Northern British Columbia Coho Salmon Information Summary

Fisheries and Oceans Canada
North Coast Stock Assessment Branch

March 2022

Pacific Salmon Commission Technical Report No. 47

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For

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LIST OF ACRONYMS WITH DEFINITIONS

ADF&G	Alaska Department of Fish and Game
AIC	Akaike Information Criterion
BC	British Columbia
BOF	Alaska Board of Fisheries
CI	Confidence Interval
CU	Conservation Unit
CWT	Coded Wire Tag
DFO	The Department of Fisheries and Oceans, Canada
FSC	Food, Social and Ceremonial fisheries
GFA	Gitanyow Fisheries Authority
GSI	Genetic Stock Identification
JFMC	Joint Fisheries Management Committee
LM	Linear Regression
MSY	Maximum Sustainable Yield
NAFP	Nisga'a Annual Fishing Plan
NBTC	Northern Boundary Technical Committee
NuSEDs	DFO's New Salmon Escapement Database
PBT	Parentage-Based Tagging
PSC	Pacific Salmon Commission
PSF	Pacific Salmon Foundation
RST	Rotary Screw Trap
SFF	Sustainable Fisheries Framework
TCNB	Northern Boundary Technical Committee
TCTR	Transboundary Technical Committee
WSP	Wild Salmon Policy

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Executive Summary

The Northern Boundary Technical Committee was tasked to review stock status and harvest rates for northern coho salmon, specifically providing information on abundance, exploitation, stock assessment/monitoring programs and management of northern coho salmon stocks. Information provided in this report is used to provide recommendations to improve management and conservation of these stocks. The status of northern British Columbia coho salmon (*Oncorhynchus kisutch*) was examined over 40 years, ending in 2019. This included data obtained from indicator stocks (coded wire tag and monitoring programs) and region-wide escapement estimates. Summarized data includes estimates of total abundance, escapement, smolt production, marine survival, and harvest (exploitation). The following report provides an update to the previous assessment (NBTC, 2002) of northern British Columbia coho salmon stocks.

Regional escapement estimates appear relatively stable for northern British Columbia between 1980 and 2019. However, this stable long-term trend masks major fluctuations in escapement, including the rebuilding of abundance following below average coho salmon returns in the 1990s, and a more recent decline to below average returns in 2018 and 2019. Smolt production has either increased or shown no significant change over the long-term, however marine survival has varied across the assessed indicator programs. Harvest rates in northern British Columbia dramatically declined in the late 1990s and have remained low over the past two decades. Since 2010, all-gear harvest rates have been moderate averaging 57% for Zolzap Creek, 39% for Toboggan Creek, and 45% for Taku River. Given the variability across stock status metrics, coho salmon originating in northern British Columbia demonstrate resilience to the sometimes-dramatic fluctuations of escapement and harvest rates.

Northern British Columbia coho salmon stocks are data deficient when compared to neighboring regions. Improved understanding of coho salmon production dynamics and fishery interceptions will be essential elements of coho salmon management for sustainable production for long-term fishery opportunities in British Columbia and Alaska. Investments in increased monitoring of escapement, marine survival, freshwater production, and harvest in data poor areas, as well as, the development of additional full indicator programs are needed to understand and manage northern British Columbia coho salmon. Unprecedented changes in climate conditions call for precaution and may contribute to more variable abundance and lower overall productivity in the coming years. Despite these challenges, the long-term prospects for coho salmon in northern and central British Columbia are bolstered by their relatively intact freshwater, estuary, and nearshore habitats. Coho salmon have shown their ability to adapt and thrive in diverse habitats and environmental conditions, and to recover following climate driven perturbations or periods of overfishing. Given this underlying resilience, coho salmon are likely to remain an integral part of fisheries in northern British Columbia for the foreseeable future if freshwater, estuary, and marine habitats are protected, escapement and harvest are monitored, and fisheries are managed with appropriate levels of precaution.

Introduction

Coho salmon (*Oncorhynchus kisutch*) are an integral part of commercial, recreational, and subsistence fisheries throughout northern British Columbia. The following report provides an update to the previous assessment (NBTC, 2002) of northern British Columbia coho salmon stocks to address a request by the Pacific Salmon Commission's Northern Panel. This report reviews stock status and harvest rates for northern coho salmon stocks, specifically providing information on abundance, exploitation, stock assessment/monitoring programs and management. Information in this report is used to provide recommendations to improve management and conservation of these stocks. Trends in escapement and harvest are summarized for northern British Columbia, including trends of abundance, smolt production, marine survival, and harvest rates for specific indicator programs. For the purposes of this report, we discuss two Pacific fisheries management regions: the Northern Boundary region and Transboundary region. The 'Northern Boundary' region extends from Cape Caution north to Dixon Entrance in British Columbia (Figure 1). The 'Transboundary' region refers to watersheds that cross the international border between British Columbia, Canada, and Alaska (the Alsek, Taku, and Stikine Rivers; Figure 3).

Description of Fisheries and Stocks

Northern Boundary Region

Haida Gwaii

Haida Gwaii (previously known as the Queen Charlotte Islands) is located 90 km off the west coast of Prince Rupert, British Columbia. Haida Gwaii resides within DFO Pacific Fisheries Management Areas (from here, "Area") 1, 2E and 2W (Figure 1) where 227 separate coho salmon (from here, "coho") spawning populations have been identified. In response to Canadian Wild Salmon Policy initiatives, Holtby and Ciruna (2007) aggregated these populations into three proposed Conservation Units (CU) based on genotypic information: Haida Gwaii Graham Island Lowlands, Haida Gwaii East, and Haida Gwaii West. The Haida Gwaii Graham Island Lowlands encompasses all watersheds within Area 1 and the northern portion of Area 2E, Haida Gwaii East is represented by all other portions of Area 2E, and Haida Gwaii West is represented by all Area 2W populations.

Haida Gwaii Graham Island Lowlands

The Haida Gwaii Graham Island Lowlands are the most productive coho areas and include the Yakoun and Tlell (Area 1) Rivers, which support the largest annual coho returns to Haida Gwaii. Tlell River adult weir count information has been collected consistently since 2005 and may provide a meaningful index for other Haida Gwaii Graham Island Lowland populations, and earlier timed stocks elsewhere on Haida Gwaii. Spilsted *et al.* (2010) identified middle-to-late August arrival timing for the Pallant (Area 2E), Tlell, and Yakoun Rivers. Coho returning to the Copper River (Area 2E) also exhibit earlier run timing compared to most other coho stocks on Haida Gwaii whose in-river peak migration generally occurs in early-to-middle of October. While habitat capacity and total annual return estimates are not available, the 2019 count at the Tlell River adult weir of 3,756 was below the 10-year average (9,825).

With respect to exploitation, historic coded wire tag (CWT) data from Pallant Creek was used to estimate the proportion of CWTs present in the Yakoun River coho (assumes similar survival) escapement. Results suggest that the Alaskan exploitation of Yakoun River coho relative to Pallant Creek coho is comparable but Canadian troll interception is slightly higher (+6.8%). This estimation is consistent with the broader review by Spilsted *et al.* (2010) that collates the overall proportion of encounters from Areas 1, 2E, and 2W CWT release sites. Both reviews infer that northern Canada fisheries encounter slightly more Area 1 coho over 2E when recoveries from the 2E directed fishery are removed (note that 1,055 coho were last caught in this fishery in 2006).

Haida Gwaii East

The Deena River is located on the North end of Moresby Island within the Haida Gwaii East CU (Area 2E). Data on CWT smolts and adult escapement are collected annually for Deena River coho by the Haida Fisheries program. This is the only program on Haida Gwaii that produces an exploitation rate for coho.

Deena River CWT interceptions from 2009 to 2014 result in an average Alaskan fishery harvest rate of 0.5% (± 0.42% CI) and a Canadian commercial troll fishery exploitation of 18.0% (±4.92% CI). Due to the inconsistency of CWT deployment for the Deena River, harvest rates are only summarized to inform interceptions across fisheries over reporting definitive estimates of harvest for the time-series of data. In absence of Haida Gwaii CWT data, Holtby *et al*. (2000) assumed Alaska and northern British Columbia troll interceptions of North Coast coho were similar and applied the results of Babine River CWT interceptions to develop exploitation estimates for Haida Gwaii coho from 1960 to 1999. However, 2009 to 2014 comparisons of exploitation across the different fisheries suggests that the tag interception distributions are different and that the Area F Troll fleet exploitation on Deena River coho is roughly four times that of Toboggan Creek (the Area 4 indicator program), and that Alaska fisheries rarely encounter Deena River coho. The latter is consistent with the previous review of Haida Gwaii CWT recoveries by Spilsted *et al*. (2010), which suggested a very low abundance of Haida Gwaii coho in Alaskan waters and that 1998 and 1999 exploitation rates calculated by Holtby *et al*. (2000) were overestimated.

Haida Gwaii West

The streams within Haida Gwaii West (Area 2W) are generally shorter with steep gradients and production is believed to be modest but uncertain from these systems. A very limited amount of Haida Gwaii West coho information has been collected. Adequate visual inspections of a limited number of streams on Haida Gwaii West have not occurred since 2002. As a result, there is a lack of information to accurately assess the status of coho within this CU.

Nass and Skeena Rivers

Nass River

The Nass River watershed in northern British Columbia is the third largest watershed in BC, covering an area of 20,700 km^2 and flowing 380 km from the northeastern Skeena Mountains to the Portland Canal. The watersheds draining into the Portland Canal and Observatory Inlet comprise an additional 6,000 km^2 and, along with the Nass River watershed, make up the "Nass Region", which provides spawning and rearing habitat for several genetically and geographically distinct coho populations. The Nass Region is designated Area 3.

Area 3 has 102 individual coho spawning and rearing streams; 44 of these streams are in coastal areas and 58 are within the Nass River drainage. Holtby and Ciruna (2007) proposed dividing this management area into 3 CUs (Portland Sound/Observatory Inlet/Portland Canal, Lower Nass, and Upper Nass). Ecology, life history, and genotypic variation was considered but genetic tissue were only available from four of the 102 spawning locations.

Coho escapements vary considerably among streams but only two systems have consistent counts (Meziadin River and Zolzap Creek). Currently, there is only one program (Zolzap Creek) that infers marine survival and smolt production of an unenhanced stock in the northern British Columbia. Since 2000, the Nisga'a Lisim's government has been working with a consulting firm (LGL Limited) to estimate the aggregate escapement to the Nass River drainage. Currently, the aggregate Nass River escapement estimates are under review, and are therefore not included in this report. Harvest patterns and exploitation rates of Zolzap Creek coho are discussed in subsequent sections (see Harvest Rates).

The Nisga'a Treaty came into effect on May 11, 2000 and corresponded with the implementation of the Nisga'a Annual Fishing Plan (NAFP), developed by the Joint Fisheries Management Committee (JFMC), and governed by the terms of the Nisga'a Final Agreement and the Nisga'a Harvest Agreement. The NAFP defines escapement goals for management decisions regarding Nass and Skeena salmon stocks, calculates Nisga'a allocations for each salmon species and provides the general regulatory requirements for catches. The NAFP remains in effect until replaced the following year. The fishing plan applies to persons who harvest fish, other than steelhead trout, in Nisga'a fisheries.

Skeena River

The Skeena River drains 51,200 km^2 and is the second largest watershed in British Columbia. Originating in the Skeena Mountains, the Skeena River flows southwest for 400 km to the Skeena estuary and Chatham Sound. Coho spawn in virtually every accessible stream throughout the Skeena River watershed, which includes approximately 25 major coho producing systems and numerous smaller ones. In the mainstem Skeena River, stream discharges generally peak in June, corresponding to peak snowmelt (Gottesfeld and Rabnett, 2008). However, especially in the tributaries of the lower river basin, peak flows during late fall and early winter are becoming more frequent due to the increased occurrence of intense precipitation events during this period. There is considerable variation in habitat, environmental conditions, and the degree of anthropogenic impact between the interior and the lower coastal areas of the Skeena River watershed. Holtby and Ciruna (2007) proposed dividing this management area into 4 CUs (Skeena Estuary, Lower Skeena, Middle Skeena and Upper Skeena). The Skeena River is designated Area 4.

The Skeena River has a history of small enhancement operations with CWTs deployed at locations centered near the communities of Terrace, Fort Babine, and Smithers. Spilsted and Hudson (1994) identified a widespread presence of CWT coho originating from the Lower Skeena CUs in troll and net fisheries throughout Southeast Alaska and northern British Columbia Areas 1, 3, 4 and 5. To present, coho tagged at the Zymacord River CWT program continue to be encountered in the same fisheries.

Toboggan Creek Hatchery has operated as a coho incubation and rearing facility since 1984. CWT releases from this facility are the basis for data used to assess exploitation rates of Toboggan Creek coho (Middle Skeena CU). Estimates of Toboggan Creek escapement began in 1988, and now provides the longest time series for estimating exploitation rates and marine survival for coho in northern British Columbia. This site uses a counting fence and likely provides very reliable spawner return and tag recovery data. Harvest patterns and exploitation rates of Toboggan Creek coho are discussed in subsequent sections (see Harvest Rates).

Central Coast

The Central Coast is designated as the region within northern British Columbia coastline ranging from Cape Caution (Smith Inlet; Area 10) in the south, to Grenville and Principe Channels in the north (Area 5). For this report, the Central Coast region is designated as Area 5-10.

Coho production on the central coast comes from hundreds of watersheds, with considerable variability in stream size, habitat and environmental conditions, and the degree of anthropogenic impacts. Habitats range from low elevation watersheds along the outer coast, dominated by rain or rain-snow transitional hydrology with peak flows during fall and winter and low summer flows, to fjords with large rivers and creeks draining the coast mountains through broad glacial valleys, dominated by snowmelt hydrology with peak flows during spring snowmelt and low winter flows. In aggregate, the smaller watersheds of the coast produce large numbers of coho, however the escapement of spawners within any single population rarely exceeds 10,000 fish. In contrast, the larger, inner fjord watersheds have the highest historical production of coho including the Bella Coola River (mean = 24,000 spawners), Kemano River (5,400 spawners), and Martin Rivers (2,980 spawners). In many larger watersheds, like the Kitimat, Kitlope, Dean and Kimsquit Rivers, coho spawner escapement is currently unmonitored. For the purposes of harvest management, Central Coast coho stocks have been divided into eight CUs, which group stocks according to similarities in their genetics, biogeographic conditions, run timing, and fishery vulnerability.

Note that the following description of Central Coast fisheries and stocks is organized by CU. As currently defined, Central Coast Areas do not necessarily represent discrete or whole CU’s and therefore discussion of these populations is more accurate when based on CU rather than by Area.

The largest CU on the Central Coast, both in terms of geographic extent and the number of known populations is the Hecate Strait Mainland, which stretches from Porcher Island in Area 5 to Fitz Hugh Sound in Area 8, this CU includes at least 173 locations where coho spawning has been documented historically. Among these stocks 36 have previously been deemed *escapement indicators*[1], with abundance estimated from overflights or ground based counts. At present, annual escapement monitoring is ongoing in only six of these populations. Following the recommendations of the 2000 Pacific Salmon Treaty coho technical report, a weir and CWT marking program was established for the wild population returning to West Arm Creek in Drake Inlet, however this project was discontinued in 2009 due to a lack of funding. Enhancement for coho is ongoing at two community-development hatcheries in the CU, one in Klemtu on Kitasoo Creek with an annual egg take goal of 75,000, and another in Bella Bella at the McLoughlin hatchery with an annual egg take goal of 90,000. CWT marking was formerly conducted at both facilities, but a lack of capacity and resources for fishery recoveries and escapement monitoring led to these programs being discontinued. Currently, there are no CWT indicator stocks for the Hecate Strait Mainland CU.

The Northern Coastal CU includes at least 58 populations with historical data, 17 that have been previously identified as escapement indicators, distributed across Areas 6, 7, and 8. In recent years, only 14 populations of the 17 have had regular escapement monitoring. For many watersheds in this CU, spawner enumeration is challenged by the large amount of habitat area where coho regularly spawn, high glacial turbidity that limits the effectiveness of visual surveys, and remote access. Notably, two major coho producing systems in this CU - the Kitlope and Kimsquit Rivers - are lacking escapement information. There are no hatchery enhanced stocks in the Northern Coastal CU.

The remaining six CUs (Douglas Channel-Kitimat, Brim-Wahoo, Mussel-Kynoch, Rivers Inlet and Smith Inlet) are more geographically constrained, and are made up of smaller regional aggregations of populations. Anderson and Foch Creek in the Douglas Channel-Kitimat have count-based estimates of coho escapements in about half of recent years, although the largest population in the CU, the Kitimat River, is unmonitored. The Brim-Wahoo CU comprises only two populations, and coho returning to both watersheds have been enumerated using visual counts each year since the late-1990s. Historic count data exist for 14 locations in the Mussel-Kynoch CU, however only the Green River has been counted since 2008, and budget challenges and logistical constraints have limited escapement monitoring to the Green in some recent years.

In the Bella Coola-Dean CU, recent monitoring is limited to a dozen tributaries of the Bella Coola River, however these counts do not provide an estimate of total escapement to the Bella Coola watershed. Prior to 2008, the Department made annual escapement estimates of coho escapement in the Bella Coola watershed, however the methods used to derive these estimates are poorly documented and may have changed over time. The Dean River is unmonitored for escapement. Coho were formerly CWT marked at Snootli hatchery and released at a number of locations in the

[1] Escapement indicators are streams with consistent escapement monitoring over time without coded-wire-tag application. Survey methodologies may differ between streams but are consistent within a stream between years.

Bella Coola watershed. Harvest rate estimates for Bella Coola River coho were challenged by limited resources for escapement monitoring and coho enhancement was discontinued in 2010.

The Rivers Inlet CU, which overlaps fully with Area 9, includes at least 24 populations with historic count data on coho escapement. Among these populations, only the Chuckwalla and Kilbella Rivers are considered escapement indicators, however overflight counts for coho enumeration were discontinued after 2013 due to their high cost, and uncertainty about data quality. Currently no coho populations in Area 9 are monitored for escapement.

The Smith Inlet CU overlaps fully with Area 10 and includes 12 populations with historic count data. From 1998 to 2014, the Docee River counting fence at the outlet of Long Lake was used to count the number of returning coho. This program was discontinued in 2014. Consequently, no coho populations in Area 10 are currently monitored for escapement.

Transboundary Region

In the Transboundary region, some small coastal stream salmon populations do exist but the larger Alsek, Taku and Stikine rivers, along with their numerous tributaries, are predominant.

Alsek River

The Alsek River is approximately 200 km long with a drainage area of 28,000 km² (Bigelow *et al*., 1995). Over 90% of the watershed is located in northern British Columbia and Yukon. The Alsek River originates in the St. Elias Mountains of the Yukon Territory, flows through northwestern British Columbia and into the Gulf of Alaska at Dry Bay, approximately 80 km southeast of Yakutat, Alaska. The watershed is of glacial origin and its primary tributaries include the Alsek and the Tatshenshini rivers (Nowosad *et al*., 2017). The Tatshenshini-Alsek River confluence is located 15km upstream of the BC-Alaska border. Glaciers dominate the watershed, and the Alsek River is a conduit for vast quantities of glacier-eroded sediment. This process causes high levels of suspended solids and turbidity in the river during spring and summer and ensures cold water temperatures (Nowosad *et al*., 2017).

A preliminary estimate of the required escapement level for coho spawning in the Canadian section of the Alsek River is cited in the February 1987 Transboundary Technical Committee report (PSC, 1987); this was a range of 5,400 to 25,000 spawners. However, the estimate was based on very little data and was not adopted. To date, an escapement goal for coho in the Alsek River has not been established. Annual escapements have not been identified due to the lack of an assessment program; there is only an annual weir count for one tributary (the Klukshu River) which does not cover the entire migration period (DFO, 2018).

Taku River

The Taku River is a large transboundary river in northwestern British Columbia and Alaska. Approximately 90% of the 19,000 km^2 drainage area lies within BC, with the remainder flowing through and draining into the ocean approximately 45 km north-east of Juneau. The river is formed by the confluence of two large upstream rivers, the southern Inklin and northern Nakina Rivers. Clear water tributaries include the northern portions of the Taku watershed from the Nakina and Nahlin rivers. The lower Taku River is highly braided, confined within a wide mountainous valley with major glacial influences (Eiler, 1995; Pestal and Johnston, 2015). Major subdrainages within this part of the watershed include the Tulsequah River, King Salmon Creek, Sittakanay Creek, and Stuhini Creek. Most of these larger tributaries are of glacial origin except King Salmon Creek. The heavy glacial silt load typical of the high-water period on the Taku River decreases substantially in the fall and winter. Winter flows can be less than 100m^3/s but increase in late spring and can exceed 700 m^3/s during freshet in June (Clark *et al*., 1986; Murphy *et al*., 1989). Summer flooding is typical in the lower river when ice dams impounding glacial melt from the Tulsequah River break and release a surge of water know as a jökulhlaup. Known spawning locations include the mainstem Taku River, Nakina River, Dudidontu River, Hackett River, Nahlin River, Tatsatua River, Kowatua River, Tulsequah River, Sloko River, plus streams located in the U.S. section of the river (e.g., Yehring Creek). Coho spawning has also been recorded in the Sittakanay and Stuhini watersheds.

