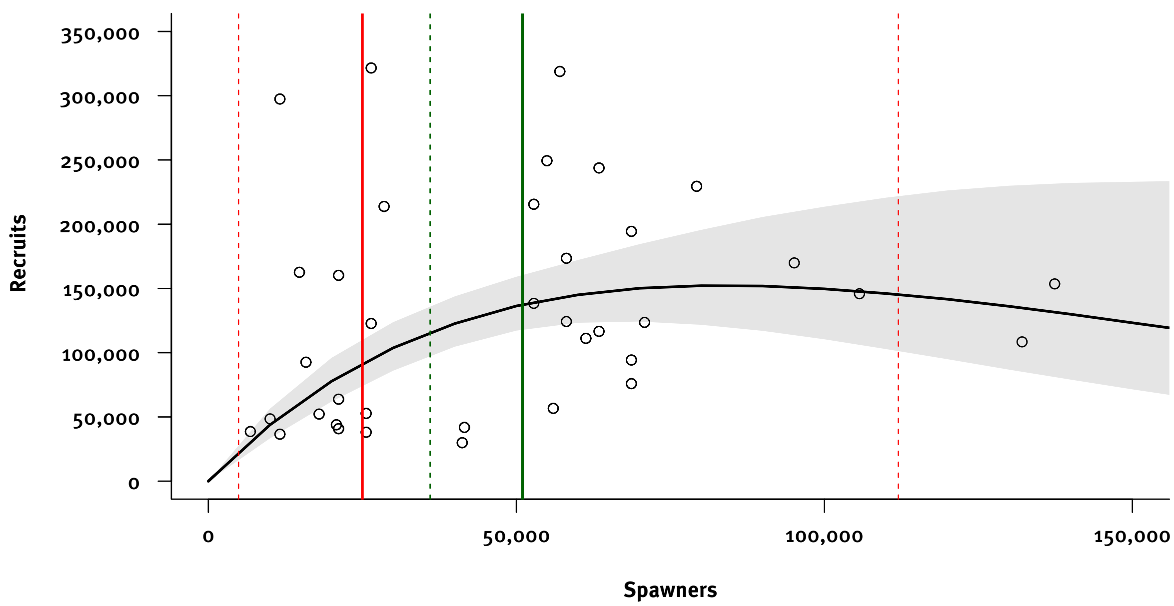

FIGURE A.13. Observed spawner-recruit data for the Portland Sound – Observatory Inlet – Portland Canal coho CU with fitted Ricker curve and associated benchmarks using a Bayesian hierarchical Ricker model. The shaded grey area shows the uncertainty associated with the fit of the Ricker curve to these spawner-recruit data. The solid green line denotes the upper stock-recruitment benchmark and the solid red line denotes the lower stock-recruitment benchmark. Dashed green and red lines indicate 95% credible intervals (CIs) for the upper and lower benchmarks respectively, delineated by 2.5th and 97.5th posterior densities.

