Review of available abundance, age, and stock composition data useful for reconstructing historical stock specific runs, harvest, and escapement of Yukon River Chinook salmon (*Oncorhynchus tshawytscha*), 1981-2019

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Review of available abundance, age, and stock composition data useful for reconstructing historical stock specific runs, harvest, and escapement of Yukon River Chinook salmon (*Oncorhynchus tshawytscha*), 1981-2019

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April 2022

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ABSTRACT

G. Pestal et al. 2022. Review of available abundance, age, and stock composition data useful for reconstructing historical stock specific runs, harvest, and escapement of Yukon River Chinook salmon (*Oncorhynchus tshawytscha*), 1981-2019. Pacific Salmon Commission Tech. Rep. 48: iii + 347 p.

Available abundance data for Yukon River Chinook Salmon (*Oncorhynchus tshawytscha*) were compiled and reviewed through a United States (U.S.) and Canada multi-agency process to support the development of a formal Bayesian state-space run reconstruction model and spawner-recruit analysis for the Canadian-origin stock. Data from U.S. assessment projects were required to develop a multi-stock run reconstruction model and better inform abundance estimates of the Canadian-origin stock component. The data review was conducted by a subcommittee of the Yukon River Joint Technical Committee (JTC). To identify survey data for inclusion in the model, the subcommittee compiled a detailed inventory of available data and associated survey descriptions (e.g., general approach, changes over time, critical assumptions, potential issues). The individual data reviews summarized in this report represent the subcommittee's understanding of the available data, which may be incomplete or lack nuance. As such, the datasets and associated reviews contained in this report do not necessarily present a consensus by the full bilateral JTC. The data reviews should be updated as new information or understanding is available. This report was set up as an automatically-generated document to streamline future updates as needed.

1 Introduction

1.1 Escapement Goal Review for Canadian-Origin Yukon River Chinook Salmon

The U.S. / Canada Yukon River Joint Technical Committee (JTC) supports the Yukon River Panel (Panel) of the Pacific Salmon Commission and is tasked with making escapement goal recommendations for Canadian-origin Chinook salmon (*Oncorhynchus tshawytscha*). In March of 2019, the JTC decided to undertake a quantitative review of the Canadian-origin Chinook salmon Interim Management Escapement Goal (IMEG) established in 2010. That decision was in response to the Panel's expressed desire to explore the possibility of establishing a biologically-based escapement goal for this stock.

An initial step by the JTC was to establish the Canadian-origin Chinook Salmon Escapement Goal Subcommittee (EGSC) which met for the first time in March of 2020.The purpose of the subcommittee was to conduct analyses and prepare supporting documentation to assist the JTC in developing recommendations regarding optimum spawning escapement objectives. These analyses will use scientifically defensible data and analytical methods to quantitatively describe the stock dynamics and associated uncertainties. The subcommittee's work and JTC recommendations will provide the Panel with tools to evaluate the IMEG and consider alternative biologically-based and scientifically-defensible escapement goals for this stock, pursuant to the Yukon River Salmon Agreement. The EGSC agreed to draft one data report and one model report to be used as the foundation of the advice they will provide to the JTC. In combination, these two reports will document:

- all data used in analyses or links to online data repositories,
- a discussion of data quality and limitations,
- model assumptions and sensitivities,
- results including estimates of uncertainty,
- discussion of the limitations of the analysis, results, and conclusions,
- all source code used to produce results, and
- user guides for any interactive visualization tools prepared by the subcommittee.

This document represents the data report component of the EGSC reporting plan.

1.2 Data Review

A central component of the EGSC work was to conduct a comprehensive review of available data that was potentially useful for informing abundance estimates of Canadian-origin Yukon River Chinook salmon. The EGSC planned to develop a multi-stock run reconstruction model with the expectation that information about U.S. stock components would help inform the Canadian-origin stock estimates. As such, data from the U.S. and Canada stock assessment programs were compiled and reviewed through a bilateral and multi-agency process.

The scope of the data review was bounded as follows through EGSC consensus:

- Review and recommend available datasets for defining the relationship between the number of spawners and recruits for the purpose of informing escapement goal setting. The expectation was that this process would focus primarily on readily available datasets as opposed to substantial reanalysis of existing information. The data review phase was intended to identify critical uncertainties, and if deemed necessary provide opportunity to explore the sensitivity of model outcomes to data decisions.
- Document all data sources used, identify data quality concerns, and recommend analytical options for addressing data quality issues.
- The data report was not required to undergo independent expert review but was made available to reviewers of the model report as needed to ensure they have the opportunity to understand data limitations and ascertain if the data were used appropriately in the analysis.

1.3 Report Outline

The *Methods* section summarizes the overall assessment approach for Yukon River Chinook salmon, summarizes the data review process, and documents the standardized data/metadata structure.

The *Results* section includes high-level summaries of all the data, comparing number of observations, time periods covered, and abundance patterns across assessment projects.

The *Discussion* section summarizes implications of the available data for run reconstruction and spawner-recruit modelling.

The appendices include detailed profiles of the assessment projects, including a timeline of operational changes, a list of potential data issues, and a list of any available project reports.

This report is a centralized repository of available data as well as a high-level summary of the context. The main intention is to have a report that can be quickly re-generated as new data is available. Towards that goal, we have kept the text brief and general, and put most of the details into figures and tables that can be efficiently updated.

2 Methods

2.1 Overall assessment approach

The Yukon River is a transboundary (U.S./Canada) river that drains a vast basin of 330,000 square miles (850,000 km^2), which is larger than eight of the 13 Provinces or Territories in Canada and larger than all U.S. states except Alaska. The Yukon River is the third longest river in North America and the sixth largest by discharge (m3/s). Compared to other key salmon-bearing river basins in North America (Fraser, Columbia, Skeena/Nass), the Yukon River basin is very sparsely populated, with limited roads, and remote salmon spawning areas that are challenging to access.

Yukon River Chinook spawning populations are grouped into three stocks for the purpose of run reconstruction and escapement goal analyses (Hamazaki 2021; Connors et al. 2022). In this report, these stocks are called *Lower*, *Middle*, and *Canada* (Figure 1). Finer-scale groupings are used by agencies (e.g., stock reporting groups used by ADF&G, conservation units identified within the Canadian stock under DFO's *Wild Salmon Policy*), and naming can be inconsistent between agencies or programs (e.g., The *Canada* stock is labelled *Upper* in many ADF&G reports and throughout Appendix D of this report). We organize the project summaries by location (e.g. lower river mainstem, Canadian tributary) and group them roughly by watershed (e.g., Tanana watershed, Teslin headwaters). In some cases, these report groupings include multiple watersheds (e.g., Carmacks area tributaries).

Chinook assessment in the Yukon basin is built around four key components (Figure 1) :

- Estimate of run size in the lower river near the community of Pilot Station, using sonar.
- Estimates of Canadian mainstem stock run size, initially using a fish wheel mark-recapture program at the U.S./Canada border, then switching to a sonar at Eagle in the mid-2000s.
- Estimates of spawner abundance for a subset of U.S. and Canadian tributaries, using a combination of sonars, weirs, towers, and aerial surveys.
- Estimates of stock-specific harvest for each fishery occurring in the U.S. (all harvest in Canada is from Canadian stock).

Detailed technical reports for many of the assessment projects are published annually by the responsible agencies, and much of the data are summarized in the JTC technical reports, available online at https://www.yukonriverpanel.com/publications/yukon-river-joint-technical-committee-reports/

This report compiles data across projects into a standardized format (Section 2.6), together with a summary of survey methods and an inventory of published project reports (Appendices).

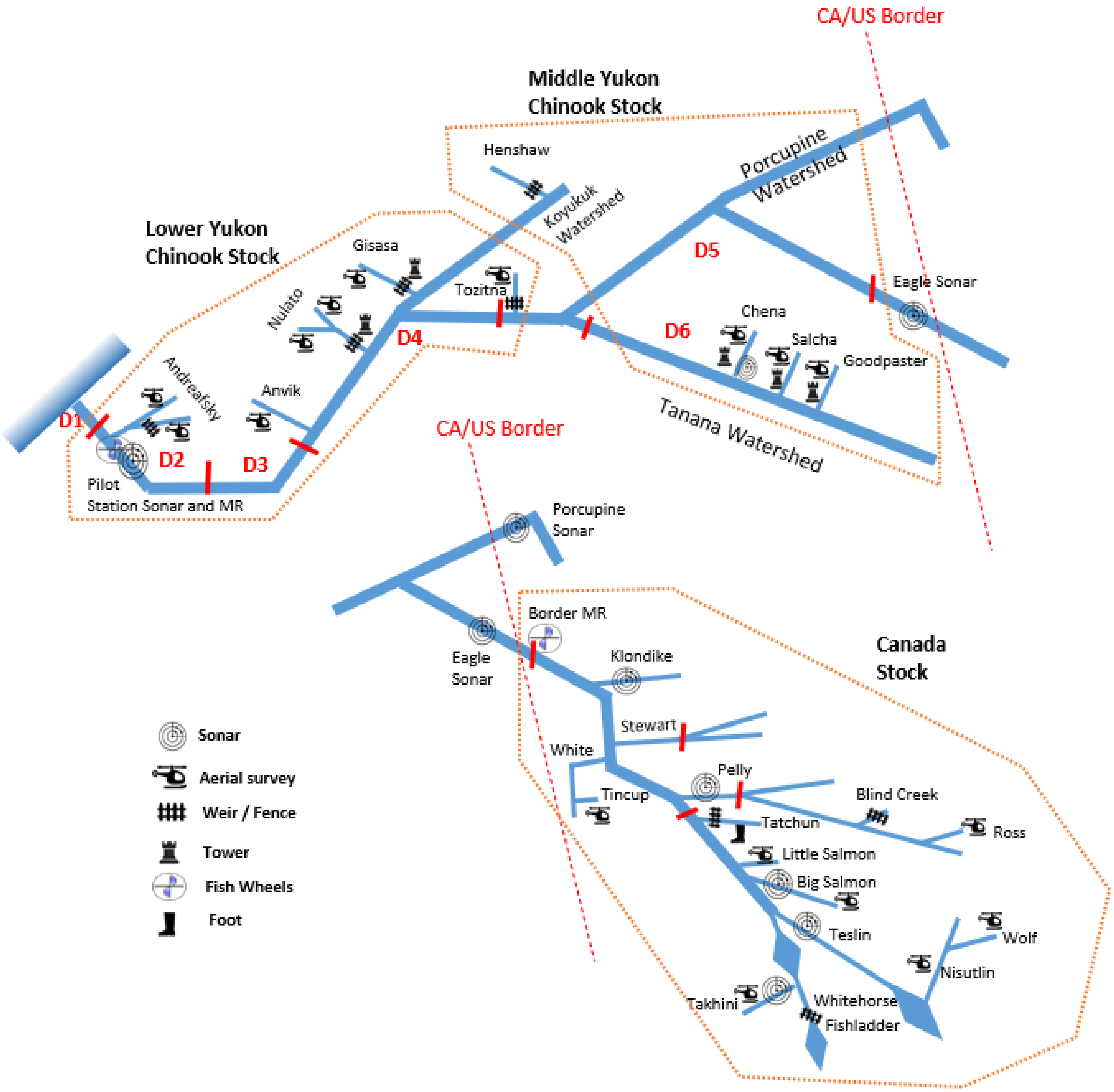


Figure 1. *Schematic Overview of Yukon Chinook Abundance Surveys*. The diagram focuses on highlighting the spatial relationship between the watersheds and assessment program components, so the distances and angles are not to scale. For most systems where both tower and weir are shown in the diagram, assessment used one approach, then had a period of overlap, then switched to the other. Upper Koyukuk River Chinook salmon, including the Henshaw population, are genetically similar to Tanana River Chinook salmon, and are therefore included in the Middle Yukon River stock. Tozitna River Chinook salmon, though spatially close to the Tanana River, are genetically grouped with the Lower Yukon stock. Porcupine River Chinook salmon are distinct from the mainstem stock Chinook salmon entering Canada. Stock assessment districts used by ADF&G (D1-D6) and Canadian fishing areas for commercial and domestic harvests are delineated with red bars. *Plot design adapted from a collaboration with Pete Nicklin (Tŝilhqot'in Fisheries)*

2.2 U.S. Stock Assessment

Chinook salmon assessment in the U.S. portion of the Yukon River drainage includes a suite of projects which provide information about the abundance and composition of the total annual run, harvest, and escapement (Figure 1).

Total run assessment includes a gill net test fishery operated near the mouth of the Yukon River and a sonar project operated at rkm 197 near the community of Pilot Station, AK. The Lower Yukon Test Fishery provides relative abundance (catch per unit effort) information suitable for informing arrival timing of Chinook salmon entering the Yukon River mouth. Chinook salmon abundance has been estimated by the Pilot Station Sonar program since 1985, and when combined with genetic sampling, which began in 2002, has provided annual estimates of stock specific run sizes.

Annual harvest of Yukon River Chinook salmon has been determined for commercial fisheries from fish tickets, subsistence harvest has been estimated from postseason surveys, and personal use harvest has been determined from permit returns. Harvest by stock has been estimated for each fishery/location based on directed sampling programs or expert elucidation. Escapement monitoring utilizes a range of techniques including one-time peak spawning aerial surveys, weirs, counting towers, and sonars. Harvest locations are organized by Districts, subdistricts, and statistical areas defined by Alaska Regulation, and ADF&G provides detailed maps of these areas on their website: https://www.adfg.alaska.gov/index.cfm?adfg=commercialbyareayukon.salmon#maps

Escapement projects have been operated annually on a relatively small subset of accessible spawning tributaries throughout the U.S. portion of the Yukon River drainage.

Age-sex-length (ASL) data have been collected from Yukon River Chinook salmon at many locations over time and used to represent run, harvest, and escapement composition. Much of the ASL data collected by various organizations within the U.S. portion of the Yukon River drainage are publicly available by ADF&G via the Arctic-Yukon-Kuskokwim Database Management System (AYKDBMS) and is documented in annual reports (e.g., Larson et al. 2020). Some Canadian samples are also archived in the AYKDBMS. A detailed data review of project-specific ASL data was not conducted, because it was not required for estimating Canada stock dynamics. Rather, ASL data review efforts were limited to published age composition estimates of Canadian-origin Chinook salmon harvested in U.S. Yukon Area fisheries and at projects operated near the U.S./Canada border. The combination of U.S. harvest and border age composition was adequate to produce annual estimates of total run age composition.

Yukon River Chinook salmon are harvested in mixed-stock fisheries outside the Yukon River drainage. Chinook salmon harvest in the Yukon Area Coastal District is estimated annually by ADF&G and stock of origin is assumed to be the same as the inriver harvest stock composition of the lower Yukon River, District 1. Yukon River Chinook salmon are also caught as bycatch in Bering Sea Aleutian Island (BSAI) groundfish (primarily pollock) fisheries. It is important to acknowledge BSAI bycatch mortality, but it was not explicitly included in our data review or subsequent analyses. This decision was made in part because historical estimates of bycatch impact rates have been small relative to other sources of harvest and are not available for all years.

The implications of ignoring the BSAI bycatch harvests is likely small. The BSAI fishery harvests Yukon River Canadian-origin salmon along with other salmon stocks from Alaska, the west coast of Canada and the United States, eastern Asia, and Russia. The BSAI groundfish fishery is managed by the U.S. Federal Government, National Marine Fisheries Service and is one the most heavily regulated and monitored fisheries in the world, with 100% observer coverage. The impact of bycatch on annual run size of Canadian-origin Chinook salmon is small relative to natural mortality and inriver harvest. The total number of all Chinook salmon stocks captured as bycatch is much larger than the number of adult Canadian-origin salmon that would have returned to the Yukon River had they not been harvested. This is largely due to the mixed-stock nature of salmon bycatch, and the fact that the bycatch is mostly immature Chinook salmon. Annually, genetic methods are used to estimate the proportion of the total bycatch that is Canadian-origin. In a subset of years (1994-2017), the bycatch estimates of immature Canadian-origin fish have been adjusted for natural mortality to produce an estimate of the adult equivalence (AEQ) bycatch (i.e., the number of fish that would have returned as adults had they not been harvested as bycatch). The 1994-2017 average bycatch impact rate of the BSAI pollock fishery is estimated to be 1.0% of the Canadian-origin Chinook salmon run, with an annual rate less than 3.1% (Ianelli and Stram 2020) .

2.3 Canadian Stock Assessment

Assessment of the mainstem Chinook salmon stock in the Canadian portion of the Yukon River drainage starts with mainstem U.S. / Canada border passage estimates (Figure 1). Since 2005, the number of Chinook salmon that pass into Canada has been estimated using a sonar operated near the community of Eagle, AK (downstream from the U.S. / Canada border) minus the harvest that occurs between the sonar site and the U.S. / Canada border. Before 2005, the border estimate was based on a mark-recapture program operated on the Canadian side of the border where fish wheels were used for marking the initial capture / marking event and the Canadian fishery was used for the recapture event. Salmon crossing the border in the mainstem are destined for spawning locations in several large sub-watersheds. Assessment projects have taken place throughout these areas on a variety of spatial and temporal scales. Aerial surveys over spawning areas were frequently conducted by DFO for several decades, to estimate escapement into different watersheds. Genetics on test fishery samples at Eagle Sonar has largely replaced aerial surveys since the mid 2000s. Additional assessment projects such as sonars and weirs take place on tributaries throughout the drainage. The Yukon River Panel's Restoration and Enhancement (R&E) funds are the major contributor, with projects undertaken over time by various combinations of DFO projects, First Nation's led initiatives and consultants. Spawning grounds surveys have also historically taken place in conjunction with DFO's aerial surveys, as well as part of R&E funding.

Harvest in Canada occurs in a First Nation, domestic, commercial, and public angling fisheries. First Nation governments manage their fisheries within their Traditional Territories and provide harvest numbers to DFO whereas commercial, domestic and public angling fisheries are administered by DFO and include mandatory catch reporting. While public angling for salmon occurs throughout the drainage, it is primarily limited to sites where access to the river is readily available with the majority of harvest occurring within the proximately of the confluence of Tatchun Creek with the Yukon River. The boundaries of the Commercial and Domestic fisheries are set by regulation and include significant portions of the Yukon River mainstem and major tributaries including the Porcupine, Steward, and Pelly Rivers. Despite this extensive fishery area, the majority of Commercial and Domestic harvest is concentrated in the Yukon River portion from the U.S. / Canada border upstream to just above the community of Dawson City (approximately 150 rkm). Spawning escapement on the Yukon River mainstem in Canada is estimated by subtracting the total Canadian mainstem harvest estimate from the border passage estimate. In addition to the mainstem Canadian stock, the Porcupine River in the northern Yukon joins the Yukon River in the U.S., downstream from the U.S. / Canada border. The Canadian Porcupine River stock is not part of the mainstem Canadian Yukon River stock. However they are a Canadian stock of importance, they contribute to the drainage-wide Chinook salmon stock composition, and returning spawners have been enumerated in Canada using sonar since 2014.

Age, Sex, and Length data has routinely been collected as part of assessment projects which include a test fishing, carcass pitch, or other fish sampling component, as well as part of spawning ground surveys. These data are available through DFO or through specific project proponents.

2.4 Survey Types

The large number of individual assessment projects across the Yukon River drainage can be organized into a few types that share basic characteristics and critical assumptions:

- *Point-in-Time Counts* (Table 1): Aerial Surveys, Other index types (ex: foot, float, boat)
- *Fixed Locations Counts* (Tables 2 and 3): Weir, Tower, Sonar, Fish wheel
- *Mark-Recapture Surveys* (Table 4)
- *Age, sex, length (ASL) and genetic sampling* (Table 4)

The individual project summaries presented in the Appendices describe the specific assumptions of each project and how well those assumptions are met, if known. Note that the project summaries in the appendices were compiled with the help of many contributors (Section 2.5) and drew on different types of source material. As a result, project descriptions cover varying levels of detail. Some provide extensive information about critical assumptions, whereas others do not. When reviewing project descriptions, the reader is advised to keep common assumptions in Tables 1 to 4 in mind, since they apply to most projects whether expressly stated in the appendices or not.

Table 1. *Overview of critical assumptions and general considerations: Point-in-time counts*.

Method	**Considerations**
Aerial Survey	Critical assumptions for one-time peak aerial surveys include: (1) counts provide a reliable and consistent index of peak spawning abundance, and (2) survey rating or other information is accurate and complete to determine reliability of reported counts.
Aerial Survey	General considerations for one-time peak aerial surveys include: (1) count type: may include live fish, carcasses, redds or a combination of types, (2) timing: attempt to fly surveys during peak abundance, the timing of which varies annually based on fish arrival, (3) visibility: water height and clarity, weather, and vegetation affect the ability to see fish in the water, (4) observer experience: observer skill, training, and number of observers may vary over time, (5) index sections: survey counts may index a standardized area or survey extent may vary over time, and (6) equipment: helicopters and planes may fly at different speeds and elevations resulting in different abilities to view fish.
Other Index Types (e.g., foot, float, boat)	Rely on similar considerations as aerial surveys with respect to timing, experience, locations, and conditions. Counts may not be comparable across survey types, because visibility and access to the watercourse may differ.

Table 2. *Overview of critical assumptions and general considerations: Fixed locations counts with weirs or towers*.

Method	**Considerations**
Weir	Critical assumptions and considerations for weir counts include: (1) method only enumerates fish which pass thought the weir (does not account for fish spawning below the weir and/or deterred by weir passage, (2) unless otherwise reported, there are no holes in weir where fish can pass undetected, (3) all instances of potential missed passage are reported, (4) some, but not all, weir projects make estimates of missed passage to account for time when the weir was compromised or inoperable, (5) weir open / closed periods and biological sampling schedules can affect fish movement, (6) all fish that pass the weir are counted and accurately identified to species by observers, and (7) weirs create potential for increased predation of salmon milling behind or in front of the structure.
Tower	Critical assumptions for tower counts include: (1) all Chinook salmon passage is visible from the tower, (2) passage of Chinook salmon is consistent within the counting shift, (3) no diurnal changes to fish passage, (4) that the sampling plan is sufficient to estimate passage over a full day, and (5) there is minimal to no milling at the site so that fish are not counted multiple times.
Fish Wheel	Critical consideration for using fishwheels as a Chinook salmon capture method include: (1) method is only able to capture fish that are swimming near shore along the same bank the fishwheel is deployed, (2) fish orientation to riverbanks can be influenced by river hydrology, fish size, abundance of other fish species, and distance to spawning tributaries, (3) fish available for capture may not be representative of the size, sex, or stock composition of all fish passing upstream, (4) units of effort can be difficult to quantify based solely on distance from shore, percent of water column covered by baskets, number of baskets, and basket rotation speed, (5) capture efficiency can vary considerably over time and space and is affected by the design, placement, water conditions, and use of a fish lead, (6) failure to use ’fish friendly’ basket, chute, and live box designs can result in fish injury, and (7) extended holding time or crowding in fish wheel live boxes have been linked to altered migratory behavior and delayed mortality of released fish.

Table 3. *Overview of critical assumptions and general considerations: Fixed locations counts with sonar*.

Category	**Considerations**
Overall	The primary considerations of a sonar project are (1) how much of the river is ensonified by the sonar beam (i.e., spatial coverage), (2) how much of the run is counted each season/day (temporal coverage), and (3) the robustness of the species apportionment program/assumptions. Many considerations go into each of these three components.
Spatial coverage	The fundamental question is whether the entire river (width and depth) is covered by the sonar beam(s), and if not how this is addressed. Specific considerations include: (1) site selection: river flow / profile / bottom composition, (2) sonar settings: aim, range and frequency of repositioning with changing conditions, (3) sonar equipment: suitability for the local conditions and type of information collected, and (4) target testing: or other methods of ensuring all salmon passing in beam are accounted for.
Temporal coverage	(1) sonar settings such as counting different spatial strata (alternating range) for specific time periods (how often), (2) methods and assumptions of expansions to estimate for times not counted, and (3) how these temporal methods account for potential diurnal changes to fish passage.
Species apportionment	(1) what proportion of marked targets are salmon (and of the specific species of interest), (2) apportionment may be addressed by various methods including test fishing and/or sonar-based length measurements, (3) if test fishery proportions are to be representative, all ensonified fish must be equally likely to be captured by test fish nets (i.e., no species-specific net avoidance), and (4) for projects without test fisheries, it is important to consider how salmon species crossover periods (i.e., change in dominant species) are handled and how salmon species are differentiated from resident species (e.g., size or behavior).
Other	(1) can upstream migrating fish be distinguished from fish moving downstream and how are downstream fish accounted, (2) minimal to no milling at site so that fish are not counted multiple times, (3) repeatability and accuracy of sonar counts and passage estimates by species, and (4) how is operational downtime addressed and beginning/end of season expansions conducted.

Table 4. *Overview of critical assumptions and general considerations: Other Survey Types*.

Method	**Considerations**
Mark-recapture closed population abundance estimate	(1) The population is closed to births, deaths, immigration and emigration, (2) Marking and handling did not affect the catchability of salmon in the second event. (3) Tagged fish did not lose their tags between the two sampling events, and (4) One of the following three conditions needed to be met: (a) All Chinook salmon had the same probability of being caught in the first event; (b) All Chinook salmon had the same probability of being captured in the second event; or, (c) Marked fish mixed completely with unmarked fish between samples.
Age, sex, length (ASL) and genetic sampling	(1) age-sex proportion estimates of subsampled individuals are reflective of the broader harvest or spawning population, (2) the ASL and genetic compositions of samples were a function of the passage rate (**EXPLAIN**), fish available for capture at that location, selectivity of gear, and time of year/day, (3) genetic stock composition is based on baseline quality and accuracy of assignment for individual reporting groups (e.g., Canadian mainstem stock vs. specific sub-drainages in Canada).

2.5 Data Review Process

The data review process represented a bilateral collaborative approach to collate Yukon River Chinook salmon abundance datasets that may be useful for informing total annual abundance, harvest, escapement, and composition of the Canadian-origin, Middle U.S., and Lower U.S. stocks. The data review process began by developing a comprehensive list of potentially relevant abundance information from U.S. and Canadian assessment programs. The goal of each review was to identify the best available time series of data, summarize data collection and estimation methods (including operational changes), provide a list of data assumptions, and identify data limitations and quality concerns. For each review, information was presented following a standardized template and included source materials and reference documentation.

The data review process occurred over an approximately one-year period and required consistent oversight by the EGSC. Responsibilities for coordinating project reviews were assigned to EGSC members from *Alaska Department of Fish and Game* or *Fisheries and Oceans Canada* with appropriate project familiarity and access to agency files. Each project review included published reports, unpublished agency files, and coordination with project leaders. In total 33 people representing 11 organizations contributed to the review process (Table 5) and the result is the product of hundreds of hours of EGSC and staff time.

There were three concurrent approaches to identify projects for review and possible incorporation into subsequent model phases. First, all projects used in the multi-stock run reconstruction model developed by Hamachan Hamazaki were reviewed, because the Hamazaki (2021) model framework formed the basis of the run reconstruction methods being developed by the EGSC. Second, ADF&G and DFO provided a detailed summary of all available assessment data, and those project lists were reviewed by the EGSC to identify any potentially useful projects that were not already identified by Hamazaki (2021). ADF&G provided a complete data extract of all Chinook salmon abundance and age-sex-length survey records from the ADF&G OceanAK database for this purpose (Appendix J). Projects identified in the ADF&G OceanAK database where ordered based on the maximum Chinook salmon survey count associated with each dataset (Table J.1). The subset of projects with at least one record exceeding 1,000 was compared to the project list used by Hamazaki (2021), and those project not already accounted for were given a comprehensive review or excluded for a specific reason. Finally, the EGSC solicited input from the JTC to identify additional projects that were not already accounted for.

41 projects were reviewed in depth and documented in this report (Tables 6 and 7). Ultimately, not all projects identified throughout these processes were reviewed as part of this report, and not all projects that were reviewed were used for the run reconstruction analysis (Tables 8 and 9). Reasons included (1) data not readily available, (2) raw data considered poor quality or inconsistent over time, (3) low priority for current run reconstruction model, (4) time series too short within the model time range.

Table 5. *List of Contributors*. Many people assisted with data reviews. The EGSC specifically sought input from JTC members and project leaders, who may have sought the assistance of others. The following individuals helped with the data review process, including identifying potentially useful datasets; providing data, project reports, or agency documents; drafting or editing project data review; or providing constructive comments regarding sections of this data review document. The EGSC apologizes if any contributor was unintentionally left off this list.

Country	Contributor	Organization	JTC Member
Canada	Carli, Christopher	Fisheries and Oceans Canada	
Canada	Connors, Brendan	Fisheries and Oceans Canada	Subcommittee
Canada	Kapaniuk, Warren	Ensero (Whitehorse Hatchery)	
Canada	MacDonald, Elizabeth	Yukon Salmon Sub-Committee	Yes
Canada	Mather, Vesta	Fisheries and Oceans Canada	Subcommittee
Canada	Mercer, Brian	Metla Environmental, Inc.	
Canada	Milligan, Marina	Fisheries and Oceans Canada	
Canada	Pestal, Gottfried	SOLV Consulting Ltd.	Subcommittee
Canada	Smith, Steve	Fisheries and Oceans Canada	Yes
Canada	Snow, Benjamin	Fisheries and Oceans Canada	
Canada	Tanner, Trix	Fisheries and Oceans Canada	
Canada	Trerice, Jesse	Fisheries and Oceans Canada	Yes
Canada	Vanos, Lawrence	Ensero (Whitehorse Hatchery)	
Canada	Wilson, Jane	J. Wilson & Associates	
U.S.	Borba, Bonnie	Alaska Dep. of Fish & Game	Yes
U.S.	Bradley, Catherine	U.S. Fish and Wildlife Service	Subcommittee
U.S.	Brown, Randy	U.S. Fish and Wildlife Service	Yes
U.S.	Carlson, Jeremy	U.S. Fish and Wildlife Service	
U.S.	Clark, Joshua	Alaska Dep. of Fish & Game	
U.S.	Cunningham, Curry	University of Alaska Fairbanks	Subcommittee
U.S.	Hamazaki, Hamachan	Alaska Dep. of Fish & Game	Subcommittee
U.S.	Kalb, Brad	Alaska Dep. of Fish & Game	
U.S.	Keyse, Matthew	U.S. Fish and Wildlife Service	
U.S.	Lazori, Jody	Alaska Dep. of Fish & Game	
U.S.	Lee, Elizabeth	Alaska Dep. of Fish & Game	
U.S.	Liller, Zachary	Alaska Dep. of Fish & Game	Yes
U.S.	Maschmann, Gerald	U.S. Fish and Wildlife Service	Yes
U.S.	Matter, Allison	Alaska Dep. of Fish & Game	
U.S.	Mckenna, Brian	Tanana Chiefs Conference (TCC)	
U.S.	Padilla, Andrew	Alaska Dep. of Fish & Game	
U.S.	Pfisterer, Carl	Alaska Dep. of Fish & Game	

Country	Contributor	Organization	JTC Member
U.S.	Stark, Chris	Bering Sea Fishermen’s Association	Yes
U.S.	West, Fred	Alaska Dep. of Fish & Game	Yes

Table 6. *Yukon Chinook salmon assessment projects operated in the Lower and Middle portions of the Yukon River drainage that were reviewed in-depth and summarized in this report for possible inclusion in the run reconstruction model (Connors et al. 2022).* Table lists project labels that will be used throughout report (*Project*), identifies the methods (*SurveyType*) and general location (*Watershed Grouping*). Projects either cover the mainstem Yukon River or a tributary system (*Coverage*), and 1 or more stocks (*Stocks*). *RR* shows whether a project is used in the current run reconstruction model (Connors et al. 2022).