The Taku River is the only river in the Transboundary region with a full indicator program. A mark-recapture program using CWTs began in 1990 to provide smolt production estimates and associated brood year escapement estimates, ocean survival, harvest rates, stock identification and contribution estimates within marine fisheries.

Stikine River

The Stikine River is approximately 540 km in length and covers an area of 52,000 km^2 (Bigelow *et al*., 1995). The headwaters are located in the semi-arid Spatsizi Plateau in northwestern British Columbia. The Stikine flows in a south-westerly direction through volcanic coastal mountains and glaciers until it reaches the ocean near Wrangell, Alaska. The majority of the Stikine River watershed is situated in Canada. Principal tributaries include the Tahltan, Chutine, Scud, Porcupine, Tanzilla, Iskut, and Tuya rivers. The headwaters of the Upper Stikine River are clear, while glacially turbid portions (Christina, Chutine, upper Iskut) of the river are mixed with clear groundwater-fed sloughs further downstream. The lower river and most tributaries are glacially occluded (e.g., Chutine, Scud, Porcupine, and Iskut rivers). Salmon are unable to migrate beyond the Stikine Grand Canyon upstream of Telegraph Creek. Migration is also restricted in the upper Iskut River due to the Iskut Canyon near Forest Kerr Creek. All five species of anadromous Pacific salmon occur in the Canadian portion of the Stikine River (PSC TCTR, 2006). Sockeye, followed by coho and Chinook salmon, are the most abundant while pink and chum salmon numbers are limited within the watershed. The primary salmon tributaries in British Columbia include the Tahltan, mainstem Stikine, Chutine, and Iskut Rivers.

At present, run size estimates are based on test fishery and/or commercial catch-per-unit-effort data with that of sockeye salmon. In the last 15 years, the estimated in-river coho run size has averaged 59,000 fish, however, these estimates are not scientifically defensible. Aerial survey data, while unreliable and of limited use, indicate that runs appear to have been in decline since very high escapements observed in 2001 and 2002.

Description of Fisheries Management

Detailed background information on the management of northern British Columbia fisheries is available in reports previously submitted to the Pacific Salmon Commission's Northern Panel (NBTC 1992, 2002). These include descriptions of historical fisheries management of Haida Gwaii, Nass and Skeena Rivers and the Central Coast. Additional detail can be found in the annual reports produced by the Northern Boundary Technical Committee (NBTC).

Canada implemented considerable salmon management policies in the 1990's due to persistent salmon conservation concerns across British Columbia, particularly for upper Skeena River coho stocks. These policies included *The Pacific Salmon Revitalization Strategy* (1996), *An Allocation Policy for Pacific Salmon* (1999), and specific conservation objectives to rebuild coho stocks. Implementation of these policies resulted in a suite of fishery changes including a reduction of the fishing fleet by 35%, redistribution of fishing access for coho between First Nation, recreational and commercial gear types. This was followed by development of *Canada's Policy for the Conservation of Wild Pacific Salmon* ("*The Wild Salmon Policy*", WSP) in 2005 which lays out objectives and strategies for the conservation of Pacific Salmon. The fundamental direction of the WSP was to maintain diversity through the protection of coho through harvest management considerations at the CU-scale. Implementation of this policy is further guided by the *Wild Salmon Policy Implementation Plan* (2018 to 2022), which is a coordinated action plan to focus the development of common guidance and standardized methods for the use of scientific and management expertise in the conservation of wild Pacific salmon. This initiative is intended to improve our understanding of salmon stocks and inform fishery management.

Transboundary salmon stocks that spawn in Canada are managed under an agreement with the U.S. through the Pacific Salmon Treaty (PST). Officially signed in March 1985, the United States and Canada agreed to cooperate in the management, research, and enhancement of Pacific salmon stocks of mutual concern. The PST, through the Pacific Salmon Commission, created the Transboundary and Yukon River Panels to manage shared salmon stocks. The Transboundary Panels are served by Joint Technical Committees as science advisory groups comprising Canadian (BC and Yukon) and the U.S. (Alaska) fisheries managers and research biologists. Under the Alaska state fisheries management system, the Alaska Board of Fisheries (BOF) reviews proposals to modify, create, or delete regulations for Southeast Alaska fisheries every three years. The board considers input from Fish and Game Advisory Committees, the general public, and State and Federal management agencies. Under Alaska and U.S. law, subsistence use has the highest priority among consumptive uses for salmon resources. The federal U.S. management system is focused on rural subsistence use in fresh waters, while the state continues to manage all fisheries in all waters inside the 3-mile limit, except for when and where federal rules supersede.

In 1999 negotiations between Canada and the U.S. resulted in the successful renewal of fishing arrangements under the PST. The PST was designed to provide catch sharing arrangements, reduce interceptions, prevent overfishing, and improve overall salmon management while avoiding undue disruption of existing fisheries. However, by 1992, when the original fishing arrangements expired, Canadian fishermen complained that their Alaskan and Washington counterparts were taking a disproportionate large number of Canadian salmon. From 1992 to 1998, both countries were not able to agree on a comprehensive arrangement, but in 1999 negotiations resulted in the successful renewal of fishing arrangements under the PST. In 2009 and again in 2019, a new 10-year agreement was implemented by both parties for the conservation and harvest sharing of salmon outside the Fraser and Yukon systems.

Historical Commercial Harvest and Management

When the Pacific Salmon Treaty was signed in 1985, it ushered in a more collective, bilateral approach to fisheries management in northern British Columbia and portions of southeast Alaska. In 1997, commercial harvest of coho in British Columbia hit an all-time low and triggered conservation measures for Canadian coho stocks (NBTC 2002). As a result, the directed harvest of coho by commercial fisheries did not occur from 1998 to 2001 in Canadian waters. Commercial fisheries in the Northern Boundary region resumed in 2002 but have remained low compared to the decades prior to 1997.

From 1952 - 1965, commercial harvest of coho in northern British Columbia averaged 1.12 million fish (Fig. 4). These high catches remained steady until the mid-1990s when the number of coho dropped below 500,000 fish for the first time since in-season monitoring began in the 1950s. In 1997, harvest hit an all-time low of 219,000 fish and triggered conservation measures that would close coho-directed commercial fisheries in northern British Columbia for the following three years (NBTC 2002). In 2002, a total 128,000 fish were harvested followed by a steady increase in commercial take of coho over the next two decades (Table 1). Since 2002, the largest harvest occurred in 2005 (422,000 fish) and overall commercial harvest has remained low in northern British Columbia.

Coho salmon harvest in southeast Alaska has been highly variable since 1942 (Priest *et al*., 2021). Prior to 1951, an average of 2.11 million coho were harvested in southeast Alaska each year. Harvests then substantially declined to an average of 887 thousand coho per year between 1956-1977, corresponding to cool conditions in the Pacific Ocean negatively affecting northern coho populations (Hickey and Royer, 2001). Following an ocean regime shift in 1977 (Mantua *et al*., 1997), southeast Alaska coho harvests increased (Beamish and Bouillon, 1993). Harvest was highest in the 1990s, averaging 2.63 million coho per year. The highest number of coho harvested in southeast Alaska commercial fisheries occurred in 1994, with a total of 5.52 million fish harvested. Southeast Alaska commercial coho harvest was the lowest on record in 2018 and 2019 (Priest *et al*., 2021).

Other Harvest

Historical recreational fisheries for coho in northern British Columbia are poorly documented and estimated catch prior to 1999 is mostly subjective (NBTC 2002). Estimates of recreational harvest for Areas 1 through 10 are provided in Table 1. In the late 1990s, Areas 1, 3 and 4 experienced rapid growth in lodge and charter operations leading to an increase in catch of coho in those areas. In the early 2000s, the commercial sector faced limitations as coho stocks originating in northern British Columbia began rebuilding, and recreational catch exceeded commercial harvest until 2002 when commercial harvest resumed. Since then, recreational coho harvest has remained lower than commercial harvest, averaging 24% of the total catch (range: 15-34%). The trend in northern British Columbia sport harvest has remained relatively stable since the early 2000s, with a peak of 113,000 fish in 2003 (Table 1; Figure 4). Average harvest over the last 10 years (2010-2019) was 84,000 fish.

Taku River coho are often caught in the Juneau area sport fishery and, to a lesser extent, in the in-river personal use fishery. The Taku River contribution can be in excess of 50% of the coho harvested in the Juneau recreational fishery. Since 1994, Taku River coho have accounted for between 16% and 66% of the total sport catch in the Juneau area, with a ten-year average of 34%. Between 1992 and 2018, the annual average number of marine-caught Taku River coho was 5,241 with a range of 431 in 1992 to 19,018 in 1994.

Coho harvest in First Nations Food, Social, and Ceremonial (FSC) fisheries occurs throughout northern British Columbia with most of the harvest being incidental take in sockeye directed fisheries, although some coho directed fishing occurs. Total harvest of coho through FSC fisheries is low compared to the annual total catch from the commercial and recreational sector. The recent 10-year average of FSC harvested coho is estimated at 13,000 fish in the Northern Boundary region.

Stock Status

Populations of coho are present in over 1,200 streams in northern British Columbia with the actual number of viable populations unknown. Since the 1950s, intermittent visual counts have been conducted on over 800 streams. Monitoring in northern British Columbia increased dramatically in response to the collapse of most stocks in the late 1990s, including increased visual counts on spawning grounds, establishment of indicator programs, and watershed-wide escapement estimates. Stock status is best represented by full indicator programs that can provide smolt production, harvest rates, marine survival, and annual escapement estimates. Currently, only two full indicator programs with reliable, long-term data exist in the Northern Boundary region, and one program exists in the Transboundary region.

To assess stock status for a large geographical range, annual visual counts to estimate escapement are most appropriate. Data collected for most of these visual surveys are too inconsistent to be considered stand-alone indicators of stock status. Watershed and sub-watershed escapement estimates were also conducted in the late 1900s and early 2000s, consisting of the estimated escapement for the Nass River aggregate (Area 3) and Bulkley River aggregate (a Skeena River tributary; Area 4). These data are considered reliable enough to assess stock status in their respective areas but are currently under review and will not be summarized in this report.

Visual surveys to estimate escapement are conducted for stocks where water conditions (e.g., water clarity) allow and mark-recapture methods and/or weirs are infeasible. Visual techniques are used to derive estimates where observers can count spawning individuals by either walking, boating, or via helicopter flights. These data have been housed in DFO's New Salmon Escapement Database (NuSEDs). Due to inconsistency of these counts and unknown estimation techniques (i.e., opportunistic, area-under-curve, peak count), these data are summarized using a qualitative approach that takes into account these uncertainties.

Full indicator programs allow for assessment of stock status to appropriately inform management decisions. In these programs, juvenile coho are tagged with a CWT and marked by the removal of the adipose fin. The internal CWT tag is specific to an individuals' cohort and geographical origin, allowing estimation of marine survival and harvest rate by fishery on the tagged cohort. These programs were expanded in the 1990s and 2000s (e.g., Deena River, Zolzap Creek, Lachmach River, and West Arm Creek), however most of these programs no longer exist. Full indicator stocks such as Zolzap Creek, Toboggan Creek, and Taku River provide the most reliable datasets and will be summarized in detail throughout this section. Useful parameters estimated for these stocks include smolt production (Zolzap Creek and Taku River only), total adult return, escapement, marine survival, and fishery specific harvest (including spatial and temporal stratification).

Escapement Monitoring

Northern Boundary Regional Escapement Trend Analysis

Model overview

To evaluate status and trends across populations in the Northern Boundary region, we developed a set of multivariate autoregressive state-space models implemented in the package MARSS (Holmes *et al*. 2012). Using MARSS, we evaluated temporal trends for 99 populations with escapement time series that included at least 15 annual counts since 1980 or a minimum of 10 counts since 2000. On average, populations that were selected had spawner estimates in 27 years between 1980 and 2019, and 13 spawner estimates in the most recent 19 years. Most coho escapement data is generated with visual counts, either on foot or during overflights, which includes non-trivial observation error. This observer error can lead to spurious conclusions about population variability and trends if count data are assumed to be free of uncertainty. To address this challenge, MARSS models decompose errors into two components: observation error and process error. Process error is the true underlying variation in the quantity of interest, in this case coho escapement. For further detailed information on the MARSS model and specific model outputs and results, see Appendix A.

We evaluated statistical support for different grouping and numbers of trends among northern British Columbia coho spawner abundance timeseries, as well as the inclusion of correlations among trend process errors. The model structure receiving the highest degree of statistical support included nine trend groups and correlated process errors among the escapement trends for these groups (Table 3). Estimates of correlations in spawner escapement among these nine regional trend groups ranged from moderate (0.36) to near zero, and parameter estimates for 29 of 36 pairwise correlations had 95% confidence intervals that did not overlap zero, providing further statistical support for the inclusion of correlations among group trends (Table 2).

Overall trends

Across the 40-year time series of escapement for Northern Boundary coho, estimated values for the u parameter (u = long-term change in escapement) in our MARSS model were near or overlapping zero, indicating relatively stable spawner abundance. However, this stable long-term trend between 1980 and 2019 masks major fluctuations in escapement, including rebuilding of abundance following 1990s crashes in coho returns, and more recent decline to below average returns. Across areas, there was a consistent pattern of low and declining abundance during the 1980s and 1990s, followed by a period of recovery after 2000. Escapement trends are visualized relative to the 40-year mean escapement value (P-mean) for each group of populations (Figure 5), and many populations experienced above average abundance in most years from 2000 to 2017. In 2018 and 2019, with the exception of the Nass Region, coho escapements were well below their long-term average, indicative of low productivity in recent brood years. These poor returns may reflect several factors, including poor marine survival since 2016 when a significant marine heatwave came to dominate the Eastern Pacific Ocean. Additionally, conditions limiting freshwater productivity, such as multiple years of low snowpack and drought conditions, may have also contributed to low returns.

Importantly, the dashed line (P-mean) is not representative of any biological escapement goal, and above average escapement is not necessarily indicative of a healthy population. The dashed line is indicative of the long-term average escapement, not a biological escapement goal. Escapement goals have yet to be developed for coho populations within the Northern Boundary region but are needed to more fully evaluate the status of coho populations.

Areas 1-2 - Haida Gwaii

Our review of escapement data for coho populations in Haida Gwaii revealed a limited number of populations with reliable time series of spawner abundance. Among contemporary monitoring initiatives, eastern Haida Gwaii has some of the most reliable escapement data since weirs are operated in a number of watersheds. Only one population time series in Area 1 - Tlell River - where spawner abundance has been monitored with a video weir since 2005 was deemed reliable. Likewise annual estimates of escapement are made on the Deena and Pallant Rivers using mark-recapture and these two populations were among a group of eight in eastern Haida Gwaii (Area 2E) that have had relatively consistent escapement monitoring since 1980. Data is more limited for western Haida Gwaii, with most escapement data coming from visual surveys made during creek walks by charter patrol. Given the data limitations and likely shared environmental conditions influencing population dynamics, model selection favored grouping Haida Gwaii areas into a single trend.

Across the 40-year time series Haida Gwaii followed a similar pattern to many other northern British Columbia coho populations: escapements declined throughout the 1980s and 90s, before recovering in the late-90s. This recovery contributed to coho spawner escapements from 2000 to 2017 that were above their 40-year average in all but two years. However, Haida Gwaii coho populations experienced a significant short-term decline in coho spawner abundance in 2018 and 2019, with escapements of 68% and 61.7% of the 40-year average, respectively.

While Haida Gwaii coho populations followed similar temporal trends to other northern British Columbia coho population groups, estimated pairwise correlations in process errors between Haida Gwaii coho were on average lower than other coho population groups (0.095). Pairwise correlations between Haida Gwaii and the Hecate Mainland (0.077) and Lower Nass (0.039) population groups were low and overlapped zero. The highest estimated correlations for Haida Gwaii were with Middle and Upper Skeena (0.124) and Area 6 - Inner Waters (0.120), however these correlations were lower than average relative to other regional pairwise correlations, likely indicating greater independence in population trends for Haida Gwaii coho.

Area 3 - Nass River, Portland and Observatory

A total of 10 coho populations in Area 3 had escapement data that met data quality standards. These included three populations in the Upper Nass (Meziadin, Kwinageese, and Brown Bear Creek), three populations in the Lower Nass (Zolzap, Ansedagan, and Diskangieg), and four populations in the coastal portion of Area 3 (Khutzeymateen, Kwinimass, Ensheshese, and Lachmach). For the purposes of the time series analysis, lower Nass and coastal populations were grouped together with a shared trend, while Upper Nass populations were modeled together.

Coho escapements to the lower Nass and coastal watersheds of Area 3 have been relatively stable across the analyzed 40 year period, and from 2000 to 2010 escapements exceeding their long-term average in all but one year. Overall, coho escapements to the Upper Nass were also relatively stable across the last 40 years, but this relatively stable trajectory in spawner abundance was punctuated by a downturn in escapement in the 1990s, with rebuilding and relatively stable abundance thereafter. Escapement in 2018 and 2019 were at or near their long-term average for Nass River coho.

Process errors for Lower Nass coho escapements were most correlated with the Lower Skeena (0.205), Middle and Upper Skeena (0.201), and Upper Nass (0.162), reflecting their geographic proximity and more similar hydrology and climate. Interestingly, Upper Nass coho process errors showed some of the strongest correlations with other regional groupings, including the Middle and Upper Skeena (0.299), Lower Skeena and Estuary (0.5), and Area 6 - Inner Waters (0.206).

Area 4 - Skeena River

Escapement time series were available for 31 coho populations in the Skeena River watershed. These included populations in the Lower Skeena (n = 12), Skeena Estuary (n = 1), Middle Skeena (n = 15), and Upper Skeena (n = 3) CUs. For the purposes of analysis, Skeena River coho populations were grouped into the Lower Skeena (including Diana Creek in the estuary) and Middle and Upper Skeena.

Lower Skeena River coho escapement trends were similar to those observed in the Nass River, with a more modest increase in average escapement after harvest rates were reduced in 1998. By contrast, coho in the Middle and Upper Skeena experienced a strong rebuilding trend from 1998 to 2005 when escapements reached their 40-year peak and were above their long-term average until 2018 and 2019 when escapement dropped below average for consecutive years. Likewise, Lower Skeena coho experienced below average escapements in 2018 and 2019.

The two groups of Skeena River coho populations showed strong correlations process error with each other (0.364), relatively strong correlations with the Nass River, and weaker correlations with populations from the Kitimat River south. Estimated correlations between Hecate Lowlands coho and both Skeena River population groups were small and overlapped zero, suggesting weaker correlation between Skeena River and outer coastal stocks (Table 2).

Areas 5-10 - Central Coast

Escapement monitoring in many management areas on the Central Coast is limited to a handful of populations, and we interpreted trends in abundance from 40 populations where counts have been conducted most regularly since 1980. These count data provide a picture of recent trends in coho spawner abundance, enabling a preliminary evaluation of the status of Central Coast coho stocks.

Areas 5 & 6 - Hecate Lowlands

Given the close geographic proximity and habitat similarities between Area 5 populations and Area 6 populations in the Hecate Lowlands CU, these two groups of populations were combined for the time series analysis. AIC model selection provides further support for grouping these two areas. In Area 5, coho escapements have been regularly monitored in four locations: Shaw, Belowe, and Sylvia Creeks, and in tributaries of Tsimtack Lake. With the exception of Shaw Creek spawner escapements in these systems have been estimated in most years since 2000, however only Shaw and Tsimtack were regularly enumerated prior to 2000. In the portions of Area 6 within the Hecate Lowlands CU, Hartley Bay Creek, Quaal River, East Arm and West Arm Creeks, as well as Arnoup, Blee, Nias and Tyler Creeks have all had semi-regular escapement monitoring since 1980. On West Arm Creek, DFO operated a weir from 2001 to 2008 as part of the CWT indicator program there. The weir program has subsequently been discontinued, and today coho in the Hecate Lowlands CU within Areas 5 and 6 are monitored using visual surveys, by either helicopter overflights or stream walks.

Visual survey data for Hecate Lowlands coho in Areas 5 and 6 show a similar trend to other northern British Columbia population groups, with below average returns in the 1980s and 1990s, and increasing abundance after 1999. Between 2000 and 2017, escapement trends were above the long-term average in most years, except for 2006 to 2008 when spawner abundance was slightly below average. However, like other northern British Columbia population groups, Areas 5 and 6 coho populations in the Hecate Lowlands had lower than average spawner abundance in 2018 and 2019, when abundance was 62% and 73% of their long-term average, respectively (Figure 5).

Pairwise correlations in process errors between Hecate Lowlands coho stocks and other population groups were low (mean = 0.105). In particular, pairwise correlations were low and overlapped zero with the Lower Skeena, Middle and Upper Skeena, Upper Nass, and Haida Gwaii population groups (Table 2). Population groups with the highest correlation values with Hecate Lowlands coho were Area 6 - Inner Waters (0.178), Areas 7 and 8 (0.11), and Areas 9 and 10 (0.15), all indicative of relatively low levels of correlation in spawner escapement.