Upper Nass Coho CU

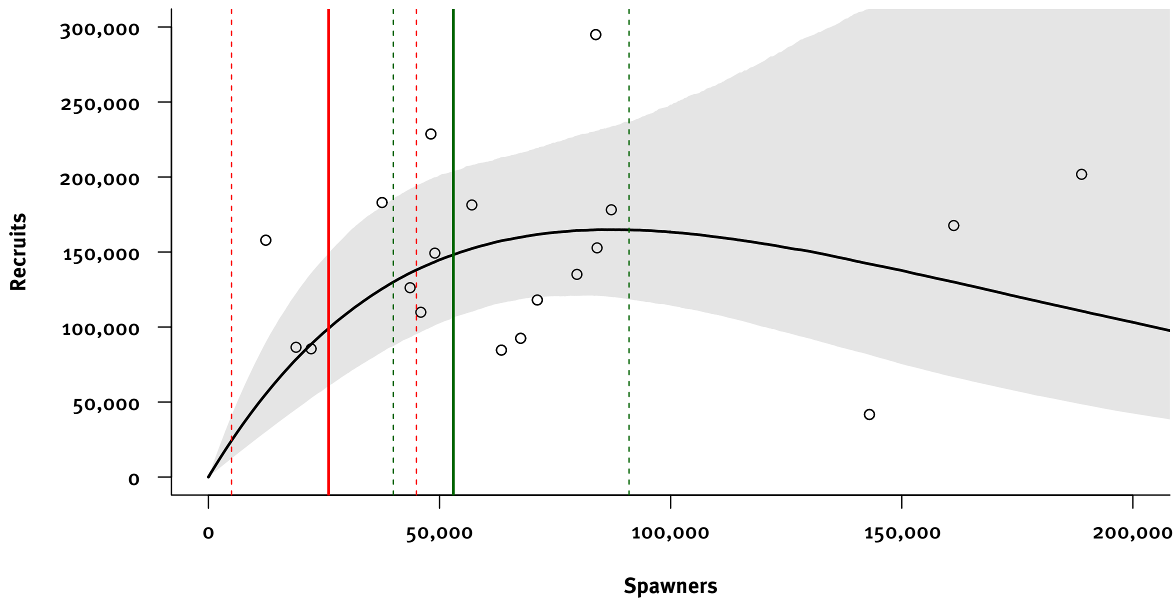

FIGURE A.14. Observed spawner-recruit data for the Upper Nass coho CU with fitted Ricker curve and associated benchmarks using a Bayesian hierarchical Ricker model. The shaded grey area shows the uncertainty associated with the fit of the Ricker curve to these spawner-recruit data. The solid green line denotes the upper stock-recruitment benchmark and the solid red line denotes the lower stock-recruitment benchmark. Dashed green and red lines indicate 95% credible intervals (CIs) for the upper and lower benchmarks respectively, delineated by 2.5th and 97.5th posterior densities.

Nass – Portland – Observatory Pink (Odd-Year) CU

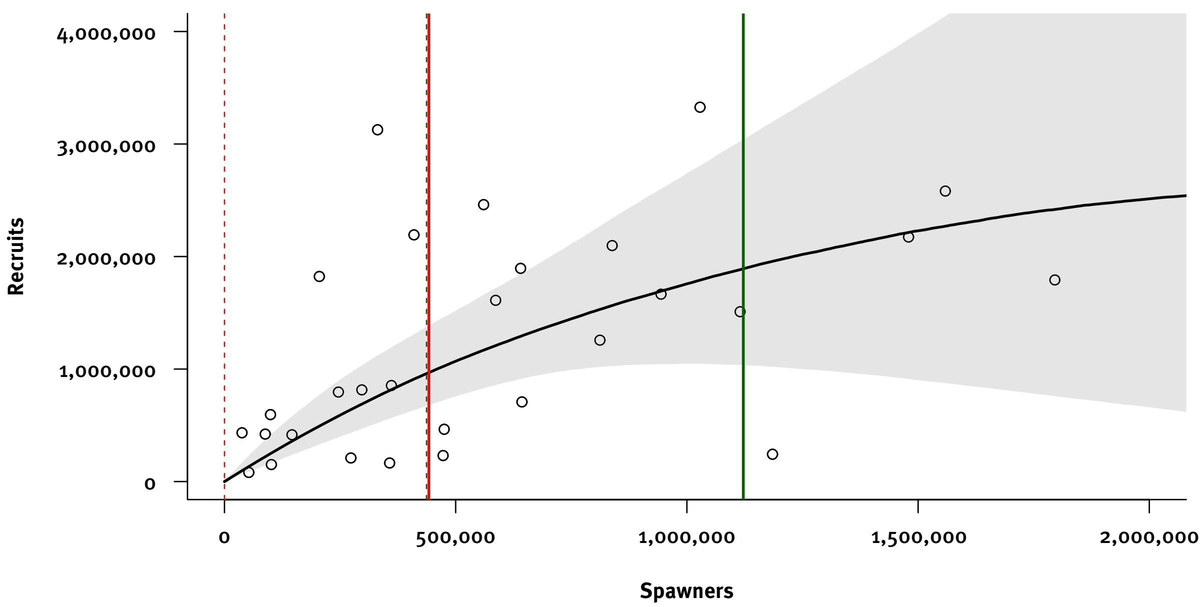

FIGURE A.15. Observed spawner-recruit data for the Nass – Portland – Observatory pink (odd-year) CU with fitted Ricker curve and associated benchmarks using a Bayesian hierarchical Ricker model. The shaded grey area shows the uncertainty associated with the fit of the Ricker curve to these spawner-recruit data. The solid green line denotes the upper stock-recruitment benchmark and the solid red line denotes the lower stock-recruitment benchmark. Dashed green and red lines indicate 95% credible intervals (CIs) for the upper and lower benchmarks respectively, delineated by 2.5th and 97.5th posterior densities.