Stock	Coverage	Watershed Grouping	SurveyType	Project	RR
All	Mainstem	Mainstem	Sonar	PilotStation	Yes
All	Mainstem	Mainstem	MR	MRMainstem	Yes
Lower	Tributary	Andreafsky	Weir	AndreafskyWeir	Yes
Lower	Tributary	Andreafsky	Aerial	AndreafskyEastAerial	Yes
Lower	Tributary	Andreafsky	Aerial	AndreafskyWestAerial	Yes
Lower	Tributary	Anvik	Aerial	AnvikAerial	Yes
Lower	Tributary	Nulato	Various	NulatoTowerWeir	Yes
Lower	Tributary	Nulato	Aerial	NulatoNorthForkAerial	Yes
Lower	Tributary	Nulato	Aerial	NulatoSouthForkAerial	Yes
Lower	Tributary	Koyukuk	Various	GisasaTowerWeir	Yes
Lower	Tributary	Koyukuk	Aerial	GisasaAerial	Yes
Lower	Tributary	Tozitna	Weir	TozitnaWeir	Yes
Lower	Tributary	Tozitna	Aerial	TozitnaAerial	Yes
Middle	Tributary	Koyukuk	Weir	HenshawWeir	Yes
Middle	Tributary	Tanana	MR	RadioMRTanana	No
Middle	Tributary	Tanana	Various	ChenaSurveys	Yes
Middle	Tributary	Tanana	Aerial	ChenaAerial	Yes
Middle	Tributary	Tanana	Various	SalchaSurveys	Yes
Middle	Tributary	Tanana	Aerial	SalchaAerial	Yes
Middle	Tributary	Tanana	Tower	GoodpasterTower	Yes
Middle	Tributary	Tanana	Aerial	GoodpasterAerial	No

Table 7. *Yukon Chinook salmon assessment projects operated in Canada or at the border that were reviewed in-depth and summarized in this report for possible inclusion in the run reconstruction model (Connors et al. 2022).* Table lists project labels that will be used throughout report (*Project*), identifies the methods (*SurveyType*) and general location (*Watershed Grouping*). Projects either cover the mainstem Yukon River or a tributary system (*Coverage*), and 1 or more stocks (*Stocks*). *RR* shows whether a project is used in the current run reconstruction model (Connors et al. 2022).

Stock	Coverage	Watershed Grouping	SurveyType	Project	RR
Canada	Mainstem	Mainstem	Sonar	EagleSonar	Yes
Canada	Mainstem	Mainstem	MR	BorderMR	Yes
Canada	Mainstem	Mainstem	MR	RadioMRCanada	Yes
Canada	Tributary	Yukon River North Mainstem	Sonar	KlondikeSonar	No
Canada	Tributary	White	Aerial	TincupAerial	Yes
Canada	Tributary	Pelly	Sonar	PellySonar	No
Canada	Tributary	Pelly	Weir	BlindCreekWeir	Yes
Canada	Tributary	Pelly	Aerial	RossAerial	Yes
Canada	Tributary	Carmacks Area Tribs	Various	TatchunSurveys	Yes
Canada	Tributary	Carmacks Area Tribs	Weir	TatchunWeir	No
Canada	Tributary	Carmacks Area Tribs	Aerial	LittleSalmonAerial	Yes
Canada	Tributary	Carmacks Area Tribs	Sonar	BigSalmonSonar	Yes
Canada	Tributary	Carmacks Area Tribs	Aerial	BigSalmonAerial	Yes
Canada	Mainstem	Yukon River Headwaters	Fishway	WhitehorseFishway	Yes
Canada	Tributary	Yukon River Headwaters	Sonar	TakhiniSonar	No
Canada	Tributary	Yukon River Headwaters	Aerial	TakhiniAerial	Yes
Canada	Tributary	Teslin Headwaters	Sonar	TeslinSonar	No
Canada	Tributary	Teslin Headwaters	Aerial	NisutlinAerial	Yes
Canada	Tributary	Teslin Headwaters	Aerial	WolfAerial	Yes
Canada	Porcupine	Porcupine	Sonar	PorcupineSonar	No

Table 8. *Yukon Chinook salmon assessment projects operated in the Lower and Middle portions of the Yukon River drainage that were identified through the data review process and discussed by the EGSC, but were not reviewed in depth or used in the run reconstruction model (Connors et al. 2022)*. Reasons included (1) data not readily available, (2) raw data considered poor quality or inconsistent over time, (3) low priority for current run reconstruction model, (4) time series too short within the model time range.

Stock	Project	Comment
All	Lower Yukon Test Fishery	Many years missing catch data for drift, set or both. Only have daily CPUE data
Lower	Anvik Sonar	Project directed on Summer chum. Observe a small numbner of Chinook, but difficult to appportion species.
Lower	Marshall Test Fishery	Operated for several years. Data not yet in available in digital format.
Lower	South Fork Koyukuk weir	Not included because only a very short dataset was available
Middle	Rampart Rapids	Most CPUE data is not useful for run reconstructions. Rapids TFW from 2000-2011 chinook salmon CPUE compared to Border passage has an R2 of 0.13. Most years CPUE projects match up with timing but there have been extreme high water events that stacks fish up. Rapids is a an area particularly prone to this since the water is flowing through a canyon of rock and water velocities become so great even barges have to wait it out to pass.
Middle	Chatanika River Surveys	Tower from 1998 to 2005. Also has aerial and boat surveys off and on since 1980 and a M/R project in 1997. Estimates ranged from a few hundred to few thousand fish. Data not readily available and considered low priority for run reconstruction.
Middle	Tanana River sonar	Not included because only a very short dataset was available
Middle	Goodpaster intensive surveys	Goodpaster tower and aerial surveys are documented in this report. Intensive surveys conducted as part of the Pogo gold mine environmental assessments are not included, because they do not provide a consistent time series for run reconstruction.
Middle	Manley Fish Wheel	Operated for several years. Data not yet in available in digital format.
Middle	Nenana Fish Wheel	Operated for several years. Data not yet in available in digital format.
Middle	Sub 5-A Fish Wheel	Operated for several years. Data not yet in available in digital format.
Lower or Middle	Other	Unless otherwise noted elsewhere in this report, a comprehensive data review was not conducted for projects identified in ADF&G OceanAK databased with a max count less than 1,000 fish. In general, U.S. tributary assessment projects with small abundance counts (especially when combined with infrequent survey coverage) were considered low priority and unlikely to provide meaningful information for estimating Canadian-origin Chinook abundance.

Table 9. *Yukon Chinook salmon assessment projects operated in Canada that were identified through the data review process and discussed by the EGSC, but were not reviewed in depth or used in the run reconstruction model (Connors et al. 2022).* Reasons included (1) data not readily available, (2) raw data considered poor quality or inconsistent over time, (3) low priority for current run reconstruction model, (4) time series too short within the model time range.

Stock	Project	Comment
Canada	Chandindu Weir	Issues with high water levels leading to an incomplete dataset over a relatively short time period. Operated from 1998-2003.
Canada	Klondike Sonar	Not included as short dataset (2009 - 2011, 2020 - current) and operational during period of Eagle Sonar. Currently Trondek Hwechin operated.
Canada	McQuesten Aerial	coverage varied, inconsistent timing of survey
Canada	Pelly Sonar	Not included as short dataset (2009 to current) and operational during period of Eagle Sonar. Selkirk First Nation project.
Canada	Takhini Sonar	Not included as short dataset (2017 & 2018, resuming 2021 - Kwanlin Dun First Nation) and operational during period of Eagle Sonar.
Canada	Michie Creek Weir and Foot Surveys	Various types of enumeration including weir (1993, 1994, 1998, 1999) and redd counts (2004-current), but short datasets and above the Whitehorse Rapids Dam. Relatively small number of spawners enumerated. Project led by Kwanlin Dun First Nation.
Canada	Wolf Creek Weir	Weir on small tributary above the Whitehorse Rapids Dam. Relatively small number of spawners enumerated. Operated for short period in 1990s.

2.6 Standardized Data Structure

For each project, 3 data files were compiled in *csv* format:

- *Data* file: lists annual estimates, with error bounds where available, and includes a header with some clarification information (Figure 2). In *R*, the header information is stripped out by using the argument `comment.char = "#"` when reading in the files with `read.csv()`.
- *DataConcerns* file: lists any potential data issues, in 2 columns (*Years_Affected*, *Potential_Issue*).
- *OperationalChanges* file: lists any major modifications to the survey program, in 3 columns (*Years*, *Component*, *Change_Event*).

This structure allows for de-centralized development and maintenance of the project data in individual *csv* files that can be easily shared with contributors (small file size, only provide relevant files), while feeding into an automated data processing step that combines all the data into a single file for subsequent analyses (e.g., run reconstruction model input).

In addition, having the data concerns and operational changes in *csv* format makes it possible to automate the generation of the corresponding tables in this report via the *csasdown* package (Anderson et al. 2021).

	A	B	C	D	E	F	G	H	I	J
1	# Annual estimates run size of adult Chinook salmon larger than X at Pilot Station Sonar									
2	# Overview of site and methods at http://www.adfg.alaska.gov/index.cfm?adfg=sonar.site&site=12									
3	# Year = Run year									
4	# Estimate = run size									
5	# SE = Standard Error calculated based on INSERT									
6	# p10 and p90 = 10th abd 90th percentiles of the ?posterior distribution?									
7	Year	Estimate	SE	p10	p90					
8	1986	169067	NA	NA	NA					
9	1987	116126	NA	NA	NA					
10	1988	120656	NA	NA	NA					
11	1989	91545	NA	NA	NA					
12	1990	156097	NA	NA	NA					
13	1991	75676	NA	NA	NA					
14	1993	134854	NA	NA	NA					
15	1994	141795	NA	NA	NA					
16	1995	221357	18313	191232	251482					
17	1997	199763	20535	165983	233543					
18	1998	108038	51703	22986	193090					
19	1999	184218	57953	88886	279550					
20	2000	54560	6601	43702	65418					
21	2001	121089	9106	106109	136069					
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					

Figure 2. Illustration of Standardized Data Structure

2.7 Data Units

This data review document used a mixture of metric and imperial measurement systems and geographic coordinate systems. No effort was made to standardize measurement or coordinate systems throughout this document. Instead, we chose to present the data review materials using the systems and units used by each project that was reviewed. This ensured that the information presented in this document could be readily compared to source documentation, was truer to the review process we undertook, and prevented the potential for conversion errors.

Throughout this document, some project reviews include reference to the right or left back of a river when describing aspects of project operations. In all cases, the riverbank being referred to is based on a downriver-facing orientation.

3 Results

3.1 Available Data

Data have been compiled in this report for 21 projects in the U.S. part of the Yukon River basin (Table 10) and for 20 projects in the Canadian part of the basin (Table 11). Note that Eagle sonar is in the U.S., but focuses on border passage estimates of the Canadian mainstem stock, and is therefore included with the Canadian projects.

Also note that some projects are mainstem assessments (e.g. Eagle sonar covers all the Canadian stock except Porcupine), while the rest cover tributaries, or parts of tributaries, and in some cases, there are several surveys covering the same system (e.g., Andreafsky weir and Andreafsky aerial).

Survey projects have run for different time periods, and with variable consistency (Figure 3). Combined, the two key mainstem assessments located near Pilot Station (in the lower portion of the Yukon River) and at the U.S. / Canada border provide estimates back to the 1980's, although methods have changed over that time. For example, the Pilot Station sonar project began in the mid-1980's and provided only an index of run abundance until the mid-1990's, after which methods have been standardized and passage estimates were considered accurate. Similarly, passage estimates into Canada began in the early 1980s using mark-recapture methods which were known to be an underestimate until the mid-2000's when sonar methods were used to generate accurate passage estimates. Some tributary projects have generated long, consistent time series (e.g., Salcha tower/weir and Whitehorse fishway), while many other tributary projects have either very short time series (e.g., Klondike sonar and Teslin sonar) or have been discontinued (e.g., Goodpaster aerial and Nisutlin aerial).

Table 10. *Overview of Available Data - Lower and Middle Yukon*. *Project* is the unique project label used throughout this report, identifying survey location and method (e.g. weir, aerial). Projects with variable methods are labeled simply as “surveys.” Tributary projects in the table are listed moving upstream from the mouth of the river, based on confluence with the mainstem (Figure 1). The summary columns show the number of annual estimates available for the project (*NumEst*), number of estimates with an associated confidence interval, expressed as a coefficient of variation (*NumCV*), and the range of years covered by estimates (*FirstYr*, *LastYr*). Blank rows indicate projects that were included in the inventory for completeness, but the data have not yet been compiled into the standardized format described in Section 2.6. Note that the mainstem mark-recapture program in the lower river (*MRMainstem*) produced various estimates (e.g., drainage wide, Tanana etc.), but only the Total Run estimate is included in the data summaries in this report. Note that some of the available estimates are not currently used due to data concerns (Figure 3).

Stock	Coverage	WS Grouping	SurveyType	Project	NumEst	NumCV	FirstYr	LastYr
All	Mainstem	Mainstem	Sonar	PilotStation	32	24	1986	2019
All	Mainstem	Mainstem	MR	MRMainstem	5	5	2000	2004
Lower	Tributary	Andreafsky	Weir	AndreafskyWeir	25	25	1994	2019
Lower	Tributary	Andreafsky	Aerial	AndreafskyEastAerial	48	0	1961	2019
Lower	Tributary	Andreafsky	Aerial	AndreafskyWestAerial	55	0	1962	2019
Lower	Tributary	Anvik	Aerial	AnvikAerial	51	0	1961	2019
Lower	Tributary	Nulato	Various	NulatoTowerWeir	9	0	1994	2003
Lower	Tributary	Nulato	Aerial	NulatoNorthForkAerial	35	0	1961	2019
Lower	Tributary	Nulato	Aerial	NulatoSouthForkAerial	37	0	1961	2019
Lower	Tributary	Koyukuk	Various	GisasaTowerWeir	23	23	1995	2019
Lower	Tributary	Koyukuk	Aerial	GisasaAerial	35	0	1961	2018
Lower	Tributary	Tozitna	Weir	TozitnaWeir	9	0	2001	2009
Lower	Tributary	Tozitna	Aerial	TozitnaAerial	18	0	1985	2012
Middle	Tributary	Koyukuk	Weir	HenshawWeir	17	0	2000	2019
Middle	Tributary	Tanana	MR	RadioMRTanana	3	3	2002	2004
Middle	Tributary	Tanana	Various	ChenaSurveys	31	31	1986	2018
Middle	Tributary	Tanana	Aerial	ChenaAerial	31	0	1974	2014
Middle	Tributary	Tanana	Various	SalchaSurveys	31	30	1987	2018
Middle	Tributary	Tanana	Aerial	SalchaAerial	49	0	1960	2015
Middle	Tributary	Tanana	Tower	GoodpasterTower	15	11	2004	2018
Middle	Tributary	Tanana	Aerial	GoodpasterAerial	16	0	1990	2007

Table 11. *Overview of Available Data - Canada*. Table layout as per Table 10.

Stock	Coverage	WS Grouping	SurveyType	Project	NumEst	NumCV	FirstYr	LastYr
Canada	Mainstem	Mainstem	Sonar	EagleSonar	15	15	2005	2019
Canada	Mainstem	Mainstem	MR	BorderMR	27	16	1982	2008
Canada	Mainstem	Mainstem	MR	RadioMRCanada	3	3	2002	2004
Canada	Tributary	Yukon River North Mainstem	Sonar	KlondikeSonar	4	0	2009	2020
Canada	Tributary	White	Aerial	TincupAerial	16	0	1983	2001
Canada	Tributary	Pelly	Sonar	PellySonar	5	0	2016	2020
Canada	Tributary	Pelly	Weir	BlindCreekWeir	19	0	1995	2018
Canada	Tributary	Pelly	Aerial	RossAerial	18	0	1968	2005
Canada	Tributary	Carmacks Area Tribs	Various	TatchunSurveys	29	0	1966	1998
Canada	Tributary	Carmacks Area Tribs	Weir	TatchunWeir	4	0	1997	2000
Canada	Tributary	Carmacks Area Tribs	Aerial	LittleSalmonAerial	40	0	1968	2011
Canada	Tributary	Carmacks Area Tribs	Sonar	BigSalmonSonar	16	0	2005	2020
Canada	Tributary	Carmacks Area Tribs	Aerial	BigSalmonAerial	44	0	1968	2011
Canada	Mainstem	Yukon River Headwaters	Fishway	WhitehorseFishway	63	0	1958	2020
Canada	Tributary	Yukon River Headwaters	Sonar	TakhiniSonar	2	2	2017	2018
Canada	Tributary	Yukon River Headwaters	Aerial	TakhiniAerial	29	0	1958	2018
Canada	Tributary	Teslin Headwaters	Sonar	TeslinSonar	4	0	2012	2015
Canada	Tributary	Teslin Headwaters	Aerial	NisutlinAerial	43	0	1968	2020
Canada	Tributary	Teslin Headwaters	Aerial	WolfAerial	38	0	1970	2020
Canada	Porcupine	Porcupine	Sonar	PorcupineSonar	6	0	2014	2019

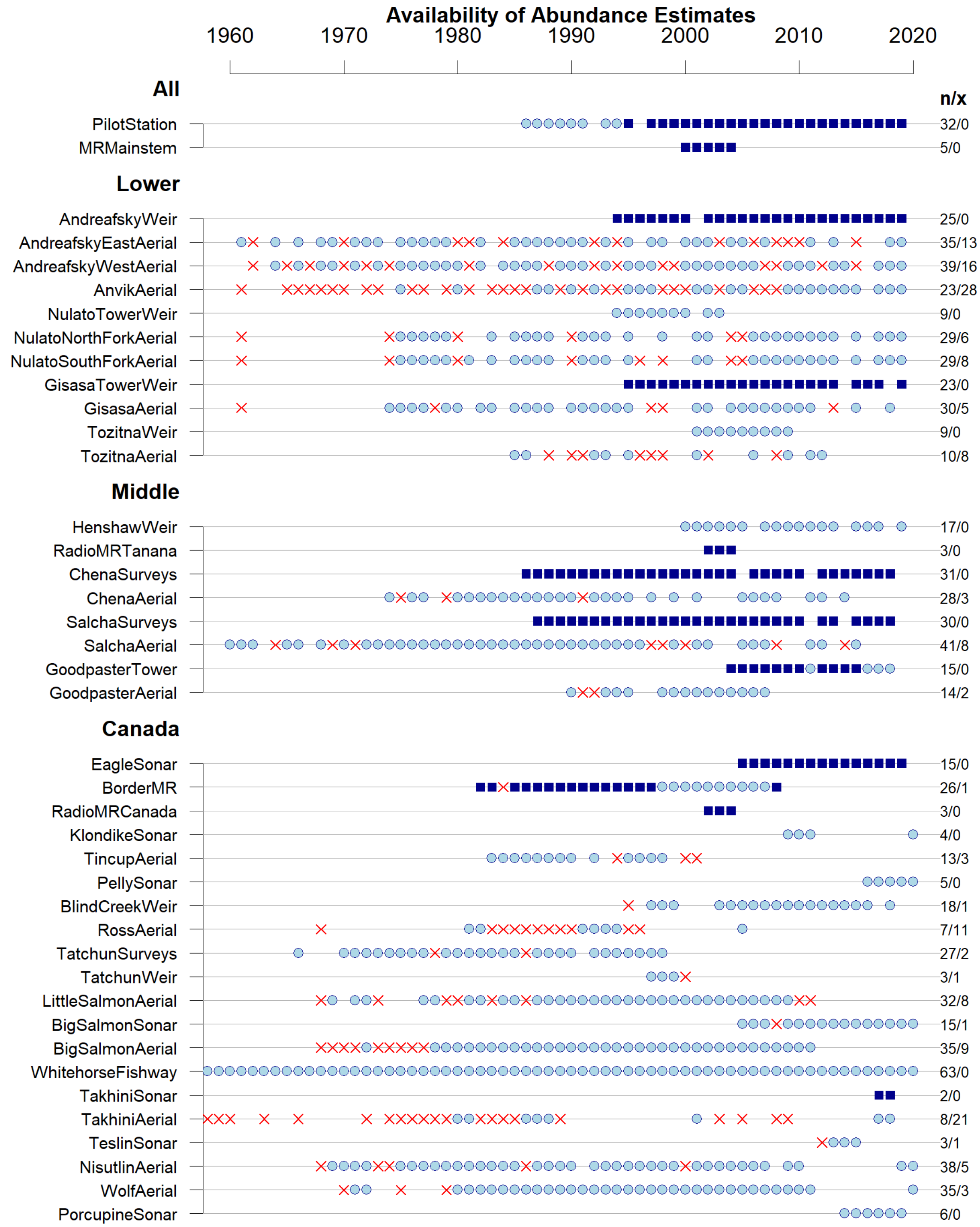


Figure 3. *Timeline of Available Data*. Horizontal lines show the timeline of available estimates summarized in Tables 10 and 11. Dark blue squares mark years where estimates have upper and lower bounds. Light blue circles are years where point estimates are available. Any estimates that are available, but currently not used due to data concerns, are marked with a red "x." Numbers on the right margin show currently used (*n*) and t not currently used (*x*) observations as *n/x*.

3.2 Overview of Observed Patterns

Run size estimates from the Pilot Station sonar program in the lower river are a key achor point for the Yukon River Chinook salmon run reconstruction analysis. Pilot Station abundance estimates have been variable, with low abundances in 2000 and the early 2010s, but without the persistent recent decline in run size observed in many other Pacific salmon stocks (Figure 4).

Harvests in U.S. and Canadian fisheries have varied substantially (Figure 7), but the relative total Yukon River Chinook salmon harvests between the countries has been very stable since the 1980s (Figure 8). The shift from commercial to subsistence fisheries in U.S. harvests was accompanied by a shift in harvest monitoring approach (Appendix B).

Annual stock composition at Pilot Station sonar has been quite stable historically with a rough split of 40% Lower, 20% Middle, and 40% Canadian stock (Figure 9). The stock composition does shift throughout the season, with the early portion of annual runs made up primarily of Middle and Canadian and Middle Yukon stocks and later portions of the annual runs made up of mostly Lower Yukon stock.

Stock composition of U.S harvests differs by fishery type (i.e., commercial vs. subsistence), but has been fairly stable over time for each type of fishery (Figure 10). Most of the U.S. sport fishery harvest occurs in the Tanana watershed, so the entire sport harvest is assigned to the Middle Yukon stock in run reconstruction estimates (Figure 11).

Harvest-based age composition estimates are similar for the three stocks, with most Chinook salmon returning at ages 5 or 6 (Figure 12). All three stocks have shifted towards younger ages since the early 2000s, with fewer age 6 and 7, and increasing proportions of ages 4 and 5.

The composition of the Canadian stock, based on genetic stock identification at the border, has varied over time, with most of the returns originating from the Teslin, Pelly, and Middle Mainstem sub-stocks (Figure 13).

Available data and observed abundance patterns vary by project, as summarized in Figure 6. The appendices include detailed data summaries and project descriptions.

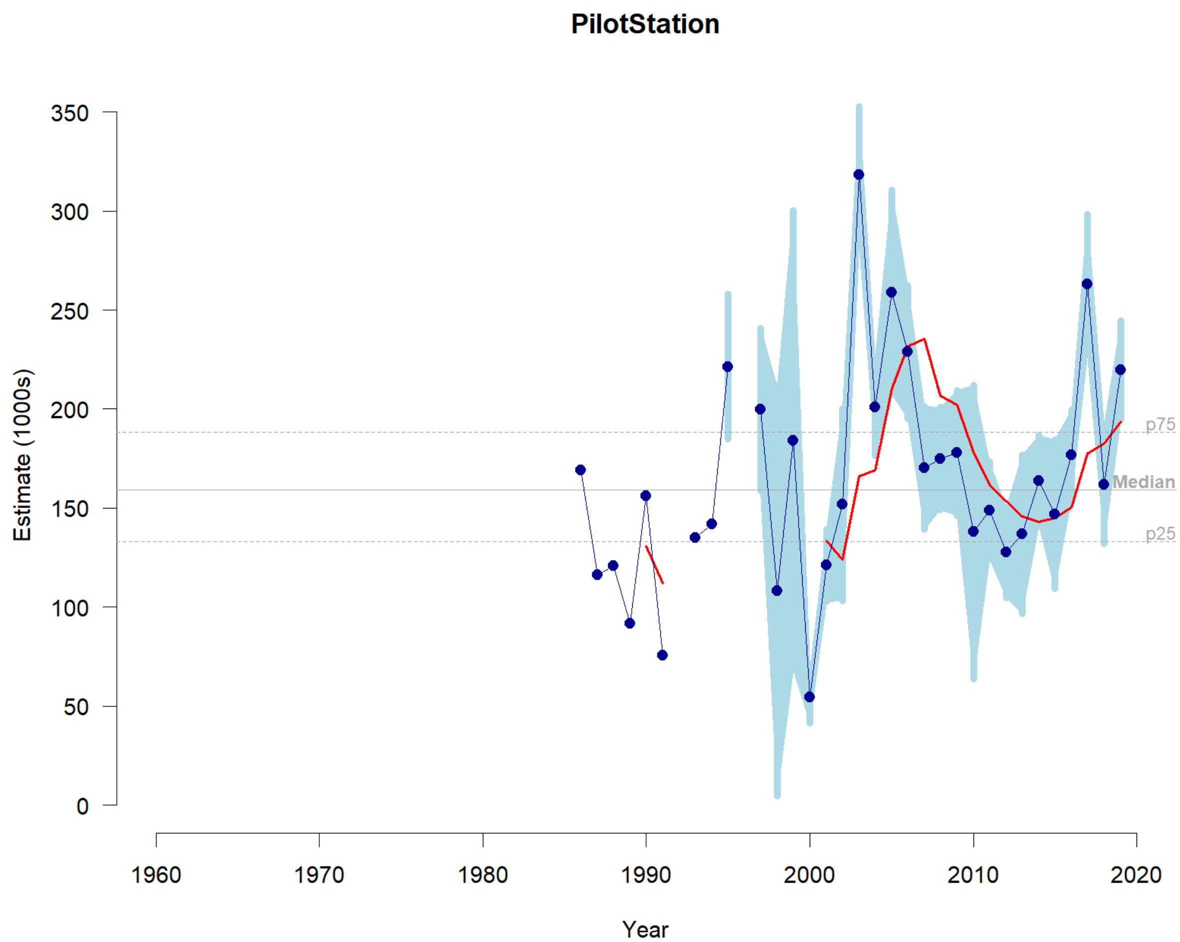
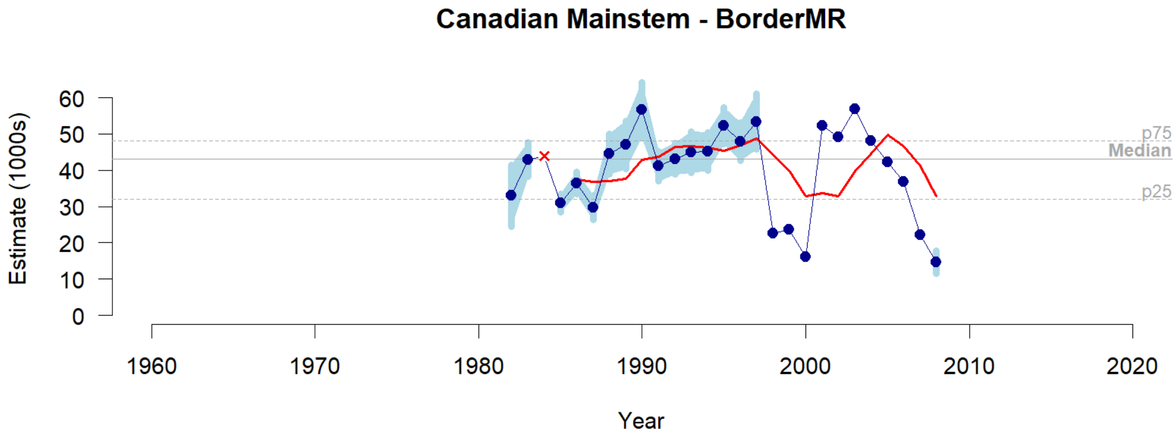


Figure 4. *Pattern in Run Size Estimated at Pilot Station*. For project context and estimate details, refer to Section E.2. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.



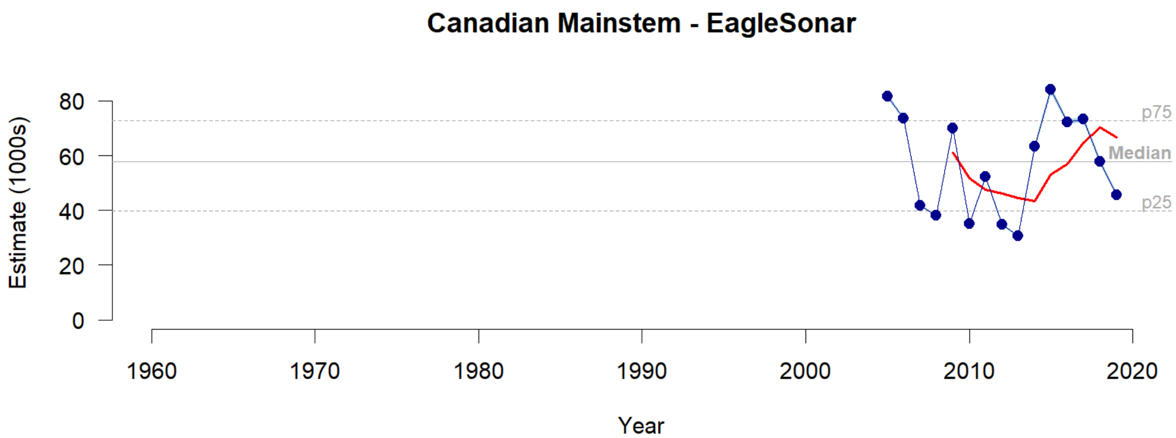


Figure 5. *Pattern in Abundance Estimates for Canadian Mainstem Border Passage*. For project context and estimate details, refer to the corresponding section of Appendix H.Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

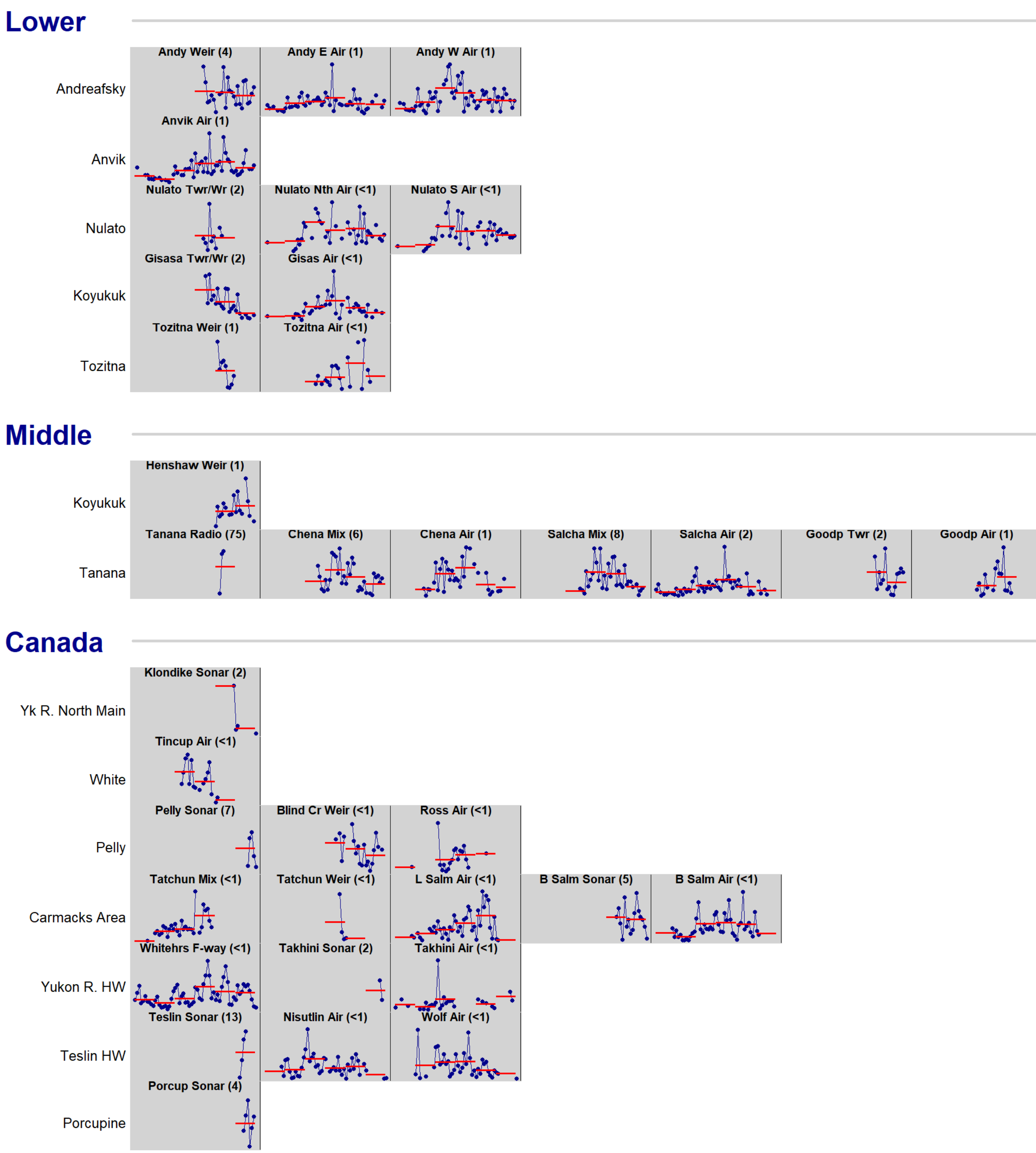


Figure 6. *Pattern in Abundance for Remaining Survey Projects in this Report (Tributaries and Headwaters).* Projects are organized by *Watershed Grouping* (Tables 6 and 7). Sparkline panels are stacked like a horizontal bar chart to highlight survey coverage across watersheds. Each panel shows the time series of annual estimates (blue line) and the mean for each decade with data (red horizontal bars). Panels are labelled with a short project label and the mean of all available estimates in 1,000s of fish.