Area 6 - Inner Waters

Area 6 spans a wide longitudinal range of the Central Coast, from the outer waters around Princess Royal Island north of Klemtu River, to the inner waters near Kitimat and south to the Kemano and Kitlope Rivers. Within the Area 6 - Inner Waters population group are four CUs of coho recognized by DFO: Brim/Wahoo, Northern Coastal, Douglas Channel/Kitimat, Mussel/Kynoch. These CUs were designated as distinct based on genotypic variation, but are found in neighboring watersheds, and therefore experience similar environmental conditions, and may have similar exposure to marine fisheries.

A total of 16 individual population time series were combined to estimate the trend for the Area 6 - Inner Waters group. Among these stocks, 11 of them have at least 30 years of count data since 1980, providing valuable information for understanding and interpreting temporal trends in coho production in Area 6. In general, coho populations in the Area 6 - Inner Waters group saw increasing abundance in the early-2000s and exceeded their long-term mean escapements between 2000 and 2017. Since 2010 coho escapement in Area 6 has been closer to the long-term mean with relatively strong escapements in 2016 and 2017, and poor returns since 2018 likely attributable to low survival resulting from unfavorable freshwater and ocean conditions (Figure 5). Escapement values in 2018 and 2019 were 55.4% and 67.6% of their long-term average, respectively. Interannual variability in coho spawner escapements for the Area 6 - Inner Waters group was most correlated with the Middle and Upper Skeena (0.233), Upper Nass (0.206), Hecate Lowlands (0.178), and Areas 9 and 10 (0.169) (Table 2).

Areas 7 & 8

Area 7 coho populations belong to both the Hecate Strait Mainland and Northern Coastal CUs. Count data are available for two wild coho populations (Roscoe and Quartcha Creeks) in the Northern Coastal CU. These two populations have 31 and 28 counts over the last 40 years respectively, providing important information on temporal trends in coho escapements within the inner portions of Area 7. In the Hecate Strait Mainland CU, escapement data are only available for two enhanced stocks (Kitasoo and McLoughlin Creeks). Unfortunately, mark-rate has not been systematically estimated for spawning coho in these watersheds. No wild populations are currently monitored within the Area 7 portions of the Hecate Strait Mainland CU and monitoring in these hatchery stocks has been sporadic in recent years. Accordingly, these hatchery populations were excluded from our analysis.

Area 8 coho populations are grouped with either the Northern Coastal or Bella Coola-Dean CUs. For three populations in the Northern Coastal CU (Elcho, Cascade, and Martin) escapements were monitored intermittently by aerial or ground-based counts during the 1980s and 90s and have been regularly monitored since 2000. In the Bella Coola-Dean CU an aggregate estimate of escapement to the Bella Coola River and tributaries was made from 1980 to 2007, however the methods used to derive these estimates are not well documented and may have changed over time. Coho escapement in the Necleetsconnay River has been regularly monitored using visual counts since 1998, and the Salloomt River has been counted regularly since 2003.

Escapement trends for Area 7 & 8 reflect a similar temporal pattern to Area 6, with an increase in escapements in the late-1990s, and higher than average escapements in most years between 2000 and 2017. Like other population groups, coho returning to Areas 7 and 8 have experienced a recent decline in escapement likely reflecting a period of low survival for cohorts of smolts that entered marine waters after 2015 and impacted coho stocks coast-wide. Pairwise correlations in process errors indicate that Areas 7 and 8 coho populations share the greatest similarity with Areas 9 and 10 (0.179). Estimated correlations in process errors between Areas 7 and 8 populations in our analysis, and neighboring populations in the Hecate Lowlands Areas 5 and 6 were relatively low (0.112), lending some credence to the idea that these population groups may respond somewhat differently to environmentally-mediated variability in freshwater or ocean conditions (Table 2).

Areas 9 & 10

Currently, Area 9 and 10 coho populations are unmonitored, and time series of spawner abundance are too limited to draw conclusions about recent trends in escapement. In Area 9 (Rivers Inlet) escapement monitoring was regularly conducted for the Chuckwalla and Kilbella Rivers from the late 1990s until 2013, when overflight counts were discontinued. Given their length, high water during coho spawning season, and issues with turbidity in the Kilbella River these counts likely include considerable observer error but can be viewed as indexes of abundance since the methods used for enumeration were similar throughout the period where recent data is available. Spawner count data from the Clyak River was also analyzed with this group, and was available for a total of 15 years from 1980 to 2019.

Coho returning to Area 10 (Smith Inlet) were formerly monitored at the Docee Counting Fence at the outlet of Long Lake, which has historically been used to monitor the abundance of sockeye returning to Long Lake. Operations at the Docee fence were extended to include the coho migration in 1998 and the fence produced reliable estimates of coho escapement until 2014. Because the fence was not operational for coho counting until 1998 the long-term average escapements are estimated only from more recent data. Despite these limitations the quality of the count data from the Docee fence provides some insight to coho escapement trends during the 16 years when it was operational.

AIC model selection supported grouping Area 9 and 10 stocks (Chuckwalla, Kilbella, Clyak, Docee) into a single trend (Table 3). This shared trend indicates that escapements appear to have increased to levels that are above or near their long-term average after coho exploitation rates were reduced in the late-90s, and like other northern British Columbia coho population groups coho in Areas 9 and 10 experienced a similar short-term drop in escapement from 2006-2008 followed by strong returns in 2009 with fluctuating escapement thereafter. While the lack of recent escapement data limits insights into trends for 2018 and 2019, anecdotal evidence from First Nations and recreational fishers indicates lower than average returns of coho in 2018 and 2019.

Full Indicator Stocks

Zolzap Creek

Zolzap Creek is a tributary to the Nass River (Area 3) that supports a wild coho population. Annual smolt production and adult escapement has been estimated since 1992. Due to funding constraints, the Zolzap Creek program was not in operation from 2005 - 2009. Juvenile out-migration populations have been estimated using variable techniques with the most recent being a semi-permanent weir structure. Returning adults have been captured using a temporary weir since the inception of the program in 1992. Adults are estimated using mark-recapture techniques. Both methods are described in Noble *et al*. (*in press*). As a result of applying CWTs to juvenile outmigrants and estimating escapement with mark rates, the Zolzap Creek program provides the most consistent long-term data series of stock status for a wild population in the Northern Boundary region. Zolzap Creek is an important indicator of harvest rates for Canadian and Alaskan commercial fisheries.

Since 1992, Zolzap Creek escapement averaged 1,349 fish (range: 145 - 3,233 fish) with total runs averaging 3,079 (range: 820 - 9,979). Average escapement and total runs over the past five years were 45% and 51% below the long-term averages, respectively (Figure 8). Since 2011, the total run to Zolzap Creek was below the 1993 - 2004 average five of the past nine years (Table 4; Figure 7).

Toboggan Creek

Toboggan Creek is a tributary to the Bulkley River that flows into the Skeena River (Area 4) near Smithers, BC. This system supports a wild coho population even though the full indicator program is augmented with a hatchery setting and has been doing so since operation began in 1987. Returning adults were captured using a temporary weir structure until 2017 when high water events destroyed the weir and inhibited operation. In 2018, a permanent weir was constructed and is currently in use. Escapement estimates are conducted using a mark-recapture technique utilizing the weir structure. Upon return, adults are collected for brood-stock to raise juveniles for the application of CWT. The number of adults used for brood-stock varies with the goal of applying >30,000 CWT annually. All juveniles receiving a CWT also have the adipose fin removed. Of the 33 years of operation, the CWT annual release goal has been achieved 27 times. The Toboggan Creek program provides the longest standing full indicator data for northern British Columbia. This stock is an important indicator of harvest rates for Canadian and Alaskan fisheries.

Since 1988, escapement averaged 3,400 fish (range: 394 - 8,878) with total runs averaging 5,834 fish (range: 798 - 11,501; Table 4). Average escapement and total runs over the past five years were 9% and 8% below the long-term averages, respectively (Figure 8). Since 2010, the total run to Toboggan Creek was below the 1989 - 2009 average in five of the last 10 years (Table 4; Figure 7).

Taku River

The Taku River has the largest coho salmon population of the Transboundary rivers. A full indicator program was established for Taku River coho in 1990. Out-migrating coho salmon smolts are captured and tagged in the nasal cartilage with a short segment of coded-wire and marked by excision of the adipose fin (Pestal and Johnston 2015). Prior to 1997, rotary screw traps installed just upstream of the border were used to capture smolts. In 1997, a combination of rotary screw traps and Gee minnow traps baited with salmon roe were used. Since then, capture methodology has involved minnow traps only. In addition, a mark-recapture program has been implemented since 1987 with adult marking in the lower Taku River (Canyon Island) and recovery in Canadian fisheries to provide in-season projections and post-season estimates of total in-river run size, escapement, major stock timing and overall age and size composition (Williams *et al.* 2016) . In-river run estimates are combined with estimates of U.S. catches of Taku River coho in troll, sport and net fisheries to produce estimates of the run size of the Taku River coho.

The average escapement for the full time series is 89,041 fish, with a range of 32,345 (1987) to 219,360 (2002; Table 4). An average total run size (between 1992-2018) of 173,417 adults has been estimated ranging from 50,886 in 1997 to 339,736 in 1994. The trend in in-river escapement from the late 1980's cycle averages of approximately 56,000 coho salmon, almost tripled to more than 137,000 fish in the early-to-mid 2000s, followed by a progressive decline from 2007 to 2018 averaging close to 83,000 coho salmon (Table 4; Figure 6).

The management intent of the U.S. was to ensure a minimum above-border in-river run of 38,000 fish (PSC TCTR 2020); this was associated with a target range of 27,500 to 35,000. This was exceeded for all years except for 1987, which fell within the range. In 2013, the TBR Panel management intent shifted to the objective of providing an in-river escapement of at least 70,000;, and escapement that year in 2013 was 68,117. An interim objective of 70,000 was set for 2014, and this was greatly exceeded with an escapement of 124,171. Prior to the 2015 fishing season, this objective was adopted by the TBR Panel as a point goal, bounded by a range of 50,000 to 90,000 fish. Escapements have exceeded the point goal for two of the five years since that time and fallen within the range for all years.

Smolt Production

Annual estimates of smolt production are available for four populations where data are most consistently available over the last decade (the Deena River, Zolzap Creek and Slamgeesh River in the Northern Boundary region, and the Taku River in the Transboundary region) and a single population with estimates for the past five years (Koeye River). Outmigration estimates for these five programs can be found in Table 5. The remainder of this section will focus on summarizing data for the Deena River, Zolzap Creek, Slamgeesh, and Taku Rivers. Smolt estimates for the Koeye River, including methodology, can be found in Appendix B.

Deena River

The Deena River is located on Haida Gwaii and drains directly into Skidegate Inlet (Area 2E). Since the program began in 1994, annual smolt production has been estimated for this wild population 21 times. Years without estimates were due to high water events that typically occur during the outmigration season. Smolt production has been estimated using various techniques, the most recent being mark-recapture using rotary screw traps (Spoljaric *et al.*, 2019). Total smolt production averaged 121,009 fish (range: 7,720 - 422,509 fish) from 1994 to 2018 (Table 5). Smolt production has been highly variable with an overall linear increase since 1994 (Figure 9). From 1994 to 2000, smolt production was consistently low relative to the following 18 years (2001-2018). As a result, there has been a significant increase in smolt production over the entire time series 1994-2018 (LM, p=0.013).

Zolzap Creek

Total Zolzap Creek coho smolt counts averaged 29,403 fish (range: 12,855 - 53,000) from 1992 - 2019 (excluding years of non-operation; Table 5). The lowest count of 12,855 fish occurred in 2017, while the highest recorded count of 53,000 fish occurred in 1992. Smolt counts remained relatively stable with an average of 36,200 fish during the first five years of operation (1992-1996) to an average of 30,102 fish in the five years from 2015-2019. Smolt counts have not decreased significantly over the entirety of project operations (1992-2019; LM, p=0.996; Figure 9).

Slamgeesh River

The Slamgeesh River is a tributary to the Skeena River (Area 4) that supports a wild coho population. Annual smolt production has been estimated since 2001. Due to funding constraints the Slamgeesh River smolt program was not in operation from 2006 - 2008. Juvenile outmigration abundance has been estimated using various techniques with the most recent being a semi-permanent weir structure in combination with mark-recapture techniques (Fernando and Whitmore 2019). Total smolt production for the Slamgeesh River averaged 43,484 fish (range: 20,716 - 66,494) from 2001 - 2019 (Table 5). The lowest estimate of 20,716 fish occurred in 2019, while the highest estimate of 66,494 fish occurred in 2004. Smolt production has remained relatively stable with an average of 39,199 fish in the first five years of the project (2001-2005) to an average of 33,972 fish in the five years from 2015-2019 (Table 5). Smolt production has not significantly decreased over the entirety of project operations (2001 - 2019; LM, p=0.852; Figure 9).

Taku River

Smolt abundance in the Taku River has averaged 1.9M fish since 1996 (Table 5). Broken out by decade, averages are as follows. For 1996-1999: 1.1M fish; 2000-2009: 2.7 fish; 2010-2019: 1.4M fish. Emigration appeared to increase very consistently from 1996 through 2004. Following this, it declined almost as consistently through 2014, ending up at almost the same level as in 1996. Since 2014 (with the exception of the 2018 emigration which was relatively modest), abundance levels have been close to average and relatively stable (Figure 9).

Central Coast

Smolt enumeration among Central Coast populations has been infrequent, however several programs have been run on the Central Coast over the years. From 1947-1960 DFO operated a smolt fence on the Hooknose River, however since the project was discontinued the population has remained unmonitored. With only a handful of smolt abundance projects in recent decades, data on freshwater production for Central Coast populations is scarce. Smolt abundance estimates are ongoing at only two locations, Mary's Cove Creek and the Koeye River.

On Mary's Cove Creek, the Kitasoo Fisheries program has run out-migrant traps since 1992, although trapping was not conducted in 1996 or 1998. The Mary's Cove Creek program is primarily focused on sockeye smolt enumeration, however coho are captured incidentally. Annual total catch of coho smolts at the Mary's Cove Creek trap has ranged from 88 to 1,204 fish, and has averaged 303 fish across the time series (PSF 2021). Unfortunately, estimates of capture efficiency are not available for Mary's Cove Creek, precluding estimates of total smolt production.

Smolt enumeration in the Koeye River has been ongoing since 2014, however estimates since 2015 are considered reliable. Smolts in Koeye are captured in a rotary screw trap (RST) operated from mid-April to mid-June just upstream of the tidal portions of the lower Koeye River. Smolts are clipped with small visually identifiable clips on the caudal fin. Recovery of these clips allows estimates of trap efficiency and total smolt abundance.

Because coho released in the Koeye smolt trap efficiency trials are batch marked, a simple pooled-Peterson estimator is used to quantify temporal trends in smolt production in the Koeye watershed. Across the five-year study period the average number of smolt out-migrating was 51,740 fish (95% CI= 42,785 to 73,810) (Table 5; Appendix B), however fish over-wintering in the tidal reaches of the lower Koeye River are not accounted for in this estimate, and preliminary seining data from the lower Koeye River and estuary indicate that the number of pre-smolts using these habitats for overwintering may be considerable.

Out-migrant trapping and CWT marking was conducted in West Arm Creek from 2001 to 2008. During the pilot season in 2001, capture efficiency trials were not conducted, so total smolt production was not estimated. From 2002 to 2003, marked releases and recaptures were pooled across the season, producing a season-wide estimate of capture efficiency. A simple pooled-

Peterson estimator was used to quantify the production of smolts in these two years (Appendix B). For the years 2004 to 2008, coho smolts were given distinct marks for each week of the trapping season, and these marks were subsequently redetected as recaptures, and used to estimate capture efficiency and expand new captures to estimates of total smolt abundance for each weekly strata.

Across all years, the mean estimated smolt numbers for West Arm Creek was 17,446 fish (95% CI = 13,045 to 22,944), with smolt production peaking at 24,349 fish (95% CI = 16,523 to 37,879). A full description of methods for time-stratified mark-recapture estimates and figures showing results are available in Appendix B.

Marine Survival

Marine survival can be estimated through full indicator programs where the number of juvenile coho receiving a CWT is known in combination with determining the number of adult coho with CWTs caught in fisheries or escapement programs. The first estimates for marine survival for northern British Columbia became available in the late 1980s with the creation of the region's first full indicator program. The Toboggan Creek program began estimating marine survival for hatchery reared coho in 1989. In the 1990's, two other programs (Deena River and Zolzap Creek) began to estimate marine survival for wild coho populations in the Northern Boundary region. In the Transboundary region, marine survival has been estimated for Taku River coho since 1996. Overall, the full time series for wild coho marine survival are incomplete, with the most complete datasets coming from Zolzap Creek and Taku River. Numerous programs began in the 1990s and 2000s but are no longer in operation (e.g., Lachmach River and West Arm Creek). For programs where data were collected in the 1990s, results are summarized in NBTC (2002). For the remainder of this section, marine survival data are summarized for the Zolzap Creek, Toboggan Creek, and Taku River coho (Table 6; Figure 10).

Mean marine survival is compared for the last five years of operation of each program. Over the last five years of operation, mean marine survival was lower in comparison to the long-term average for Zolzap Creek (2015-2019 mean= 2.8%; 1993-2014 mean= 5.4%), Toboggan Creek (2015-2019 mean= 3.1%; 1989-2014 mean= 4%), and Taku River (2015-2019 mean = 8.6%; 1997-2014 mean = 9.4%). Marine survival has been highly variable over the last decade across both Northern Boundary programs (0.5% - 11.9%). Marine survival for the transboundary Taku River has also been highly variable over the past decade (5.1% - 21.3%), and typically higher than marine survival for the Northern Boundary rivers. Causes of such variability or declines in marine survival are speculative with some evidence suggesting recent declines may be due to abnormally warm ocean conditions (i.e., marine heat waves) that have increased in frequency and intensity since 2014 and subsequent major ecological shifts (Cheung and Frolicher, 2020).

Zolzap Creek

Smolt-to-adult survival rates at Zolzap Creek have been estimated since 1993 except from 2005-2010 when the program was not operational. Survival for smolts returning as adults peaked at 11.9% in 2003 and within the last 10 years peaked at 7.3% (2013; Table 6). The 1993-2019 marine survival average (where data are available) was 4.8%. When compared to the average for 2011-2019, marine survival has decreased to 3.3%. The lowest recorded marine survival was 0.8% in 2011 with the most recent estimate in 2019 of 4.2% slightly below average.

Toboggan Creek

Smolt to adult survival rates at Toboggan Creek have been consistently estimated since 1989. Survival for smolts returning as adults peaked at 10.3% in 1999 and 9% in 2009 (Table 6). The average marine survival for 1989-2019 was 3.9% (range 0.4 - 10.3%). When compared to the average for 2010-2019, marine survival has remained stable at 4%. In the last 10 years, marine survival peaked at 7.4% in 2016 with the lowest survival in 2018 and 2019.

Taku River

Smolt-to-adult survival has averaged 9.3% over the time series. It has ranged from 4.2% in 2006 and 21.3% in 2013 (Table 6). Averages by decade are as follows: For 1996-1999: 9.2%; 2000-2009: 8.5%; 2010-2019: 10.0%. Trends are not as obvious as with abundance, and extended periods of either high or low survival are not apparent (Figure 10). The large returns of the early-mid 2000s appear to be more correlated with smolt abundance than marine survival. More detail on Taku River smolt marine survivals in a regional context are presented in Shaul *et al* (2011).

Harvest Rates

Harvest of coho originating in northern British Columbia occurs through multiple fisheries, from the outer coastal troll and marine sport fisheries surrounding Haida Gwaii, net, sport, and troll fisheries in inner coastal waters. For a few select stocks, there are also freshwater and subsistence fisheries. Compared to the 1990s, recent all-gear fishery harvest rates have decreased for the Toboggan Creek stock (Table 7). This can also be said for the Zolzap Creek stock with the exception of 2015, where harvest rates exceeded 85% (Table 7; Figure 11). The following section will summarize harvest rates for two full indicator stocks in the Northern Boundary region (Zolzap Creek and Toboggan Creek) and one population in the Transboundary region (Taku River). These data will summarize harvest rates occurring in both Canada and Alaska.

Total all-gear harvest rate estimates for Zolzap Creek coho averaged 55% (range 20-87%) from 1993-2019 (missing data from 2004 through 2011; Figure 11; Appendix C1). This is due primarily to interceptions in Alaskan fisheries given the proximity of the stock to Dixon entrance (Figure 2). The lowest all-gear harvest rate estimate (20%) occurred in 2002. The highest harvest rate occurred in 2015, when an estimated 87% of the run was harvested with 58% of the harvest occurring outside of Canadian waters. Both Canadian and Alaska troll fisheries accounted for the highest harvest rates, with a combined average exploitation rate of 40% (range 14-59%), followed by Alaskan seine (6%), Alaskan gillnet (3%), and Alaskan marine sport (2%). Troll harvest rate peaked in 2012 at 59% then declined for years 2013-2019 with an average of 43% Figure 11).

Total all-gear harvest rate estimates for Toboggan Creek coho averaged 41% (range 16-71%) from 1989-2019 (Figure 11; Appendix C2). The lowest all-gear harvest rate of 16% occurred in 2002. The highest harvest rate occurred in 1996, when an estimated 71% of the run was harvested with 41% of the harvest occurring within Canadian waters. Both Canadian and Alaska troll fisheries accounted for the highest harvest rates, with a combined average exploitation rate of 24% (range 8-45%), followed by Canadian net (4%), Alaskan seine (4%), and Canadian marine sport (3%). Troll harvest rate peaked at 45% in 1990 and has declined since 1994 with an average for years 2010-2019 hovering around the overall mean at 22% (Table 7).