Nass – Skeena Estuary Pink (Even-Year) CU

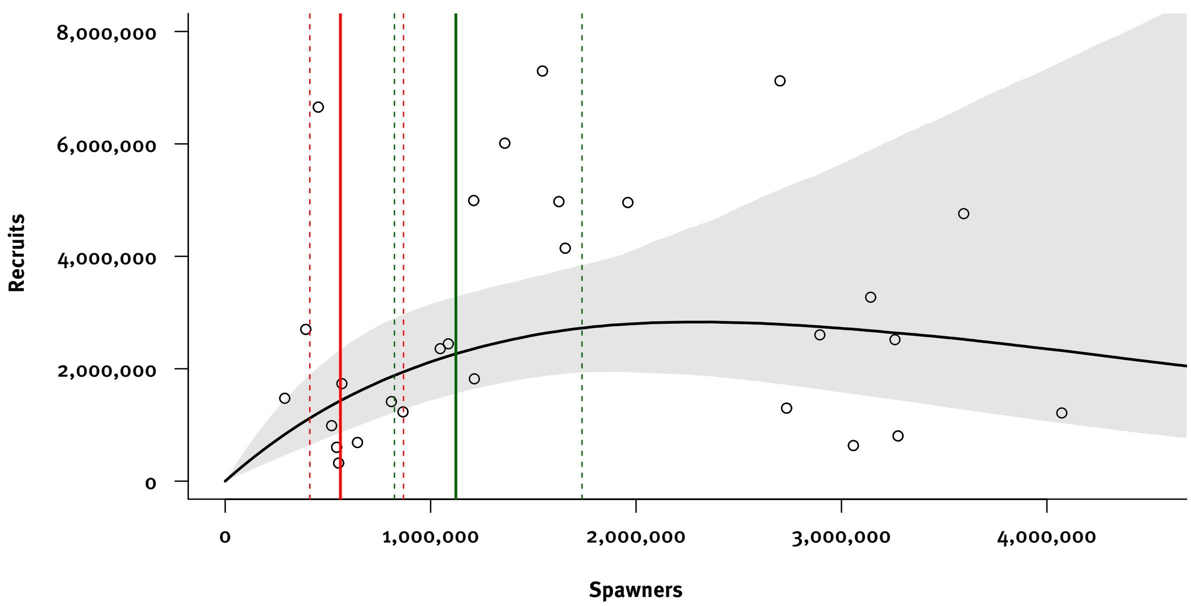

FIGURE A.16. Observed spawner-recruit data for the Nass – Skeena Estuary pink (even-year) CU with fitted Ricker curve and associated benchmarks using a Bayesian hierarchical Ricker model. The shaded grey area shows the uncertainty associated with the fit of the Ricker curve to these spawner-recruit data. The solid green line denotes the upper stock-recruitment benchmark and the solid red line denotes the lower stock-recruitment benchmark. Dashed green and red lines indicate 95% credible intervals (CIs) for the upper and lower benchmarks respectively, delineated by 2.5th and 97.5th posterior densities.