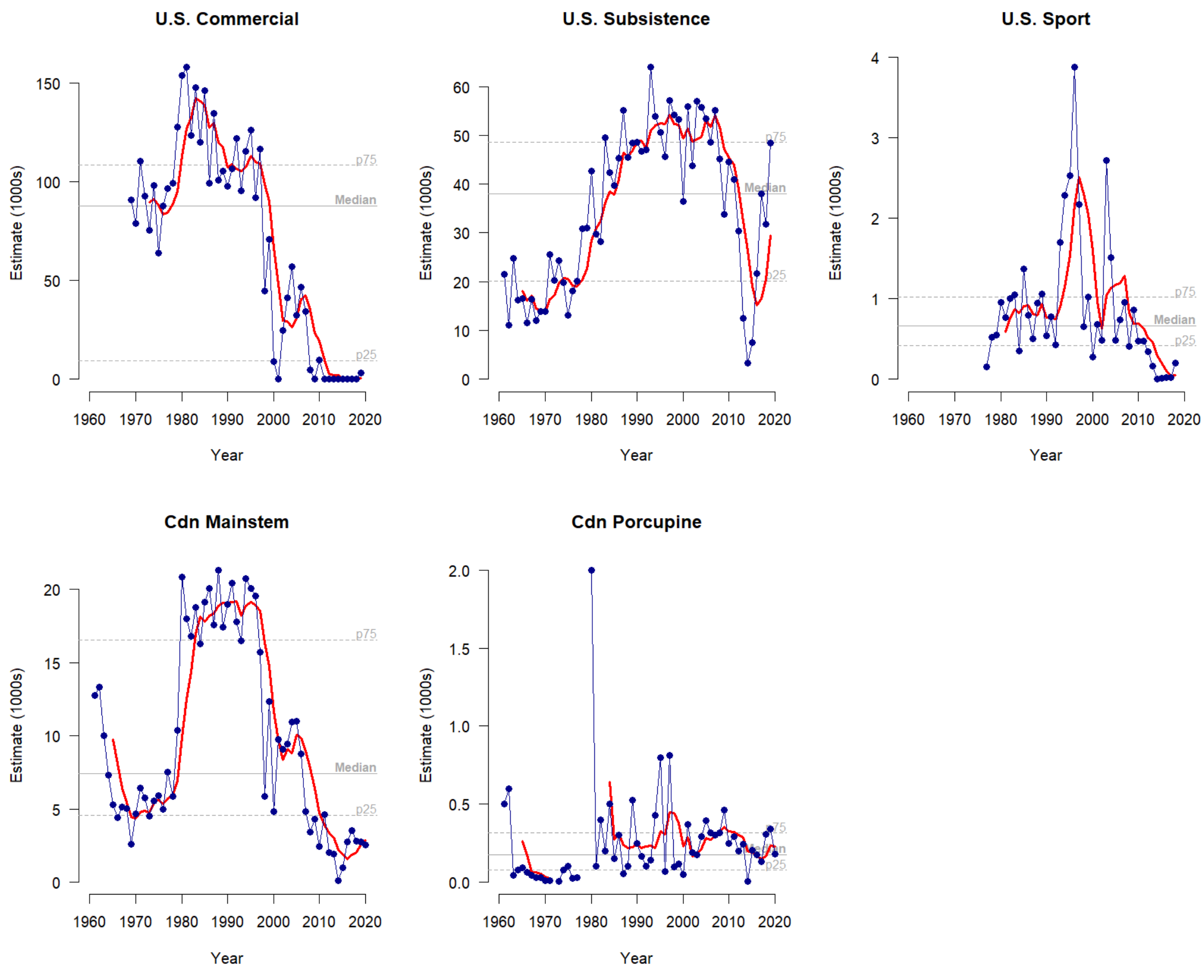


Figure 7. *Pattern in Total Harvest (All Stocks) by Country and Type*. Figure shows annual estimates (points) and 5-yr running average. U.S. Commercial harvests are estimated from fish tickets, U.S. sport harvests with a mail survey, and U.S. subsistence harvests (including coastal district and personal use harvests) from a household survey (Appendix B). Canadian harvest estimates are presented by area as the total of commercial, domestic, recreational, and First Nations harvests. Canadian estimates are based on licence reporting requirements for commercial and angling harvests, and a combination of reported harvest and observed catch proportions for First Nations harvests (Appendix C). Annual harvests for 4 of the 5 fisheries have varied substantially over time. U.S. Commercial, U.S. Sport, and Cdn. Mainstem all peaked in the 1980s/1990s, and declined to very small numbers in recent years. U.S. Subsistence peaked in the 1990s and early 2000s, then dropped to very low levels in the early 2010s, with increases in recent years. Note that U.S. harvest includes Lower, Middle, and Canadian stock (including Porcupine), while Canadian harvest includes on Canadian stock (mainstem and Porcupine). Note that U.S. Subsistence harvest includes only Yukon River harvests (excluding coastal area harvests). Red trend line shows the 5-yr running average.

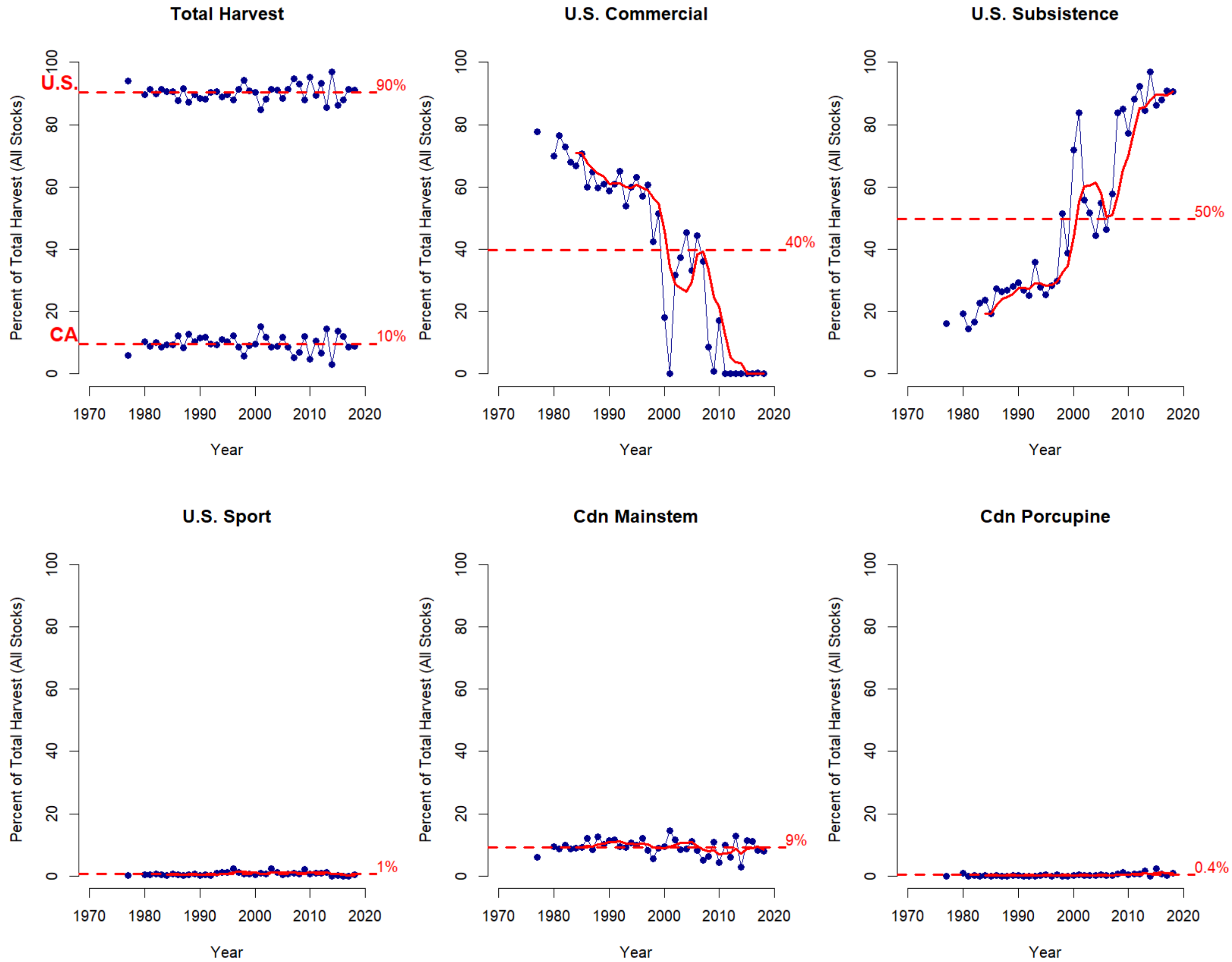


Figure 8. *Percent of Total Harvest (All Stocks) by Country and Type*. Panels show each component's percent contribution to the total harvest of all 3 stocks (Lower, Middle, Canada), for those years where all 5 components have estimates. U.S. fisheries, which access all 3 stocks, consistently account for most of the total harvest, with the percent U.S. harvest becoming a bit more variable in recent years (top left panel). U.S. harvests have shifted over time from mostly commercial to mostly subsistence, with U.S. Sport harvests accounting for a very small proportion. Canadian fisheries access only the Canadian stock, mostly in the mainstem. Canadian harvest estimates are presented by area as the total of commercial, domestic, recreational, and First Nations harvests. Note that U.S. Subsistence harvest includes only Yukon River harvests (excluding coastal area harvests). Red trend line shows the 5-yr running average.

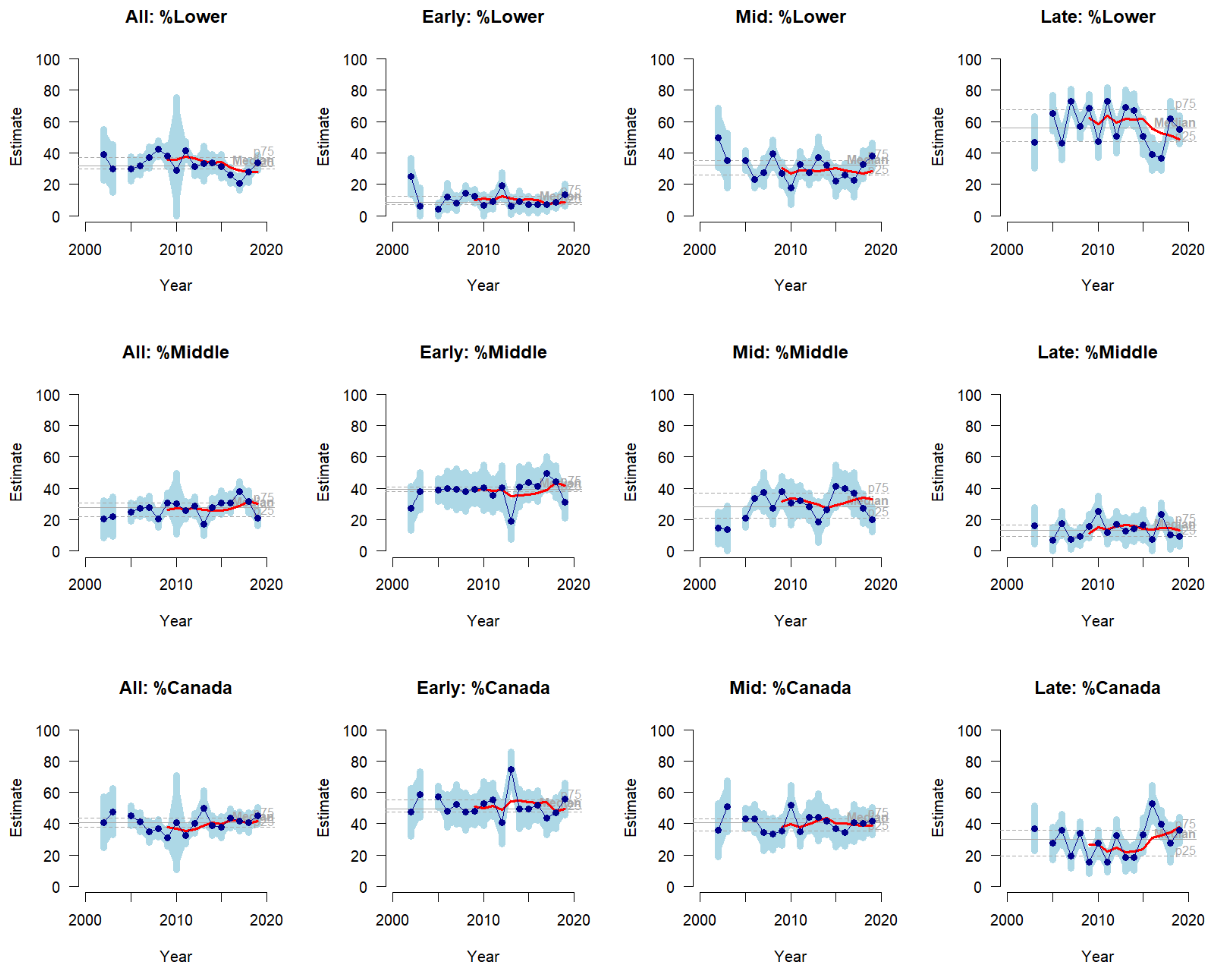


Figure 9. *Stock Composition of Returns at Pilot Station*. Annual returns are split into 3 standardized timing strata for stock composition estimates, but dates vary from year to year. Uncertainty bounds (shaded area) reflect stock ID sample sizes and noise in the data. The level of uncertainty differs by stock, time period and stratum. Stock composition follows the typical pattern for large basins, with stocks that migrate further upstream returning earlier (i.e. late stratum is mostly Lower Yukon stock, largest contribution of Canadian stock is in the early stratum). 2010 estimates are highly uncertain due to sampling issues (Table D.2). Note that 2006 had a 4th stratum, which captured a small part of the run and is not included here. Figure shows annual estimates (points), 5-yr running average (red line), and confidence interval (± 2 standard errors) based on reported coefficients of variation for the annual estimates.

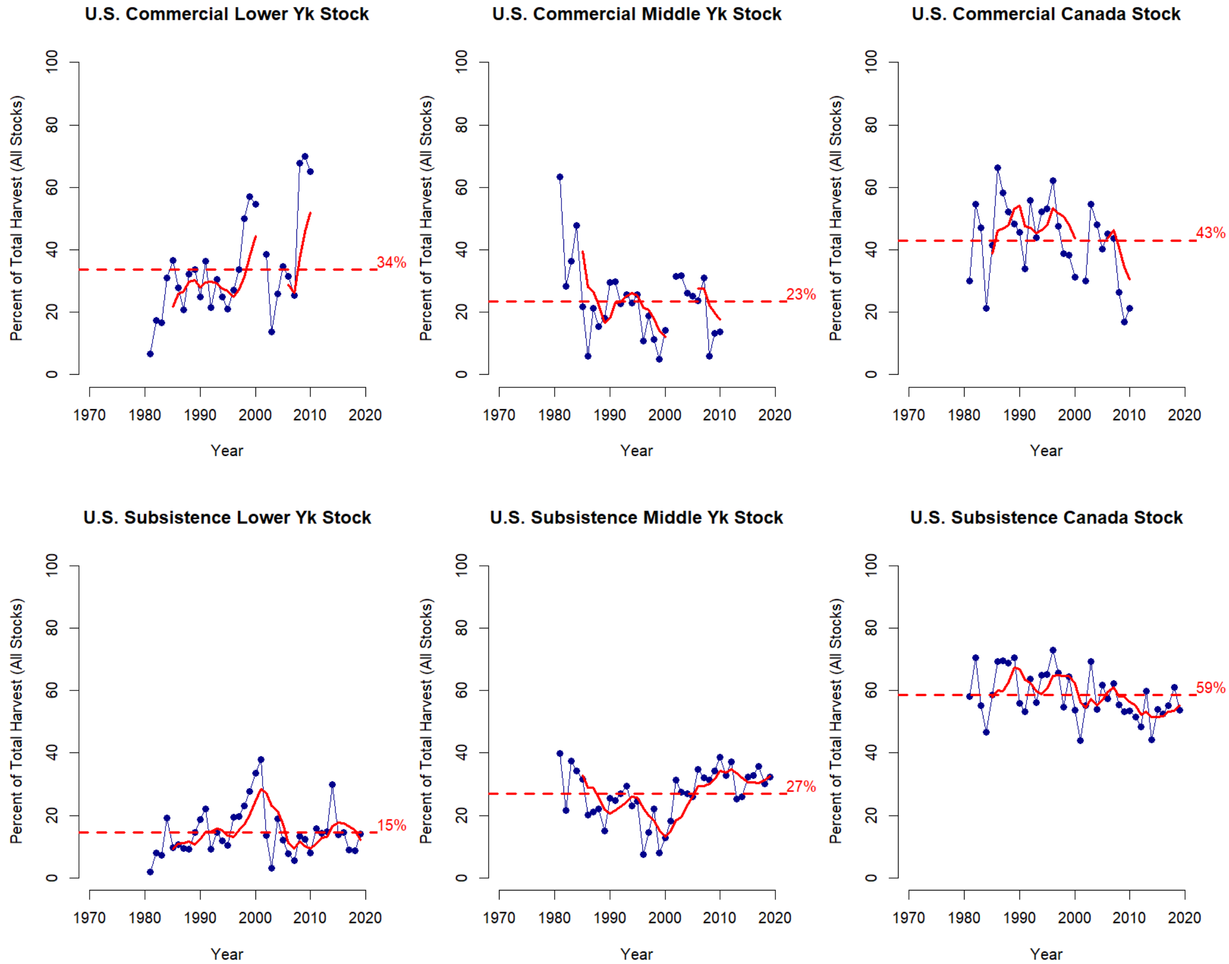


Figure 10. *Stock Composition of U.S. harvest by Type*. Stock composition differs by fishery type and varies over time. About half of the U.S. Commercial harvests are Canadian stock. The remaining U.S. Commercial harvest is split between Lower Yukon stock and Middle Yukon stock, but shifting towards a larger proportion of Lower Yukon stock as total U.S. Commercial harvest declined (Figure 8). U.S. Subsistence harvest is about 2/3 Canadian stock, with a gradual shift towards Lower Yukon and Middle Yukon stock harvests over time. U.S. Sport harvests are primarily in the Tanana watershed (District 6), and are all assigned to the Middle Yukon stock (Figure 11). Red trend line shows the 5-yr running average.

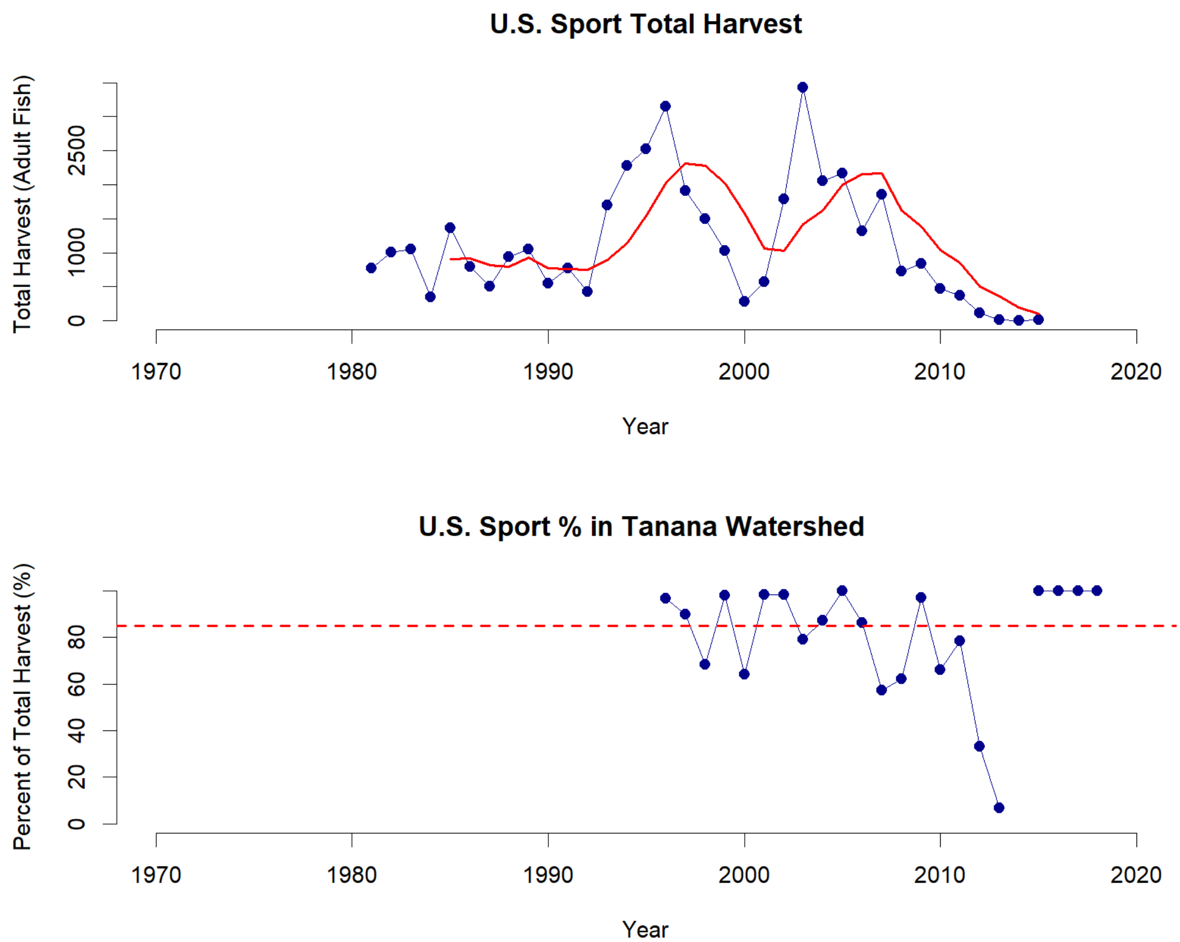


Figure 11. *U.S. Sport Fishery Patterns*. Total harvests are small relative to other U.S. harvest (top) and most of the harvest occurs in the Tanana watershed (bottom; horizontal red line shows mean % of harvest in Tanana, weighted by total U.S. sport harvest). Based on this observation, the entire U.S. sport harvest is assigned to the Middle Yukon stock. Red trend line in top panel shows the 5-yr running average.

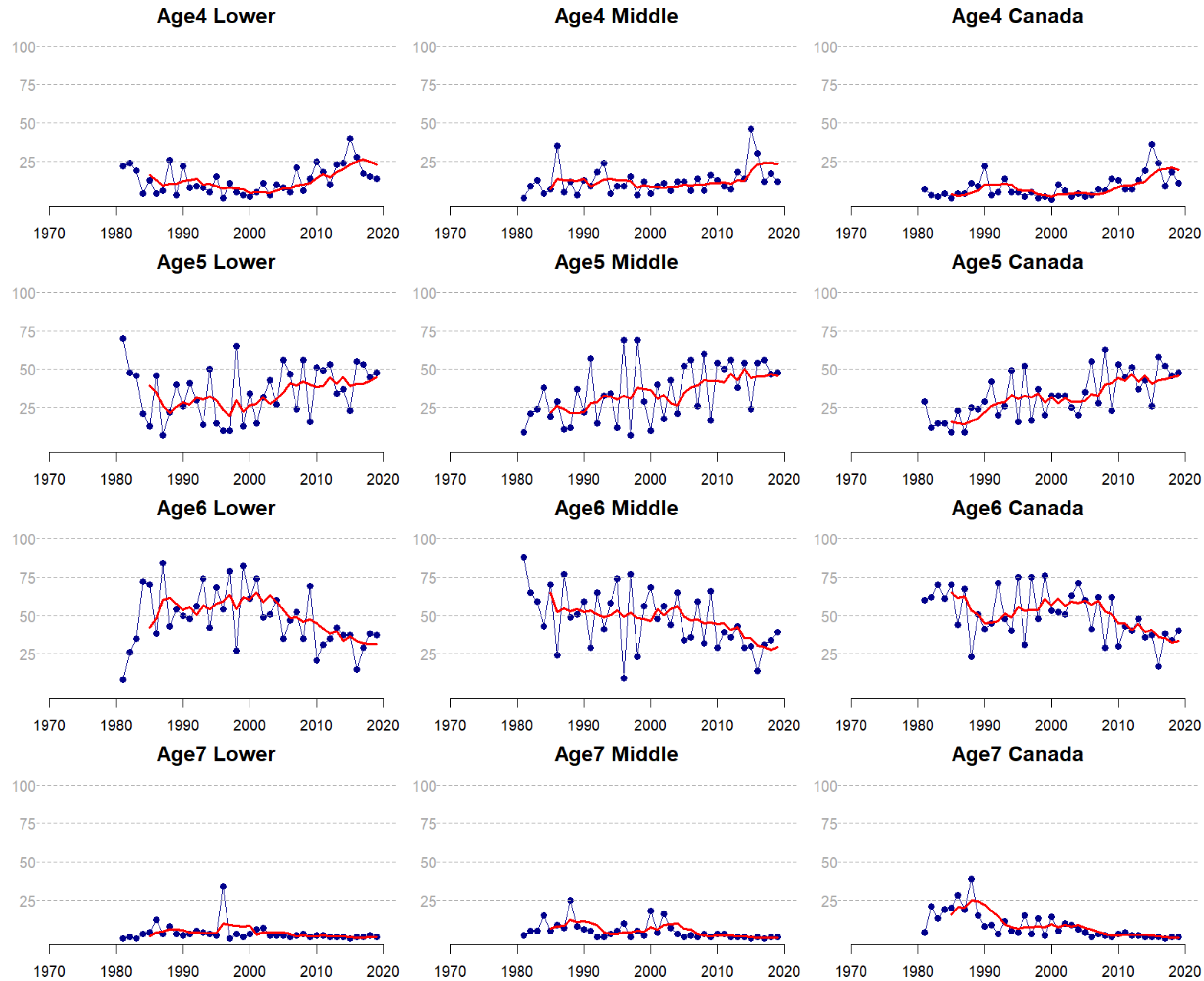


Figure 12. *Annual Age Composition in Total Harvest By Stock.* Age composition of harvested fish combined across countries. Red trend line shows the 5-yr running average. Harvests of all three stocks are shifting towards younger fish, from mainly Age 6 to mainly Age 5, and an increasing proportion of Age 4. The Canadian harvest had a substantial component of Age 7 fish in the 1980s (ca. 25%), which decreased in the 1990s, and essentially disappeared in the early 2000s. There have been major gear shifts in all fisheries that drive the observed patterns. The same age composition shifts are observed in the total run as well, but less pronounced when changes in fishery gear and timing are accounted for.

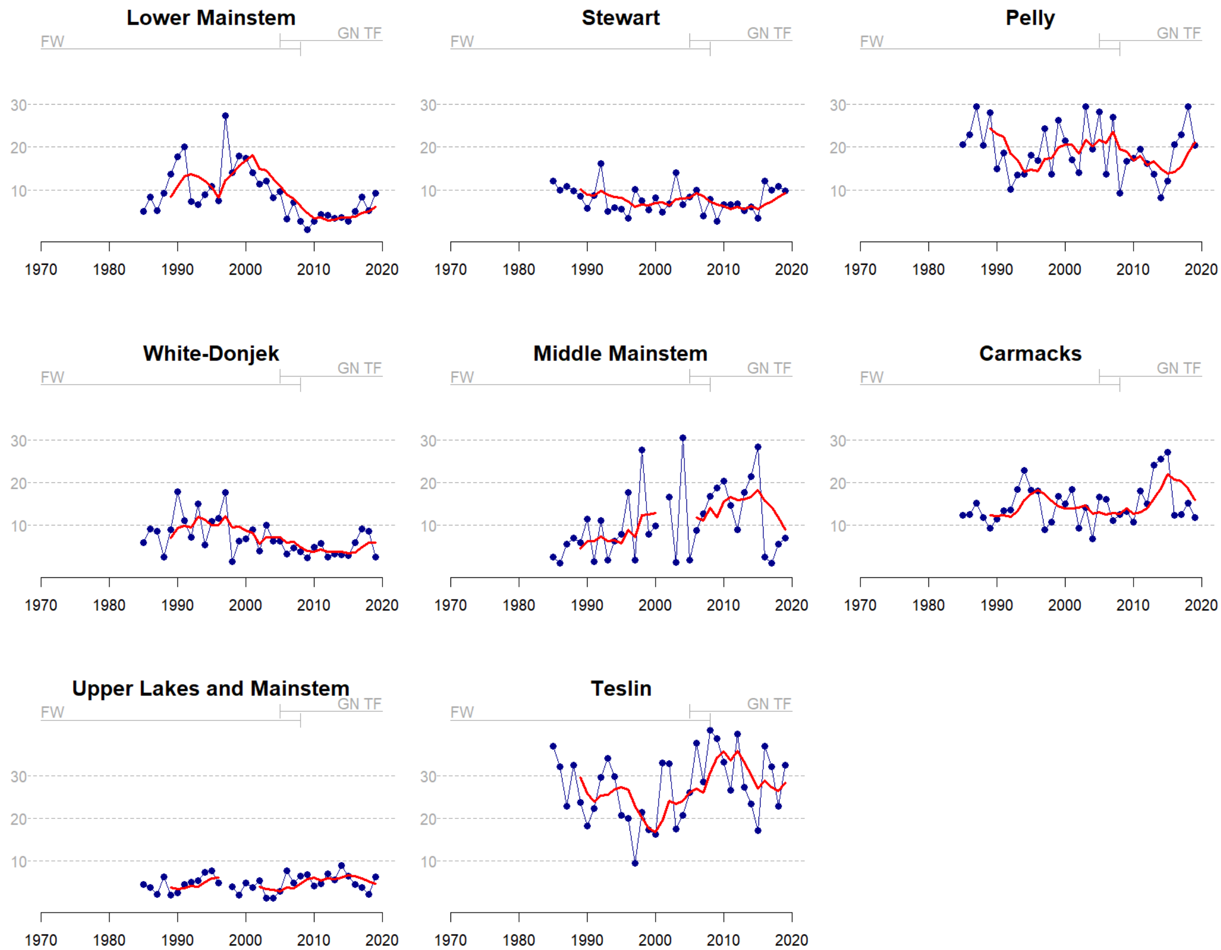


Figure 13. *Genetic Stock Composition at the Border*. Estimates for Canadian sub-stocks from Connors et al. (2019). Red trend line shows the 5-yr running average. Horizontal reference lines mark 10%, 20%, and 30% of the total run. The median of individual assignment probabilities for each year ranged from 53p to 79p with a median annual assignment probability of 63p (5th and 95th percentile values are 55p and 76p; respectively). Data used comes from fish wheels (FW) at White and Sheep rocks up to 2008, and from the gill net test fishery at Eagle (GN TF) since 2005.

4 Discussion

4.1 Scoping Decisions Made

4.1.1 Key data sets for inclusion in the multi-stock run reconstruction model

The EGSC recommends using all data sets identified in Appendix A of Hamazaki (2021) as inputs for multi-stock run reconstruction model purposes. This recommendation includes 3 datasets germane to abundance at the U.S./Canada border, and 10 datasets representing 9 individual tributaries in Canada. This recommendation also includes 5 datasets representing 3 Middle Stock tributaries and 9 datasets representing 4 Lower Stock tributaries. All datasets were revised consistent with the best available estimates as documented in published project report or as indicated by the responsible agencies/investigators. This revision process resulted in minor deviations from the annual abundance estimates used by Hamazaki (2021). The EGSC recommends using the revised datasets presented in this review.

Specific to the Tatchun River surveys in Canada, the EGSC recommends a notable change compared to Hamazaki (2021). From 1966 until 2000, various methods were used to assess Chinook salmon abundance within the Tatchun River. Foot surveys (n=27) were by far the most common method used, but estimates from aerial (n=1), boat (n=1), and weir (n=4) are also available. Hamazaki (2021) treated all survey types equally and categized them as foot surveys. The EGSC recommends not using the aerial or boat survey data. Two years of overlap indicate the foot survey accounts for only a fraction (approximately 25%) of the weir count. As such, EGSC recommends the foot survey data be separated from the weir survey data, and only the foot survey dataset be used as input to the run reconstruction at this time.