The average total harvest of Taku River coho since 1992 is 78,986 fish (44.9% of the total run; Table 7). Broken out by decade, averages are as follows. For 1992-1999: 101,375 fish; 2000-2009: 84,064 fish; 2010-2019: 55,996 fish. Inter-decadal patterns were similar to those of run sizes, with catch generally correlated with abundance. However, the 1990s did have the highest catch average, almost double that of the 2010s. This was largely driven by the 1994 catch of 243,393 fish. Harvest by fishery is presented by decade in Appendix C3 and D3. Through 2009, Canadian harvest comprised 7-8% of the total. For 2010-2019, it increased to 21%. District 111 has accounted for about 30-40% of the total over the full period. The troll fishery contribution has been the most significant, ranging from 62% in the 2000-2009 period to 45% in the most recent decade. Exploitation rates have ranged from a low of 28% in 2002 to a high of 72% in 1994, which happen to coincide with the two largest run sizes (339,736 fish in 1994 followed by 303,275 in 2002). The 1992-1999 period had the highest exploitation, averaging 55%. The most recent decade average is 40%.

Discussion

Survival and Abundance Trends

Smolt production of northern British Columbia stocks described in this report are similar to the long-term average or show a significant increase. Marine survival was variable across three full indicator programs with Zolzap Creek showing a slight decline and Toboggan Creek and Taku River remaining stable over the past 25 years. Overall marine survival remains low when compared to Alaskan indicator stocks (Priest *et al*., 2021). The overall trend in escapement for northern British Columbia shows high variability in adult returns but is stable over the 40-year time series. Since the inception of the full indicator programs at Zolzap and Toboggan Creeks, total returns have shown no significant changes over time (Zolzap Creek 1993-2019, LM, $p= 0.253$; Toboggan Creek 1989-2019, LM, $p= 0.886$). For the Taku River, the most recent decade showed fairly consistent escapement estimates; however, escapements were, on average, lower than in previous decades. Overall trends in abundance have been similar based on visual counts across northern British Columbia and full indicator programs, however marine survival and escapement estimates for the past two years have been low for all monitoring programs.

Factors Affecting Survival and Abundance

Numerous environmental factors have likely contributed to changes in coho survival and abundance in British Columbia. Post-smolt growth and survival is a primary driver of coho population dynamics (Holtby *et al.* 1990). Warm ocean conditions and associated low productivity in marine food webs has contributed in the past to lower than average early marine growth and smolt-to-adult survival in British Columbia, and at times has been related to higher survival for Southeast Alaskan salmon (Mueter *et al*. 2002; Shaul *et al*. 2007). Recent marine heatwaves have driven persistent changes in North Pacific temperatures, biological productivity, and food web structure, and have likely contributed to recent low survival and abundance (Suryan *et al*. 2021).

In the past, survival of Canadian and Alaska coho stocks have been related to a variety of marine climate and biological indicators including sea surface temperature, the strength of the Aleutian low pressure, North Pacific Gyre Oscillation, and the magnitude and sign of Pacific Decadal Oscillation (Mantua *et al*. 1997; Briscoe *et al*. 2005; Malick *et al*. 2009). Asynchronous survival trends between British Columbia and southeast Alaska stocks, which have occurred in recent decades were attributed to the location of the bifurcation zone between the California Current and the Alaska Current system, which typically occurs near the Canada-Alaska border (Hickey and Royer 2001; Malick *et al*. 2017). However, climate change is contributing to the emergence of novel climates, altering long standing relationships between ocean climate variables, ecosystem productivity and salmon survival (Litzow *et al*. 2018). During recent years of pronounced marine heatwaves, poor smolt-to-adult survival rates were observed in both southeast Alaska and British Columbia.

Likewise, freshwater rearing environments play an important role in determining the productivity of coho populations. Drought and associated low flow and warm water conditions can reduce freshwater production of coho, likely due to changes in physical habitat area and the increased bioenergetic costs of survival and growth at the upper range of their thermal tolerance (e.g., Ohlberger *et al*. 2018). Summer temperatures in northern British Columbia have reached record highs in the last five years, with drought becoming a more common feature of summer climate conditions. Warming and drought in freshwater in recent years (e.g., 2015 and 2018) has likely contributed to below average freshwater production of coho smolts. Increasing intensity of storm events and flooding can also lead to lower egg-to-fry and juvenile survival for coho and other salmon species (Holtby and Healy 1986; Scheuerell *et al*. 2006). However, individual watersheds and populations may exhibit asynchronous responses to climate variability (Malick *et al*. 2009; Leppi *et al*. 2014, Mauger *et al*. 2017). For example, lower elevation coastal systems with rain-dominated hydrology may be more sensitive to drought and warming, while watershed features such as lakes, wetlands, and intact floodplains habitats can dampen the impact of high flows on survival and productivity.

Top-down control of coho survival by predators may also play a role in driving population dynamics, particularly by contributing to lower smolt-to-adult survival (LaCroix *et al*. 2009;

Sobocinski *et al.* 2021). Larger bodied smolts like coho, steelhead trout, and yearling Chinook salmon are more likely to be targeted by predatory pinnipeds (Thomas *et al*. 2017; Nelson *et al.* 2019; Allegue *et al*. 2020). Whether predators are the proximate or ultimate cause of increased mortality is the subject of active scientific debate and quantifying the impacts of predation on coho population dynamics on the British Columbia coast is hindered by a lack of historic or contemporary monitoring of predator populations. Research in more well-studied regions and the observations of local knowledge holders and fishers from northern British Columbia suggest that increasing pinniped abundance in particular may be contributing to reduced survival for salmon.

Harvest Rates

Harvest rates of northern British Columbia coho stocks have remained relatively stable for Zolzap Creek since the late 1990s, while harvest rates for Toboggan Creek and Taku River have exhibited a downward trend from peak levels in the early to mid-1990s. Total annual harvest rates for Zolzap and Toboggan Creeks were 49% during the years 2010-2019 when compared to an average of 55% during the 1990s. Similarly, for Taku River coho, harvest rates have declined in the most recent decade (annual average harvest rate 41% of total run) compared with the 1990s (55%). Declines in the troll harvest for both Canada and Alaska have contributed to lower harvest rates in the last decade compared to the historical average for all programs. Commercial harvest in northern British Columbia has declined substantially due to fleet restructuring and spatial and temporal closures.

Changes in the dynamics of the Canadian commercial fleet have impacted harvest rates in stocks originating in both Canada and Alaska. British Columbia's troll fishery plays a substantial role in influencing harvest rates for Canadian coho stocks, though impacts on Alaska's southern inside stocks is minimal (Shaul *et al*. 2019). Canadian troll harvest rates remained steady from 1989 - 1997, after which Canadian harvest decreased to zero until 2002 due to fishing restrictions focused on conservation concerns surrounding upper Skeena River coho stocks (NBTC 2002). Once restrictions were reduced in 2002, harvest rates from Canadian fisheries increased but remained low compared to the early 1990s. Increased harvest rates from the Canadian marine recreational sector became apparent throughout the last decade, averaging 5% across both Zolzap and Toboggan Creeks with the peak harvest rate by Canadian marine recreational fisheries for Toboggan Creek reaching 14% in 2011. All-gear harvest rates of Toboggan Creek in Canadian fisheries from 2010-2019 averaged 18%. This is substantially lower than the period prior to the Canadian fishery restrictions occurring from 1998-2002 (1989-1997; average=28%).

The difference in troll fishery harvest rates between the two Northern Boundary region indicator stocks is largely explained by geographical location and migration patterns. This determines their temporal and spatial vulnerability among active fisheries in both Canada and Alaska. The substantial differences in harvest rates of Zolzap Creek and Toboggan Creek stocks in the Alaskan fisheries suggests coho originating in Area 3 (Nass Region) exhibit different migration patterns than coho from Area 4 (Skeena River). Conversely, the relatively non-migratory Deena River population located on Haida Gwaii (Area 2E) were encountered less frequently than stocks originating in nearby management areas (Splisted *et al*. 2010).

Taku River coho are harvested by U.S. troll fisheries, gillnet fisheries (District 111 gillnet fishery in Stephen's Passage), and Canadian in-river commercial fisheries (including a test fishery). The U.S. troll fishery contribution has been the largest, ranging from 62% in the 2000-2009 period to 45% in the most recent decade, while the District 111 gillnet fishery has accounted for about 30-40% of the total harvest catch over the full period. Declines in U.S. commercial catch are apparent since the 1990s. Canadian harvests date back to 1979, and range from 2,690 fish in 1997 (which, as previously noted, had the lowest run size) to 16,568 fish in 2016. Through 2009, Canadian harvest comprised 7-8% of total and increased to 21% during the 2010-2019 period. Total harvest is largely driven by the commercial fishery, however in some years (e.g., 2005) the test fishery has accounted for up to 38% of the catch. The second and third largest harvests were taken in 1994 and 1995, respectively. However, apart from these years, and 1987 which had a harvest of 6,519 fish, harvests were under 6,000 fish until 2003. At this point, levels jumped to about 10,000 fish; this can be attributed for the most part to the test fishery. For the preceding three years, this assessment fishery had involved release of fish captured. This was supplemented by FSC harvest which had increased from less than 170 fish to up to 688 fish with the intent of providing assessment information.

Management Outlook

Over the last 40 years, overall escapement trends have been largely stable or increasing for northern British Columbia coho stocks. These trends are likely related to generally lower harvest rates in British Columbia and Alaskan fisheries since 1998. However, many stocks originating in northern British Columbia are data deficient, creating uncertainty in assessment of stock status. Nonetheless, the available data showed stability in escapement across the entire geographical region with a widespread recent decline in 2018 and 2019. Following the collapse of coho stocks in 1997, coho abundance fluctuated considerably between 2000 and 2017, and coho populations across Areas 1-10 generally remained at or above long-term average escapements. However, recent poor survival has contributed to lower catches and spawner escapement since 2018.

Recent low coho returns coincide with successive years of anomalously warm conditions in the North Pacific, when widespread and persistent warm ocean conditions contributed to major changes in marine food webs, air temperatures, and freshwater discharge around the Northern Pacific Rim (Suryan *et al*. 2021). Reductions in marine survival were identified in the full indicator programs summarized in this report, indicating less favorable environmental conditions for coho survival. Likewise, warm air temperatures and prolonged drought conditions in 2015 and 2018 may have contributed to below average freshwater production in the full indicators and other regional coho stocks.

Climate conditions influencing coho production in northern British Columbia have continued to vary to unprecedented extremes in recent years, and these novel climates may reflect new realities as anthropogenic climate change continues to accelerate (Mantua, 2019). Thus, ongoing climate change and its contribution to diminished survival and abundance remains a significant source of concern and uncertainty for coho populations in the region. Despite these challenges, coho have historically demonstrated resilience to climate variability and moderate to high (16%-87%) harvest rates.

Information Needs

Northern British Columbia coho stocks are data deficient when compared to neighboring regions. The reduction of monitoring programs in the mid-2000s in combination with the absence of escapement goals for the indicator programs and the largest salmon producing watersheds (e.g., Skeena, Kitimat, and Bella Coola Rivers) continue to pose challenges for stock assessment and fishery management. It is paramount that additional full indicator programs are developed to represent coho stocks throughout northern British Columbia. These types of programs currently provide the most reliable annual estimates of smolt production, marine survival, escapement, and fishery specific harvest rates. Escapement goals are needed to identify if fishery management decisions are appropriate to account for unpredictable, less favorable ocean conditions. Establishing a standardized quantitative approach to estimate harvest rates and survival will further support management decisions. Improved preseason forecasting and adaptive in-season management can assist managers seeking to reduce risk or increase fishing opportunities as biological opportunities allow. The current in-season indicator for coho harvest management has become less reliable over time, and investments in catch and escapement monitoring could strengthen management and conservation efforts.

Full Indicator Programs

Full indicator stocks are the basis for developing estimates of parameters needed to inform fishery managers. Currently, there are only three full indicator programs for coho that provide a time-series of data appropriate to quantify stock status. However, even these three programs provide limited information, as Zolzap Creek represents a wild coho stock in Area 3 (Figure 1), Toboggan Creek represents an enhanced stock in Area 4, and Taku River represents a wild stock in the Transboundary region. Given the limited geographic extent of these indicator stocks, and well documented differences in marine migration routes and harvest rates among coho stocks, these three programs are likely not representative of coho stock status or harvest rates across northern British Columbia.

The objective surrounding the establishment of a full indicator program on the Deena River (Area 2E) was to represent Haida Gwaii coho stocks (Areas 1, 2E, and 2W). Due to environmental conditions, this program does not consistently estimate smolt production (e.g., smolt trapping did not occur in 2019) or meet the CWT deployment objective. Further, CWT encounter data suggest this relatively non-migratory stock is less susceptible to commercial harvest in Alaskan waters (Spilsted *et al*. 2010), and suggests stocks originating in Area 2E only provide insight of harvest in domestic fisheries. The Deena River program is an invaluable asset for understanding and managing wild coho stocks originating in Areas 2E, and will be supported in future years.

However, we recommend the establishment of an additional full indicator program on Haida Gwaii, specifically for Area 1. Currently, the Yakoun River is hypothesized to be the best candidate for a full indicator program in Area 1 due to the ongoing efforts by the Haida Fisheries Department to develop an escapement estimate. The established infrastructure on the Yakoun River increases the probability of a successful program.

Over the past 20 years, multiple programs have attempted to establish a full indicator program that represents a wild coho stock in the Skeena River (Area 4). Toboggan Creek provides the most consistent time series of data in Area 4. However, efforts to estimate the wild smolt component of Toboggan Creek are underway though currently data is inadequate for analysis or inclusion in this report. The Kitwanga River program operated by the Gitanyow Fisheries Authority (GFA) has been operating a smolt and adult program for over 15 years. Though primarily focused on sockeye salmon, GFA is working to develop a full indicator program to represent wild coho stocks in the middle Skeena CU. There have also been recent attempts to establish a full indicator program on the Zymacord River. However, due to challenging river conditions within this system during outmigration, coho smolts receiving a CWT are augmented in a hatchery. Further, attempts to estimate escapement with mark rates have proven difficult. Ongoing efforts to establish such a program will continue into the future.

There are no full indicator programs currently operating on British Columbia's Central Coast (Areas 5-10). This region spans seven CUs and six Areas, and given the capacity needed to operate full indicator programs, it is unfeasible to establish a program within each Area. Nonetheless, full indicator programs are necessary and will need to be strategically placed on systems with current monitoring initiatives, ease of access, and where coho migrations and fishery vulnerability are hypothesized to represent a larger geographical area. Even though wild stock full indicator programs are preferred, they are sometimes unfeasible. There are three hatchery programs (Kitimat River, Kitasoo Rver, and McLoughlin Creek) currently producing coho in Areas 6, 7, and 8. With the current infrastructure to capture broodstock and rear juveniles on site, little is needed to increase capacity to estimate escapement with mark-rates compared to systems with no such infrastructure. It is recommended that a CWT program be established prior to pursuing a more intense full indicator program to ensure these stocks are sufficiently distributed throughout fisheries. Prior work has been conducted on a smaller scale since the 1990s, with stocks receiving CWTs to quantify their marine distribution (Spilsted *et al*. 2010). This led to the establishment of full indicator programs on the Central Coast in the early 2000s (e.g., West Arm Creek), though all programs have since been discontinued. Recent findings show that regional CWT indicator stocks may not always have identical spatial distribution and encounter rates in marine fisheries when compared to other nearby stocks (Beacham *et al*. 2020b). This suggests that CWT programs should not be established based on marine distribution from neighboring populations, and that marine distribution for a specific stock needs to be quantified prior to the creation of a full indicator program. In Area 8, the Koeye River program has been estimating freshwater production for coho since 2015, and recently upgraded to a floating weir to enable video counting through the late-fall migration of coho. This wild coho monitoring program, led by the Heiltsuk Nation, provides the greatest opportunity to establish a full indicator program in Area 8. Current initiatives aim to quantify Koeye River coho marine distribution. Further south, in Smith Inlet, Fisheries and Oceans

Canada are working with the Gwa'sala-'Nakwaxda'xw Nation to reestablish operation of the Docee River program (Area 10), which would prove to be a valuable asset to a future full indicator program.

Overall, support is needed to establish additional programs in data deficient regions and support ongoing programs (e.g., Zolzap Creek) important for monitoring coho stocks in both Canada and Alaska. For example, funding constraints caused the ADF&G's Ford Arm Creek program to cease operation in 2015, cancelling the only program that represented stocks on the outer coast of southeast Alaska and representing a vital component of Alaska's regional assessment program. Full commensuration of all proposed or ongoing full indicator programs are paramount to assist fishery managers in both Canada and Alaska in understanding regional trends in survival, harvest, and freshwater production.

In the Transboundary Region, there is currently one full indicator program for coho (Taku River). However, a multi-year coded wire tagging program commenced on the Stikine River in 2000 and is ongoing, involving tagging of smolts on the lower Stikine River. The assessment program for Stikine River coho currently includes a mark-recapture program using adipose fin clips; fish are also coded-wire-tagged to facilitate marine harvest estimate. Unfortunately, a reliable stock assessment program for Stikine River coho has not yet been established. This is due to a number of factors, including the extended fall run timing, challenging water and weather conditions at this time of year, and the remote nature of the watershed. Development of this program into a full indicator stock is achievable requiring development of a biological escapement goal, preseason forecasts, and annual abundance estimates to allow for more effective monitoring of Stikine River coho.

Genetic Stock Identification and Catch Monitoring

DFO has begun monitoring the harvest of coho stocks using genetic stock identification (GSI) in commercial and recreational fisheries occurring in northern British Columbia (Beacham *et al*. 2017b). The coho genetic baseline is updated annually and represents coho stocks coast-wide, thus allowing regional estimates of harvest. The resolution of harvest estimation (i.e., watershed to sub-watershed) is limited to the populations represented in the genetic baseline and the amount of genetic differentiation among populations. The initiative to augment the genetic baseline to represent all regions and sub-regions in both northern British Columbia and Southeast Alaska began in 2019 and has since transitioned into an international collaboration of data sharing to establish a comprehensive genetic baseline that meets management objectives for both Canada and Alaska. Once completed, applying GSI methods to commercial and recreational fisheries in both countries will be possible. These genetic tools will complement monitoring programs. For example, if a stock of interest is present in the genetic baseline and is genetically distinct from all other populations, then marine distribution can be determined using GSI. Understanding marine distribution is the first step in establishing full indicator programs. GSI can also complement full indicator programs augmented with hatcheries by estimating harvest of unmarked fish. Applying GSI to terminal test fisheries has aided the development of watershed-wide aggregate escapement estimates for Chinook salmon using mark-recapture techniques (Winther *et al*. 2020) and are currently under development for coho. Further, parental-based tagging (PBT) becomes a possible application of genetic-based assessment for coho once GSI is conducted across all fisheries. Key advantages of PBT are outlined in Beacham *et al* (2017a), who suggests continued support is needed to assess the effectiveness of implementing PBT across fisheries in both Canada and Alaska.

To apply genetic stock identification proportions to coho fishery catches, more reliable data are needed on catch in some fisheries in northern British Columbia. While catch is routinely and reliably estimated for commercial fisheries, and recreational catches are quantified with creel surveys in Haida Gwaii and the Prince Rupert area, recreational and FSC catches of coho are not systematically quantified for Areas 5-10. DFO's North Coast Stock Assessment Branch has supported several pilot initiatives to improve catch monitoring, including a Heiltsuk Nation-led creel survey that was piloted in 2019 and 2020. This work is ongoing and could provide quantitatively robust estimates of harvest in recreational and FSC fisheries around the Central Coast region if expanded to a regional initiative (e.g. Steel *et al*. 2021).

Beacham *et al*. (2018) demonstrated that genetic stock differentiation has been observed among baselines of other salmon species in the Stikine and Taku rivers. Sample sizes and protocols were developed by the TTC in 2007 at a Transboundary Genetic Stock Identification Workshop held at the Pacific Salmon Headquarters in Vancouver BC. (PSC TCTR, 2007). Based on results obtained from a 1995 telemetry survey (Eiler, 1995), and a preliminary/exploratory field season baseline year (2019), it appears that coho salmon spawning stocks are present in at least five or six reproductively isolated tributaries of the Taku watershed. To collect the requisite number of tissue samples per spawning stock to establish a DNA baseline for identification of spawning stocks in Canadian portion of the Taku River, 6-10 specific areas would need to be sampled. It is anticipated that 50 to 100 samples could be obtained per area each year and it would take at least three years to reach the goal of 200 per stock. This assumes that water conditions, stock abundance, run timing and spawning distribution are suitable.

Limit Reference Points

Sustainable fisheries management requires the development of escapement goals, and other benchmarks for resource managers. For example, the newly ratified Sustainable Fisheries Framework (SFF) in Canada seeks to identify three stock status zones: healthy, cautious, and critical. These zones are delineated by two levels of abundance, **(1)** an ***upper stock reference point*** and **(2)** a ***limit reference point***. Under SFF mandated management, upper stock reference points are the boundary between healthy and cautions zones, and limit reference points mark the level of abundance where a stock moves from cautious to critical.