Damdochax Lake-Type Sockeye CU

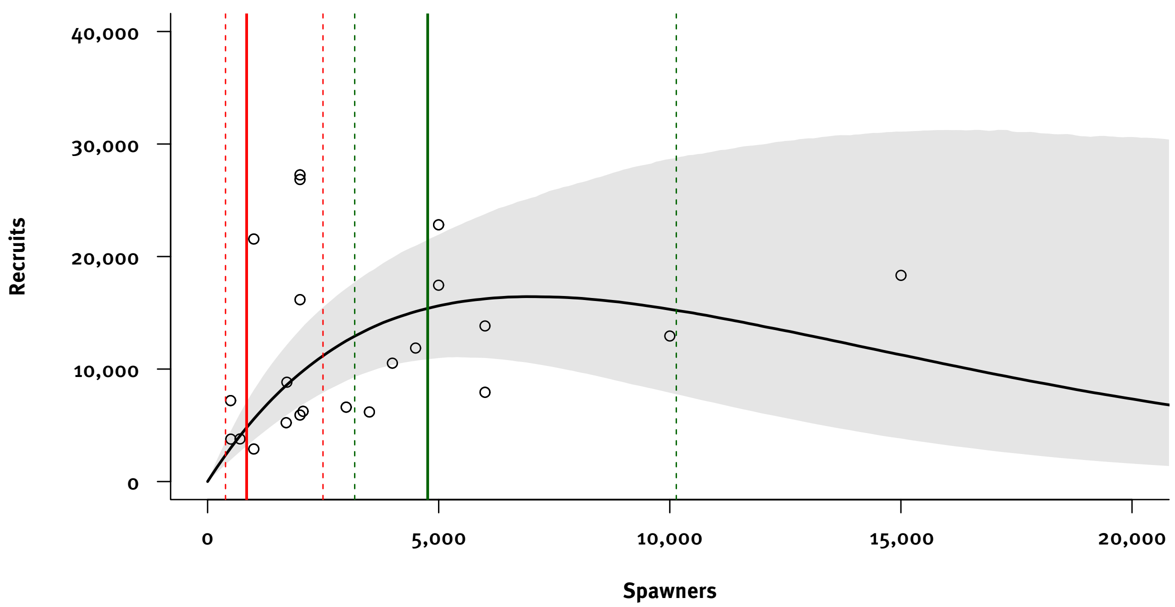

FIGURE A.17. Observed spawner-recruit data for the Damdochax lake-type sockeye CU with fitted Ricker curve and associated benchmarks using a Bayesian hierarchical Ricker model. The shaded grey area shows the uncertainty associated with the fit of the Ricker curve to these spawner-recruit data. The solid green line denotes the upper stock-recruitment benchmark and the solid red line denotes the lower stock-recruitment benchmark. Dashed green and red lines indicate 95% credible intervals (CIs) for the upper and lower benchmarks respectively, delineated by 2.5th and 97.5th posterior densities.