In addition to the projects identified by Hamazaki (2021), the EGSC recommends that the Tozitna River aerial and weir datasets (Lower River stock) and Takhini River aerial (Canada stock) be incorporated into the run reconstruction model framework. These projects indexed a notable number of Chinook salmon and had relatively long datasets that were readily available. No other new datasets are recommended for multi-stock run reconstruction purposes at this time.

The EGSC discussed the potential value of including survey data associated with the Goodpaster River (Middle stock), Chatanika River (Middle stock), and various test fishery projects operated along the Yukon River mainstem in Alaska. However, data were not readily available (Chatanika River), still under agency review for inclusion in electronic databases (test fisheries), or the most appropriate estimates to use were not clarified through our review efforts (Goodpaster River). These projects should be considered for future incorporation after additional data review and standardization is complete. U.S. test fishery projects may provide relevant information on Chinook salmon abundance and run timing and should be considered further once all data are made available in digital format.

The EGSC also discussed the potential value of including relatively short-duration datasets in the U.S. (e.g., Tanana River sonar/mark-recapture) and Canada (e.g., weir: Chandindu River and Wolf Creek; sonar: Klondike, Pelly, Takhini, Porcupine rivers). It was decided that the available short datasets were unlikely to provide substantially more information to improve run reconstruction model estimates. However, several short-term or new Canadian tributary projects should be reconsidered if project operations continue and a longer timeseries of abundance data is available in the future.

4.1.2 Projects with notable operational changes that require special treatment

Our data review reveled that many projects experienced operational changes from time to time. However, most were considered by the EGSC to be aligned with best practices, unlikely to have a meaningful impact on estimates of Canada stock run size, and not requiring of special treatment within a run reconstruction model context. For example, some programs undergo regular review and updates to historical datasets. While we attempted to document these updates in the individual project reviews, the EGSC considered the most recent estimates to be the best available and recommends those data be used. In other situations, a range of methods were used by a single project to assess Chinook salmon abundance, but all methods were appropriate and likely produce comparable estimates. For example, estimates for the Chena and Salcha rivers (Middle stock) represent a complex mix of tower, sonar, and mark-recapture methods, all of which produce estimates of total escapement with arguably similar levels of precision. There were only a few projects recommended for use in the run reconstruction model that has significant operational changes to justify special treatment.

The EGSC recommends that the Pilot Station estimates of abundance be considered separately for the years 1985–1994 and 1995–current. The 1985–1994 period was feasibility and likely represents an underestimate of true abundance. Although there have been regular refinements to project methods throughout 1995–current period, all changes can be aptly described as systematic improvements incorporating new technologies and site-specific best practices as they became available. Infrequent operational challenges suggest that the relative accuracy of the project may change over time. As such the EGSC recommends that Pilot Station estimates be compared to other sources, such as independent mark-recapture studies, to help determine if additional time stratification may be warranted for data weighting purposes.

The EGSC recommends that the Bio Island fish wheel mark-recapture estimates presented in this data review report be used for run reconstruction purposes, and additional uncertainty be considered. The JTC 2021 report presents a timeseries of published historical abundance estimates for the Bio-Island fishwheel mark-recapture project (see Appendix B11, JTC 2021). The EGSC review revealed that different methods were used to calculate abundance over time, some published estimates could not be replicated with available information, and violations of mark-recapture assumptions were likely in some years. Upon further review, it was determined that tag loss was not accounted for in several early years. As such DFO recalculated and provided updated estimates for years 1982, 1983, 1985, 1987, and 1989. The EGSC recommends using the revised estimates provided by DFO and accounting for additional estimation uncertainty within the run reconstruction model.

A variety of studies rely on stock identification methods which have changed over time. Most notably scale pattern analysis was used to determine U.S. harvest stock of origin from 1982–2003 and various genetic mixed stock analysis techniques have been used in harvest and sonar apportionment studies since 2004. Targeted investigations during the transition from one stock separation method to the next revealed stock composition estimates were generally similar regardless of which method was used, albeit different levels of precision exist. As such, the

EGSC does not recommend different treatment of stock proportion data based solely on the stock identification method used.

Pilot Station Sonar and U.S. harvest assessment are the two projects that produce estimates of stock proportion needed for multi-stock run reconstruction, and temporal changes in study design should be considered when determining how best to weight stock proportion estimates within a model context. There have been no substantial changes to the Pilot Station Sonar test fish or genetic sampling programs. Conversely, methods used to estimate U.S. harvest stock proportions have changed over time, but most changes can be aptly described as operational shifts in survey effort to collect representative samples from harvests occurring in different fisheries, locations, and time. As such, the EGSC determined that project specific stock-proportion estimates should be weighted the same throughout time, however, the sensitivity of model results to weighting decisions should be explored.

The EGSC review identified various limitations to stock identification programs. First, historical stock identification techniques have prevented separation of the Canada Porcupine River stock from the Canada Mainstem stock. In 2020, ADF&G developed a new baseline that can separate these two Canadian stock components; however, a full retrospective analysis of historical stock proportion estimates was not possible in time to inform the EGSC work. Second, the proportion of the annual run/harvest that is Canada stock includes fish propagated artificially and released from the Whitehorse Fish Hatchery and other smaller hatchery operations in Canada. Finally, harvest stock sampling was not done in U.S. District 5 prior to 2004, and all Chinook salmon harvested in District 5 were incorrectly assumed to be Canada stock. Separately and in combination, these limitations result in overestimating the proportion of wild Canadian-origin Yukon River Mainstem Chinook Salmon at locations like Pilot Station Sonar and U.S. harvest. The EGSC recommends exploring the implications of overestimating the wild Canada Mainstem stock proportions on the integrated run reconstruction and spawner-recruitment model results.

4.1.3 Consideration of assessment uncertainty and data utilization

The EGSC identified that only a subset of U.S. and Canadian assessment projects produce annual estimates of survey uncertainty. However, there are likely variable uncertainties associated with all annual surveys, and in some cases reported uncertainties may not fully represent the accuracy or precision of the estimates. The EGSC recommends that future run reconstruction models be structured to allow for explicit inclusion of survey uncertainty when that information exists, and a parallel structure to allow for additional uncertainty and data weighting options be developed.

The EGSC recognized that there are many factors that may contribute to the reliability of survey counts/estimates, some which are well documented and other are only known to the responsible agencies/investigators. As such the EGSC recommends that annual survey counts/estimates deemed unreliable by the responsible agencies/investigators should not be used in run reconstruction efforts or should be properly weighted such that the carry limited influence.

4.2 Spatial Coverage of the Compiled Data

Recent work published by Brown et al. (2017) used a variety of sources including published articles, gray literature, and information archived in agency databases to classify Yukon River Chinook salmon spawning areas as major or minor producers. Their work documented 183 spawning areas in the Yukon River basin, 79 in the United States, and 104 in Canada. Of those, 32 were categorized as major producers and 151 were minor producers. Brown et al. (2017) provides a convenient baseline for understanding the spatial coverage of projects reviewed by the EGSC and recommended for inclusion in a multi-stock run reconstruction model.

The mainstem assessment projects recommended by the EGSC indirectly provide information about the abundance of all major and minor Chinook salmon producing tributaries upriver from rkm 197 (i.e., near the community of Pilot Station). In the lower river, the Pilot Station Sonar (1985–2019) and associated genetic stock proportion estimates (2005–2019) provide information about the relative abundance of all tributaries that make up a portion of the Lower stock and the entire Middle and Canada stocks. The five-year (2000–2004) mark–recapture study operated near Russian Mission provides similar information compared to Pilot Station sonar, and the distribution of radiotagged fish (2002–2004) was a primary dataset used by Brown et al 2017 to categorize Chinook salmon spawning locations in the U.S. and Canada. Mainstem projects operated near the U.S./Canada border (Bio-Island fish wheel mark-recapture, 1982–2008; radiotelemetry mark–recapture 2002–2004; and Eagle Sonar, 2005–2019) provide information about the relative abundance of all tributaries in Canada.

Mainstem assessment projects, while extremely informative, are imperfect and do not always have strong or consistent correlations with tributary assessment projects. As such the EGSC reviewed numerous tributary assessment projects and recommended a subset be used to provide additional context for informing a multi-stock run reconstruction model. Like Brown et al. (2017), the EGSC determined that many assessment projects were associated with tributary locations that are consistently minor producers of Chinook salmon. For efficiency purposes, the EGSC choose to list projects associated with minor producers and prioritize in-depth reviews for the subset of assessment projects that consistently count relatively large numbers of Chinook salmon. The EGSC decided to provide an in-depth review of all projects we could locate that had at least one record of Chinook salmon abundance greater than 1,000 fish. This arbitrary criterion set by the EGSC was larger than the 500 escapement (e.g., weir, tower, sonar) and 165 aerial survey count thresholds used by Brown et al. (2017) to categorize major producers. The result is the EGSC review and subsequent run reconstruction included most, but not all, of the major producers identified by Brown et al. (2017).

The 9 geographic regions used by Brown et al. (2017) to group major and minor producers do not align precisely with the Lower, Middle, and Canada stock groupings used by the EGSC. Region 1 and parts of Region 2 align with the Lower stock group. Parts of Region 2 and Regions 3 and 4 align with the Middle stock group. Regions 5–9 are Canada stock.

Within the U.S. portion of the drainage, Brown et al. (2017) identified 17 major producers. Of those, the following projects were not given an in-depth review by the EGSC because they did not meet the 1,000 fish minimum abundance threshold: Archuelinguk and Rodo rivers (Lower stock); Barton Creek, and Teedeiinjik rivers (Middle stock). The South Fork Koyukuk River assessment was considered but not given a detailed review because the project had a very short timeseries. Abundance data pertaining to all other major producers were reviewed in depth by the EGSC and all were recommended for inclusion in the run reconstruction except for projects associated with the Chatanika and Goodpaster rivers, due to lack of clarity or access to best estimates. The EGSC project recommendations for use in the run reconstruction model include indices of abundance for all other major producers in the U.S.: the entire Andreafsky, Anvik, Nulato, Gisasa, Henshaw Cr., Tozitna, Chena, and Salcha rivers.

Within the Canada portion of the drainage, Brown et al. (2017) identified 15 major producers. Of those, the projects associated with the Sheenjek, McQuesten, Nisling, and South Macmillan rivers were not reviewed in depth. The Canada tributary projects that were reviewed in depth represent the Yukon River North Mainstem, White River, Pelly River, Carmacks area, Yukon River Headwaters, Teslin Headwaters, and Porcupine River tributary groupings. The Canada projects recommended by the EGSC for use in the run reconstruction model include indices of the following major producers: Big Salmon, Little Salmon, Tatchun, Blind Cr., Ross, and Wolf rivers. The EGSC did review projects with short datasets that were associated with other major producers (e.g., Klondike) or groups of tributaries (e.g., Pelly and Porcupine rivers), but did not recommend them for use as run reconstruction inputs until more years of data are available.

4.3 Process Challenges and Benefits

The EGSC data review process was tremendously helpful in educating the EGSC about the range of Yukon River Chinook salmon abundance data available and the operational context needed to determine how those data should be used. The process required extensive coordination with agency staff and project leaders, which provided an opportunity to learn about project and data realities that were not readily available in published reports or open-source databases. The amount of information gathered, created data management, display, and quality review challenges. We addressed many of these challenges by implementing an automated dataflow and report compilation process.

Our review, however, is incomplete and represents only what the EGSC was able to learn in the relatively short period of time during which we undertook this work. A complete anthology of Yukon River Chinook salmon assessment efforts in U.S. and Canada could easily consume an entire career and would likely still be missing information. Many knowledge gems are tucked away in agency file cabinets, written in margins of field logbooks, found only in obscure publications, or lost altogether with the departure of field technicians and project leaders who knew these projects so well. Although incomplete, we believe this review represent one of the most comprehensive efforts to collate information about Yukon River Chinook salmon into one place, and we hope this document will provide value to others for years to come. The automated process we implemented for combining data files into a comprehensive report provides efficient future opportunity to update this document regularly as new data is collected or new perspectives about historical data are revealed.

5 References

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APPENDIX A Project Data Summaries

The information in this appendix is organized by stock and watershed. For each stock, this appendix includes a summary of correlations in abundance estimates across projects, for two time periods: Up to 1999, Since 2000. For each watershed, this appendix includes:

- for each survey:
  - time series plot for each survey
  - data tables listing annual estimates, survey types, and notes on data quality
- if there are multiple surveys:
  - pairwise scatterplots showing the relationship between alternative estimates for the same system
  - pairwise scatterplots showing the relationship between main series in the watershed

Lower Yukon:

- Mainstem (Appendix A.1.1): Pilot Station Sonar, Mark Recapture
- Andreafksy (Appendix A.1.2): East Fork Weir, East Fork Aerial, West Fork Aerial
- Anvik (Appendix A.1.3): Aerial
- Nulato (Appendix A.1.4): Tower/Weir, North Fork Aerial, South Fork Aerial
- Koyukuk (Appendix A.1.5): Gisasa Tower/Weir, Gisasa Aerial
- Tozitna (Appendix A.1.6): Tozitna Weir, Tozitna Aerial

Middle Yukon:

- Tanana (Appendix A.2.2): Chena Surveys, Chena Aerial, Salcha Surveys, Salcha Aerial, Goodpaster Tower, Goodpaster Aerial

Border and Canada:

- Mainstem (Appendix A.3.1): Eagle Sonar, Border Mark-Recapture
- Klondike (Appendix A.3.2): Klondike Sonar
- White (Appendix A.3.3): Tincup Aerial
- Pelly (Appendix A.3.4): Pelly Sonar, Blind Creek Weir, Ross Aerial
- Carmacks Area Tributaries (Appendix A.3.5): Tatchun Foot Surveys, Tatchun Weir, Big Salmon Sonar, Big Salmon Aerial, Little Salmon Aerial

- Yukon River Headwaters (Appendix A.3.6): Whitehorse Fishway
- Teslin Headwaters (Appendix A.3.7):Teslin Sonar, Nisutlin Aerial, Wolf Aerial
- Porcupine (Appendix A.3.8): Porcupine Sonar

A.1 Lower Yukon Stock (and Lower River Mainstem)

A.1.1 Correlations

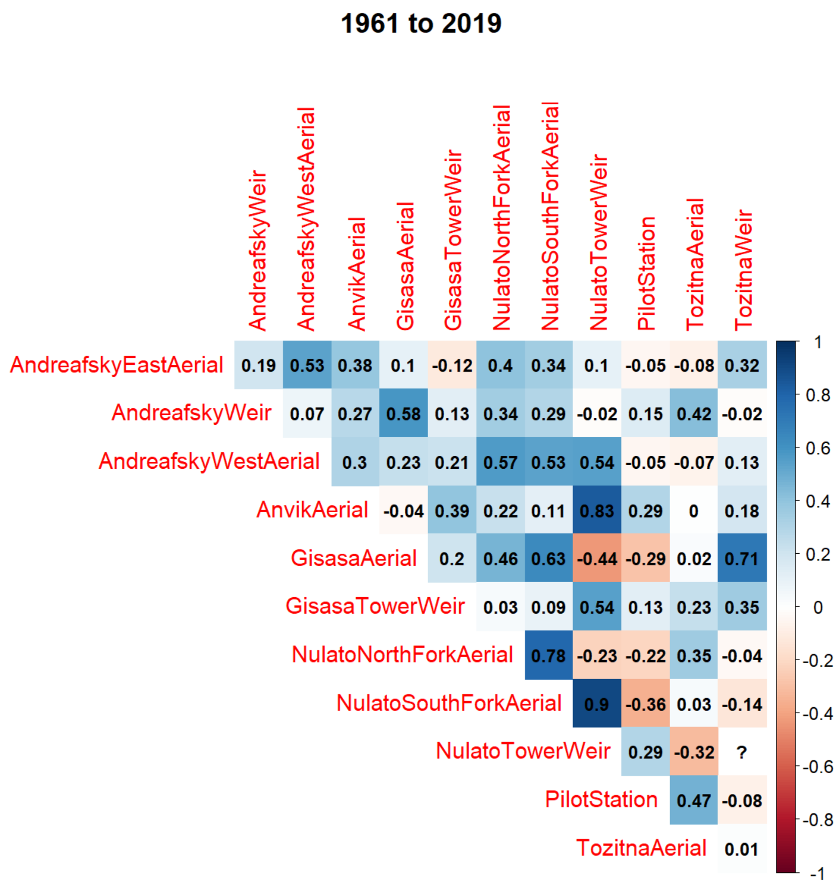

Figure A.1. *Correlation in Abundance Estimates - Lower Yukon Projects - All Years*. Plot shows pairwise correlations of all available data points for each pair of time series. Note that high correlations could be due to few paired obs (i.e. only few yrs where both projects had an estimate). Tables below list sample sizes. Figures in next sections show individual time series, and scatterplots for comparing key projects. The *?* identifies pairs with less than 5 data points for which correlations were not calculated.

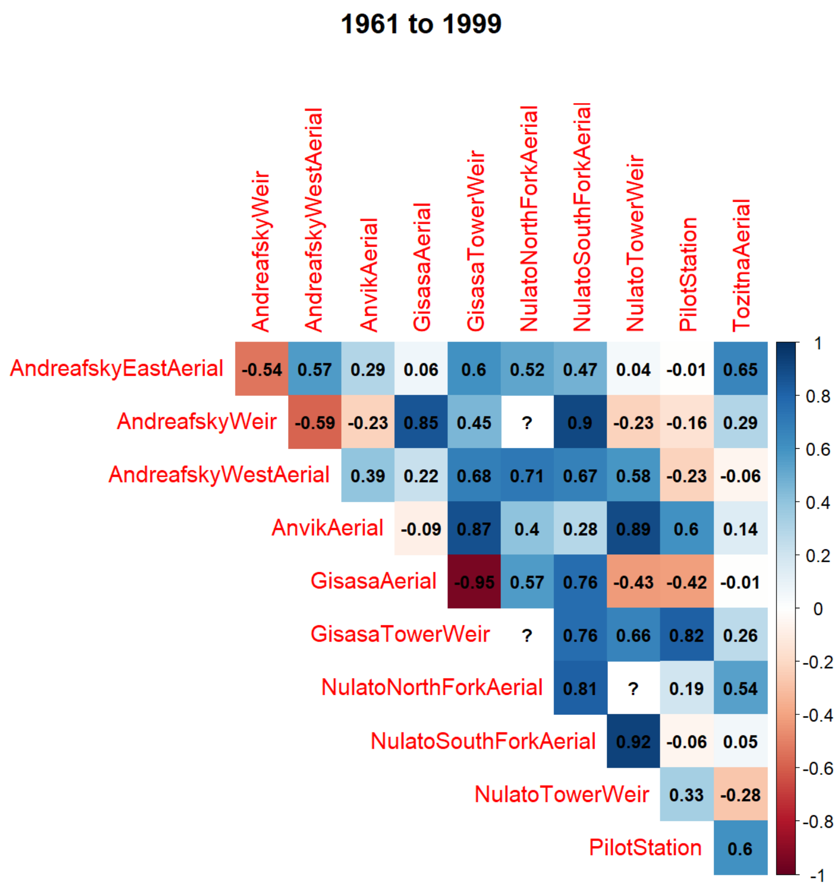

Figure A.2. *Correlation in Abundance Estimates - Lower Yukon Projects - Earlier Years*. Figure layout as per Figure A.1.

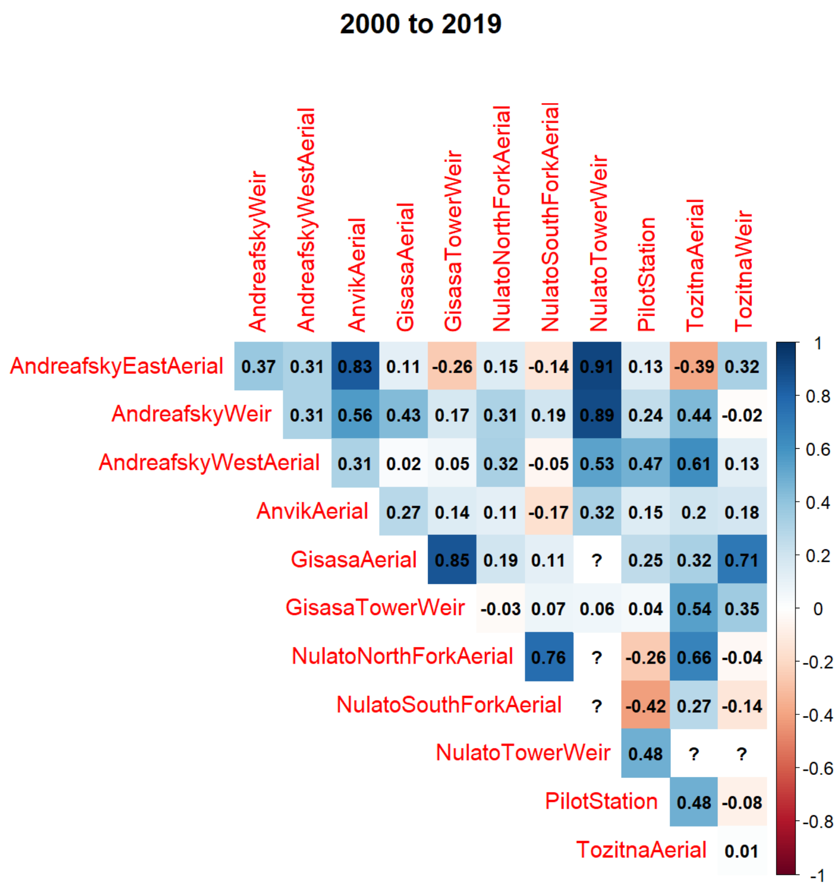

Figure A.3. *Correlation in Abundance Estimates - Lower Yukon Projects - Recent Years*. Figure layout as per Figure A.1.

1982 to 2019

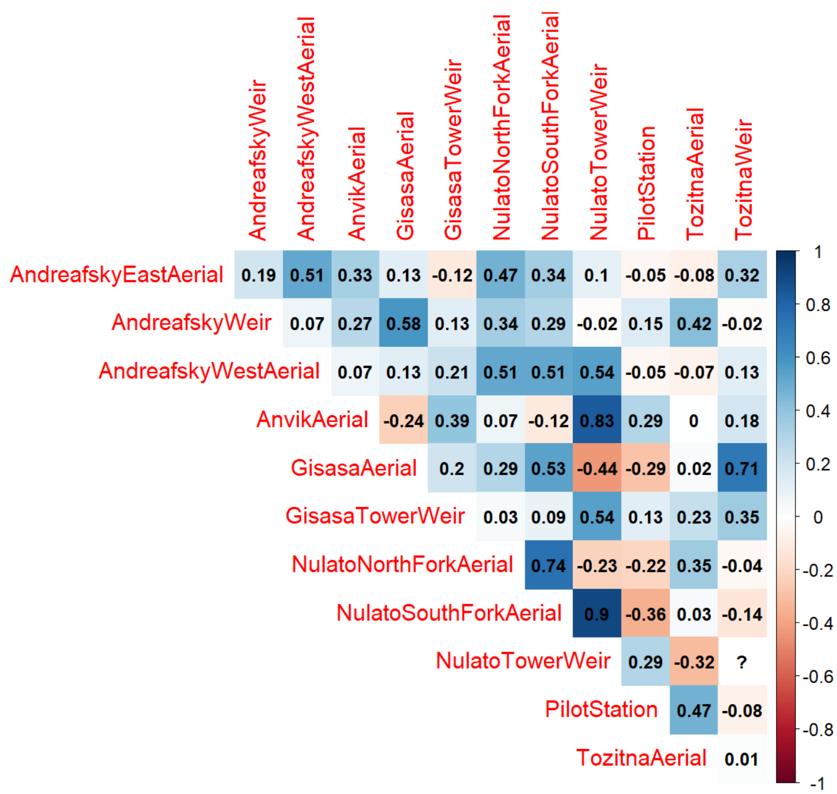

Figure A.4. *Correlation in Abundance Estimates - Lower Yukon Projects - Model Years (1982-2019)*. Covering the same time window as the integrated run reconstruction and spawner-recruit model by Connors et al. (2022). Figure layout as per Figure A.1.

Table A.1. *Correlation in Abundance Estimates - Lower Yukon Projects*. Table lists all the pairwise correlations shown in Figures A.1 to A.3. Correlations larger than 0.4 are highlighted in light blue for positive correlations and orange for negative correlations.

		1961 to 2019		1961 to 1999		2000 to 2019		1982 to 2019	
Project 1	**Project 2**	**Corr**	**Obs**	**Corr**	**Obs**	**Corr**	**Obs**	**Corr**	**Obs**
AndreafskyEastAerial	AndreafskyWeir	0.19	19	-0.54	4	0.37	15	0.19	19
AndreafskyEastAerial	AndreafskyWestAerial	0.53	47	0.57	31	0.31	16	0.51	31
AndreafskyEastAerial	AnvikAerial	0.38	43	0.29	27	0.83	16	0.33	30
AndreafskyEastAerial	GisasaAerial	0.1	33	0.06	20	0.11	13	0.13	26
AndreafskyEastAerial	GisasaTowerWeir	-0.12	18	0.6	3	-0.26	15	-0.12	18
AndreafskyEastAerial	NulatoNorthForkAerial	0.4	31	0.52	17	0.15	14	0.47	24
AndreafskyEastAerial	NulatoSouthForkAerial	0.34	32	0.47	18	-0.14	14	0.34	24
AndreafskyEastAerial	NulatoTowerWeir	0.1	7	0.04	4	0.91	3	0.1	7
AndreafskyEastAerial	PilotStation	-0.05	27	-0.01	11	0.13	16	-0.05	27
AndreafskyEastAerial	TozitnaAerial	-0.08	16	0.65	10	-0.39	6	-0.08	16
AndreafskyEastAerial	TozitnaWeir	0.32	9			0.32	9	0.32	9
AndreafskyWeir	AndreafskyWestAerial	0.07	24	-0.59	6	0.31	18	0.07	24
AndreafskyWeir	AnvikAerial	0.27	24	-0.23	6	0.56	18	0.27	24
AndreafskyWeir	GisasaAerial	0.58	16	0.85	4	0.43	12	0.58	16
AndreafskyWeir	GisasaTowerWeir	0.13	22	0.45	5	0.17	17	0.13	22
AndreafskyWeir	NulatoNorthForkAerial	0.34	17		2	0.31	15	0.34	17
AndreafskyWeir	NulatoSouthForkAerial	0.29	18	0.9	3	0.19	15	0.29	18
AndreafskyWeir	NulatoTowerWeir	-0.02	9	-0.23	6	0.89	3	-0.02	9
AndreafskyWeir	PilotStation	0.15	24	-0.16	5	0.24	19	0.15	24
AndreafskyWeir	TozitnaAerial	0.42	10	0.29	4	0.44	6	0.42	10
AndreafskyWeir	TozitnaWeir	-0.02	8			-0.02	8	-0.02	8
AndreafskyWestAerial	AnvikAerial	0.3	49	0.39	30	0.31	19	0.07	35
AndreafskyWestAerial	GisasaAerial	0.23	33	0.22	20	0.02	13	0.13	26
AndreafskyWestAerial	GisasaTowerWeir	0.21	22	0.68	5	0.05	17	0.21	22
AndreafskyWestAerial	NulatoNorthForkAerial	0.57	33	0.71	17	0.32	16	0.51	26
AndreafskyWestAerial	NulatoSouthForkAerial	0.53	35	0.67	19	-0.05	16	0.51	27
AndreafskyWestAerial	NulatoTowerWeir	0.54	9	0.58	6	0.53	3	0.54	9
AndreafskyWestAerial	PilotStation	-0.05	31	-0.23	12	0.47	19	-0.05	31
AndreafskyWestAerial	TozitnaAerial	-0.07	18	-0.06	11	0.61	7	-0.07	18
AndreafskyWestAerial	TozitnaWeir	0.13	9			0.13	9	0.13	9
AnvikAerial	GisasaAerial	-0.04	32	-0.09	19	0.27	13	-0.24	26
AnvikAerial	GisasaTowerWeir	0.39	22	0.87	5	0.14	17	0.39	22
AnvikAerial	NulatoNorthForkAerial	0.22	33	0.4	17	0.11	16	0.07	27
AnvikAerial	NulatoSouthForkAerial	0.11	35	0.28	19	-0.17	16	-0.12	28
AnvikAerial	NulatoTowerWeir	0.83	9	0.89	6	0.32	3	0.83	9

Project 1	Project 2	Corr	Obs	Corr	Obs	Corr	Obs	Corr	Obs
AnvikAerial	PilotStation	0.29	31	0.6	12	0.15	19	0.29	31
AnvikAerial	TozitnaAerial	0	18	0.14	11	0.2	7	0	18
AnvikAerial	TozitnaWeir	0.18	9			0.18	9	0.18	9
GisasaAerial	GisasaTowerWeir	0.2	15	-0.95	3	0.85	12	0.2	15
GisasaAerial	NulatoNorthForkAerial	0.46	32	0.57	19	0.19	13	0.29	24
GisasaAerial	NulatoSouthForkAerial	0.63	32	0.76	19	0.11	13	0.53	24
GisasaAerial	NulatoTowerWeir	-0.44	5	-0.43	4		1	-0.44	5
GisasaAerial	PilotStation	-0.29	23	-0.42	10	0.25	13	-0.29	23
GisasaAerial	TozitnaAerial	0.02	16	-0.01	10	0.32	6	0.02	16
GisasaAerial	TozitnaWeir	0.71	8			0.71	8	0.71	8
GisasaTowerWeir	NulatoNorthForkAerial	0.03	17		2	-0.03	15	0.03	17
GisasaTowerWeir	NulatoSouthForkAerial	0.09	18	0.76	3	0.07	15	0.09	18
GisasaTowerWeir	NulatoTowerWeir	0.54	8	0.66	5	0.06	3	0.54	8
GisasaTowerWeir	PilotStation	0.13	22	0.82	4	0.04	18	0.13	22
GisasaTowerWeir	TozitnaAerial	0.23	11	0.26	4	0.54	7	0.23	11
GisasaTowerWeir	TozitnaWeir	0.35	9			0.35	9	0.35	9
NulatoNorthForkAerial	NulatoSouthForkAerial	0.78	35	0.81	19	0.76	16	0.74	27
NulatoNorthForkAerial	NulatoTowerWeir	-0.23	3		2		1	-0.23	3
NulatoNorthForkAerial	PilotStation	-0.22	24	0.19	8	-0.26	16	-0.22	24
NulatoNorthForkAerial	TozitnaAerial	0.35	16	0.54	9	0.66	7	0.35	16
NulatoNorthForkAerial	TozitnaWeir	-0.04	8			-0.04	8	-0.04	8
NulatoSouthForkAerial	NulatoTowerWeir	0.9	4	0.92	3		1	0.9	4
NulatoSouthForkAerial	PilotStation	-0.36	24	-0.06	8	-0.42	16	-0.36	24
NulatoSouthForkAerial	TozitnaAerial	0.03	17	0.05	10	0.27	7	0.03	17
NulatoSouthForkAerial	TozitnaWeir	-0.14	8			-0.14	8	-0.14	8
NulatoTowerWeir	PilotStation	0.29	8	0.33	5	0.48	3	0.29	8
NulatoTowerWeir	TozitnaAerial	-0.32	5	-0.28	4		1	-0.32	5
NulatoTowerWeir	TozitnaWeir		2				2		2
PilotStation	TozitnaAerial	0.47	15	0.6	8	0.48	7	0.47	15
PilotStation	TozitnaWeir	-0.08	9			-0.08	9	-0.08	9
TozitnaAerial	TozitnaWeir	0.01	5			0.01	5	0.01	5