At present no limit reference points have been developed for coho stocks or stock aggregates, and the development of goals and reference points for fishery management is a priority. Specific methodologies have yet to be developed, however Canadian Federal and First Nations governments are doing work to develop limit and upper stock reference points in other species (e.g., Skeena/Nass, Owikeno sockeye escapement goals). These processes can inform the approach taken towards developing these targets.

Indicator of Abundance

Specific stipulations in amendments to the Pacific Salmon Treaty (1999) allow potential early or midseason fishery closures that affect troll fisheries in northern British Columbia and Southeast Alaska. For example, if regional wild coho stock catch is projected to be less than 1.1 million (as determined from the historical relationship between average catch per boat day in the Alaskan troll fishery during statistical weeks 28 and 29 and the total all-gear catch in Southeast Alaska), both countries will close their respective troll fisheries for a specific period of time. When this regulation was established, commercial harvest of coho was considered the best proxy for coho abundance returning to the region. However, the behavior of the troll fishery in Southeast Alaska has changed over the past 20 years, questioning the validity of the troll fishery catch as the sole indicator of projected coho abundance. Evaluation of alternative data sources to inform in-season management of the troll fishery is recommended. Once alternative methodologies are agreed upon by both countries, the performance of these in-season indicators will be assessed using real time data.

Conclusions

Based on available data from a limited number of systems, northern British Columbia coho have shown resilience to highly variable, sometimes unacceptable harvest rates. Escapement trends suggest current overall stability in northern British Columbia stocks although there is substantial variability across years and geographical region. While there don’t appear to be negative impacts directly caused by fisheries on northern British Columbia coho stocks, data in most regions is lacking and there are no escapement goals established for the indicator programs in the Northern Boundary region. Major issues surrounding the management of coho include the reduction or complete absence of regional monitoring, unpredictable environmental conditions that directly affect marine survival and freshwater productivity, and changes in fishery dynamics. It is paramount that monitoring of northern British Columbia stocks be expanded to ensure the most informed management decisions are made to support conservation of coho populations and sustainable fisheries .

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Tables and Figures

Table 1. Harvest of coho salmon in Canadian waters from 1997-2019. Commercial is the total catch for all-gear. Recreation includes tidal and non-tidal catch. First Nation is all catch including FSC (Food, Social, and Ceremonial) and commercial directed fisheries.

Year	Commercial	Recreation	First Nation	Total
1997	219,234	NA	1,535	220,769
1998	991	NA	3,439	4,430
1999	3,380	4,200	5,350	12,930
2000	3,416	10,450	1,748	15,614
2001	15,013	90,986	32,680	138,679
2002	128,867	81,199	24,435	234,501
2003	221,967	119,387	6,692	348,046
2004	336,023	87,448	151,900	575,371
2005	422,084	81,363	27,291	530,738
2006	178,994	64,143	21,733	264,870
2007	294,411	61,452	20,829	376,692
2008	95,308	57,148	10,758	163,214
2009	256,928	80,015	32,327	369,270
2010	137,732	72,187	17,978	227,897
2011	353,482	96,173	5,699	455,354
2012	209,788	83,411	16,273	309,472
2013	374,482	106,706	28,100	509,288
2014	211,632	85,441	15,816	312,889
2015	276,821	89,882	12,732	379,435
2016	253,030	82,236	26,136	361,402
2017	353,011	93,822	8,775	455,608
2018	177,642	60,780	3,695	242,117
2019	179,551	76,202	3,943	259,696
Average	204,512	75,459	20,864	294,273

Table 2. Estimated pairwise correlation matrix for process error variance in nine regional trend groupings of northern British Columbia coho salmon populations. Estimated correlations with 95% confidence intervals that did not overlap zero are highlighted in pink.

Trend Group	Hecate Mainland Areas 5&6	Area 6 – Inner Waters	Areas 7 & 8	Areas 9 & 10	Lower Skeena & Estuary	Middle & Upper Skeena	Lower Nass & Coastal Area 3	Upper Nass
1. Hecate Mainland - Areas 5 & 6								
2. Area 6 - Inner Waters	0.178316							
3. Areas 7 & 8	0.111967	0.125984						
4. Area 9 & 10	0.149979	0.169605	0.179299					
5. Lower Skeena & Estuary	0.060476	0.141133	0.14254	0.17237				
6. Middle & Upper Skeena	0.093699	0.232574	0.143989	0.18465	0.364147			
7. Lower Nass & Coastal Area 3	0.098031	0.134957	0.098745	0.12569	0.205298	0.200684		
8. Upper Nass	0.072264	0.206184	0.068761	0.0789	0.255325	0.299208	0.16218	
9. Haida Gwaii	0.077413	0.120575	0.089879	0.1134	0.102438	0.124198	0.038966	0.09122

Table 3. Comparison of candidate models for time series analysis of coho salmon population trends. For each model we report the number of trends fit, the underlying structure of process error variance, the AIC score, and the rank of each model.

Model	N trends Process error (Q)	AIC	Rank		Model
5b	9	correlated	6484.649	1	5b
4b	10	correlated	6499.416	2	4b
2b	8	correlated	6521.05	3	2b
2a	8	independent	6571.732	4	2a
5a	9	independent	6606.223	5	5a
1	1	independent	6625.095	6	1
4a	10	independent	6625.519	7	4a
3a	14	independent	6702.789	8	3a
3b	14	correlated	did not converge	NA	3b

Table 4. Estimated escapement and total run for coho salmon full indicator programs from 1987-2019.

	Zolzap Creek		Toboggan Creek		Taku River	
	Escapement	Total Run	Escapement	Total Run	Escapement	Total Run
1987	-	-	-	-	55,457	-
1988	-	-	1401	-	39,450	-
1989	-	-	2,131	8,997	56,808	-
1990	-	-	2,751	8,835	72,196	-
1991	-	-	3,336	5,721	127,484	-
1992	-	-	1,981	2,027	83,729	212,798
1993	1,048	2,888	1,407	-	119,330	249,320
1994	2,536	9,979	2,385	2,890	96,343	339,736
1995	908	3,117	1,761	4,122	55,710	181,116
1996	1,039	3,250	1,181	798	44,635	94,283
1997	470	1,021	394	3,056	32,345	50,886
1998	967	1,840	2,467	11,318	61,382	119,925
1999	1,393	2,772	8,878	5,485	60,768	117,176
2000	456	871	3,930	8,235	64,700	109,148
2001	1,897	3,762	6,080	4,744	104,394	162,777
2002	3,233	4,049	3,980	6,992	219,360	303,275
2003	2,855	4,789	5,269	4,702	183,112	265,090
2004	1,631	3,174	2,700	6,628	129,327	251,537
2005	-	-	4,900	4,443	135,558	222,997
2006	-	-	3,100	4,965	122,384	226,694
2007	-	-	2,630	4,090	74,246	133,301
2008	-	-	2,420	9,994	95,226	174,070
2009	-	-	6,130	6,221	103,950	224,010
2010	-	-	4,200	3,991	126,830	246,822
2011	438	937	2,100	5,061	70,871	129,939
2012	976	2,166	3,050	8,480	70,775	112,947
2013	2,649	7,314	5,300	9,324	68,117	143,410
2014	2,352	3,914	7,304	4,713	124,171	189,655
2015	145	1,111	2,752	11,501	60,178	104,344
2016	731	2,297	6,640	7,326	87,704	125,323
2017	1,287	2,883	4,100	1,123	57,868	108,263
2018	430	820	649	2,436	51,173	82,675
2019	879	1,710	1,484	8,997	82,759	117,031
Average	1,349	3,079	3,464	5,943	89,041	171,377

Table 5. Total coho salmon smolt production for five wild coho salmon producing streams in northern British Columbia by sea-entry outmigration (smolt) year, 1992-2019.

Smolt Year	Deena River	Zolzap Creek	Slamgeesh River	Koeye River	Taku River
1992	-	53,000	-	-	-
1993	-	51,000	-	-	-
1994	19,831	41,000	-	-	-
1995	-	13,000	-	-	-
1996	42,040	23,000	-	-	-
1997	13,758	18,000	-	-	759,763
1998	7,720	19,000	-	-	853,662
1999	-	16,000	-	-	1,184,195
2000	60,267	34,500	-	-	1,728,240
2001	262,534	28,000	25,875	-	1,846,629
2002	116,828	15,000	23,871	-	2,718,816
2003	160,401	30,005	46,000	-	2,988,349
2004	69,965	29,793	66,494	-	2,961,344
2005	138,956	-	33,757	-	3,755,274
2006	193,006	-	-	-	2,149,673
2007	106,393	-	-	-	3,152,471
2008	94,370	-	-	-	2,073,988
2009	148,308	-	51,046	-	2,949,043
2010	110,288	35,158	60,855	-	2,270,500
2011	175,531	15,002	53,794	-	1,526,065
2012	46,500	46,663	51,837	-	1,463,444
2013	202,923	31,536	52,975	-	1,330,594
2014	422,509	26,100	59,380	-	888,434
2015	-	35,130	26,979	83,009	700,632
2016	-	34,531	61,228	36,485	1,879,107
2017	80,000	12,855	23,522	55,723	2,101,774
2018	69,056	20,743	37,416	61,604	1,618,411
2019	-	47,251	20,716	42,914	1,061,978
Average	121,009	29,403	43,484	55,947	1,911,408

Table 6. Estimated survival rates (percent) of coho salmon smolts from three full indicator programs in northern British Columbia, 1989-2019.

Return Year	Zolzap Creek	Toboggan Creek	Taku River
1989	-	2.4	-
1990	-	3.5	-
1991	-	5.3	-
1992	-	1.5	-
1993	2.1	-	-
1994	9.1	5.4	-
1995	3.6	1.5	-
1996	6.8	2.2	-
1997	2.2	0.5	6.7
1998	3.0	1.6	14
1999	7.0	10.3	9.9
2000	3.8	4.2	6.3
2001	7.6	7.8	8.8
2002	8.4	3.5	11.2
2003	11.9	5.0	8.9
2004	5.1	2.9	8.5
2005	-	3.0	5.9
2006	-	3.5	10.5
2007	-	1.8	4.2
2008	-	2.0	8.4
2009	-	9.0	7.6
2010	-	6.3	10.9
2011	0.8	4.8	8.5
2012	2.7	4.5	7.7
2013	7.2	2.6	10.7
2014	5.1	6.6	21.3
2015	1.1	2.4	14.9
2016	2.6	7.4	6.7
2017	4.1	2.8	5.1
2018	2.2	1.5	5.2
2019	4.2	1.3	11
Average	4.8	2.9	9.3

Table 7. Estimates of total all-gear harvest for three coho salmon indicator stocks, 1989-2019. All-gear includes harvest rates for all fisheries in both Canada and Alaska.

	Total Harvest Rate		
Year	Zolzap Creek	Toboggan Creek	Taku River
1989	-	62.0%	-
1990	-	69.4%	-
1991	-	62.2%	-
1992	-	65.4%	60.7%
1993	63.7%	-	52.1%
1994	74.6%	66.1%	71.6%
1995	70.9%	39.1%	69.2%
1996	68.0%	71.3%	52.7%
1997	54.0%	50.6%	36.4%
1998	47.4%	19.3%	48.8%
1999	49.7%	21.6%	48.1%
2000	47.6%	28.4%	40.7%
2001	49.6%	26.2%	35.9%
2002	20.2%	16.1%	27.7%
2003	40.4%	24.6%	30.9%
2004	48.6%	42.6%	48.6%
2005	-	26.1%	39.2%
2006	-	30.2%	46.0%
2007	-	47.0%	44.3%
2008	-	40.8%	45.3%
2009	-	38.7%	53.6%
2010	-	32.5%	48.6%
2011	53.3%	47.4%	45.5%
2012	54.9%	39.7%	37.3%
2013	63.8%	37.5%	52.5%
2014	39.9%	21.7%	34.5%
2015	86.9%	41.6%	42.3%
2016	68.2%	42.3%	30.0%
2017	55.4%	44.0%	46.5%
2018	47.6%	42.2%	38.1%
2019	48.6%	39.1%	29.3%
Average	54.9%	40.8%	44.9%

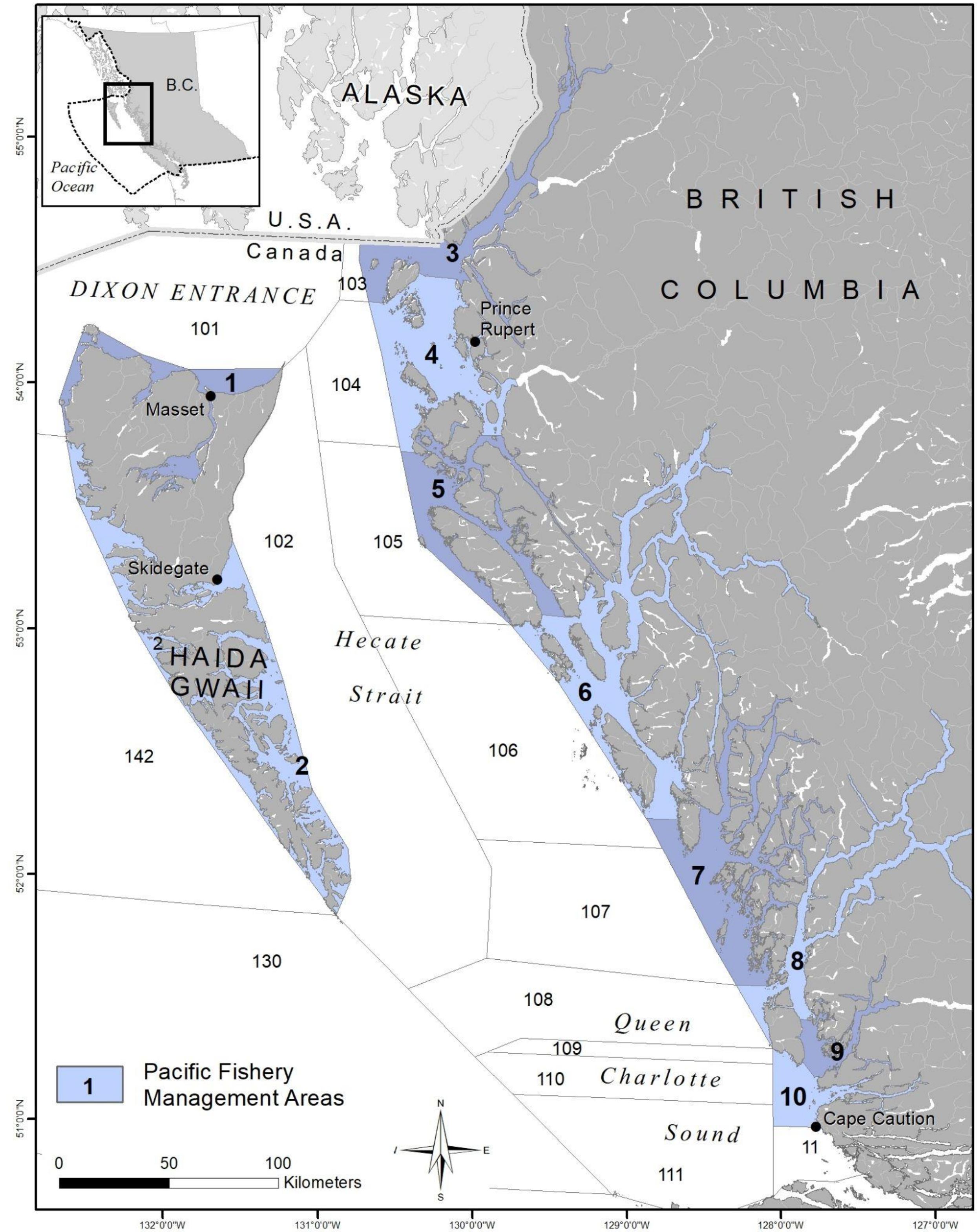

Figure 1. Locator map of the Northern Boundary Pacific Fisheries Management Areas from Cape Caution north to Dixon Entrance, British Columbia.

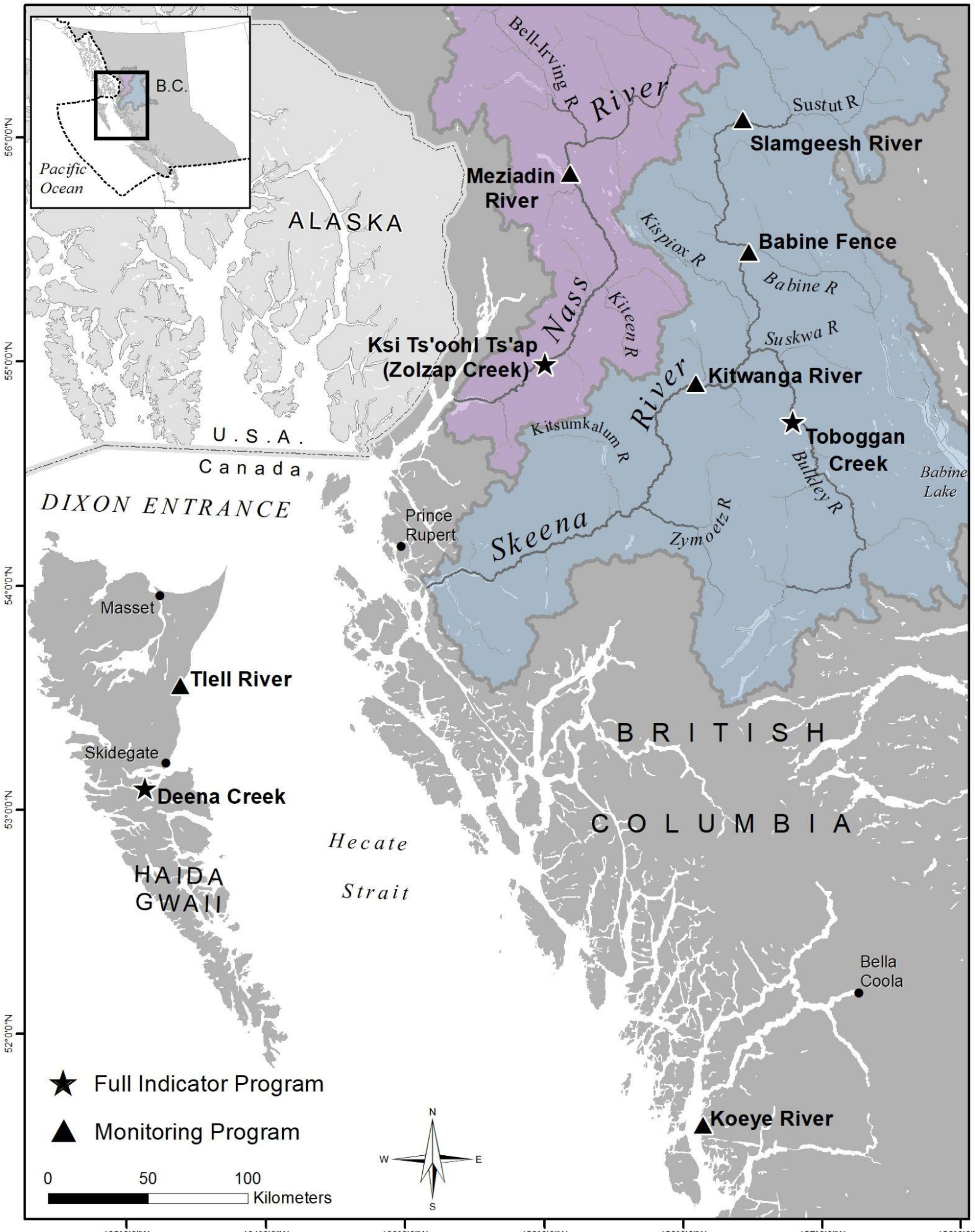

Figure 2. Locator map of Northern Boundary region in-stream coho monitoring programs showing full indicator programs (stars) and monitoring programs (triangles).