Fred Wright Lake-Type Sockeye CU

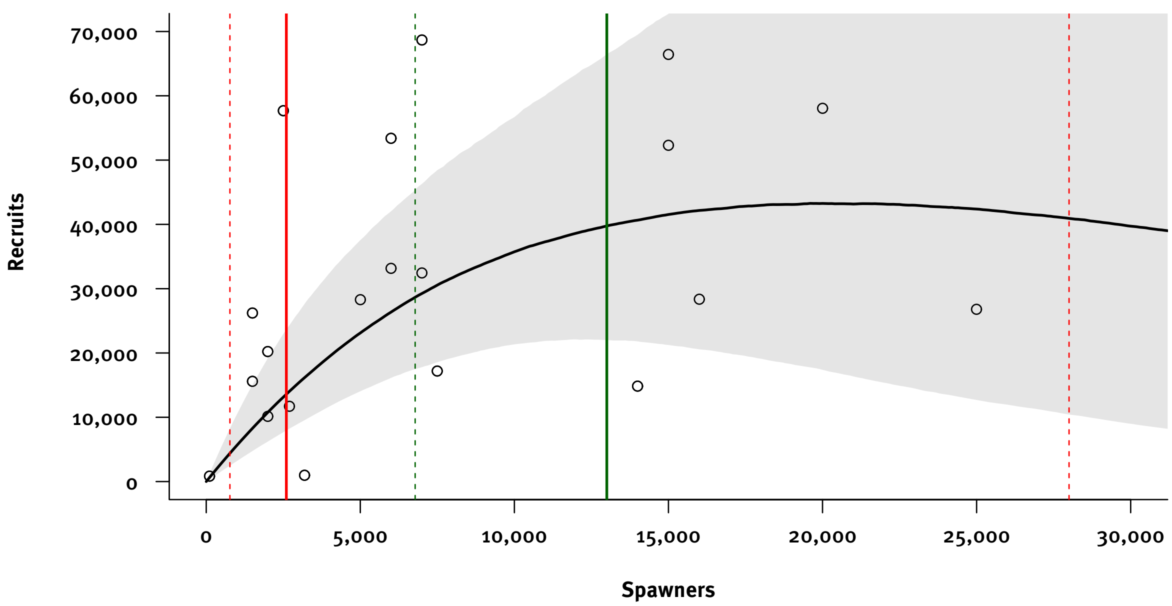

FIGURE A.18. Observed spawner-recruit data for the Fred Wright lake-type sockeye CU with fitted Ricker curve and associated benchmarks using a Bayesian hierarchical Ricker model. The shaded grey area shows the uncertainty associated with the fit of the Ricker curve to these spawner-recruit data. The solid green line denotes the upper stock-recruitment benchmark and the solid red line denotes the lower stock-recruitment benchmark. Dashed green and red lines indicate 95% credible intervals (CIs) for the upper and lower benchmarks respectively, delineated by 2.5th and 97.5th posterior densities.

Meziadin Lake-Type Sockeye CU

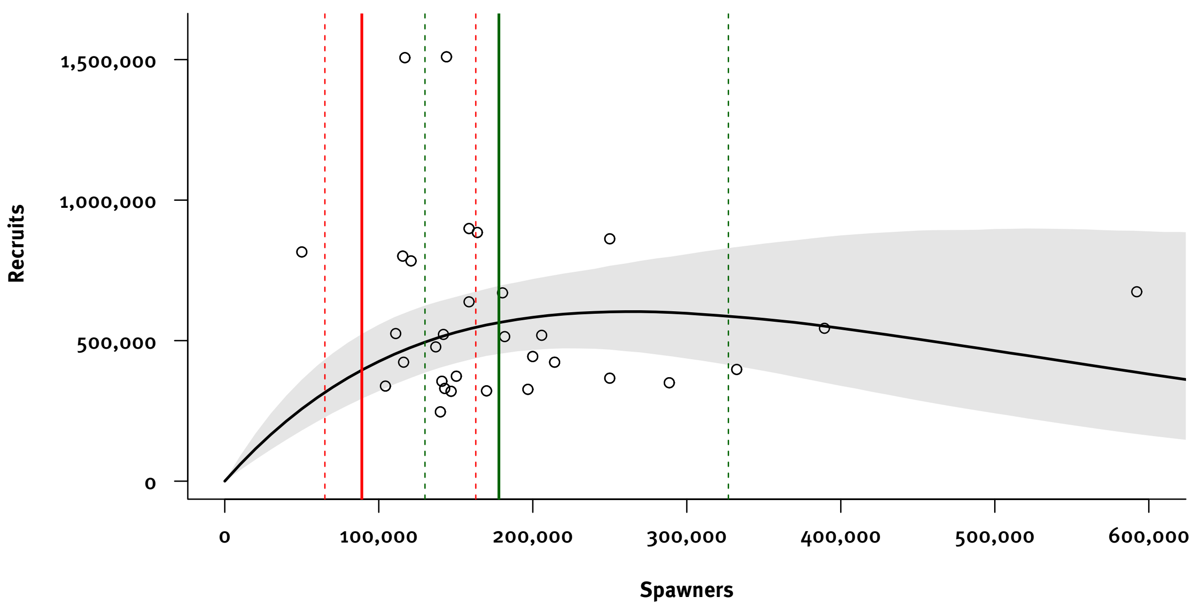

FIGURE A.19. Observed spawner-recruit data for the Meziadin lake-type sockeye CU with fitted Ricker curve and associated benchmarks using a Bayesian hierarchical Ricker model. The shaded grey area shows the uncertainty associated with the fit of the Ricker curve to these spawner-recruit data. The solid green line denotes the upper stock-recruitment benchmark and the solid red line denotes the lower stock-recruitment benchmark. Dashed green and red lines indicate 95% credible intervals (CIs) for the upper and lower benchmarks respectively, delineated by 2.5th and 97.5th posterior densities.

January 31, 2019


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