A.1.2 Lower Yukon - Mainstem

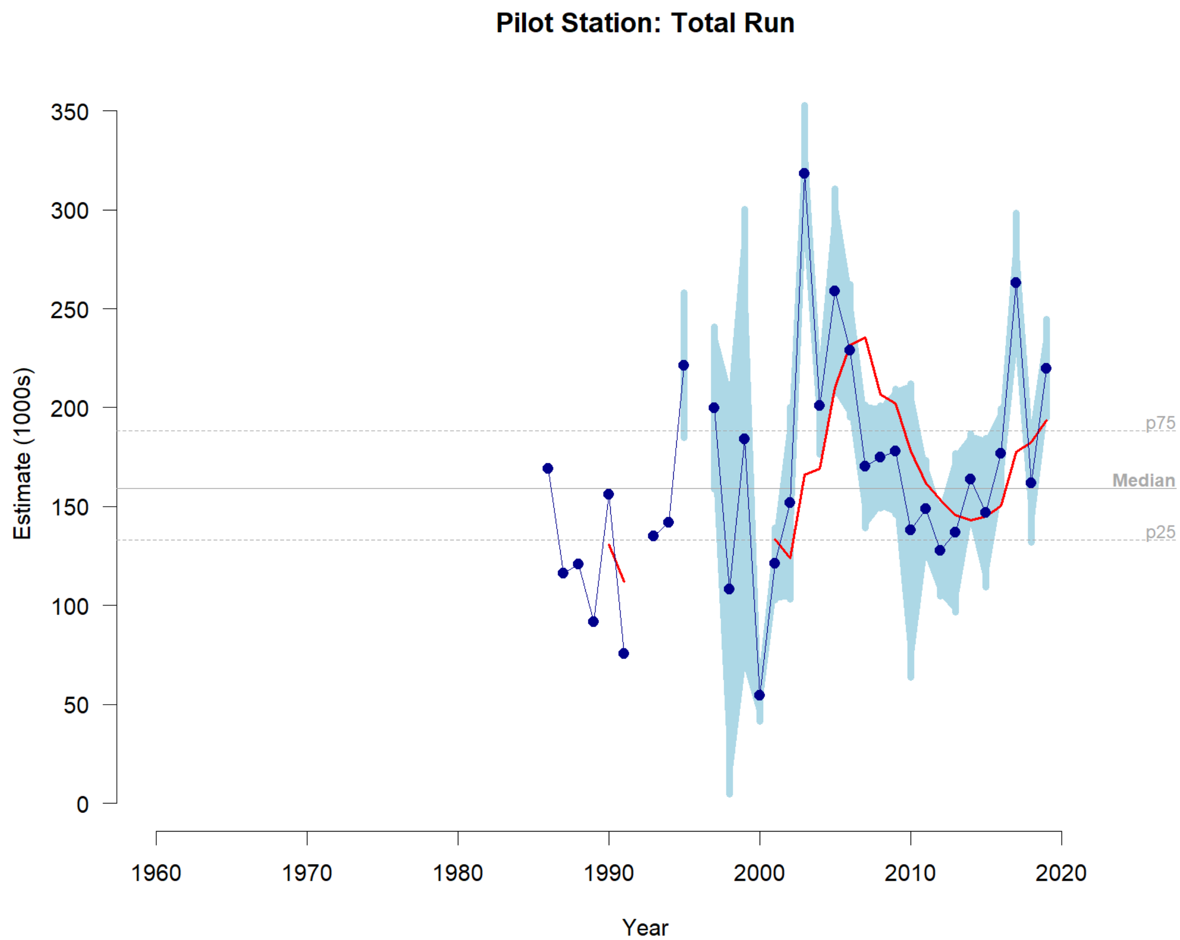

Figure A.5. *Available Estimates from Pilot Station Sonar*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

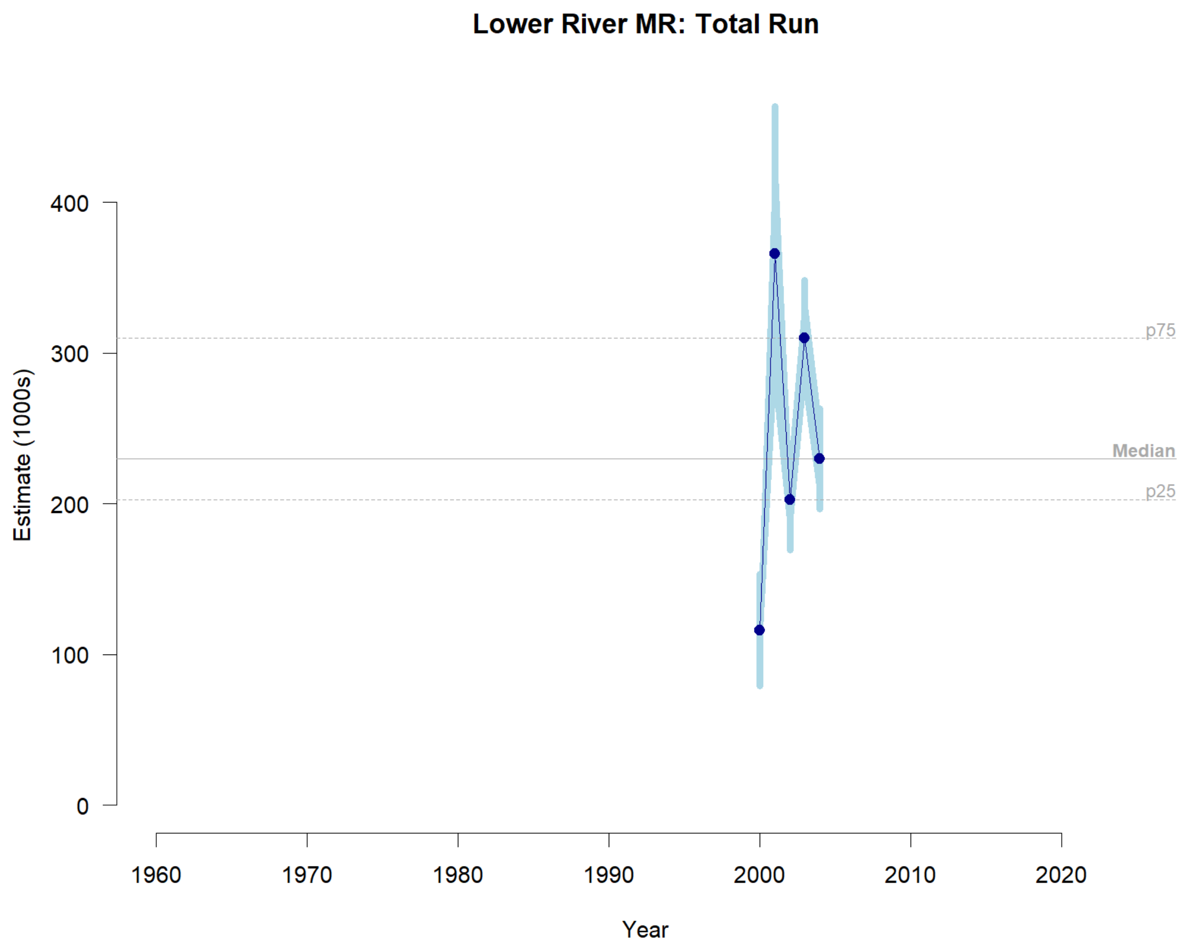

Figure A.6. *Available Estimates from Lower River Radiotag Mark-Recapture*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

Table A.2. *Annual Survey Types and Escapement Estimate - Pilot Station Sonar*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1986	Sonar	169,067	NA	NA	Yes	
1987	Sonar	116,126	NA	NA	Yes	
1988	Sonar	120,656	NA	NA	Yes	
1989	Sonar	91,545	NA	NA	Yes	
1990	Sonar	156,097	NA	NA	Yes	
1991	Sonar	75,676	NA	NA	Yes	
1993	Sonar	134,854	NA	NA	Yes	
1994	Sonar	141,795	NA	NA	Yes	
1995	Sonar	221,357	184,731	257,983	Yes	
1997	Sonar	199,763	158,693	240,833	Yes	
1998	Sonar	108,038	4,632	211,444	Yes	
1999	Sonar	184,218	68,312	300,124	Yes	
2000	Sonar	54,560	41,358	67,762	Yes	
2001	Sonar	121,089	102,877	139,301	Yes	
2002	Sonar	151,713	103,117	200,309	Yes	
2003	Sonar	318,088	283,370	352,806	Yes	
2004	Sonar	200,761	176,471	225,051	Yes	
2005	Sonar	259,014	207,400	310,628	Yes	
2006	Sonar	228,763	195,091	262,435	Yes	
2007	Sonar	170,246	139,200	201,292	Yes	
2008	Sonar	175,046	149,068	201,024	Yes	
2009	Sonar	177,796	146,026	209,566	Yes	
2010	Sonar	137,899	63,587	212,211	Yes	
2011	Sonar	148,797	124,269	173,325	Yes	
2012	Sonar	127,555	104,877	150,233	Yes	
2013	Sonar	136,805	96,803	176,807	Yes	
2014	Sonar	163,895	141,117	186,673	Yes	
2015	Sonar	146,859	109,219	184,499	Yes	
2016	Sonar	176,898	154,446	199,350	Yes	
2017	Sonar	263,014	227,622	298,406	Yes	
2018	Sonar	161,831	131,997	191,665	Yes	
2019	Sonar	219,624	194,728	244,520	Yes	

Table A.3. *Annual Survey Types and Escapement Estimate - Lower River Radiotag Mark-Recapture*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
2000	MR	116,176	79,277	153,075	Yes	Sum of large (>630) and small estimates
2001	MR	365,929	268,152	463,706	Yes	Sum of large (>640) and small estimates
2002	MR	202,678	169,169	236,187	Yes	Sum of large (>650) and small estimates
2003	MR	309,887	271,337	348,437	Yes	Sum of large (>650) and small estimates
2004	MR	229,739	196,375	263,103	Yes	Large (>520) estimate only, very few small fish.

Table A.4. *Alternative Radiotag Mark-Recapture Estimates*. *Size* is size of adult fish in mm. Bias is the % bias estimated from a bootstrap test.

Type	Year	Method	Size	Estimate	SE	Bias
Canada	2002	Local MR	≤ 650	51,428	10,880	4.9
	2003	Local MR	≤ 650	90,037	13,458	1.7
	2004	Local MR	≤ 520	59,415	7,987	1.7
	2002	Prop	≤ 650	38,264	5,212	1.4
	2003	Prop	≤ 650	100,956	8,292	6.6
	2004	Prop	≤ 520	68,178	5,872	0.9
Drainage	2000	Recon	All fish	144,173		
	2001	Recon	All fish	392,000		
	2002	Recon	All fish	243,443		
	2003	Recon	All fish	372,697		
	2004	Recon	All fish	311,377		
Drainage at Russian Mission	2000	MR	≤ 630	112,389	18,439	
	2001	MR	≤ 640	358,098	48,877	
	2002	MR	≤ 650	125,255	14,429	1.9
	2003	MR	≤ 650	261,545	18,911	6.6
	2004	MR	≤ 520	229,739	16,682	0.9
	2000	Size Prop	< 630	3,787	621	
	2001	Size Prop	< 640	7,831	1,069	
	2002	Size Prop	< 650	77,423	8,516	
	2003	Size Prop	< 650	48,342	3,727	
	2004	Size Prop	< 520	0	0	
Tanana River	2002	Local MR	≤ 651	14,932	1,312	0.9
	2003	Local MR	≤ 653	48,382	3,268	8.6
	2004	Local MR	≤ 521	50,803	3,602	0.7
	2002	Prop	≤ 650	18,235	1,846	1.1
	2003	Prop	≤ 652	45,247	3,061	6.5
	2004	Prop	≤ 520	46,812	3,254	0.4

A.1.3 Lower Yukon Stock - Andreafsky Watershed

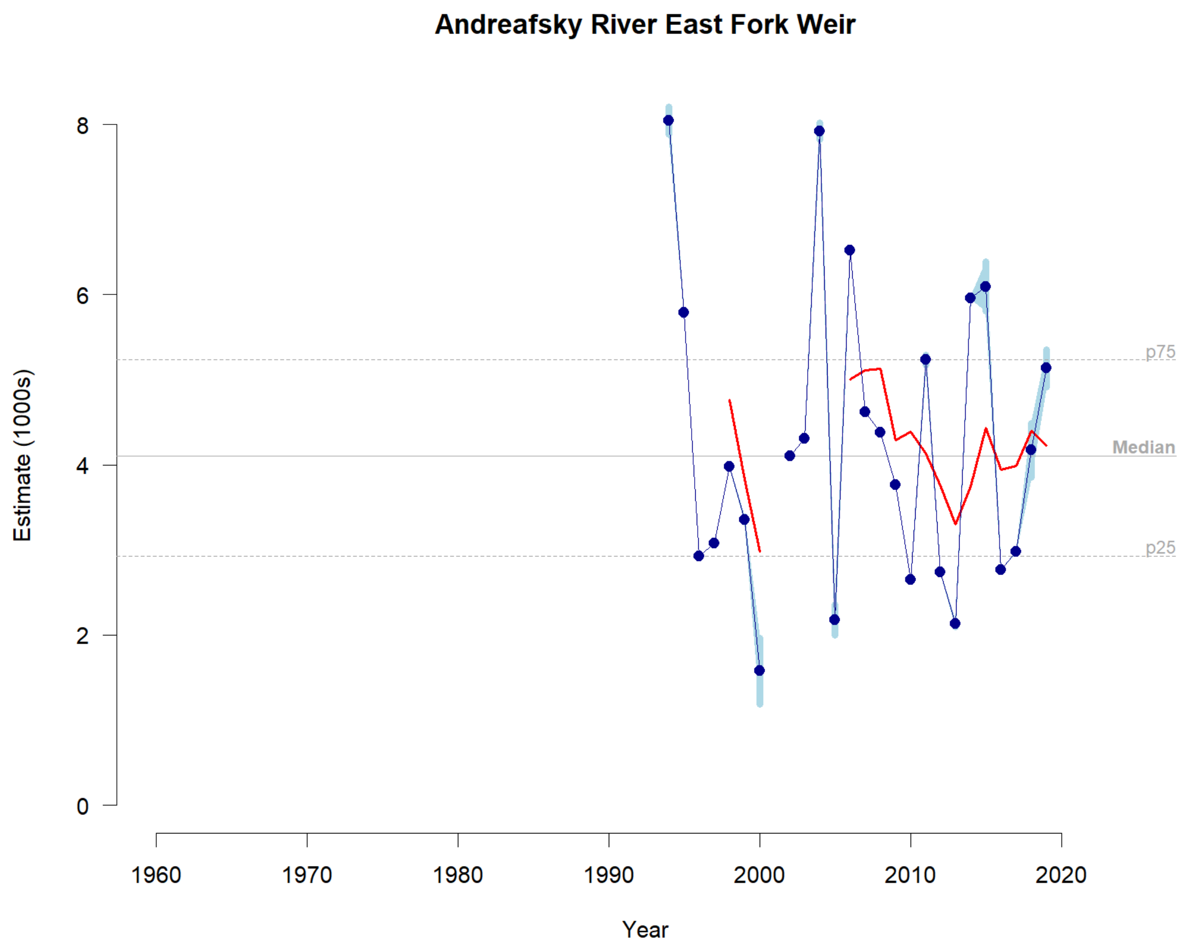

Figure A.7. *Available Estimates from Andreafsky River East Fork Weir*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

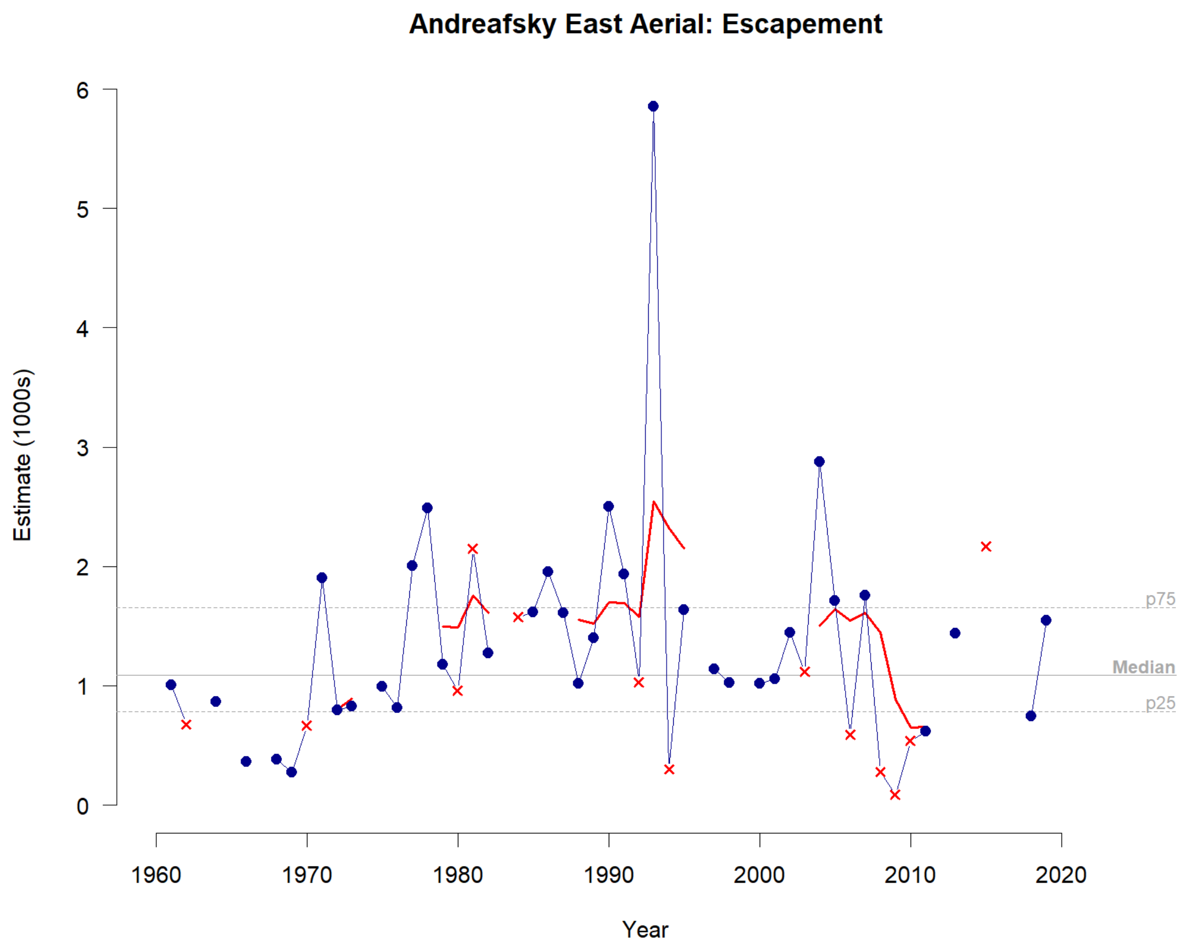

Figure A.8. *Available Estimates from Andreafsky River East Fork Aerial Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

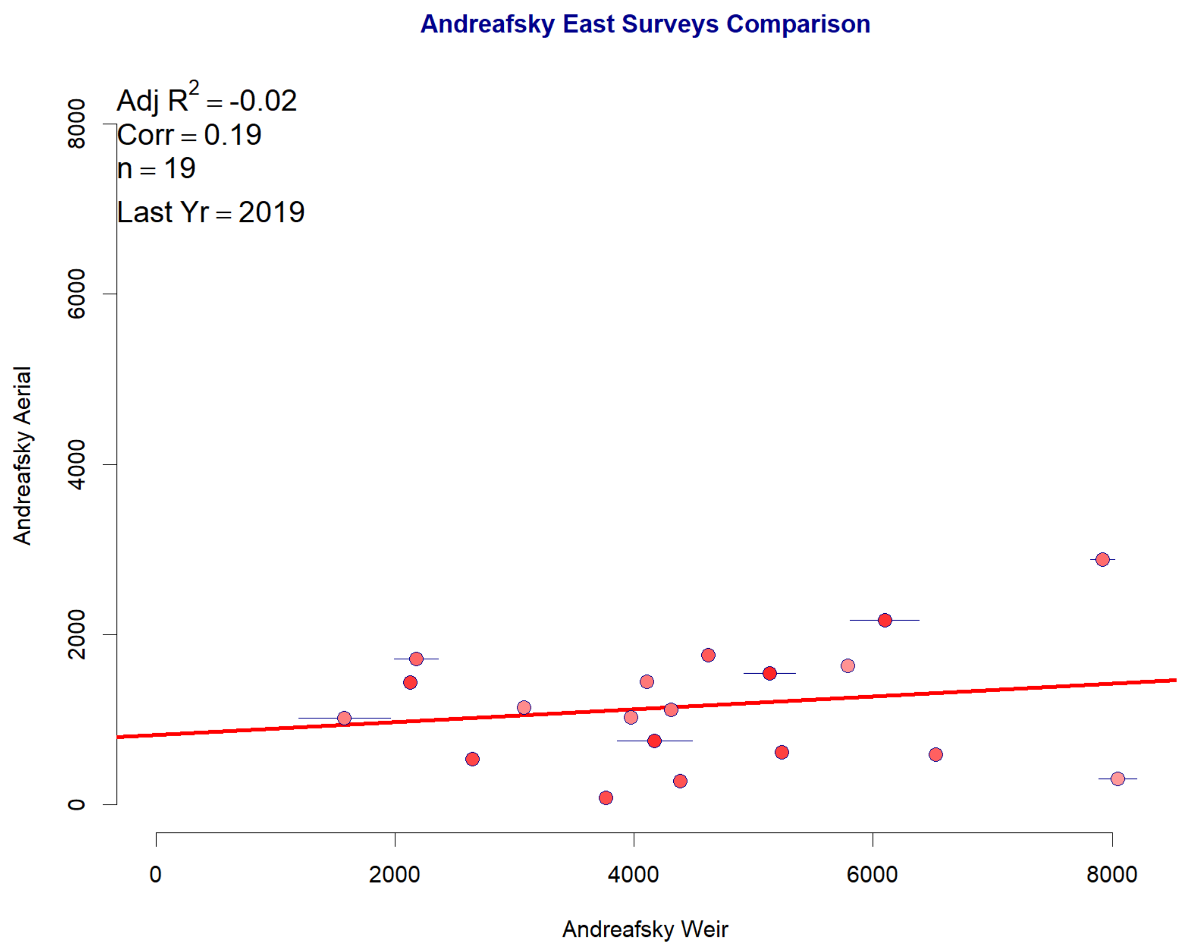

Figure A.9. *Andreafsky East Survey Comparison*.

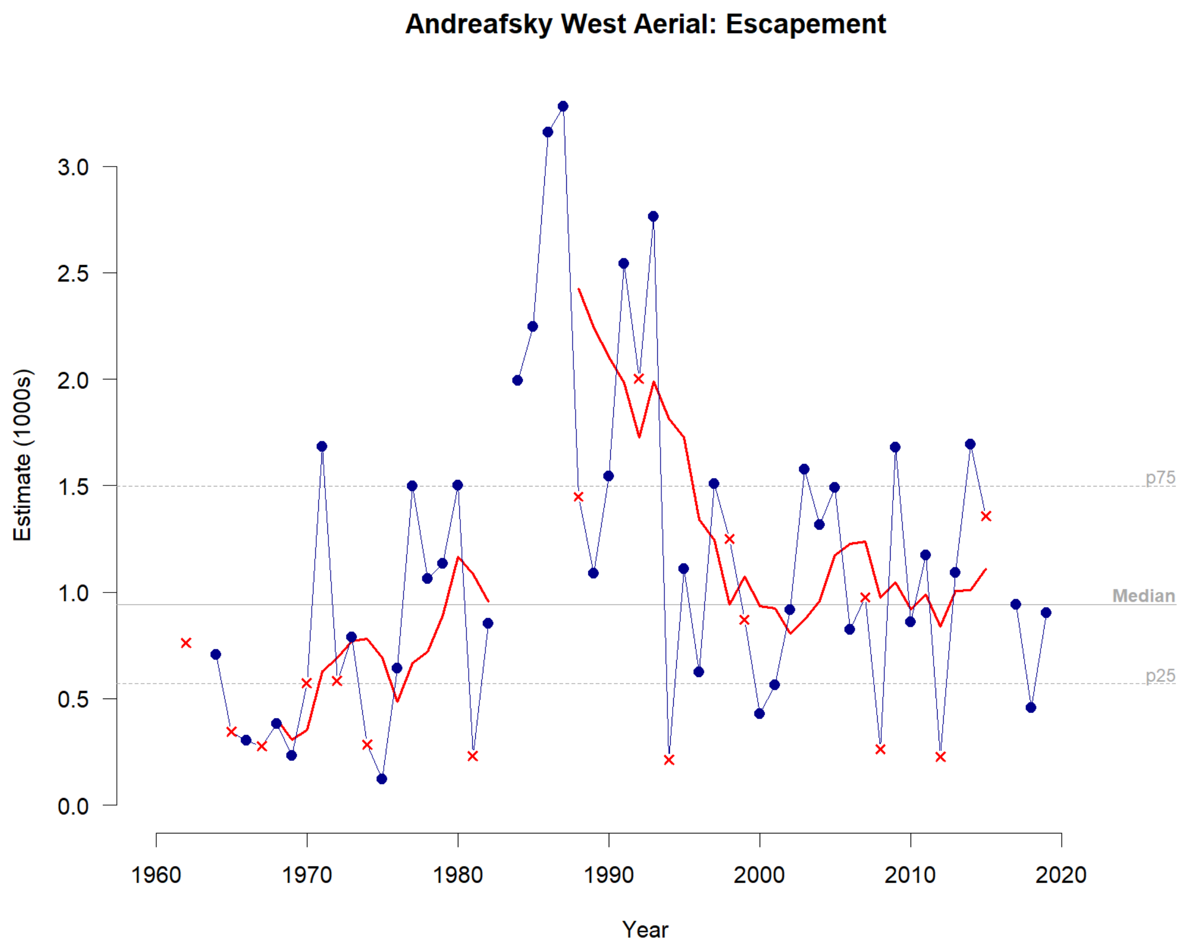

Figure A.10. *Available Estimates from Andreafsky River West Fork Aerial Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

Table A.5. *Annual Survey Types and Escapement Estimate - Andreasfky East Fork Weir*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1994	Weir	8,046	7,886	8,206	Yes	
1995	Weir	5,790	5,790	5,790	Yes	
1996	Weir	2,928	2,928	2,928	Yes	
1997	Weir	3,076	3,076	3,076	Yes	
1998	Weir	3,975	3,975	3,975	Yes	
1999	Weir	3,357	3,326	3,388	Yes	
2000	Weir	1,576	1,191	1,961	Yes	
2002	Weir	4,106	4,106	4,106	Yes	
2003	Weir	4,311	4,311	4,311	Yes	
2004	Weir	7,920	7,820	8,020	Yes	
2005	Weir	2,177	1,995	2,359	Yes	
2006	Weir	6,522	6,522	6,522	Yes	
2007	Weir	4,620	4,620	4,620	Yes	
2008	Weir	4,383	4,383	4,383	Yes	
2009	Weir	3,762	3,762	3,762	Yes	
2010	Weir	2,647	2,647	2,647	Yes	
2011	Weir	5,234	5,176	5,292	Yes	
2012	Weir	2,742	2,742	2,742	Yes	
2013	Weir	2,129	2,096	2,162	Yes	
2014	Weir	5,961	5,946	5,976	Yes	
2015	Weir	6,096	5,808	6,384	Yes	
2016	Weir	2,764	2,764	2,764	Yes	
2017	Weir	2,975	2,968	2,982	Yes	
2018	Weir	4,171	3,856	4,486	Yes	
2019	Weir	5,134	4,916	5,352	Yes	

Table A.6. *Annual Survey Types and Escapement Estimate - Andreafsky East Fork Aerial*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1961	Aerial	1,003	NA	NA	Yes	
1962	Aerial	675	NA	NA		???
1964	Aerial	867	NA	NA	Yes	
1966	Aerial	361	NA	NA	Yes	
1968	Aerial	383	NA	NA	Yes	
1969	Aerial	274	NA	NA	Yes	
1970	Aerial	665	NA	NA		???
1971	Aerial	1,904	NA	NA	Yes	
1972	Aerial	798	NA	NA	Yes	
1973	Aerial	825	NA	NA	Yes	
1975	Aerial	993	NA	NA	Yes	
1976	Aerial	818	NA	NA	Yes	
1977	Aerial	2,008	NA	NA	Yes	
1978	Aerial	2,487	NA	NA	Yes	
1979	Aerial	1,180	NA	NA	Yes	
1980	Aerial	958	NA	NA		Poor
1981	Aerial	2,146	NA	NA		???
1982	Aerial	1,274	NA	NA	Yes	
1984	Aerial	1,573	NA	NA		???
1985	Aerial	1,617	NA	NA	Yes	
1986	Aerial	1,954	NA	NA	Yes	
1987	Aerial	1,608	NA	NA	Yes	
1988	Aerial	1,020	NA	NA	Yes	
1989	Aerial	1,399	NA	NA	Yes	
1990	Aerial	2,503	NA	NA	Yes	
1991	Aerial	1,938	NA	NA	Yes	
1992	Aerial	1,030	NA	NA		Poor
1993	Aerial	5,855	NA	NA	Yes	
1994	Aerial	300	NA	NA		Incomplete
1995	Aerial	1,635	NA	NA	Yes	
1997	Aerial	1,140	NA	NA	Yes	
1998	Aerial	1,027	NA	NA	Yes	
2000	Aerial	1,018	NA	NA	Yes	
2001	Aerial	1,059	NA	NA	Yes	
2002	Aerial	1,447	NA	NA	Yes	
2003	Aerial	1,116	NA	NA		???
2004	Aerial	2,879	NA	NA	Yes	
2005	Aerial	1,715	NA	NA	Yes	
2006	Aerial	591	NA	NA		Incomplete
2007	Aerial	1,758	NA	NA	Yes	
2008	Aerial	278	NA	NA		Poor
2009	Aerial	84	NA	NA		Poor
2010	Aerial	537	NA	NA		Poor
2011	Aerial	620	NA	NA	Yes	
2013	Aerial	1,441	NA	NA	Yes	
2015	Aerial	2,167	NA	NA		Poor
2018	Aerial	746	NA	NA	Yes	
2019	Aerial	1,547	NA	NA	Yes	

Table A.7. *Annual Survey Types and Escapement Estimate - Andreafsky West Fork Aerial*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1962	Aerial	762	NA	NA		Poor
1964	Aerial	705	NA	NA	Yes	
1965	Aerial	344	NA	NA		Poor
1966	Aerial	303	NA	NA	Yes	
1967	Aerial	276	NA	NA		Poor
1968	Aerial	383	NA	NA	Yes	
1969	Aerial	231	NA	NA	Yes	
1970	Aerial	574	NA	NA		Poor
1971	Aerial	1,682	NA	NA	Yes	
1972	Aerial	582	NA	NA		Poor
1973	Aerial	788	NA	NA	Yes	
1974	Aerial	285	NA	NA		Undefined
1975	Aerial	120	NA	NA	Yes	
1976	Aerial	643	NA	NA	Yes	
1977	Aerial	1,499	NA	NA	Yes	
1978	Aerial	1,062	NA	NA	Yes	
1979	Aerial	1,134	NA	NA	Yes	
1980	Aerial	1,500	NA	NA	Yes	
1981	Aerial	231	NA	NA		Poor
1982	Aerial	851	NA	NA	Yes	
1984	Aerial	1,993	NA	NA	Yes	
1985	Aerial	2,248	NA	NA	Yes	
1986	Aerial	3,158	NA	NA	Yes	
1987	Aerial	3,281	NA	NA	Yes	
1988	Aerial	1,448	NA	NA		Incomplete
1989	Aerial	1,089	NA	NA	Yes	
1990	Aerial	1,545	NA	NA	Yes	
1991	Aerial	2,544	NA	NA	Yes	
1992	Aerial	2,002	NA	NA		Poor
1993	Aerial	2,765	NA	NA	Yes	
1994	Aerial	213	NA	NA		Incomplete
1995	Aerial	1,108	NA	NA	Yes	
1996	Aerial	624	NA	NA	Yes	
1997	Aerial	1,510	NA	NA	Yes	
1998	Aerial	1,249	NA	NA		Poor
1999	Aerial	870	NA	NA		Incomplete
2000	Aerial	427	NA	NA	Yes	
2001	Aerial	565	NA	NA	Yes	
2002	Aerial	917	NA	NA	Yes	
2003	Aerial	1,578	NA	NA	Yes	
2004	Aerial	1,317	NA	NA	Yes	
2005	Aerial	1,492	NA	NA	Yes	
2006	Aerial	824	NA	NA	Yes	
2007	Aerial	976	NA	NA		Incomplete
2008	Aerial	262	NA	NA		Poor
2009	Aerial	1,678	NA	NA	Yes	
2010	Aerial	858	NA	NA	Yes	
2011	Aerial	1,173	NA	NA	Yes	
2012	Aerial	227	NA	NA		Poor
2013	Aerial	1,090	NA	NA	Yes	
2014	Aerial	1,695	NA	NA	Yes	
2015	Aerial	1,356	NA	NA		Poor