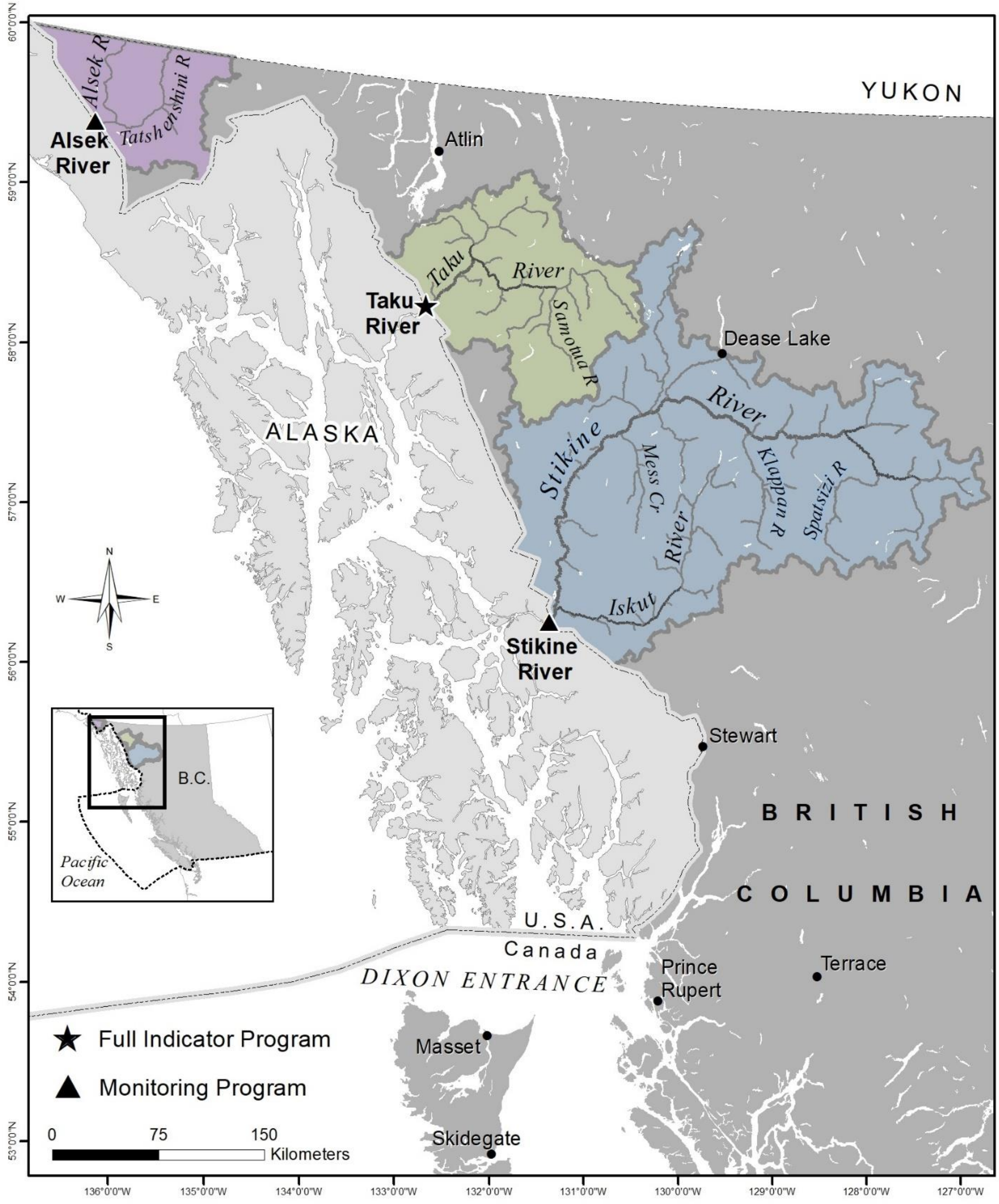

Figure 3. Locator map of Transboundary region Pacific Fisheries Management Area. In-stream coho monitoring programs showing full indicator programs (stars) and monitoring programs (triangles) are indicated on the map.

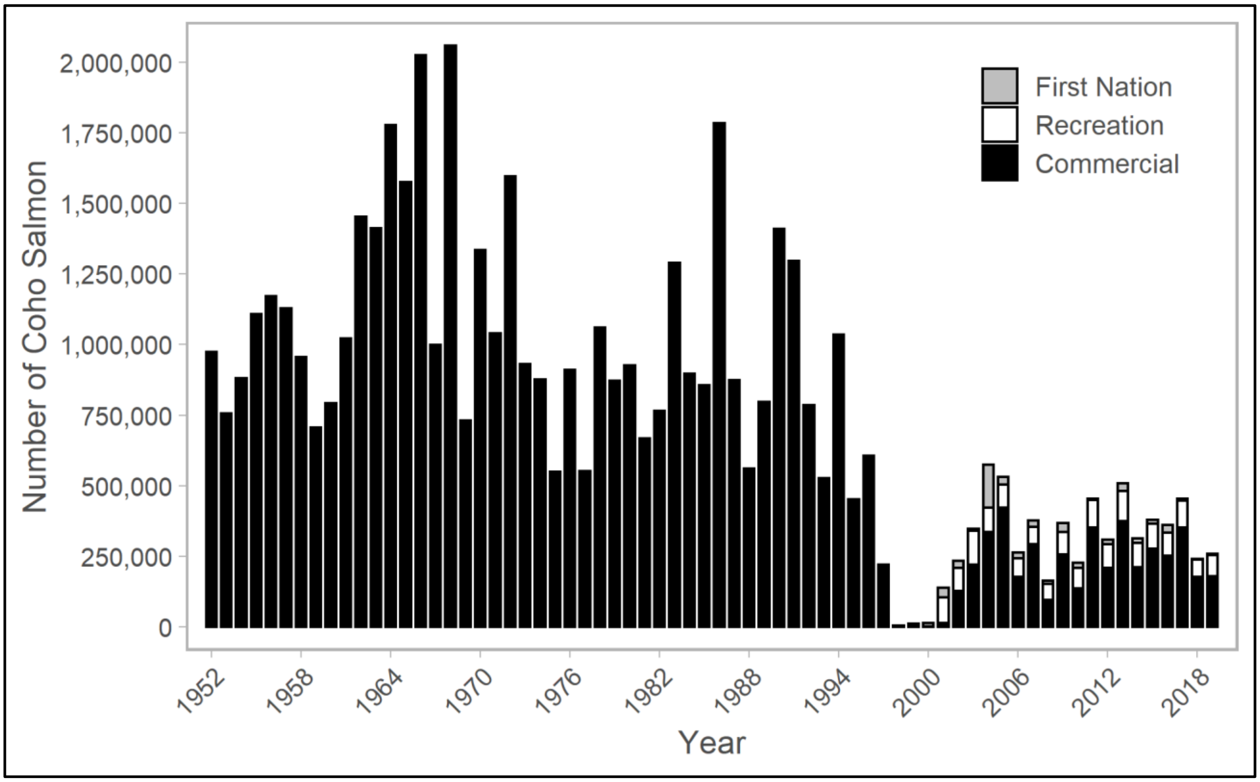

Figure 4. Harvest of coho salmon in the Northern Boundary region, 1952-2019.

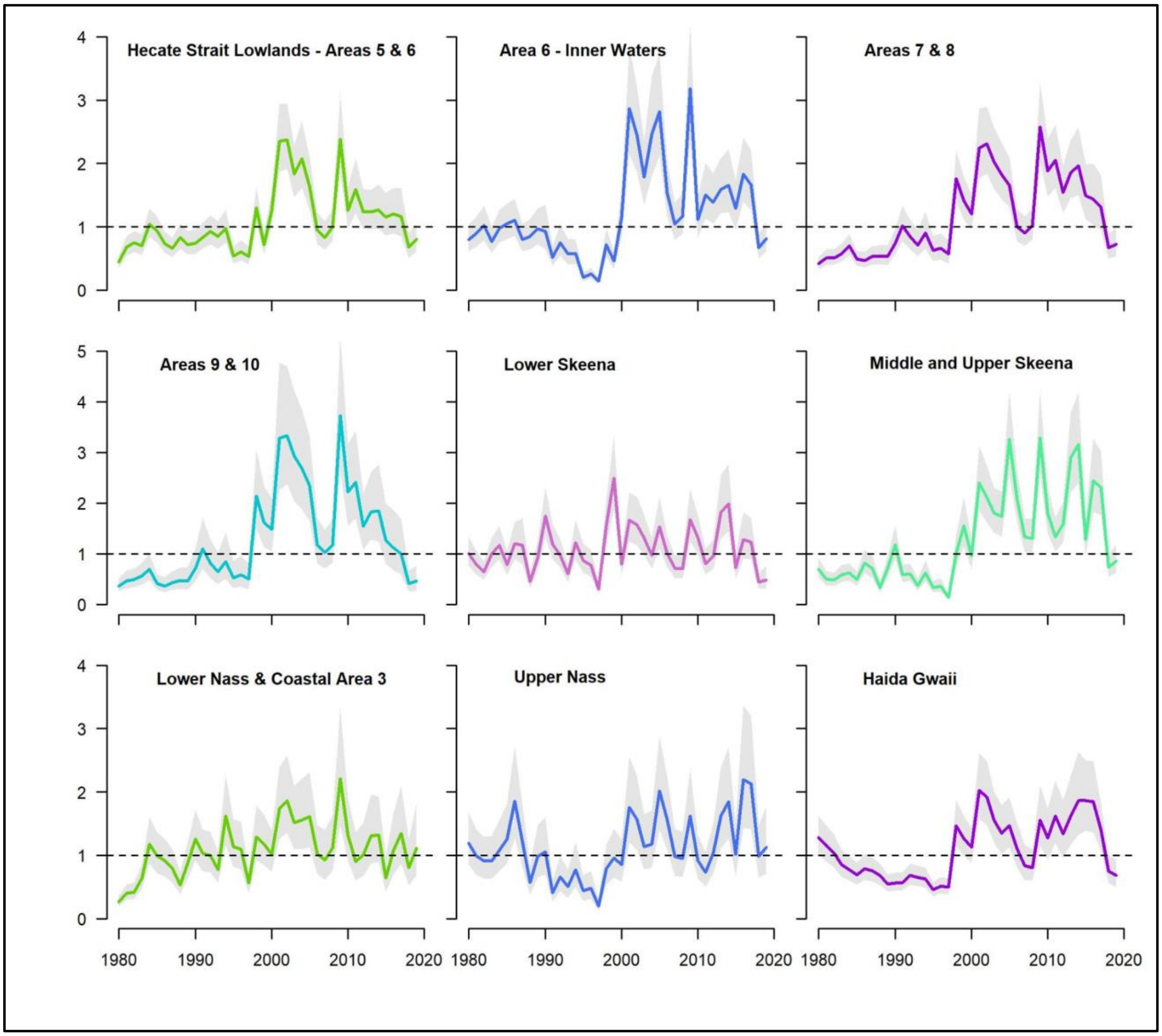

Figure 5. Trends in the natural log of escapement across a 40 year time-series for nine groups of coho salmon populations encompassing Pacific Fisheries Management Areas 1-10. Dashed lines represent the mean escapement for the respective area. Gray shaded areas are the credible intervals.

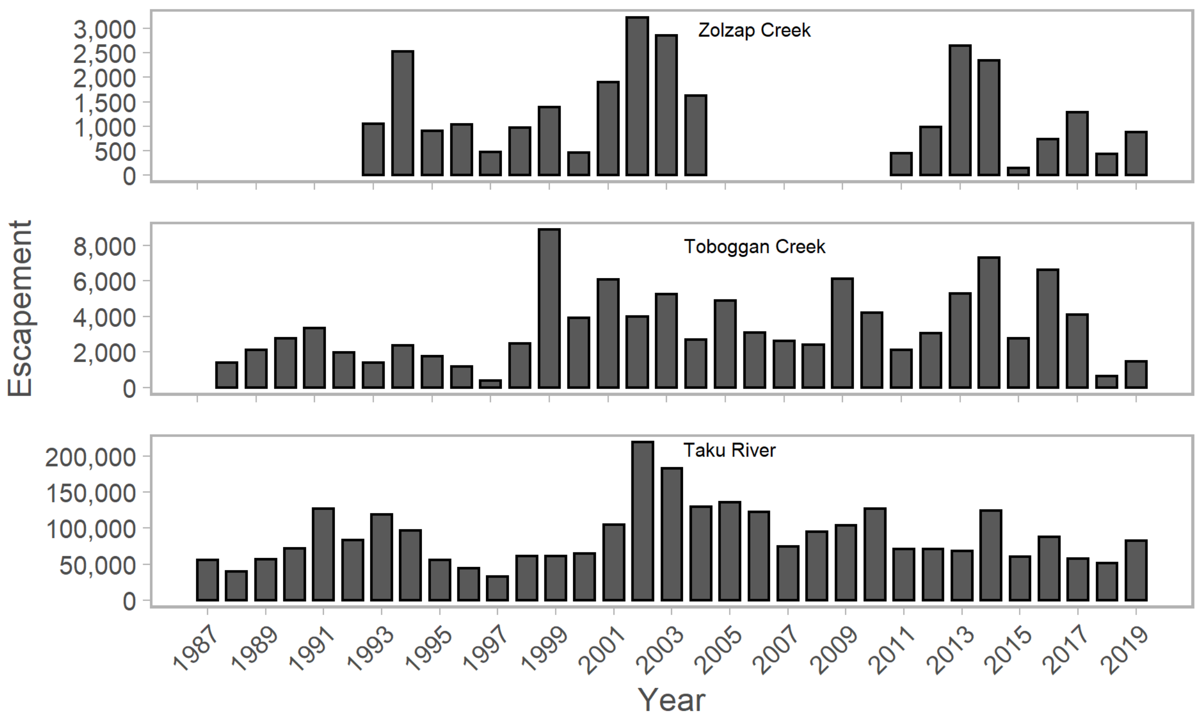

Figure 6. Coho salmon escapement estimates for three full indicators systems in northern British Columbia, 1987-2019.

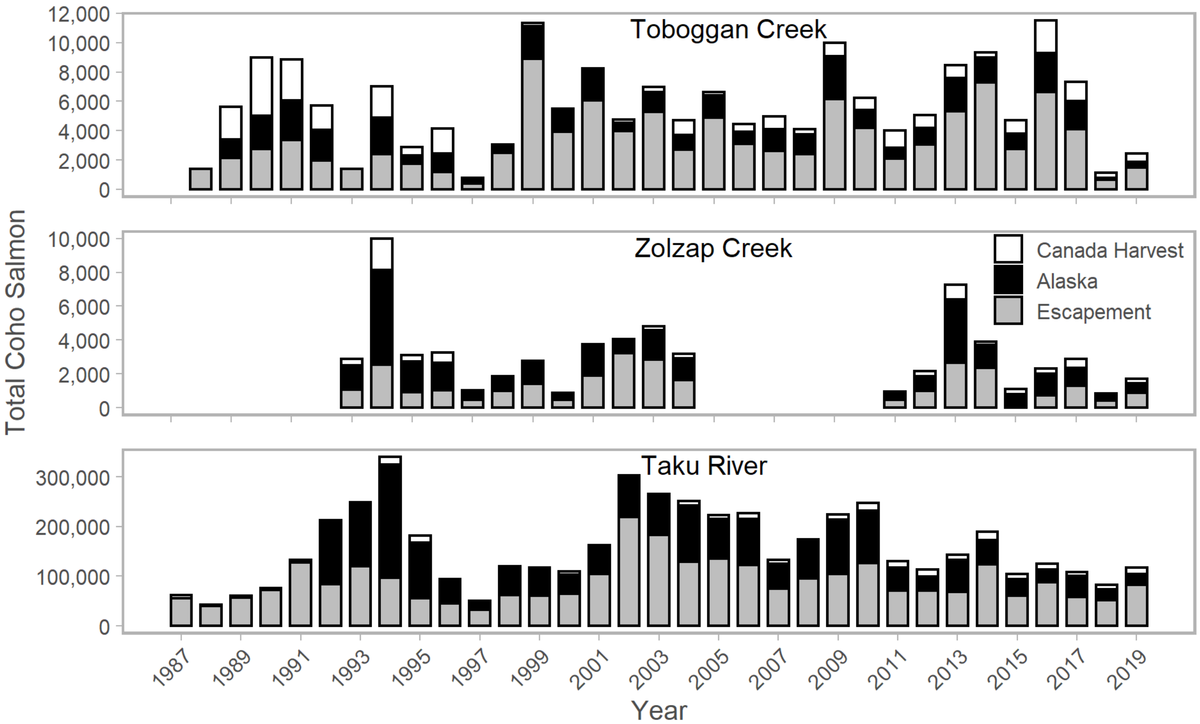

Figure 7. Total estimated run size, harvest, and escapement for three full indicator programs in northern British Columbia, 1987-2019. For Toboggan Creek 1993, only escapement is reported. Alaskan harvest for Taku River was not reported until 1992.

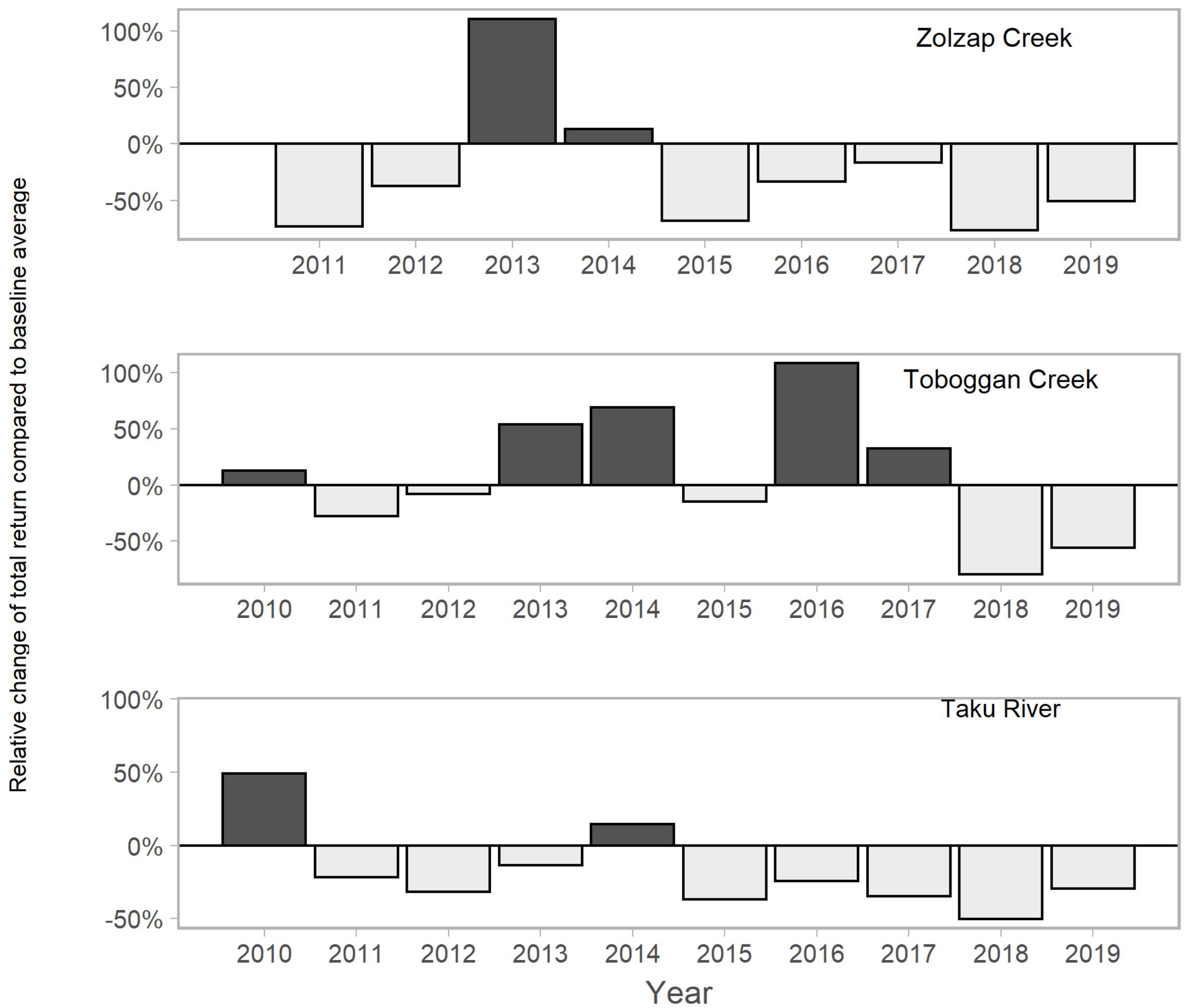

Figure 8. Annual percent deviation of years 2011-2019 for Zolzap Creek and years 2010-2019 for Toboggan Creek and Taku River coho salmon total run (escapement and harvest) relative to the program's average.

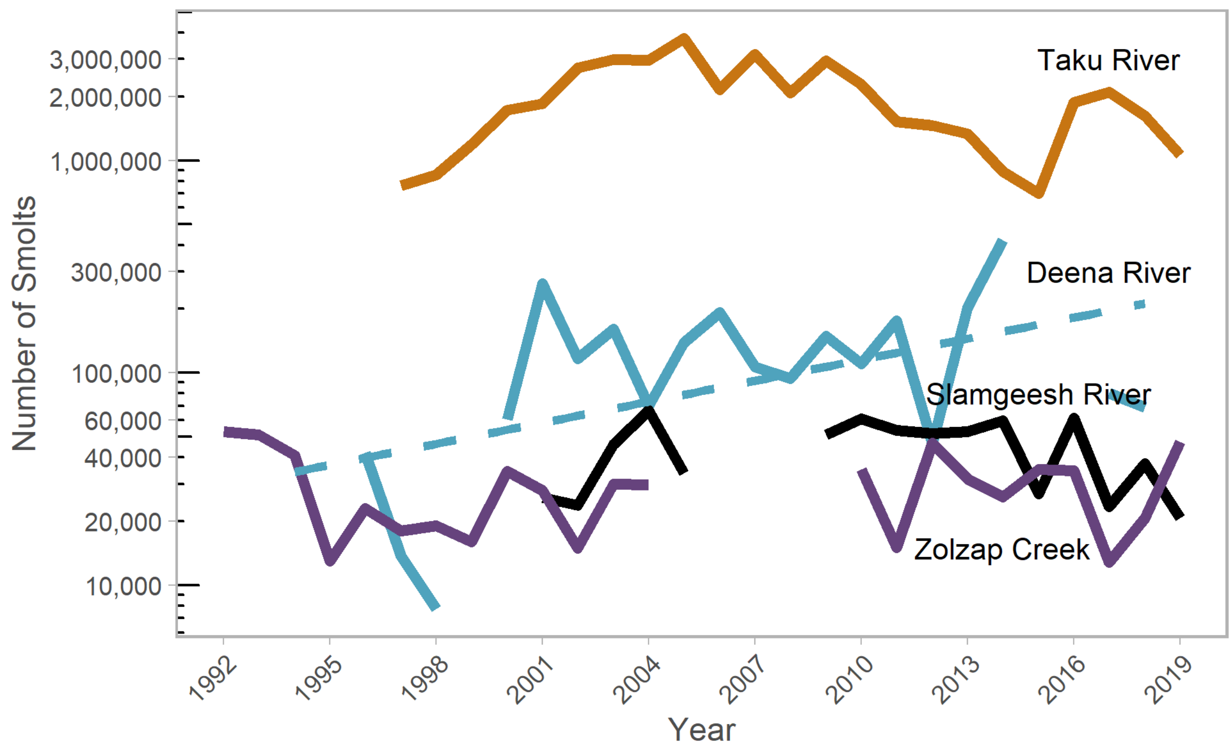

Figure 9. Annual coho salmon smolt abundance estimates for four wild populations in northern British Columbia, 1992-2019. Dashed line indicates a significant linear trend in annual abundance for the Deena River ($p \leq 0.05$).

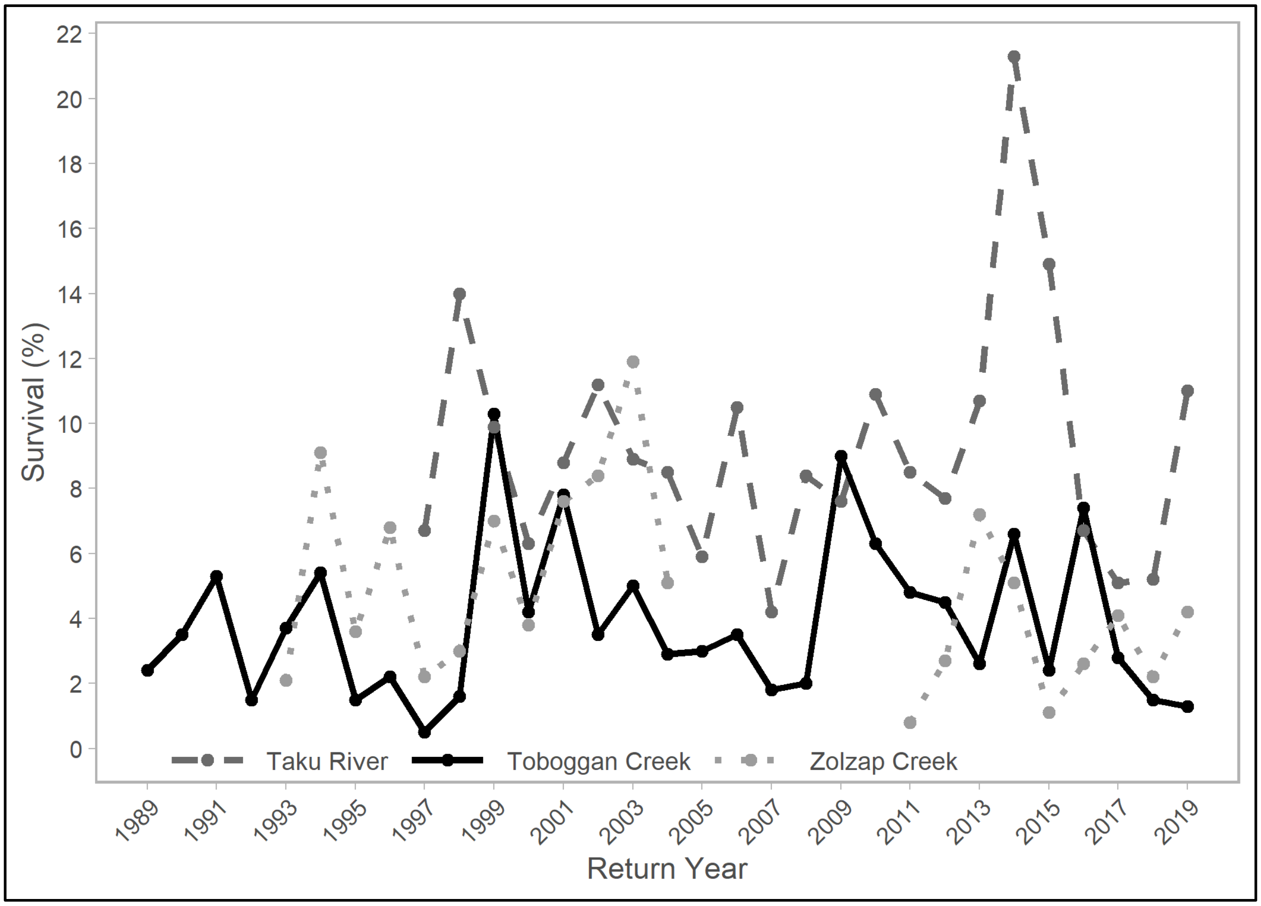

Figure 10. Estimated marine (smolt to adult) survival rates of coho salmon from three systems in northern British Columbia, 1989-2019.

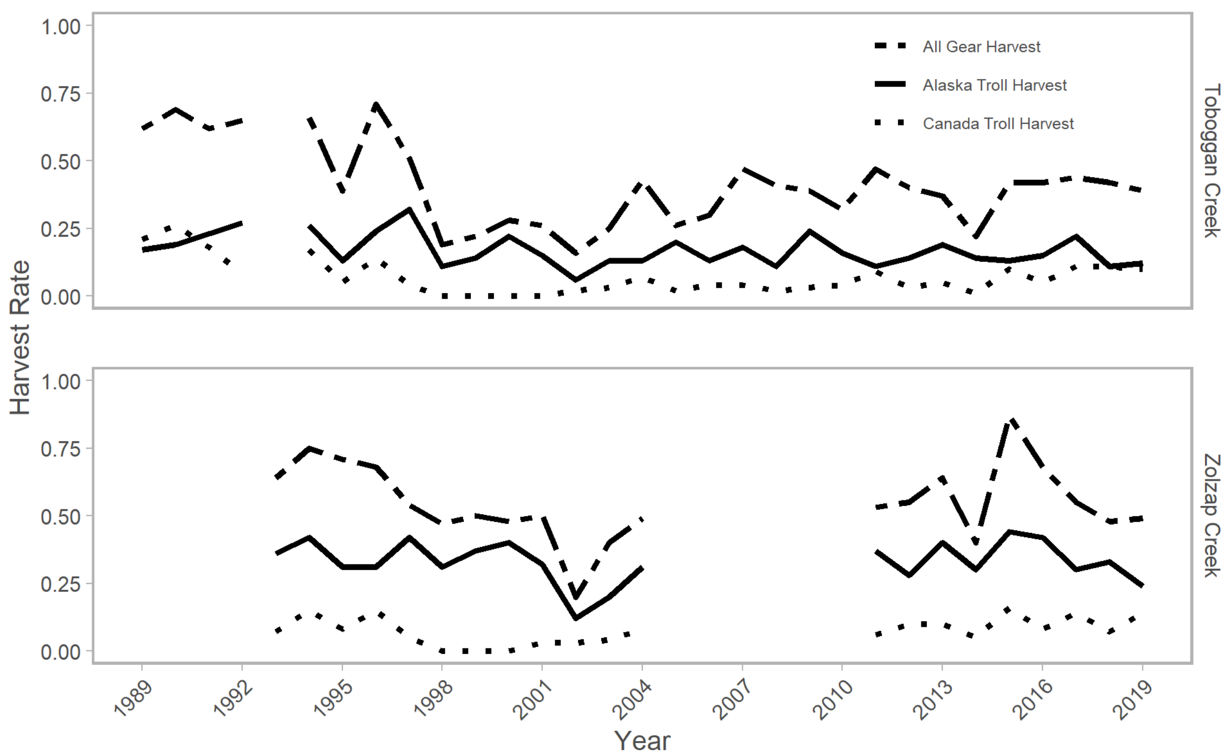

Figure 11. Estimated harvest rates by all gear types, Alaska troll, and Canadian troll fisheries for two coded wire tagged northern British Columbia coho salmon populations, 1989-2019.

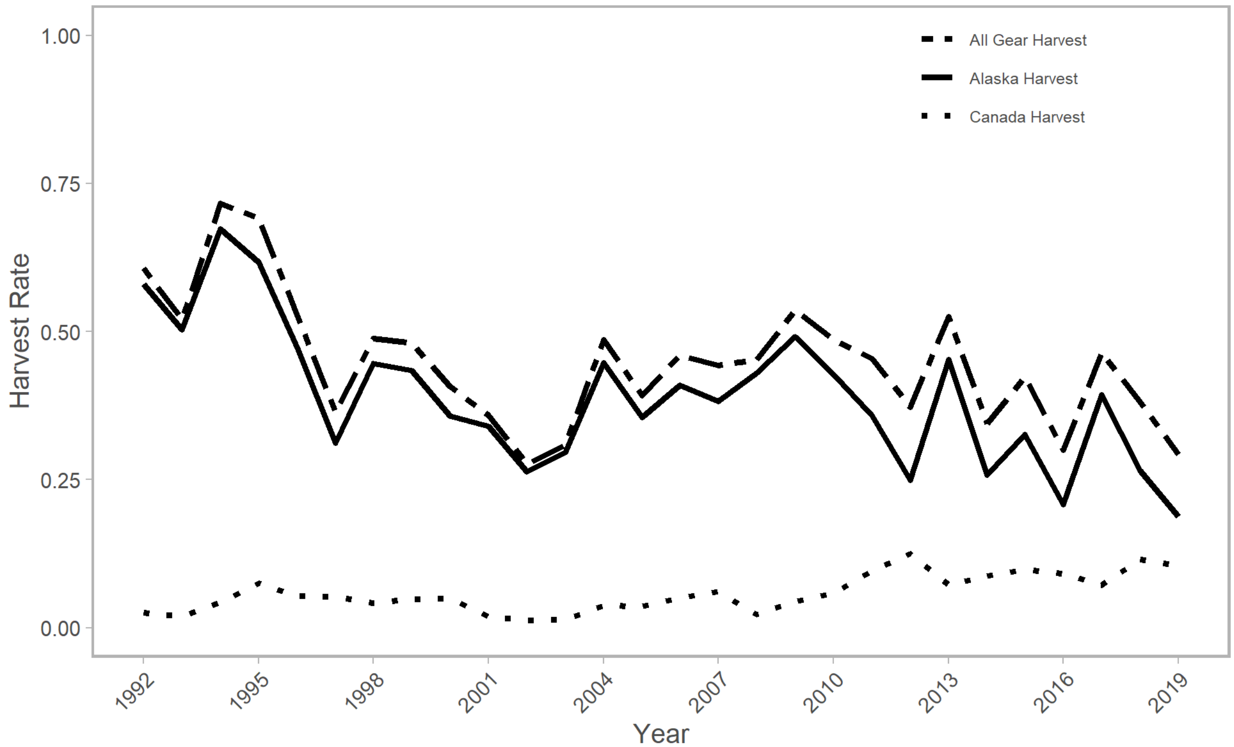

Figure 12. Estimated harvest rates by all gear types, Alaska, and Canadian fisheries for the Taku River, 1992-2019.

Appendix A:

MARSS modeling to evaluate status and trends in coho populations

Appendix A: Multivariate Autoregressive State-space modeling to evaluate status and trends background, methods, and results**.**

To evaluate status and trends across northern British Columbia coho populations in Areas 1-10, we developed a set of multivariate autoregressive state-space models implemented in the package MARSS (Holmes *et al*. 2021).

The MARSS model takes the form:

$$x_t = B_t x_{t-1} + u_t + w_t, where\ w_t \sim MVN(0, Q_t)$$

$$y_t = Z_t x_t + a_t + v_t, where\ v_t \sim MVN(0, R_t)$$

Where the x equation is the state process, which is an unobserved quantity, in this case the true escapement. The autoregressive process in the model comes from the relationship between x_t and x_{t-1} which is estimated as variable B_t. The y equation is the observation process, with data (y) at time t. Each x_t is the realization of the state process at time t with a slope parameter u_t representing the overall trend in the timeseries, and the Z matrix relating the state process to the observations and a_t is a time and population specific intercept. Process errors w_t are drawn from a multivariate normal distribution with a mean zero and a process error variance of Q_t. Likewise observation errors are estimated as a multivariate normal distribution with a mean of zero and an observation error variance of R_t.

Process error and observation error variances are introduced into the model as an n x n matrix where n is the number of trends being estimated, with the diagonals representing the variance for a given trend, and the off diagonals representing the correlation matrix between the process error variances of each trend. Observation error is estimated as a similar matrix with i x i dimensions representing the observation error for each individual population (i). Because of challenges with parameter identifiability, it is recommended that analysts estimate correlation matrices for either the process error or observation error variance terms. In our case, we were most interested in quantifying the correlations between process error variance, and observation errors were estimated as independent variables for each population.

MARSS model outputs include estimates of the true state (x) of each time series trend being estimated in the model, the long-term change in the state-process (u), an estimate of observation error for each population, and an estimate of process error variance and correlations between each trend. In cases where multiple observations (time series) of the same underlying trend are estimated, the model outputs also include estimates of a_t which can be interpreted as the population-specific intercept for an individual time series on the trend. MARSS models can also deal with missing data, which is fed into the model as NAs, and infills data for trends when data is missing by leveraging the autoregressive component, and estimated correlations in process error variance.

Methods

We developed, fit, and evaluated a set of MARSS models to time series of escapement for 99 coho salmon populations, from Area 10 in the south, north to Area 2, and analyzed escapement trends since 1980. The most recent 40 years of data were deemed most relevant to this analysis.

Population time series were included if they were a.) continuous, b.) had more than 15 years of escapement across the 40 year period of interest, and/or c.) they had 10 or more years of count data since 2000. Populations were grouped by their conservation unit (CU) and their pacific fisheries management area (Areas for short). The Areas with the fewest time series was Area 10, where only the Docee fence data is available for analyzing escapement trends, and Area 7, where data from Quartcha and Roscoe Rivers are available.

To understand shared trends in coho salmon populations across northern British Columbia, we evaluated 11 candidate models with different assumed relationships between the individual population time series and the overall trends, as well as the assumption of correlations in the process error variance. These models were: 1.) All populations share a single trend and have the same process error variance. 2a.) Populations within the same Area share a trend, for a total of 8 trends since Areas 9 and 10 were grouped due to their close geographic proximity and limited data, and process errors for each trend are independent and uncorrelated. 2b.) 8 total trends organized by Area, with correlated process errors. 3a.) Each CU has its own trend for a total of 14 trends with independent process errors, 3b.) 14 total trends organized by CU, with correlated process errors.

For model configurations 4a and 4b we fit a total of 10 trends for populations by CU and Area for the following groups: i.) Hecate Strait Mainlands CU in Areas 5/6, ii.) Northern Coastal, Brim Wahoo, Douglas Channel Kitimat, and Mussel Kynoch CUs grouped for Area 6, iii.) Northern Coastal and Bella Coola Dean CUs grouped in Areas 7/8, iv.) Rivers and Smith Inlet CU, v.) Lower Skeena and Skeena estuary in Area 4, vi.) Middle Skeena and Upper Skeena in Area 4, vii.) Lower Nass, Portland Canal and Inlet, Observatory Inlet, and Work Channel in Area 3, viii.) Upper Nass in Area 3, ix.) Western Haida Gwaii in Area 2, and x.) Eastern Haida Gwaii in Area 2. Like the previous models, process errors were independent in model 4a, and process errors in model 4b were correlated. For model configurations 5a and 5b we fit a total of 9 trends, with identical configuration to model 4a and b, except that Western Haida Gwaii was grouped with Eastern Haida Gwaii, since model convergence was challenged when Western Haida Gwaii data were modeled as an independent trend.

The degree of support for each of the 11 aforementioned model structures was evaluated post-hoc using AIC. Trends estimated from the model with the highest support were visualized and analyzed across the 40-year period from 1980 to 2019.

Models were implemented in the R-package MARSS, and run for up to 30,000 iterations to ensure convergence of the likelihood and associated parameter estimates. Observation error variances were assumed to be independent and uncorrelated to improve the ability of the model to estimate process error variance values and associated correlations in models with correlated process errors. Notably, model 3b which included 14 unique trends and correlated process error variance failed to converge due to the large number of parameters, and the difficulty of estimating trends for more data-limited conservation units.

Results

Overall, the model with the highest support - indicated by lower AIC values - was model 5b, which estimated 9 trends across northern British Columbia coho populations, and included correlated process errors for each of the trends. This model received considerably higher support than the model with the next lowest AIC score (model 4b - which estimated separate trends for East and West Haida Gwaii). Across all models that converged, those with correlated process errors received higher support than those with independent process errors, despite the fact that the correlation matrix increased the number of parameters being estimated (Table 3). Therefore there was strong evidence across the models we evaluated for correlated process errors among northern British Columbia coho populations.

Across the 9 trends selected as our top model, most pairwise comparisons revealed evidence of correlated process errors. Indeed, only 6 of the 36 pairwise combinations had estimated correlations that overlapped zero, indicating less evidence for correlated population trends. Across the 36 estimated pairwise correlations, the average correlation was 0.145, with Middle and Upper Skeena having the highest correlations with other regional population groups (mean = 0.21) and Haida Gwaii having lowest correlation in process errors with other regional groups (mean = 0.095). In general, the strength of correlations was related to geographic proximity and likely reflects similarities in habitat and climate conditions across trend groups (Table 2). For example, the highest estimated pairwise correlations were between the Lower Skeena & Estuary and Middle & Upper Skeena (0.36), Middle & Upper Skeena and Upper Nass (0.30), Lower Skeena & Estuary and Upper Nass (0.26), Middle & Upper Skeena and Area 6 - Inner Waters (0.23), and the Lower Skeena & Estuary and Lower Nass groups (0.21).

Appendix B:

Methods for time-stratified mark-recapture estimates of smolt abundance

Appendix B: Methods for time stratified mark-recapture estimates of smolt abundance.

Mark-recapture experiments involve the use of identifiable marks on individual organisms and the recapture of marked individuals during subsequent capture events. These recapture data are used to estimate capture efficiency and expand the number of individuals captured to an estimate of total population size. The most simple mark-recapture model is a Lincoln-Petersen estimator (Eq.1) where the total population size (N) is a function of the total number of fish captured (K) in the second sampling period, the number of individuals marked during the first sampling period (m) and the number of marked recaptures (n).

$$\text{(Eq.1) } N = Km/n$$

However, the Lincoln-Petersen equation will produce a biased estimate of total abundance and uncertainty unless a number of assumptions are met, including a fully mixed population of marked and unmarked individuals, all with an equal probability of recapture. This assumption is often violated, particularly in smolt trapping projects where the probability of capture is typically temporally variable in response to changes in water level or temperature. Accordingly, time-stratified mark-recapture models are frequently used to account for temporal changes in capture probability. One common software package used to estimate abundance for time-stratified mark-recapture experiments is BTSPAS (Bonner and Schwarz 2021) implemented in the statistical software R (R-core development team 2021). BTSPAS estimates capture efficiencies across sampling strata, drawing these capture efficiency estimates from a hierarchical distribution to inform estimates during weeks with limited data, and then smooths abundance across strata using Bayesian splines.

For our analysis, we divided smolts into weekly strata starting with the first day following the release of a group of marked smolts. Across each season, smolts were marked with a unique fin clip (e.g. top of caudal, ventral, etc) so that recaptures could be assigned to their weekly release group. Total captures were compiled for each week and recapture numbers were summarized in a matrix of recapture data with the diagonal representing the number of fish recaptured in the same strata as their release. Since some coho smolts were captured after the week of their release, we used *TimeStratPetersenNonDiagError_fit()* call in BTSPAS to fit a time-stratified Lincoln-Petersen estimate with non-diagonal recaptures. This model uses a log normal distribution to estimate the downstream movement of marked fish past the trap for mark-recapture estimates.

We ran three parallel chains for 30,000 iterations with a burn in of 20,000 and thinning rate of 5 to produce posterior estimates of mark-recapture model parameters. Model convergence was evaluated using traceplots, and individual parameter estimates were evaluated for convergence using Gelman and Rubin's scale reduction factor $\hat{R}$ at a threshold of 1.05.