Year	Type	Estimate	Lower	Upper	Use	UseNotes
2017	Aerial	942	NA	NA	Yes	
2018	Aerial	455	NA	NA	Yes	
2019	Aerial	904	NA	NA	Yes	

A.1.4 Lower Yukon Stock - Anvik Watershed

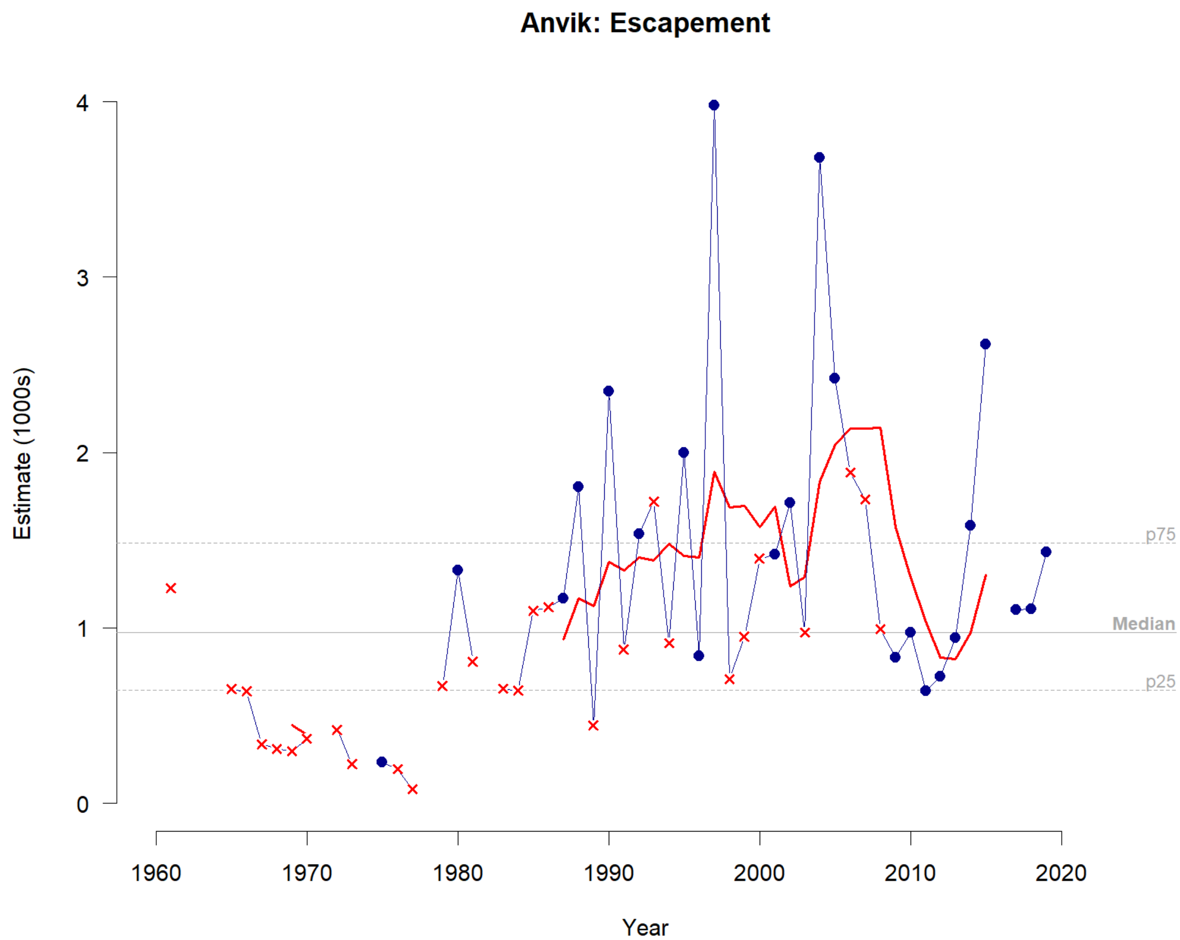

Figure A.11. *Available Estimates from Anvik Aerial Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

Table A.8. *Annual Survey Types and Escapement Estimate - Anvik Aerial*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1961	Aerial	1,226	NA	NA		???
1965	Aerial	650	NA	NA		Poor
1966	Aerial	638	NA	NA		???
1967	Aerial	336	NA	NA		Poor
1968	Aerial	310	NA	NA		Poor
1969	Aerial	296	NA	NA		Poor
1970	Aerial	368	NA	NA		???
1972	Aerial	418	NA	NA		???
1973	Aerial	222	NA	NA		Poor
1975	Aerial	232	NA	NA	Yes	
1976	Aerial	195	NA	NA		???
1977	Aerial	79	NA	NA		???
1979	Aerial	670	NA	NA		???
1980	Aerial	1,330	NA	NA	Yes	
1981	Aerial	807	NA	NA		Poor
1983	Aerial	653	NA	NA		Poor
1984	Aerial	641	NA	NA		Poor
1985	Aerial	1,097	NA	NA		???
1986	Aerial	1,118	NA	NA		???
1987	Aerial	1,169	NA	NA	Yes	
1988	Aerial	1,805	NA	NA	Yes	
1989	Aerial	442	NA	NA		Poor
1990	Aerial	2,347	NA	NA	Yes	
1991	Aerial	875	NA	NA		Poor
1992	Aerial	1,536	NA	NA	Yes	
1993	Aerial	1,720	NA	NA		???
1994	Aerial	913	NA	NA		Poor
1995	Aerial	1,996	NA	NA	Yes	
1996	Aerial	839	NA	NA	Yes	
1997	Aerial	3,979	NA	NA	Yes	
1998	Aerial	709	NA	NA		Poor
1999	Aerial	950	NA	NA		Poor
2000	Aerial	1,394	NA	NA		???
2001	Aerial	1,420	NA	NA	Yes	
2002	Aerial	1,713	NA	NA	Yes	
2003	Aerial	973	NA	NA		Poor
2004	Aerial	3,679	NA	NA	Yes	
2005	Aerial	2,421	NA	NA	Yes	
2006	Aerial	1,886	NA	NA		Incomplete
2007	Aerial	1,731	NA	NA		???
2008	Aerial	992	NA	NA		???
2009	Aerial	832	NA	NA	Yes	
2010	Aerial	974	NA	NA	Yes	
2011	Aerial	642	NA	NA	Yes	
2012	Aerial	722	NA	NA	Yes	
2013	Aerial	941	NA	NA	Yes	
2014	Aerial	1,584	NA	NA	Yes	
2015	Aerial	2,616	NA	NA	Yes	
2017	Aerial	1,101	NA	NA	Yes	
2018	Aerial	1,109	NA	NA	Yes	
2019	Aerial	1,432	NA	NA	Yes	

A.1.5 Lower Yukon Stock - Nulato Watershed

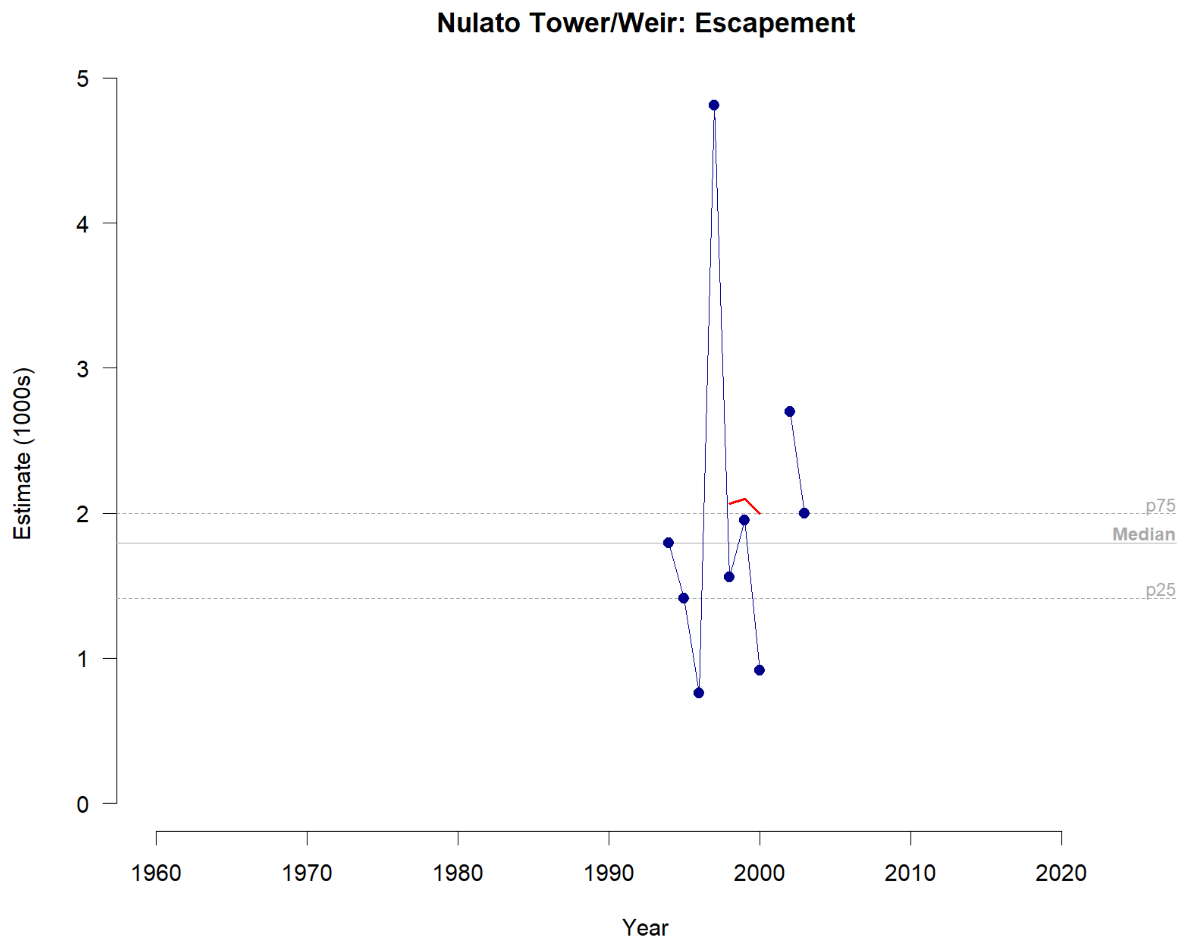

Figure A.12. *Available Estimates from Nulato Tower/Weir Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

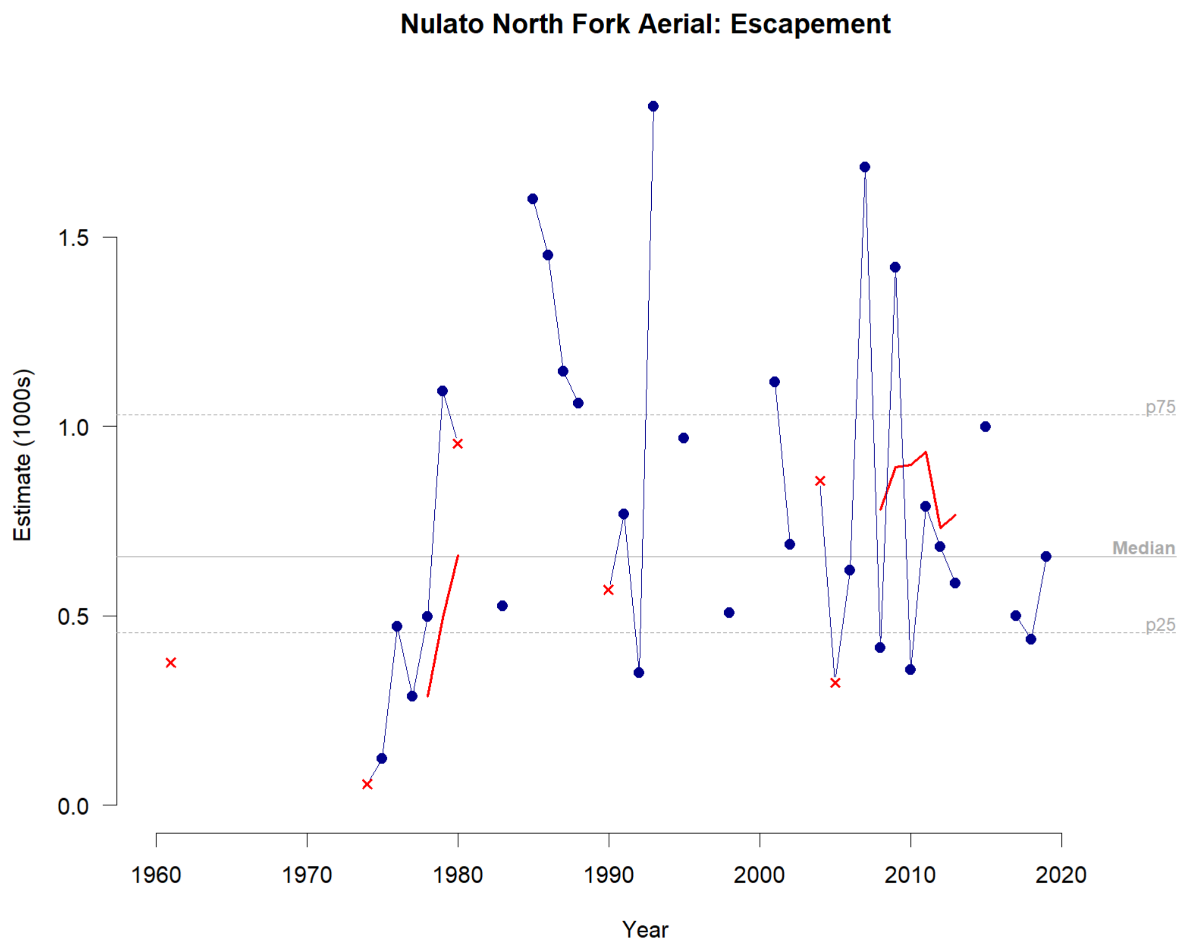

Figure A.13. *Available Estimates from Nulato North Fork Aerial Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

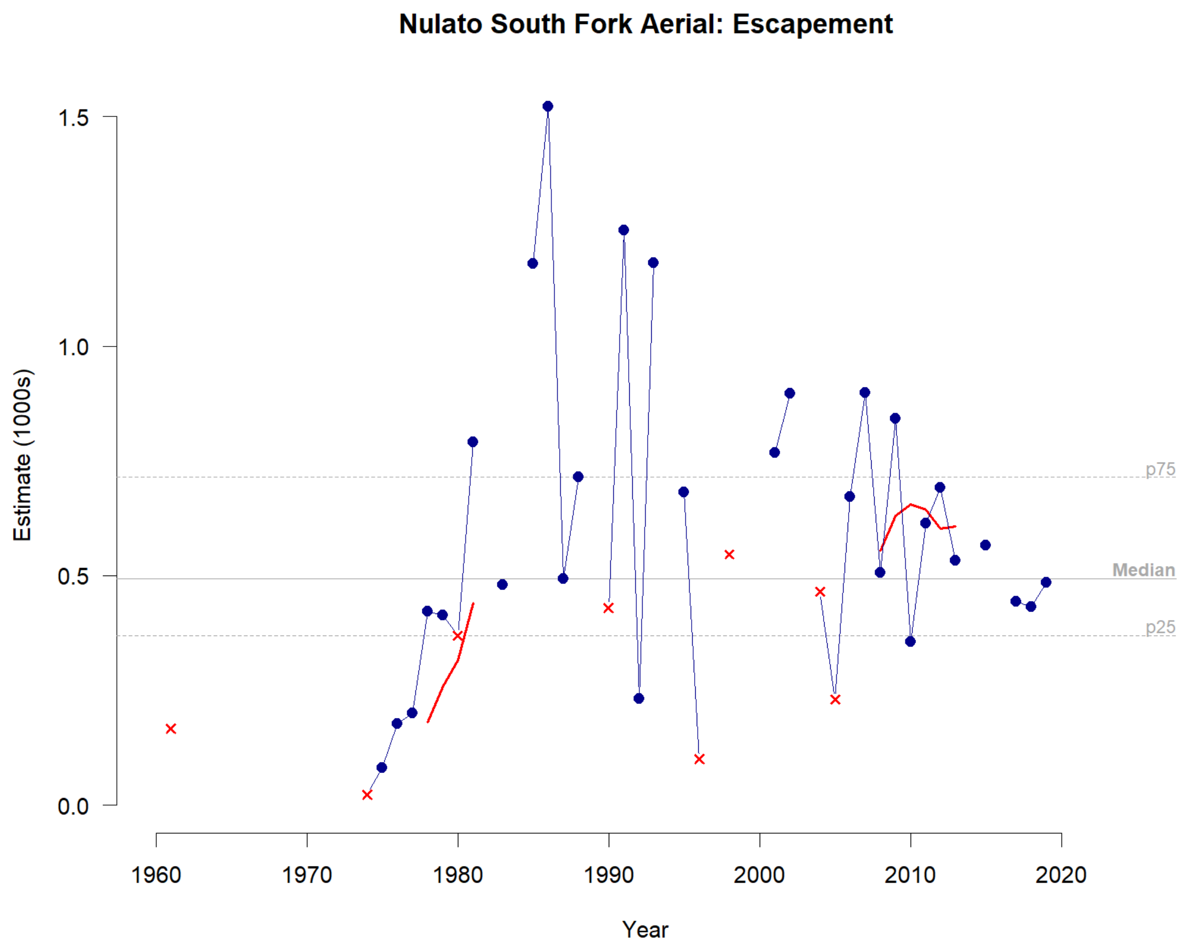

Figure A.14. *Available Estimates from Nulato South Fork Aerial Surveys.* Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

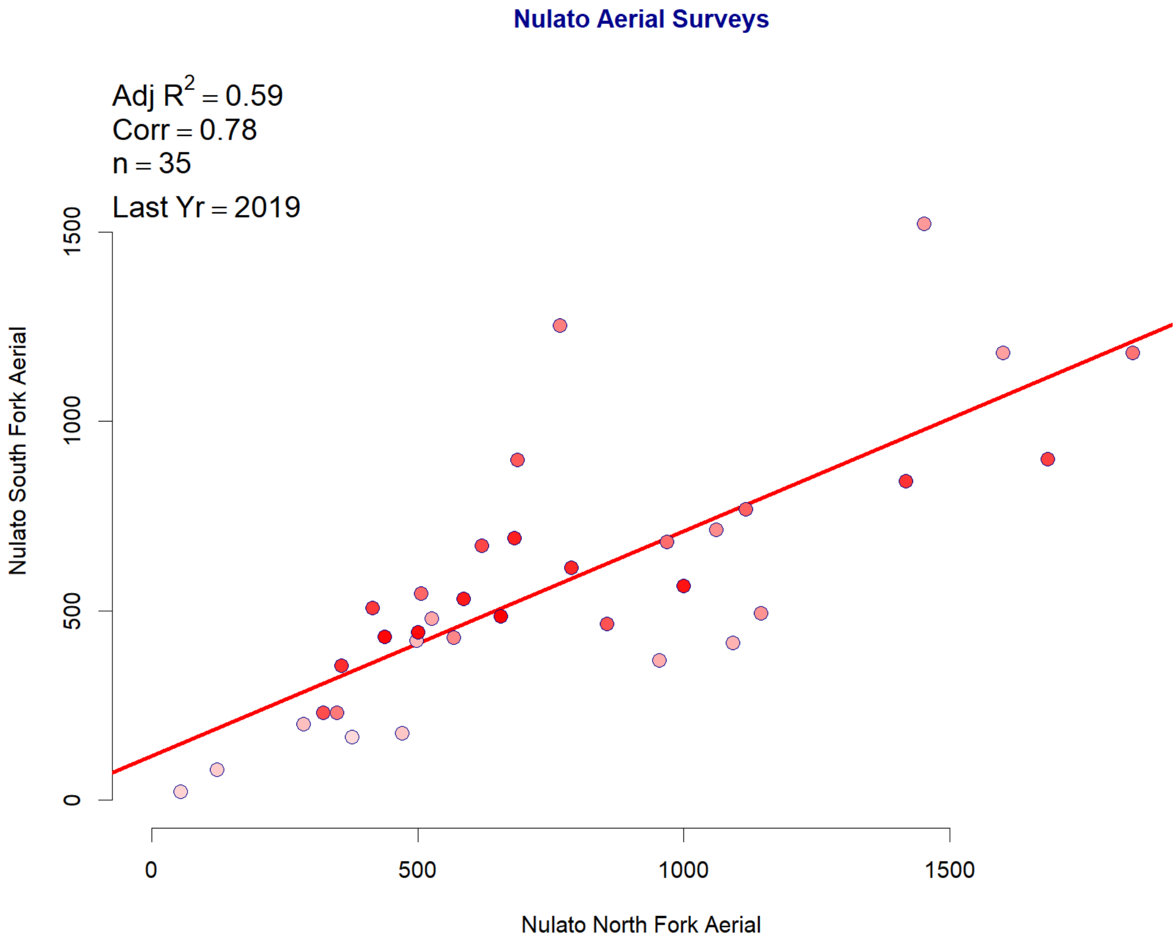

Figure A.15. *Nulato Aerial Survey Comparison*.

Table A.9. *Annual Survey Types and Escapement Estimate - Nulato Tower/Weir*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1994	Tower	1,795	NA	NA	Yes	
1995	Tower	1,412	NA	NA	Yes	
1996	Tower	756	NA	NA	Yes	
1997	Tower	4,811	NA	NA	Yes	
1998	Tower	1,556	NA	NA	Yes	
1999	Tower	1,953	NA	NA	Yes	
2000	Tower	916	NA	NA	Yes	
2002	Tower	2,696	NA	NA	Yes	
2003	Weir	1,997	NA	NA	Yes	

Table A.10. *Annual Survey Types and Escapement Estimate - Nulato North Fork Aerial*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1961	Aerial	376	NA	NA		Poor
1974	Aerial	55	NA	NA		Poor
1975	Aerial	123	NA	NA	Yes	
1976	Aerial	471	NA	NA	Yes	
1977	Aerial	286	NA	NA	Yes	
1978	Aerial	498	NA	NA	Yes	
1979	Aerial	1,093	NA	NA	Yes	
1980	Aerial	954	NA	NA		Poor
1983	Aerial	526	NA	NA	Yes	
1985	Aerial	1,600	NA	NA	Yes	
1986	Aerial	1,452	NA	NA	Yes	
1987	Aerial	1,145	NA	NA	Yes	
1988	Aerial	1,061	NA	NA	Yes	
1990	Aerial	568	NA	NA		Poor
1991	Aerial	767	NA	NA	Yes	
1992	Aerial	348	NA	NA	Yes	
1993	Aerial	1,844	NA	NA	Yes	
1995	Aerial	968	NA	NA	Yes	
1998	Aerial	507	NA	NA	Yes	
2001	Aerial	1,116	NA	NA	Yes	
2002	Aerial	687	NA	NA	Yes	
2004	Aerial	856	NA	NA		???
2005	Aerial	323	NA	NA		???
2006	Aerial	620	NA	NA	Yes	
2007	Aerial	1,684	NA	NA	Yes	
2008	Aerial	415	NA	NA	Yes	
2009	Aerial	1,418	NA	NA	Yes	
2010	Aerial	356	NA	NA	Yes	
2011	Aerial	788	NA	NA	Yes	
2012	Aerial	682	NA	NA	Yes	
2013	Aerial	586	NA	NA	Yes	
2015	Aerial	999	NA	NA	Yes	
2017	Aerial	500	NA	NA	Yes	
2018	Aerial	438	NA	NA	Yes	
2019	Aerial	656	NA	NA	Yes	

Table A.11. *Annual Survey Types and Escapement Estimate - Nulato South Fork Aerial*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1961	Aerial	167	NA	NA		???
1974	Aerial	23	NA	NA		Poor
1975	Aerial	81	NA	NA	Yes	
1976	Aerial	177	NA	NA	Yes	
1977	Aerial	201	NA	NA	Yes	
1978	Aerial	422	NA	NA	Yes	
1979	Aerial	414	NA	NA	Yes	
1980	Aerial	369	NA	NA		Poor
1981	Aerial	791	NA	NA	Yes	
1983	Aerial	480	NA	NA	Yes	
1985	Aerial	1,180	NA	NA	Yes	
1986	Aerial	1,522	NA	NA	Yes	
1987	Aerial	493	NA	NA	Yes	
1988	Aerial	714	NA	NA	Yes	
1990	Aerial	430	NA	NA		Poor
1991	Aerial	1,253	NA	NA	Yes	
1992	Aerial	231	NA	NA	Yes	
1993	Aerial	1,181	NA	NA	Yes	
1995	Aerial	681	NA	NA	Yes	
1996	Aerial	100	NA	NA		Incomplete
1998	Aerial	546	NA	NA		Incomplete
2001	Aerial	768	NA	NA	Yes	
2002	Aerial	897	NA	NA	Yes	
2004	Aerial	465	NA	NA		???
2005	Aerial	230	NA	NA		???
2006	Aerial	672	NA	NA	Yes	
2007	Aerial	899	NA	NA	Yes	
2008	Aerial	507	NA	NA	Yes	
2009	Aerial	842	NA	NA	Yes	
2010	Aerial	355	NA	NA	Yes	
2011	Aerial	613	NA	NA	Yes	
2012	Aerial	692	NA	NA	Yes	
2013	Aerial	532	NA	NA	Yes	
2015	Aerial	565	NA	NA	Yes	
2017	Aerial	443	NA	NA	Yes	
2018	Aerial	432	NA	NA	Yes	
2019	Aerial	485	NA	NA	Yes	

A.1.6 Lower Yukon Stock - Koyukuk Watershed

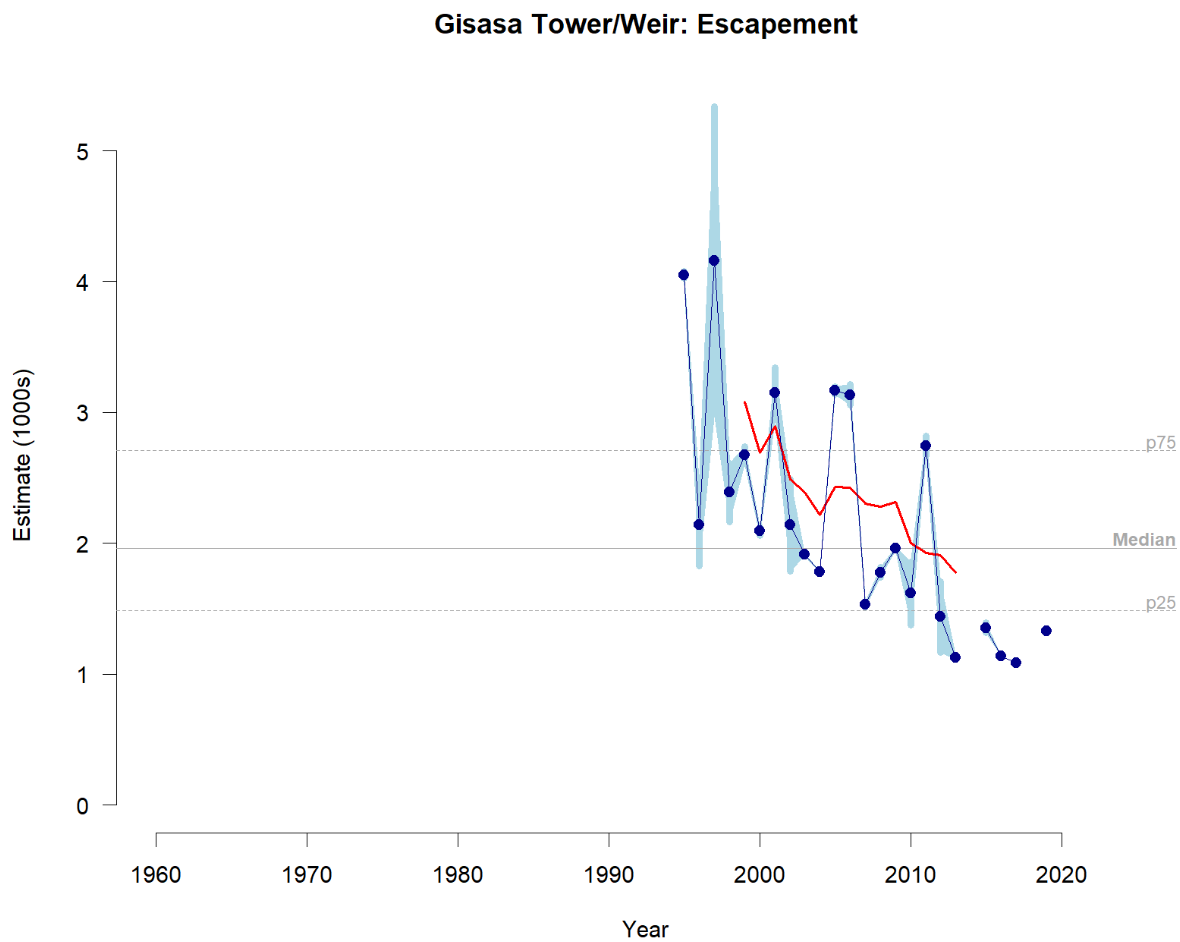

Figure A.16. *Available Estimates from Gisasa River Tower/Weir*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

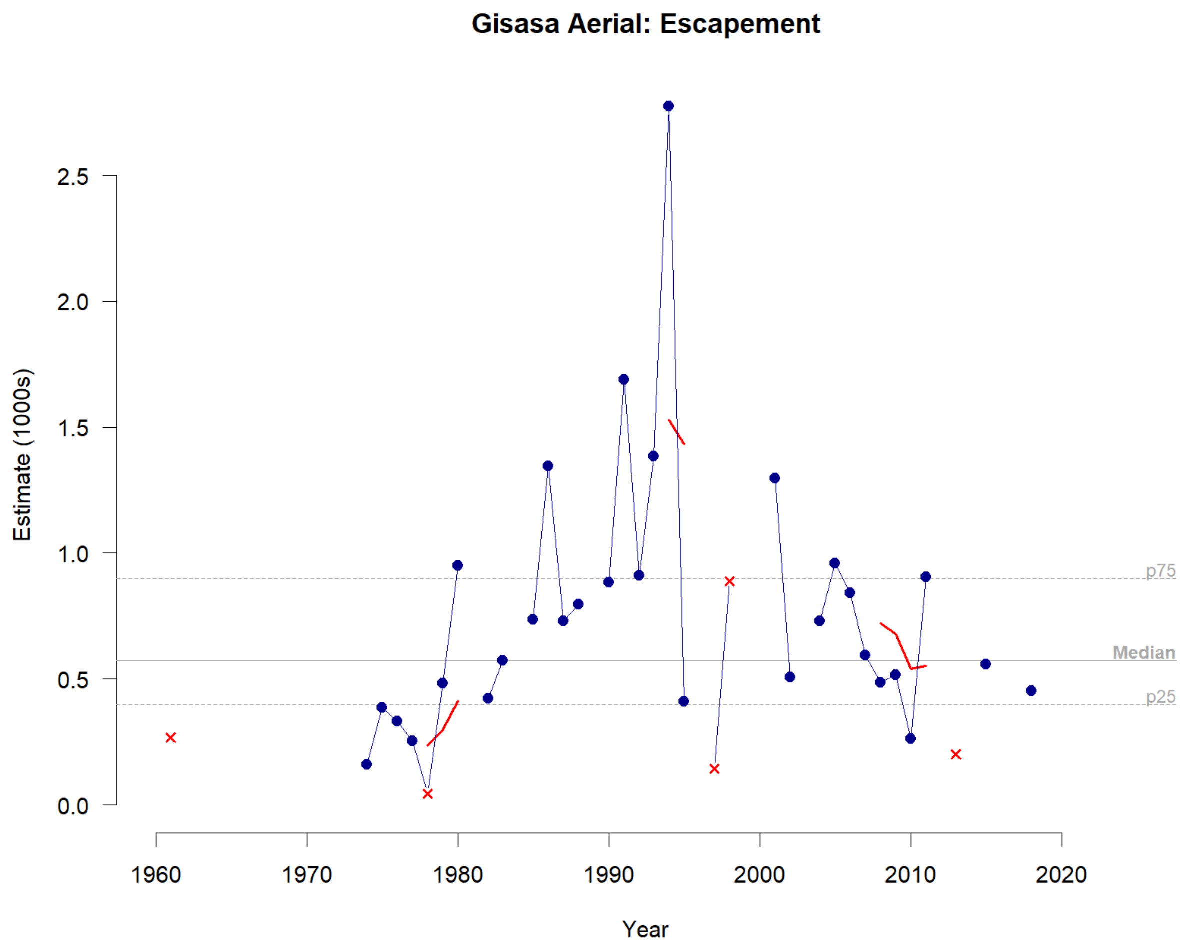

Figure A.17. *Available Estimates from Gisasa River Aerial Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