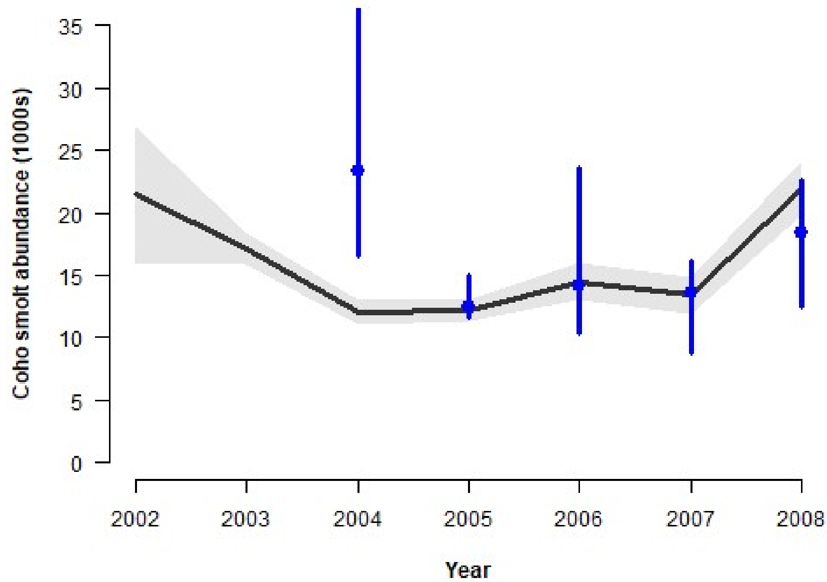

Figure B1: Estimated smolt abundance for West Arm Creek from 2002 to 2008. The gray line and shaded area indicates the basic Lincoln-Petersen estimate and it's 95% CI, while the blue points and lines represent the median estimate and 95% CIs for a time-stratified Petersen estimate implemented in BTSPAS.

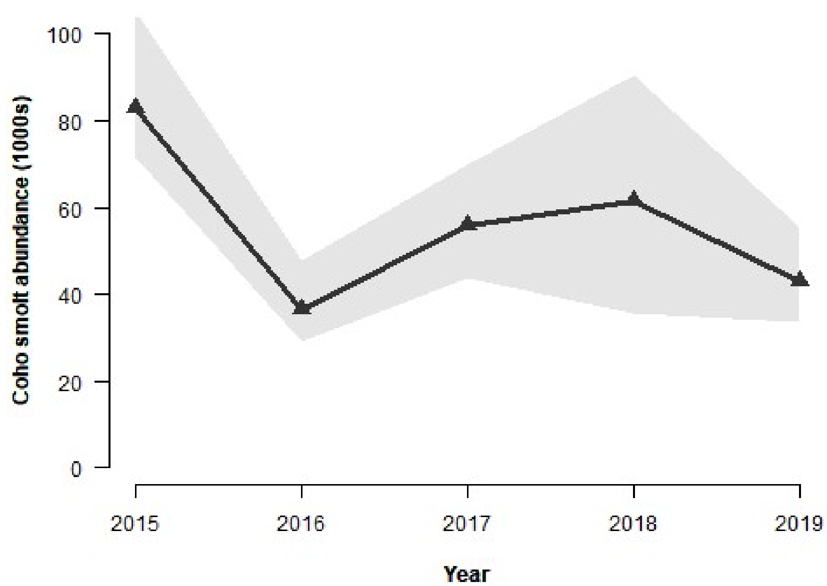

Figure B2: Estimated number of coho smolts migrating past the RST in the lower Koeye River from 2015 to 2019. Triangles indicate the median estimate and the gray shaded area is the 95% CI.

Appendix C:

Northern British Columbia Indicator Program Harvest Rates

Appendix C1: Estimated harvest (by gear type) and escapement as a percent of the total Zolzap Creek coho salmon run, 1993-2019. The dash (-) denotes insufficient data or years the program was not operating.

		Number of Fish										
		Alaska					**British Columbia**					
Year	**Fishery Sample Size**	**Troll**	**Seine**	**Drift Gillnet**	**Sport**	**Other Net**	**Troll**	**Net**	**Sport**	**Total Harvest**	**Escapement**	**Total Run**
1993	154	56.1	7.2	11.9	2.8	1.3	10.5	10.1	-	63.7	36.3	100.0
1994	431	56.5	15.3	1.7	1.4	0.3	19.6	5.2	-	74.6	25.4	100.0
1995	215	44.3	22.5	8.3	5.3	1.2	11.9	6.5	-	70.9	29.1	100.0
1996	142	45.5	11.2	3.1	12.4	0.0	21.4	6.4	-	68.0	32.0	100.0
1997	89	78.5	3.3	7.6	0.0	0.9	9.7	0.0	-	54.0	46.0	100.0
1998	68	66.1	21.2	10.2	2.6	0.0	0.0	0.0	-	47.4	52.6	100.0
1999	166	73.8	7.2	11.5	6.6	0.3	0.0	0.6	-	49.7	50.3	100.0
2000	106	83.9	5.4	0.6	10.1	0.0	0.0	0.0	-	47.6	52.4	100.0
2001	360	63.9	15.1	9.2	4.0	1.5	6.1	0.2	-	49.6	50.4	100.0
2002	114	57.1	16.3	8.8	3.2	0.0	14.0	0.5	-	20.2	79.8	100.0
2003	146	49.5	22.2	10.8	6.4	0.0	9.8	1.3	-	40.4	59.6	100.0
2004	160	62.8	6.3	4.4	8.9	0.0	16.8	0.8	-	48.6	51.4	100.0
2005	-	-	-	-	-	-	-	-	-	-	-	-
2006	-	-	-	-	-	-	-	-	-	-	-	-
2007	-	-	-	-	-	-	-	-	-	-	-	-
2008	-	-	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-	-	-	-	-	-
2011	56	68.9	4.5	7.0	7.1	0.0	10.9	0.0	1.7	53.3	46.7	100.0
2012	74	51.7	14.5	7.3	0.0	1.1	18.3	0.0	7.1	54.9	45.1	100.0
2013	569	63.3	8.3	6.8	2.3	0.6	15.0	0.7	3.0	63.8	36.2	100.0
2014	154	74.1	7.2	3.4	1.4	0.0	11.8	0.0	2.0	39.9	60.1	100.0
2015	77	50.1	8.7	5.7	2.3	0.0	18.1	4.9	10.1	86.9	13.1	100.0
2016	166	61.2	8.9	8.0	3.0	0.0	11.7	2.8	4.4	68.2	31.8	100.0
2017	207	54.1	4.2	2.1	6.1	0.4	25.8	1.2	6.2	55.4	44.6	100.0
2018	31	68.4	9.7	0.0	3.6	0.0	15.3	0.0	3.0	47.6	52.4	100.0
2019	121	49.6	11.5	3.5	0.9	0.0	28.1	0.0	6.4	48.6	51.4	100.0
Average	172	60.9	11.0	6.3	4.3	0.4	13.1	2.0	4.9	54.9	45.1	100.0

Appendix C2: Estimated harvest (by gear type) and escapement as a percent of total Toboggan Creek coho salmon run, 1989-2019. The dash (-) denotes insufficient data.

		Percent of Total Run												
		Alaska					British Columbia							
Year	**Fishery Sample Size**	**Troll**	**Seine**	**Drift Gillnet**	**Sport**	**Other Net**	**Troll**	**Net**	**Sport**	**First Nations**	**Tyee Test Fishery**	**Total Harvest**	**Escapement**	**Total Run**
1989	153	27.1	5.8	3.1	0.0	0.0	33.4	29.8	0.8	-	-	62.0	38.0	100.0
1990	240	26.9	7.1	1.0	1.3	0.0	37.4	25.6	0.7	-	-	69.4	30.6	100.0
1991	408	37.2	9.2	2.0	1.0	0.3	29.4	19.8	1.2	-	-	62.2	37.8	100.0
1992	110	41.6	10.6	3.0	0.0	0.0	12.5	30.8	1.5	-	-	65.4	34.6	100.0
1993	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1994	421	39.8	13.1	0.5	0.0	0.0	26.4	11.2	3.0	5.9	-	66.1	33.9	100.0
1995	122	33.2	14.1	1.7	0.0	0.0	12.3	27.9	5.1	5.7	-	39.1	60.9	100.0
1996	247	34.2	8.9	0.0	0.0	0.0	19.7	30.4	2.8	3.9	-	71.3	28.7	100.0
1997	39	73.1	8.6	3.5	0.0	0.0	9.1	0.0	4.3	1.5	-	47.0	53.0	100.0
1998	36	59.3	22.6	9.2	0.0	3.4	0.0	0.0	3.7	1.8	-	19.0	81.0	100.0
1999	266	65.2	14.3	7.6	6.5	0.0	0.0	0.1	3.3	3.1	-	21.4	78.6	100.0
2000	256	77.2	14.7	2.4	4.7	0.0	0.0	0.0	0.0	1.0	-	28.4	71.6	100.0
2001	467	57.2	24.5	1.6	8.4	0.0	0.9	0.4	0.0	7.1	-	26.2	73.8	100.0
2002	355	36.0	15.4	12.0	8.8	0.0	11.0	0.0	7.2	9.7	-	16.1	83.9	100.0
2003	202	51.3	13.4	7.5	7.2	0.0	13.5	6.2	0.0	0.9	-	24.6	75.4	100.0
2004	87	31.6	5.9	2.2	10.4	0.0	15.7	8.9	23.5	1.7	-	42.6	57.4	100.0
2005	78	76.9	3.1	2.7	5.2	0.0	6.6	0.0	1.1	4.4	-	26.1	73.9	100.0
2006	76	42.9	3.3	1.8	12.3	0.0	13.3	1.0	15.7	9.6	-	30.2	69.8	100.0
2007	73	37.7	12.6	2.5	9.6	0.0	8.3	13.7	12.4	3.1	-	47.0	53.0	100.0
2008	53	26.9	7.7	17.0	29.0	0.0	4.3	0.0	13.4	1.8	-	40.8	59.2	100.0
2009	295	62.1	8.8	2.8	2.9	0.0	6.6	0.4	11.6	4.8	-	38.7	61.3	100.0
2010	184	48.8	6.1	4.1	1.3	0.0	12.6	0.2	12.6	14.3	-	32.5	67.5	100.0
2011	238	23.3	7.8	4.2	2.9	0.0	19.7	9.1	30.2	2.6	-	47.4	52.6	100.0
2012	132	36.4	14.7	3.2	1.6	0.0	7.2	0.0	30.8	6.1	-	39.7	60.3	100.0
2013	106	51.2	12.1	3.0	5.2	0.5	12.9	0.7	2.7	11.8	-	37.5	62.5	100.0
2014	137	66.9	13.4	0.9	1.8	0.0	5.5	0.8	3.4	7.4	-	21.7	78.3	100.0
2015	112	30.9	18.8	1.5	1.3	0.0	23.2	3.6	14.3	6.5	-	41.6	58.4	100.0
2016	279	36.4	11.0	3.8	3.0	0.0	11.3	12.4	14.6	7.0	0.4	42.3	57.7	100.0
2017	123	49.0	1.4	1.6	7.0	0.8	26.0	1.0	6.3	6.6	0.2	44.0	56.0	100.0
2018	51	25.0	5.5	1.3	0.0	0.0	27.0	2.2	13.1	25.9	0.0	42.2	57.8	100.0
2019	48	30.8	5.7	3.9	0.0	0.0	26.7	0.0	24.5	6.9	1.5	39.1	60.9	100.0
Average	180	44.5	10.7	3.7	4.4	0.2	14.4	7.9	8.8	6.2	0.5	41.1	58.9	100.0

Appendix C3: Estimated harvest and escapement as a percent of total Taku River coho salmon run, 1992-2019.

Year	Percent of total run					
	Canadian Harvest	**US Harvest**	**US Troll**	**Total Harvest**	**Escapement**	**Total Run**
1992	2.6	35.1	22.9	60.7	39.3	100.0
1993	1.9	14.3	36.0	52.1	47.9	100.0
1994	4.3	29.8	37.5	71.6	28.4	100.0
1995	7.6	32.7	28.9	69.2	30.8	100.0
1996	5.4	18.1	29.2	52.7	47.3	100.0
1997	5.3	12.7	18.4	36.4	63.6	100.0
1998	4.2	14.2	30.4	48.8	51.2	100.0
1999	4.8	7.7	35.7	48.1	51.9	100.0
2000	5.0	10.6	25.2	40.7	59.3	100.0
2001	1.9	7.2	26.8	35.9	64.1	100.0
2002	1.3	11.0	15.5	27.7	72.3	100.0
2003	1.4	9.5	20.1	30.9	69.1	100.0
2004	3.8	10.3	34.4	48.6	51.4	100.0
2005	3.7	9.7	25.8	39.2	60.8	100.0
2006	5.1	16.0	24.9	46.0	54.0	100.0
2007	6.1	12.5	25.8	44.3	55.7	100.0
2008	2.3	14.0	29.0	45.3	54.7	100.0
2009	4.4	19.2	30.1	53.6	46.4	100.0
2010	5.8	22.4	20.4	48.6	51.4	100.0
2011	9.6	7.2	28.6	45.5	54.5	100.0
2012	12.5	10.2	14.6	37.3	62.7	100.0
2013	7.2	17.6	27.6	52.5	47.5	100.0
2014	8.7	16.4	9.4	34.5	65.5	100.0
2015	9.8	9.2	23.4	42.3	57.7	100.0
2016	9.2	11.1	9.7	30.0	70.0	100.0
2017	7.2	12.5	26.9	46.5	53.5	100.0
2018	11.5	15.3	11.3	38.1	61.9	100.0
2019	10.5	6.6	12.2	29.3	70.7	100.0
Average	5.8	14.8	24.3	44.9	55.1	100.0

Appendix D:

Northern British Columbia Indicator Program Harvest and Escapement

Appendix D1: Estimated fishery samples size (expanded CWT recoveries), harvest by gear type, escapement, and total run of coho salmon returning to Zolzap Creek, 1993-2019. The dash (-) denotes insufficient data or years the program was not operating.

		Number of Fish											
		Alaska					British Columbia						
Year	Fishery Sample Size	Troll	Seine	Drift Gillnet	Sport	Other Net	Troll	Net	Sport	Total Harvest	Escapement	Total Run
1993	154	1,033	133	220	52	23	193	186	-	1,840	1,048	2,888
1994	431	4,205	1,136	126	104	25	1,458	390	-	7,443	2,536	9,979
1995	215	978	498	183	116	27	262	144	-	2,209	908	3,117
1996	142	1,005	249	69	274	0	472	141	-	2,211	1,039	3,250
1997	89	432	18	42	0	5	54	0	-	551	470	1,021
1998	68	576	185	89	23	0	0	0	-	873	967	1,840
1999	166	1,017	99	159	91	4	0	9	-	1,379	1,393	2,772
2000	106	348	22	3	42	0	0	0	-	415	456	871
2001	360	1,192	282	171	74	28	115	3	-	1,865	1,897	3,762
2002	114	466	133	72	26	0	114	4	-	816	3,233	4,049
2003	146	958	429	209	124	0	189	25	-	1,934	2,855	4,789
2004	160	969	97	69	137	0	259	13	-	1,543	1,631	3,174
2005	-	-	-	-	-	-	-	-	-	-	-	-
2006	-	-	-	-	-	-	-	-	-	-	-	-
2007	-	-	-	-	-	-	-	-	-	-	-	-
2008	-	-	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-	-	-	-	-	-
2011	56	344	22	35	35	0	54	0	8	499	438	937
2012	74	615	172	87	0	13	218	0	84	1,190	976	2,166
2013	569	2,952	387	317	108	30	699	34	138	4,665	2,649	7,314
2014	154	1,157	113	54	22	0	184	0	32	1,562	2,352	3,914
2015	77	484	84	55	23	0	175	47	98	966	145	1,111
2016	166	958	140	125	47	0	183	43	69	1,566	731	2,297
2017	207	863	67	33	97	7	412	19	99	1,596	1,287	2,883
2018	31	267	38	0	14	0	60	0	12	390	430	820
2019	121	412	96	29	8	0	233	0	53	831	879	1,710
Average	172	1,011	210	102	67	8	254	50	66	1,731	1,349	3,079

Appendix D2: Estimated fishery samples size (expanded CWT recoveries), harvest by gear type, escapement, and total run of coho salmon returning to Toboggan Creek, 1989-2019. The dash (-) denotes insufficient data.

		Number of Fish													
		Alaska					British Columbia								
Year	Fishery Sample Size	Troll	Seine	Drift Gillnet	Sport	Other Net	Troll	Net	Sport	First Nations	Tyee Test Fishery	Total Harvest	Escapement	Total Run
1989	153	941	201	107	0	0	1,162	1,037	28	-	-	3,476	2,131	5,608
1990	240	1,681	443	64	80	0	2,337	1,598	45	-	-	6,247	2,751	8,997
1991	408	2,043	505	110	58	14	1,614	1,088	66	-	-	5,499	3,336	8,835
1992	110	1,556	395	113	0	0	467	1,151	57	-	-	3,740	1,981	5,721
1993	-	-	-	-	-	-	-	-	-	-	-	-	1,407	-
1994	421	1,850	609	23	0	0	1,227	522	141	273	-	4,644	2,385	7,029
1995	122	374	159	20	0	0	139	315	58	64	-	1,129	1,761	2,890
1996	247	1,007	263	0	0	0	580	895	82	113	-	2,941	1,181	4,122
1997	39	256	30	12	0	0	32	0	15	5	-	350	394	744
1998	36	342	131	53	0	20	0	0	21	10	-	578	2,467	3,045
1999	266	1,571	344	182	156	0	0	3	79	75	-	2,411	8,878	11,289
2000	256	1,201	229	38	73	0	0	0	0	15	-	1,555	3,930	5,485
2001	467	1,232	527	35	180	0	19	9	0	153	-	2,155	6,080	8,235
2002	355	275	117	91	67	0	84	0	55	74	-	764	3,980	4,744
2003	202	885	231	129	125	0	232	106	0	16	-	1,723	5,269	6,992
2004	87	634	118	44	209	0	314	178	471	35	-	2,002	2,700	4,702
2005	78	1,329	53	46	90	0	114	0	19	77	-	1,728	4,900	6,628
2006	76	576	44	24	166	0	179	13	211	129	-	1,343	3,100	4,443
2007	73	881	294	59	225	0	194	320	288	73	-	2,335	2,630	4,965
2008	53	449	128	284	485	0	71	0	223	30	-	1,670	2,420	4,090
2009	295	2,401	338	108	113	0	254	15	450	185	-	3,864	6,130	9,994
2010	184	985	123	82	26	0	255	4	256	290	-	2,021	4,200	6,221
2011	238	441	148	79	56	0	372	172	572	50	-	1,891	2,100	3,991
2012	132	732	296	64	33	0	145	0	619	122	-	2,011	3,050	5,061
2013	106	1,629	385	95	165	14	409	22	84	377	-	3,180	5,300	8,480
2014	137	1,351	270	18	36	0	110	16	69	149	-	2,020	7,304	9,324
2015	112	605	368	29	25	0	455	70	280	128	-	1,961	2,752	4,713
2016	279	1,772	533	183	148	0	551	603	712	341	19	4,861	6,640	11,501
2017	123	1,581	45	52	227	25	840	32	202	214	8	3,226	4,100	7,326
2018	51	119	26	6	0	0	128	11	62	123	0	474	649	1,123
2019	48	293	54	38	0	0	254	0	233	65	14	952	1,484	2,436
Average	180	1,033	247	73	91	2	418	273	180	123	10	2,425	3,464	5,958

Appendix D3: Estimated harvest, escapement, and total run of coho salmon returning to the Taku River, 1992-2019.

Year	Number of Fish					
	Canadian Harvest	US Harvest	US Troll	Total Harvest	Escapement	Total run
1992	5,541	74,745	48,783	129,069	83,729	212,798
1993	4,634	35,703	89,653	129,990	119,330	249,320
1994	14,693	101,292	127,408	243,393	96,343	339,736
1995	13,738	59,240	52,428	125,406	55,710	181,116
1996	5,052	17,019	27,577	49,648	44,635	94,283
1997	2,690	6,479	9,372	18,541	32,345	50,886
1998	5,090	17,042	36,411	58,543	61,382	119,925
1999	5,575	9,009	41,824	56,408	60,768	117,176
2000	5,447	11,520	27,481	44,448	64,700	109,148
2001	3,099	11,739	43,545	58,383	104,394	162,777
2002	3,802	33,238	46,875	83,915	219,360	303,275
2003	3,643	25,139	53,196	81,978	183,112	265,090
2004	9,684	25,898	86,628	122,210	129,327	251,537
2005	8,259	21,718	57,462	87,439	135,558	222,997
2006	11,669	36,170	56,471	104,310	122,384	226,694
2007	8,073	16,617	34,365	59,055	74,246	133,301
2008	3,973	24,390	50,481	78,844	95,226	174,070
2009	9,766	42,946	67,348	120,060	103,950	224,010
2010	14,408	55,254	50,330	119,992	126,830	246,822
2011	12,478	9,393	37,197	59,068	70,871	129,939
2012	14,072	11,554	16,546	42,172	70,775	112,947
2013	10,375	25,300	39,618	75,293	68,117	143,410
2014	16,568	31,149	17,767	65,484	124,171	189,655
2015	10,183	9,558	24,425	44,166	60,178	104,344
2016	11,520	13,930	12,169	37,619	87,704	125,323
2017	7,802	13,516	29,077	50,395	57,868	108,263
2018	9,505	12,657	9,340	31,502	51,173	82,675
2019	12,252	7,693	14,327	34,272	82,759	117,031
Average	8,700	27,140	43,147	78,986	92,391	171,377