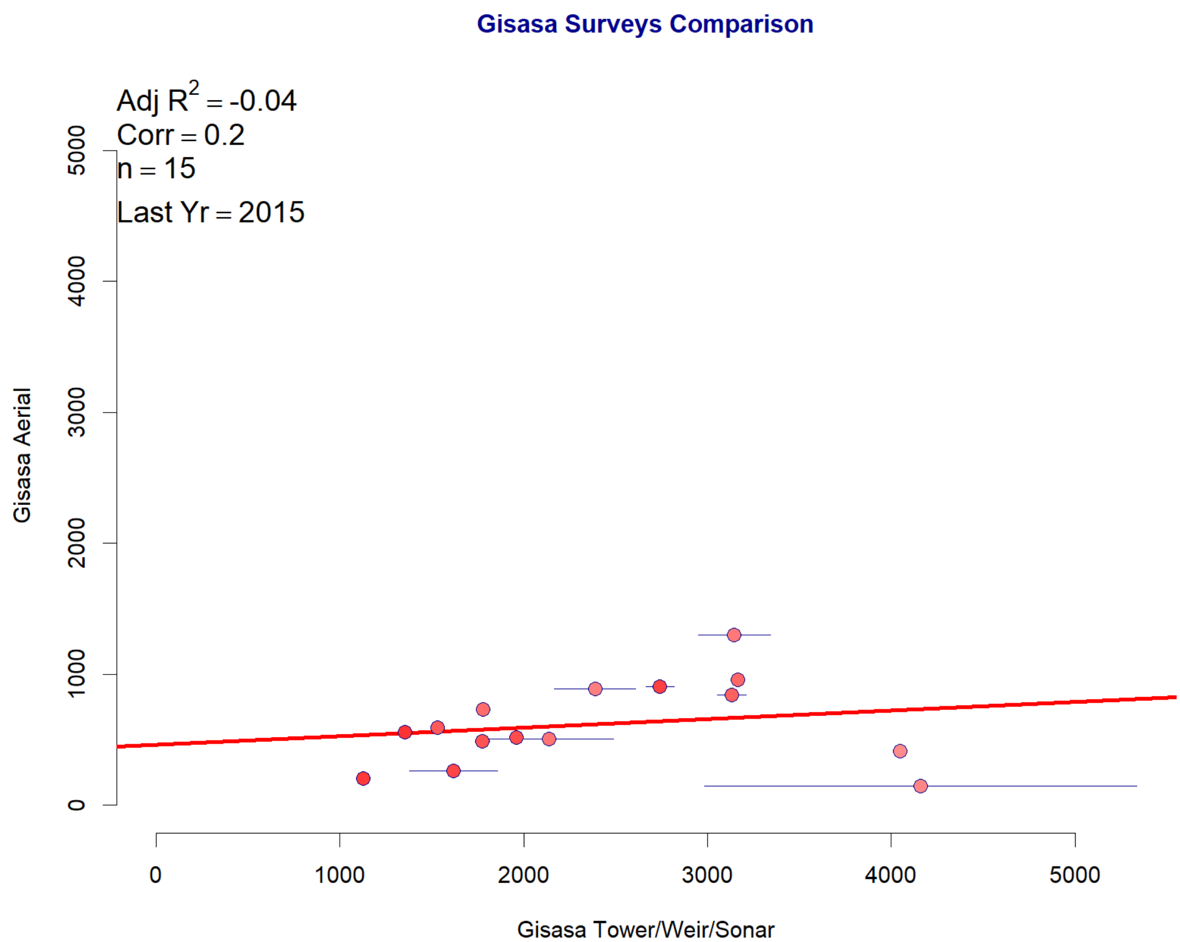

Figure A.18. Gisasa Survey Comparison

Table A.12. *Annual Survey Types and Escapement Estimate - Gisasa Tower/Weir*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1995	Various	4,050	4,024	4,076	Yes	
1996	Various	2,140	1,826	2,454	Yes	
1997	Various	4,161	2,985	5,337	Yes	
1998	Various	2,388	2,166	2,610	Yes	
1999	Various	2,672	2,608	2,736	Yes	
2000	Various	2,094	2,062	2,126	Yes	
2001	Various	3,147	2,951	3,343	Yes	
2002	Various	2,139	1,787	2,491	Yes	
2003	Various	1,912	1,902	1,922	Yes	
2004	Various	1,781	1,773	1,789	Yes	
2005	Various	3,166	3,136	3,196	Yes	
2006	Various	3,133	3,055	3,211	Yes	
2007	Various	1,532	1,514	1,550	Yes	
2008	Various	1,777	1,738	1,816	Yes	
2009	Various	1,962	1,952	1,972	Yes	
2010	Various	1,618	1,378	1,858	Yes	
2011	Various	2,742	2,666	2,818	Yes	
2012	Various	1,437	1,169	1,705	Yes	
2013	Various	1,128	1,116	1,140	Yes	
2015	Various	1,354	1,316	1,392	Yes	
2016	Various	1,137	1,137	1,137	Yes	
2017	Various	1,083	1,083	1,083	Yes	
2019	Various	1,328	1,328	1,328	Yes	

Table A.13. *Annual Survey Types and Escapement Estimate - Gisasa Aerial*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1961	Aerial	266	NA	NA		Poor
1974	Aerial	161	NA	NA	Yes	
1975	Aerial	385	NA	NA	Yes	
1976	Aerial	332	NA	NA	Yes	
1977	Aerial	255	NA	NA	Yes	
1978	Aerial	45	NA	NA		Poor
1979	Aerial	484	NA	NA	Yes	
1980	Aerial	951	NA	NA	Yes	
1982	Aerial	421	NA	NA	Yes	
1983	Aerial	572	NA	NA	Yes	
1985	Aerial	735	NA	NA	Yes	
1986	Aerial	1,346	NA	NA	Yes	
1987	Aerial	731	NA	NA	Yes	
1988	Aerial	797	NA	NA	Yes	
1990	Aerial	884	NA	NA	Yes	
1991	Aerial	1,690	NA	NA	Yes	
1992	Aerial	910	NA	NA	Yes	
1993	Aerial	1,385	NA	NA	Yes	
1994	Aerial	2,775	NA	NA	Yes	
1995	Aerial	410	NA	NA	Yes	
1997	Aerial	144	NA	NA		Incomplete
1998	Aerial	889	NA	NA		Poor
2001	Aerial	1,298	NA	NA	Yes	
2002	Aerial	506	NA	NA	Yes	
2004	Aerial	731	NA	NA	Yes	
2005	Aerial	958	NA	NA	Yes	
2006	Aerial	843	NA	NA	Yes	
2007	Aerial	593	NA	NA	Yes	
2008	Aerial	487	NA	NA	Yes	
2009	Aerial	515	NA	NA	Yes	
2010	Aerial	264	NA	NA	Yes	
2011	Aerial	906	NA	NA	Yes	
2013	Aerial	201	NA	NA		Poor
2015	Aerial	558	NA	NA	Yes	
2018	Aerial	452	NA	NA	Yes	

A.1.7 Lower Yukon Stock - Tozitna Watershed

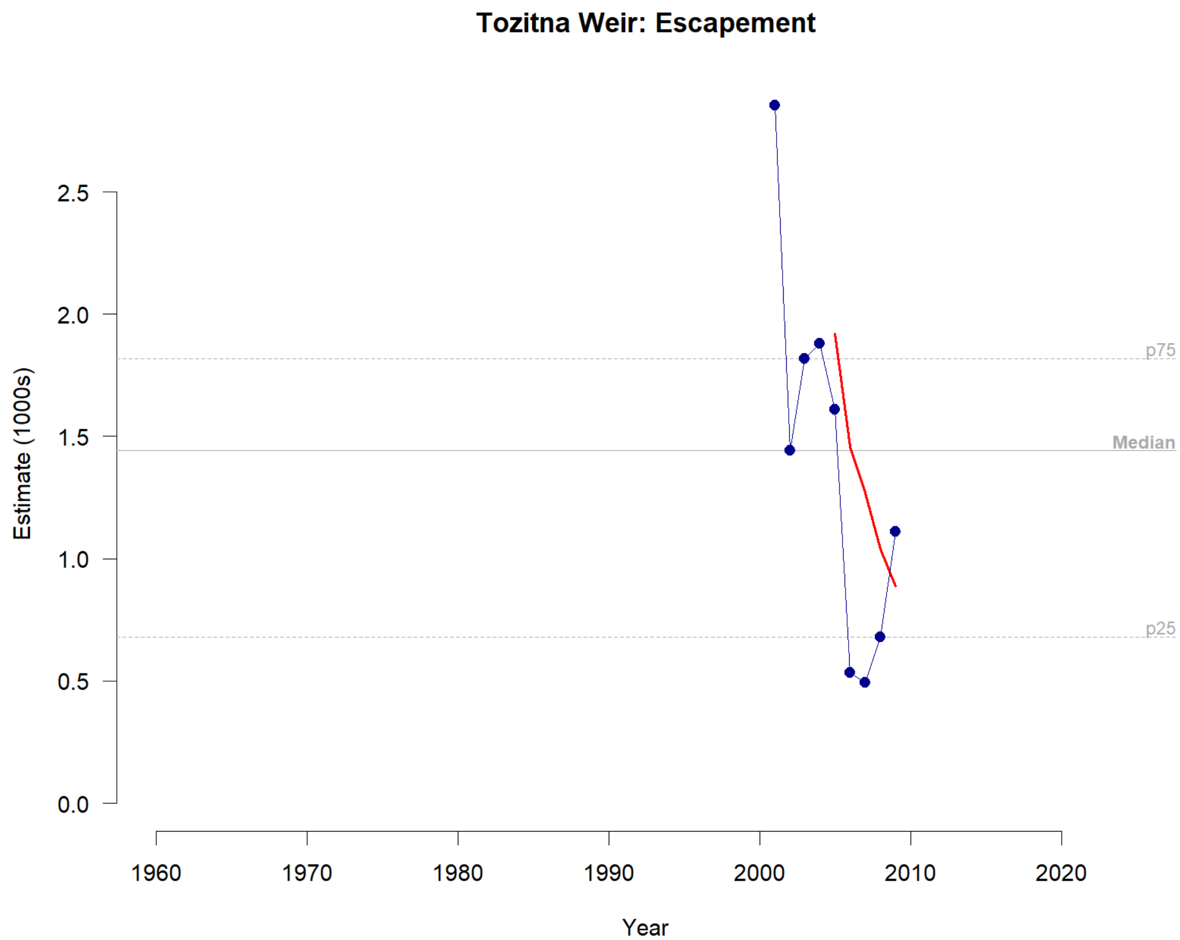

Figure A.19. *Available Estimates from Tozitna River Tower/Weir*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

Table A.14. *Annual Survey Types and Escapement Estimate - Tozitna Weir*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
2001	Weir	2,854	NA	NA	Yes	
2002	Weir	1,441	NA	NA	Yes	
2003	Weir	1,819	NA	NA	Yes	
2004	Weir	1,880	NA	NA	Yes	
2005	Weir	1,611	NA	NA	Yes	
2006	Weir	533	NA	NA	Yes	
2007	Weir	494	NA	NA	Yes	
2008	Weir	681	NA	NA	Yes	
2009	Weir	1,112	NA	NA	Yes	

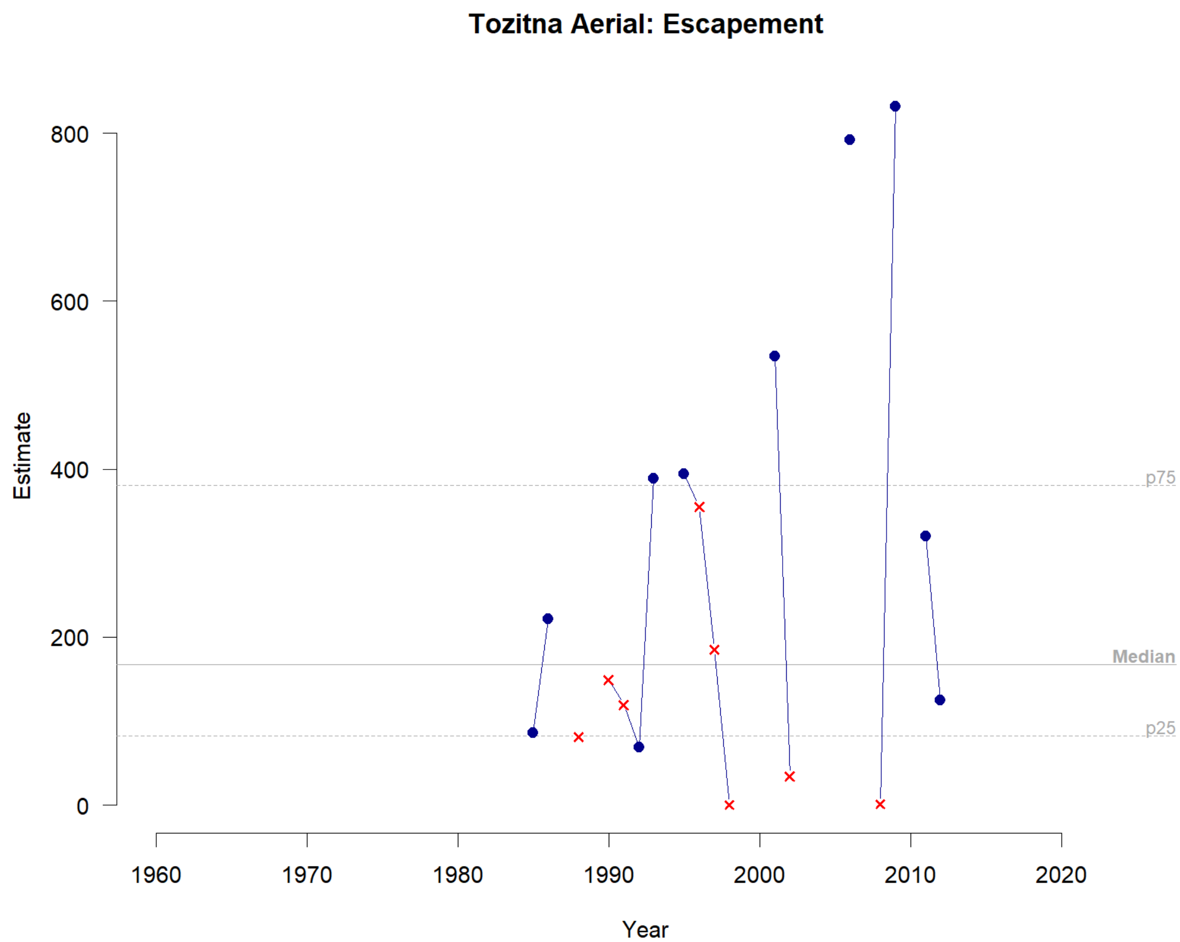

Figure A.20. *Available Estimates from Tozitna River Aerial*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

Table A.15. *Annual Survey Types and Escapement Estimate - Tozitna Aerial*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1985	Aerial	86	NA	NA	Yes	
1986	Aerial	222	NA	NA	Yes	
1988	Aerial	81	NA	NA		Good, but incomplete
1990	Aerial	149	NA	NA		Fair, but can not separate count to index area
1991	Aerial	119	NA	NA		Fair, but can not separate count to index area
1992	Aerial	69	NA	NA	Yes	
1993	Aerial	389	NA	NA	Yes	
1995	Aerial	394	NA	NA	Yes	
1996	Aerial	355	NA	NA		Fair, but can not separate count to index area
1997	Aerial	185	NA	NA		Poor
1998	Aerial	0	NA	NA		Poor
2001	Aerial	534	NA	NA	Yes	
2002	Aerial	34	NA	NA		Good, but outside index area
2006	Aerial	792	NA	NA	Yes	
2008	Aerial	1	NA	NA		Good, but incomplete - focus was redd counts
2009	Aerial	832	NA	NA	Yes	Good, but includes counts upriver from index area
2011	Aerial	320	NA	NA	Yes	
2012	Aerial	125	NA	NA	Yes	

A.2 Middle Yukon

A.2.1 Correlations

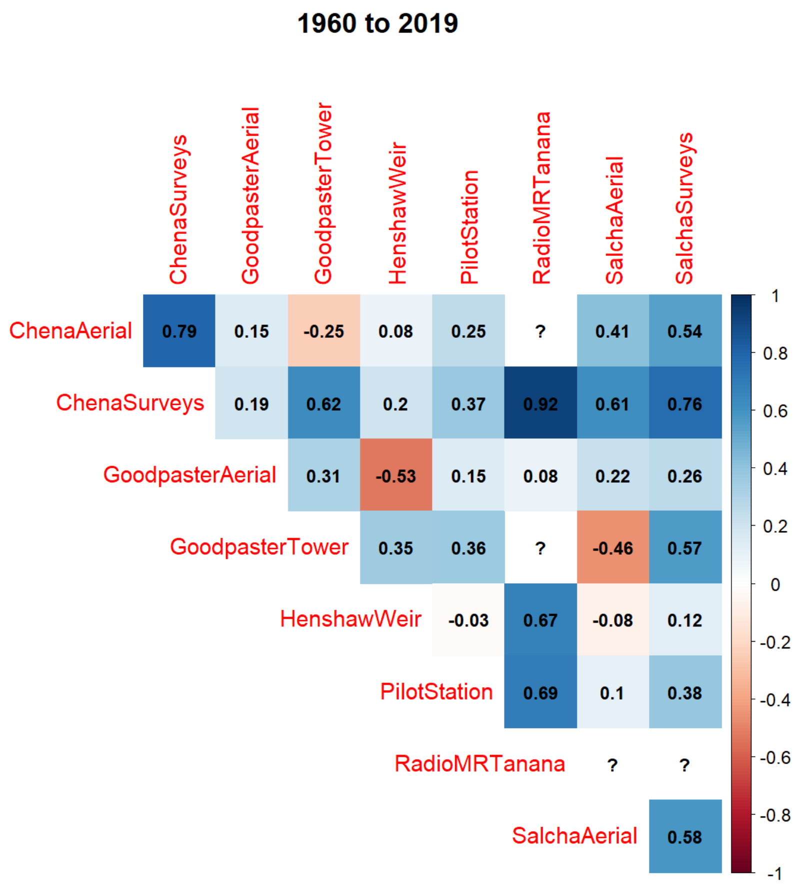

Figure A.21. *Correlation in Abundance Estimates - Middle Yukon Projects - All Years*. Plot shows pairwise correlations of all available data points for each pair of time series. Note that high correlations could be due to few paired obs (i.e. only few yrs where both projects had an estimate). Tables below list sample sizes. Figures in next sections show individual time series, and scatterplots for comparing key projects. The *?* identifies pairs with less than 5 data points for which correlations were not calculated.

Figure A.22. *Correlation in Abundance Estimates - Middle Yukon Projects - Earlier Years*. Figure layout as per Figure A.21.

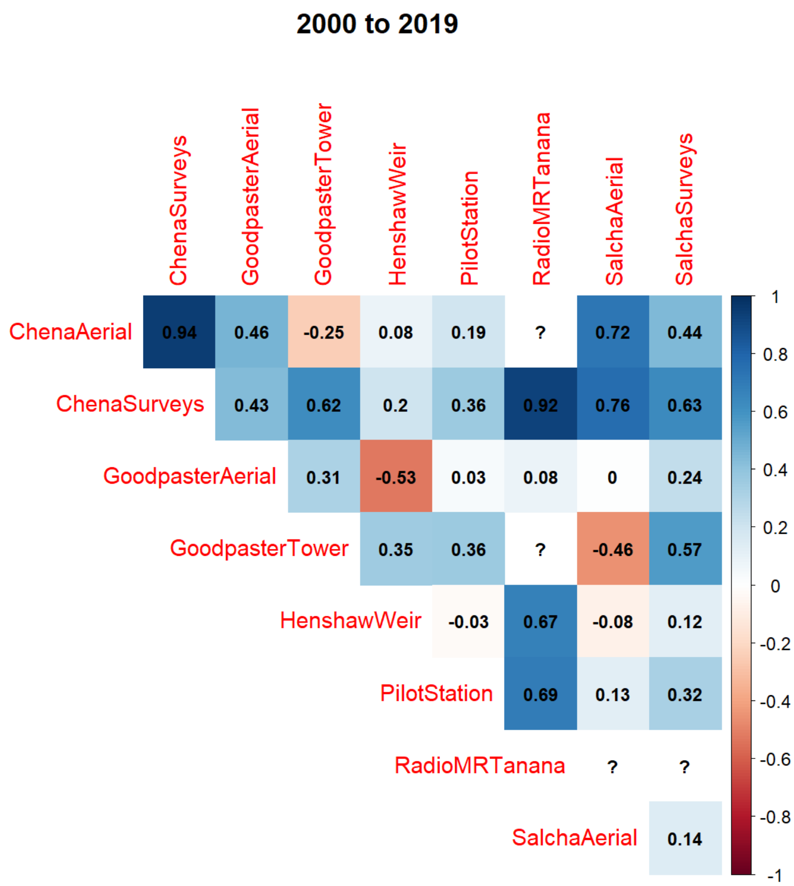

Figure A.23. *Correlation in Abundance Estimates - Middle Yukon Projects - Recent Years.* Figure layout as per Figure A.21.

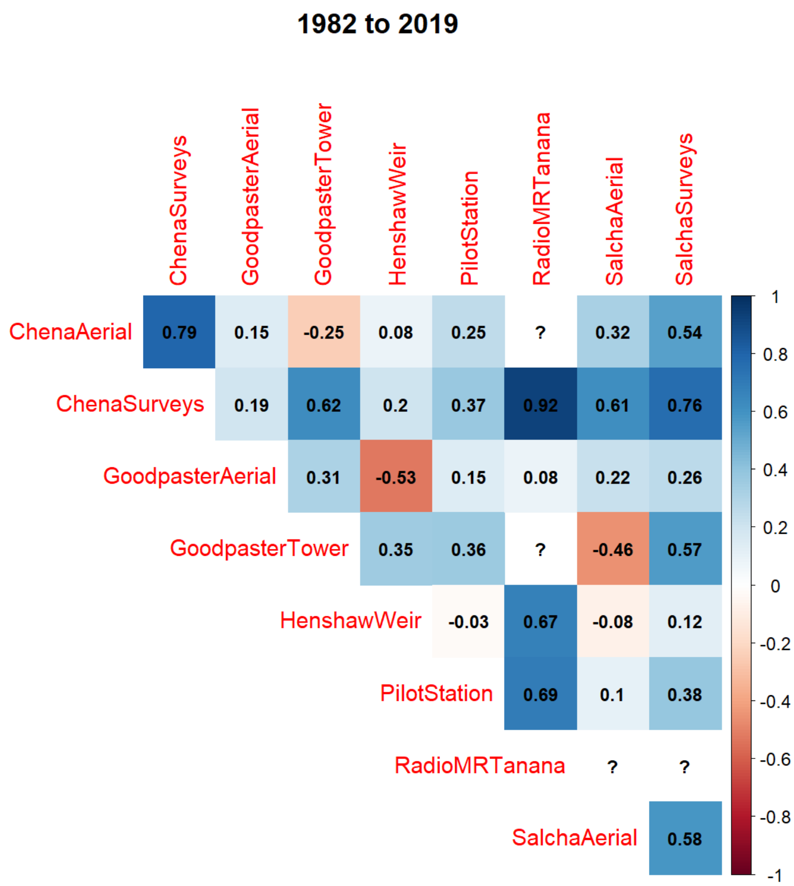

Figure A.24. *Correlation in Abundance Estimates - Middle Yukon Projects - Model Years (1982-2019)*. Covering the same time window as the integrated run reconstruction and spawner-recruit model by Connors et al. (2022). Figure layout as per Figure A.21.

Table A.16. *Correlation in Abundance Estimates - Middle Yukon Projects*. Table lists all the pairwise correlations shown in Figures A.21 to A.23. Correlations larger than 0.4 are highlighted in light blue for positive correlations and orange for negative correlations.

		1960 to 2019		1960 to 1999		2000 to 2019		1982 to 2019	
Project 1	**Project 2**	**Corr**	**Obs**	**Corr**	**Obs**	**Corr**	**Obs**	**Corr**	**Obs**
ChenaAerial	ChenaSurveys	0.79	18	0.72	12	0.94	6	0.79	18
ChenaAerial	GoodpasterAerial	0.15	11	0.05	7	0.46	4	0.15	11
ChenaAerial	GoodpasterTower	-0.25	7			-0.25	7	-0.25	7
ChenaAerial	HenshawWeir	0.08	6			0.08	6	0.08	6
ChenaAerial	PilotStation	0.25	19	0.79	11	0.19	8	0.25	19
ChenaAerial	RadioMRTanana		0				0		0
ChenaAerial	SalchaAerial	0.41	31	0.33	23	0.72	8	0.32	24
ChenaAerial	SalchaSurveys	0.54	18	0.56	11	0.44	7	0.54	18
ChenaSurveys	GoodpasterAerial	0.19	15	0.05	8	0.43	7	0.19	15
ChenaSurveys	GoodpasterTower	0.62	13			0.62	13	0.62	13
ChenaSurveys	HenshawWeir	0.2	14			0.2	14	0.2	14
ChenaSurveys	PilotStation	0.37	29	0.7	12	0.36	17	0.37	29
ChenaSurveys	RadioMRTanana	0.92	3			0.92	3	0.92	3
ChenaSurveys	SalchaAerial	0.61	23	0.52	14	0.76	9	0.61	23
ChenaSurveys	SalchaSurveys	0.76	29	0.87	13	0.63	16	0.76	29
GoodpasterAerial	GoodpasterTower	0.31	4			0.31	4	0.31	4
GoodpasterAerial	HenshawWeir	-0.53	7			-0.53	7	-0.53	7
GoodpasterAerial	PilotStation	0.15	15	0.2	7	0.03	8	0.15	15
GoodpasterAerial	RadioMRTanana	0.08	3			0.08	3	0.08	3
GoodpasterAerial	SalchaAerial	0.22	14	0.52	8	0	6	0.22	14
GoodpasterAerial	SalchaSurveys	0.26	16	0.35	8	0.24	8	0.26	16
GoodpasterTower	HenshawWeir	0.35	12			0.35	12	0.35	12
GoodpasterTower	PilotStation	0.36	15			0.36	15	0.36	15
GoodpasterTower	RadioMRTanana		1				1		1
GoodpasterTower	SalchaAerial	-0.46	8			-0.46	8	-0.46	8
GoodpasterTower	SalchaSurveys	0.57	14			0.57	14	0.57	14
HenshawWeir	PilotStation	-0.03	17			-0.03	17	-0.03	17
HenshawWeir	RadioMRTanana	0.67	3			0.67	3	0.67	3
HenshawWeir	SalchaAerial	-0.08	9			-0.08	9	-0.08	9
HenshawWeir	SalchaSurveys	0.12	16			0.12	16	0.12	16
PilotStation	RadioMRTanana	0.69	3			0.69	3	0.69	3
PilotStation	SalchaAerial	0.1	23	0.22	12	0.13	11	0.1	23
PilotStation	SalchaSurveys	0.38	29	0.72	11	0.32	18	0.38	29
RadioMRTanana	SalchaAerial		1				1		1
RadioMRTanana	SalchaSurveys		3				3		3

Project 1	Project 2	Corr	Obs	Corr	Obs	Corr	Obs	Corr	Obs
SalchaAerial	SalchaSurveys	0.58	23	0.67	13	0.14	10	0.58	23

A.2.2 Middle Yukon Stock - Koyukuk Watershed

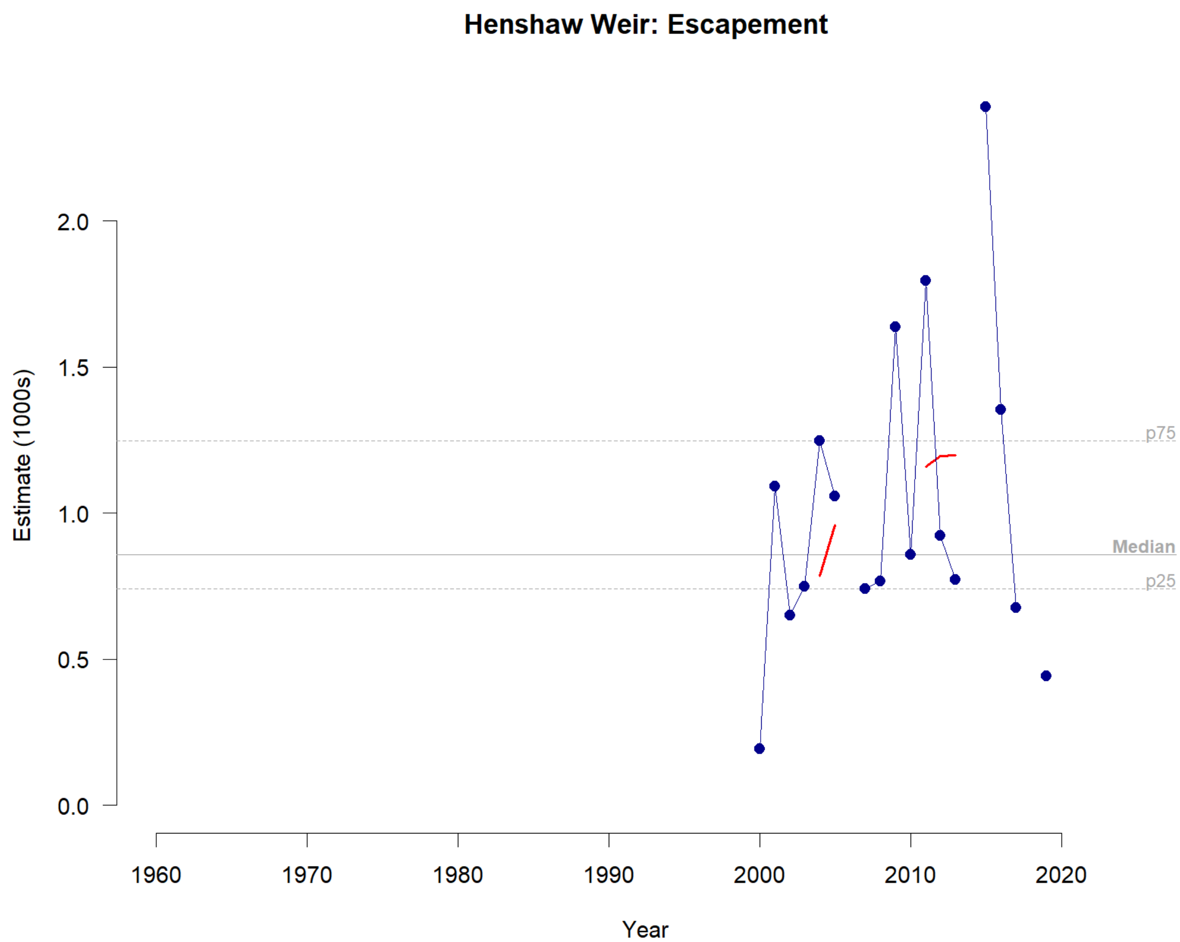

Figure A.25. *Available Estimates from Henshaw Creek Weir Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

Table A.17. *Annual Survey Types and Escapement Estimate - Henshaw Creek Weir Estimate*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
2000	Weir	193	NA	NA	Yes	
2001	Weir	1,091	NA	NA	Yes	
2002	Weir	649	NA	NA	Yes	
2003	Weir	748	NA	NA	Yes	
2004	Weir	1,247	NA	NA	Yes	
2005	Weir	1,059	NA	NA	Yes	
2007	Weir	740	NA	NA	Yes	
2008	Weir	766	NA	NA	Yes	
2009	Weir	1,637	NA	NA	Yes	
2010	Weir	857	NA	NA	Yes	4 days with high water were filled in with linear interpolation
2011	Weir	1,796	NA	NA	Yes	
2012	Weir	922	NA	NA	Yes	
2013	Weir	772	NA	NA	Yes	5 days with high water were filled in with linear interpolation
2015	Weir	2,391	NA	NA	Yes	
2016	Weir	1,354	NA	NA	Yes	1 day with high water was filled in with linear interpolation
2017	Weir	677	NA	NA	Yes	
2019	Weir	441	NA	NA	Yes	1 day with smoke was filled in with linear interpolation

A.2.3 Middle Yukon Stock - Tanana

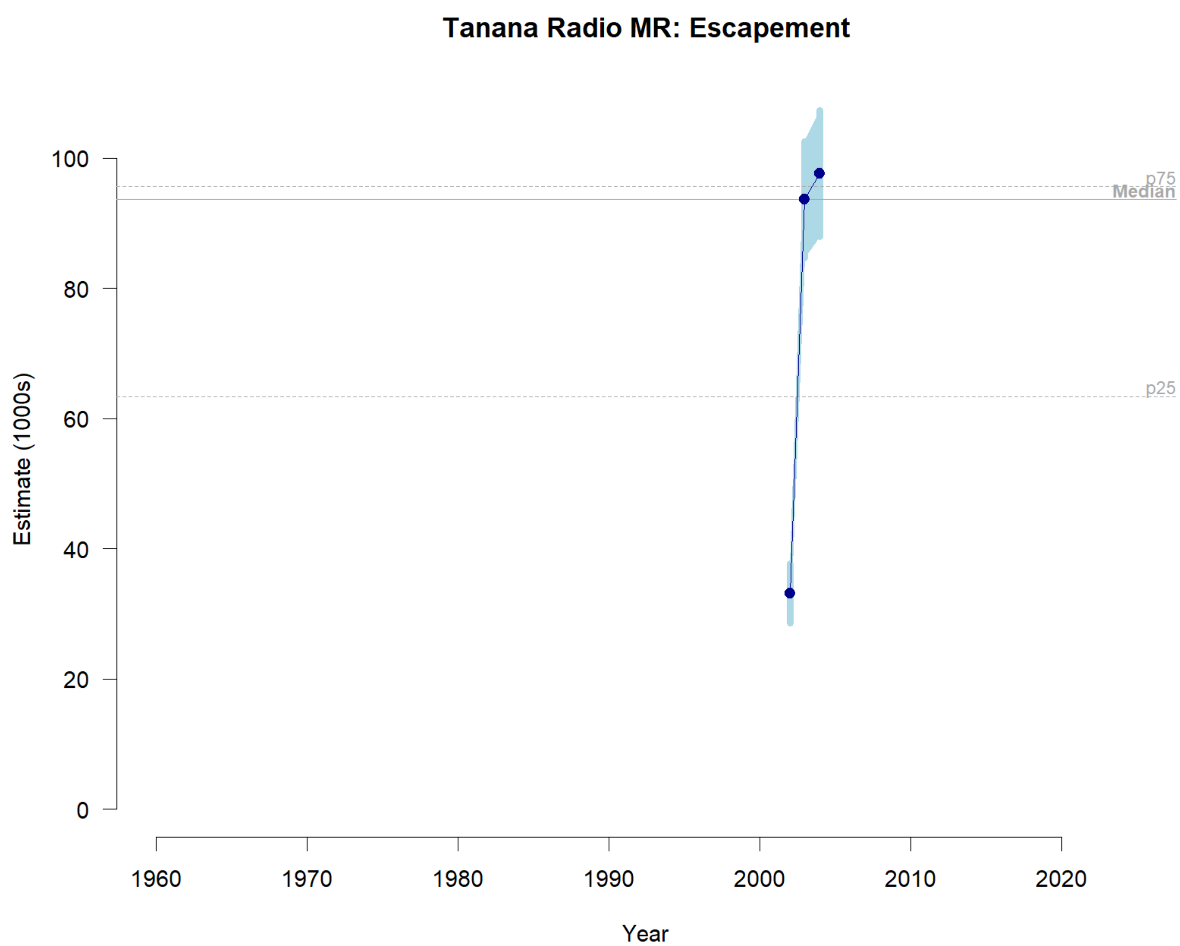

Figure A.26. *Available Estimates from Tanana Radio Mark-Recapture Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates. Survey methods varied over time, as listed in Table A.18.

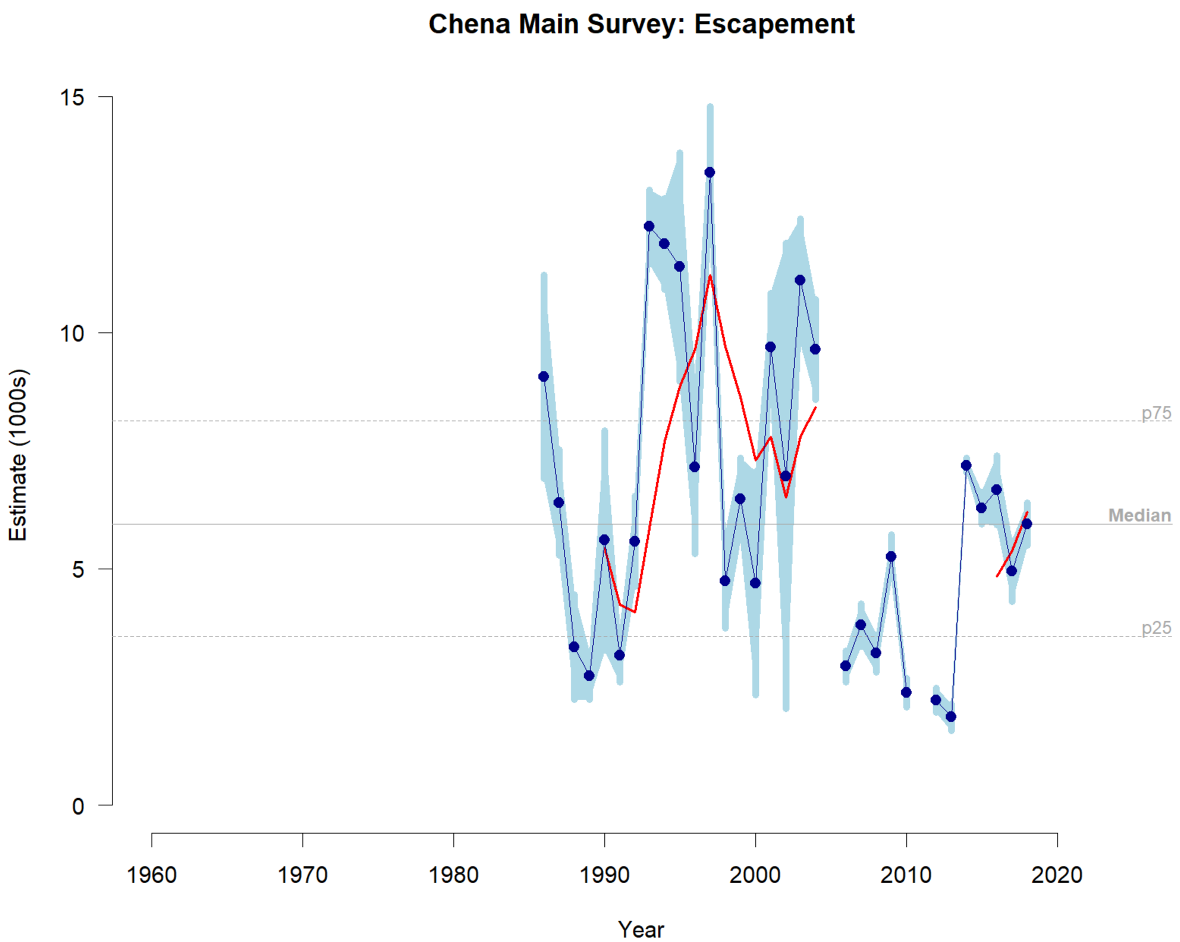

Figure A.27. *Available Estimates from Chena River Main Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates. Survey methods varied over time, as listed in Table A.19.

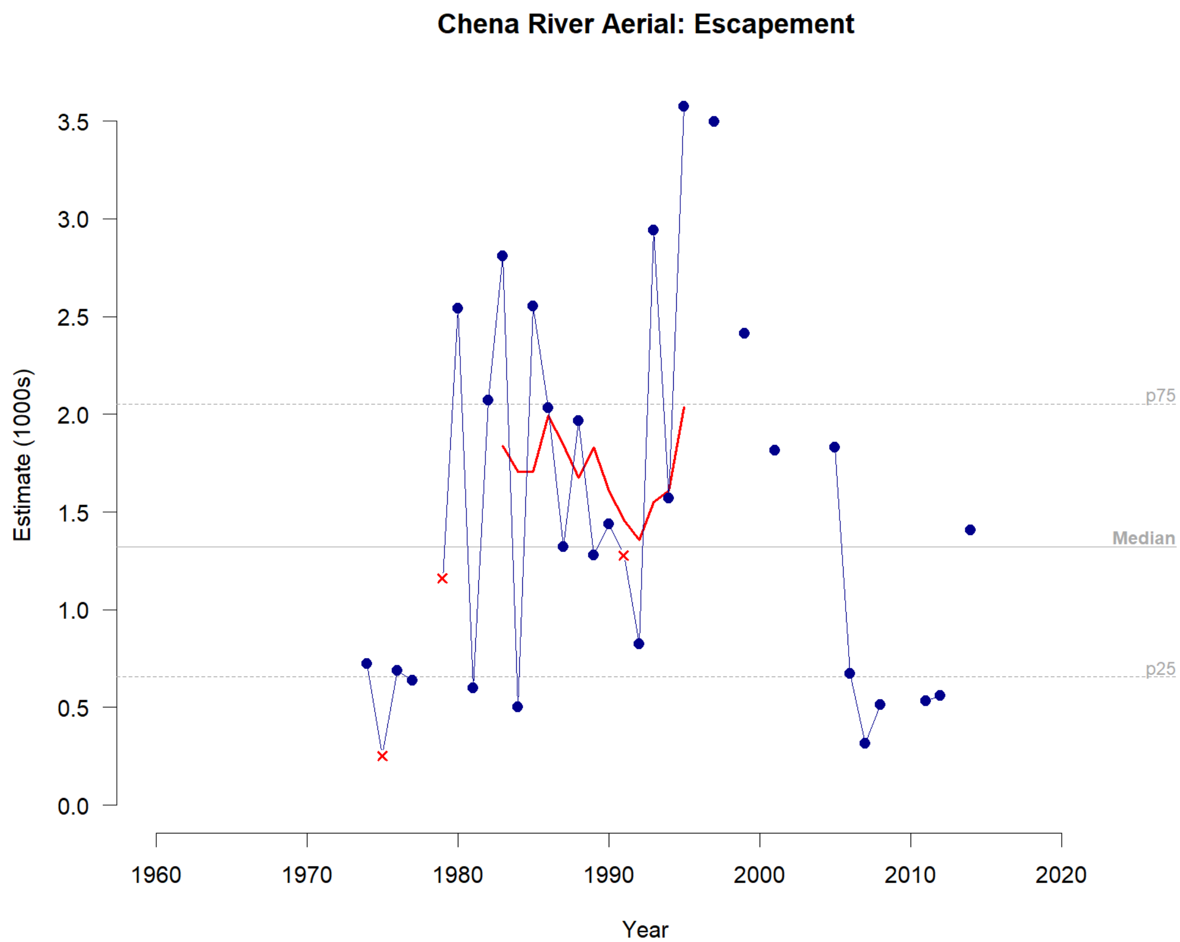

Figure A.28. *Available Estimates from Chena River Aerial Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

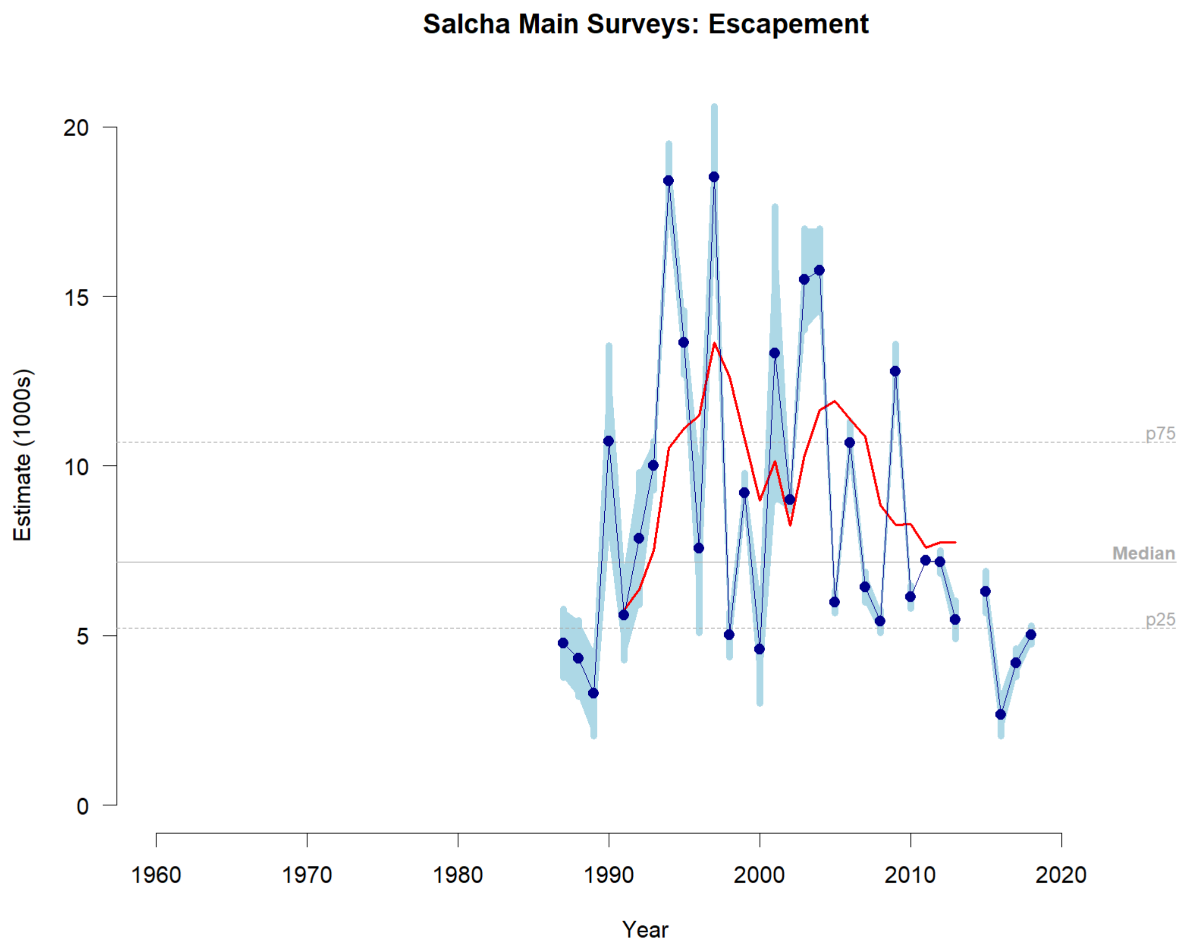

Figure A.29. *Available Estimates from Salcha River Main Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates. Survey methods varied over time, as listed in Table A.21.

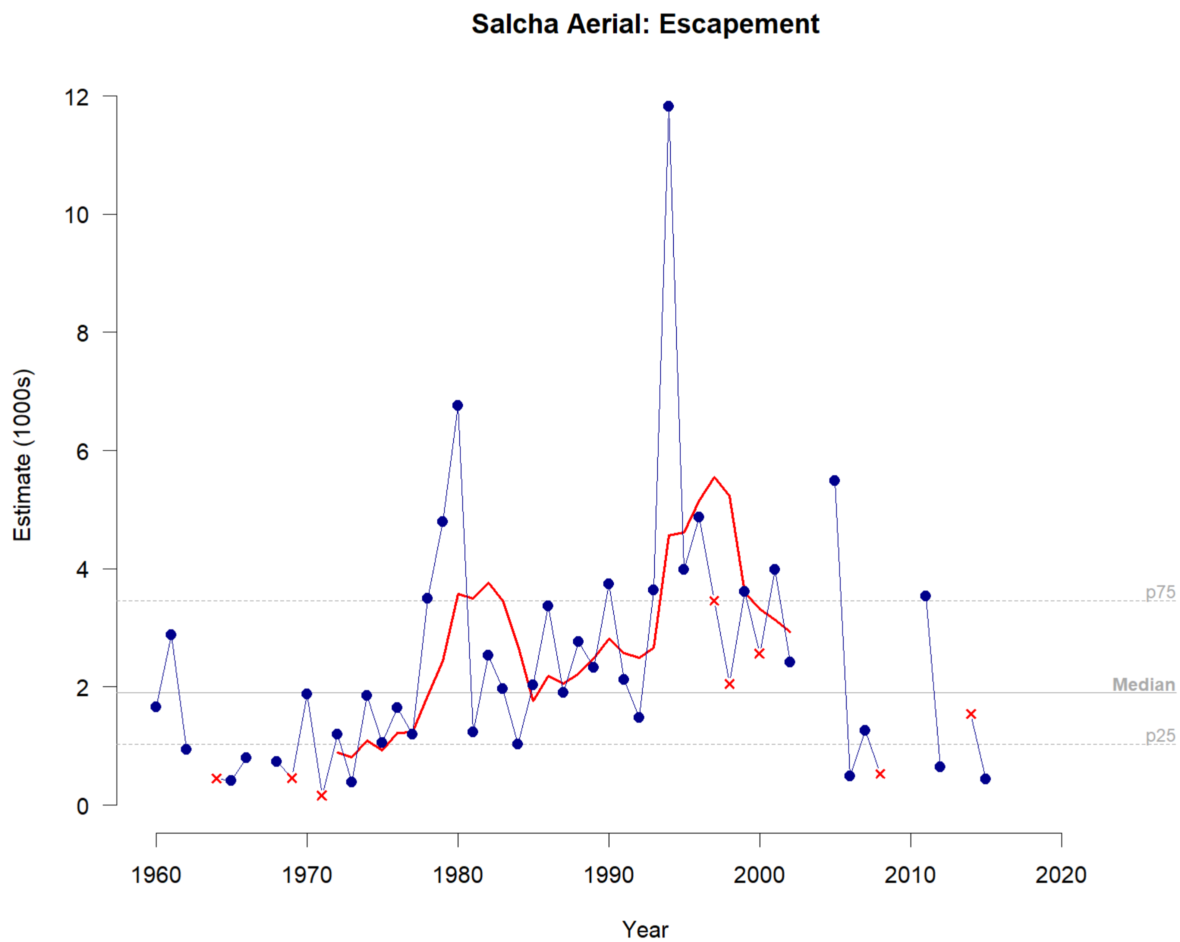

Figure A.30. *Available Estimates from Salcha River Aerial Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

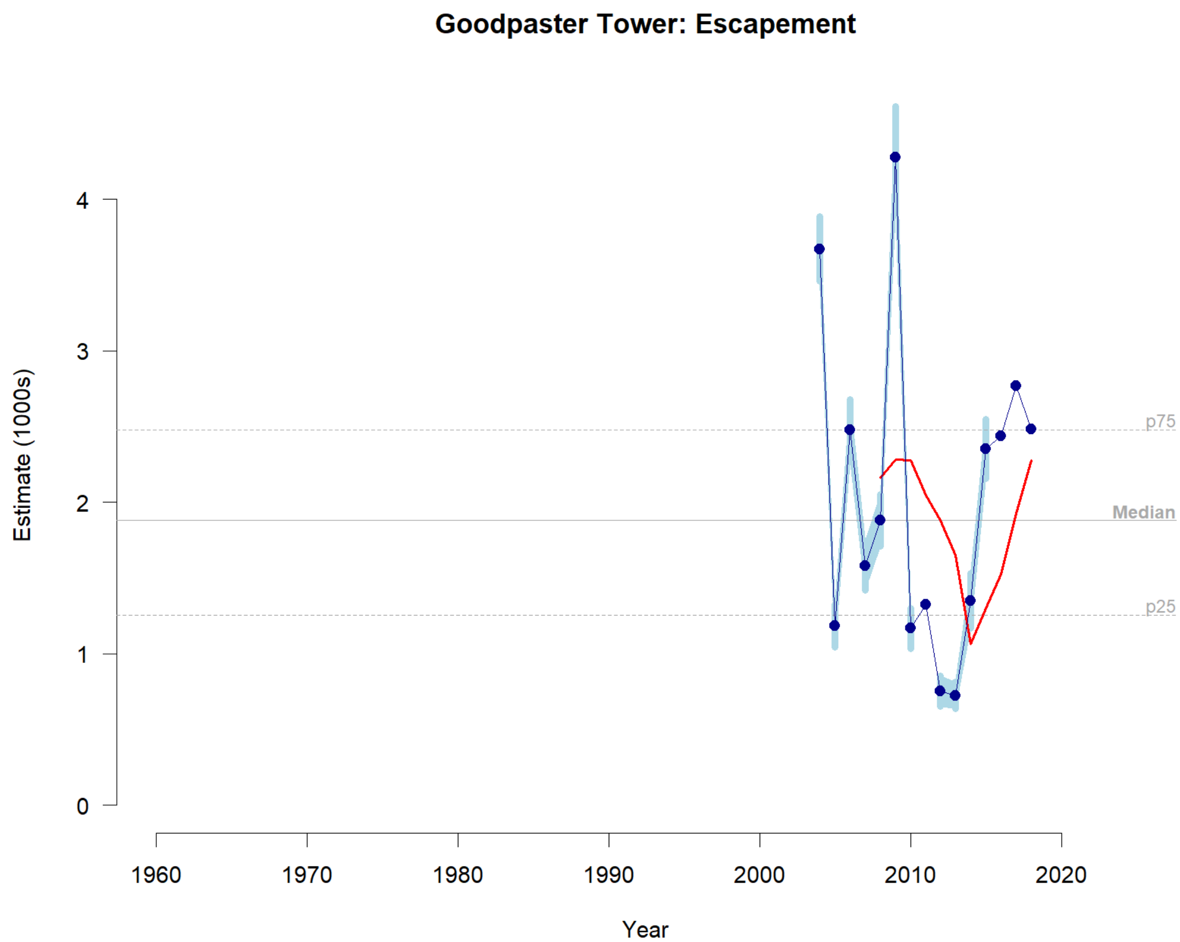

Figure A.31. *Available Estimates from Goodpaster River Tower and Weir*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

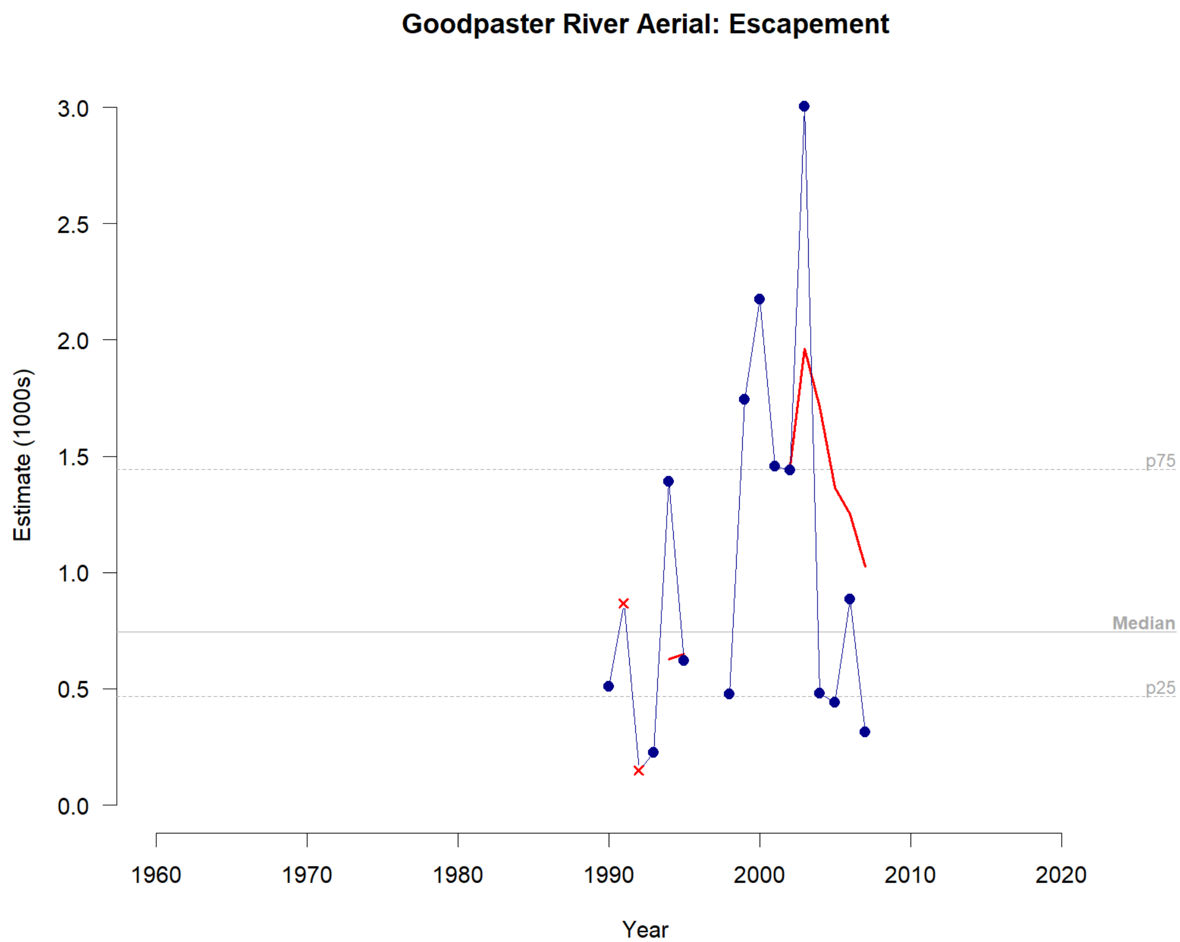

Figure A.32. *Available Estimates from Goodpaster River Aerial Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

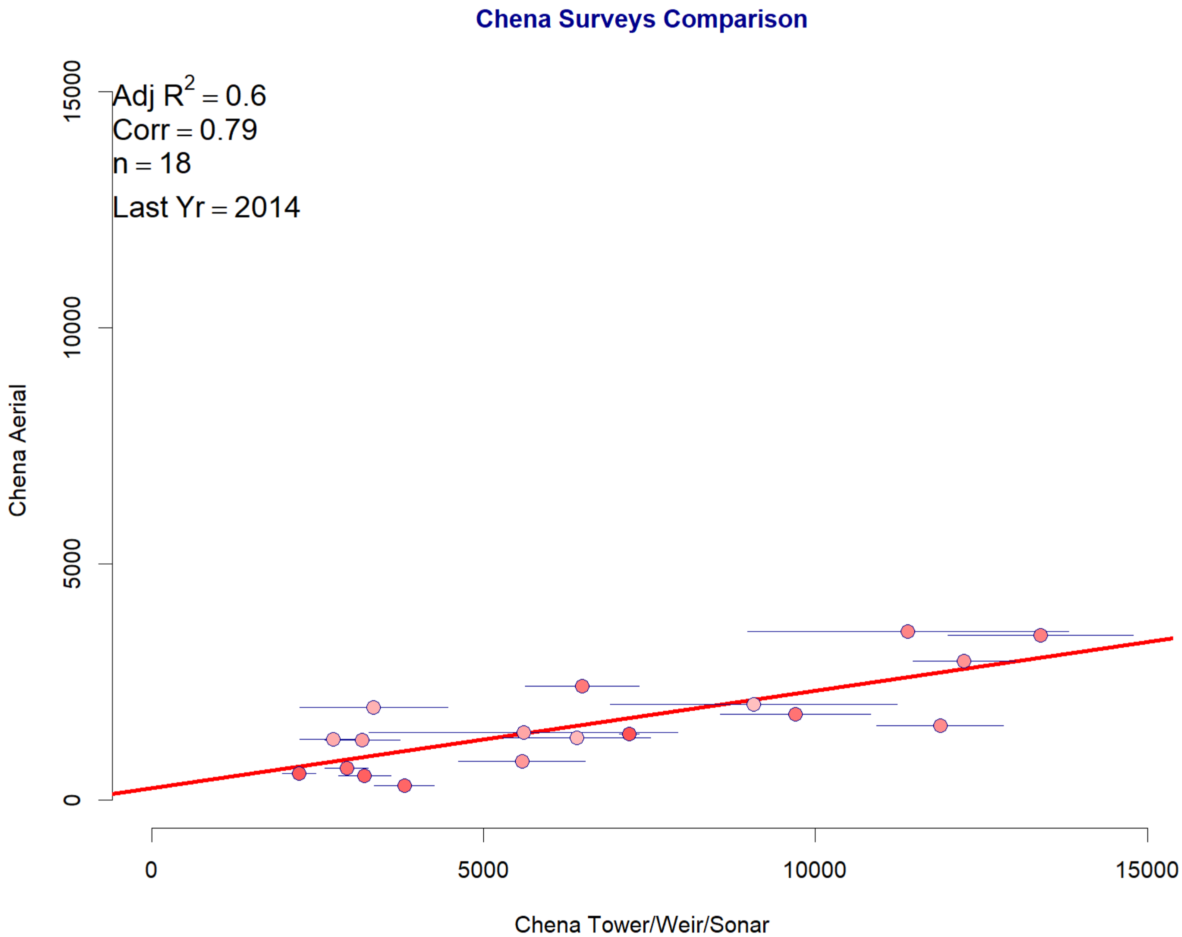

Figure A.33. *Chena Survey Comparison*. Survey methods varied over time, as listed in Table A.19.

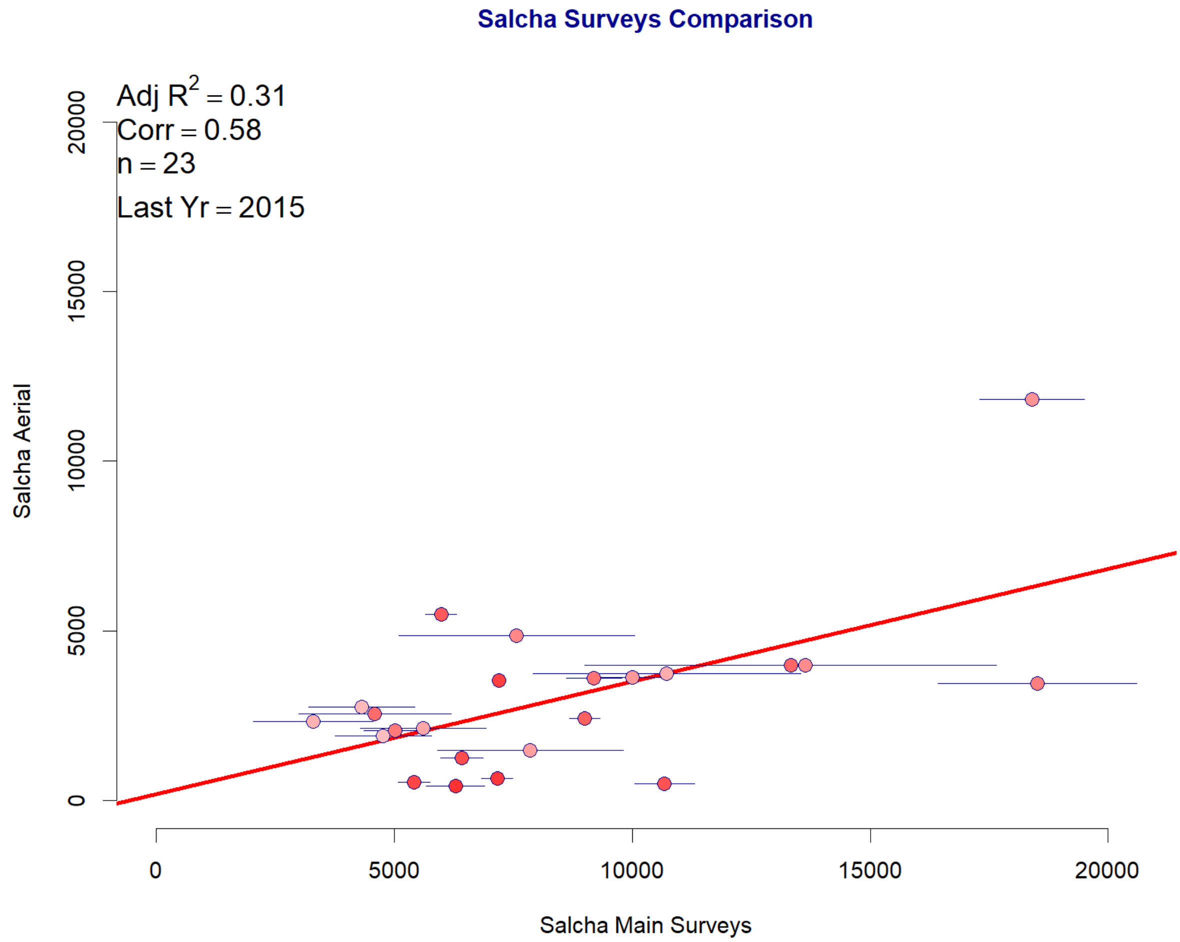

Figure A.34. *Salcha Survey Comparison*. Survey methods varied over time, as listed in Table A.21.

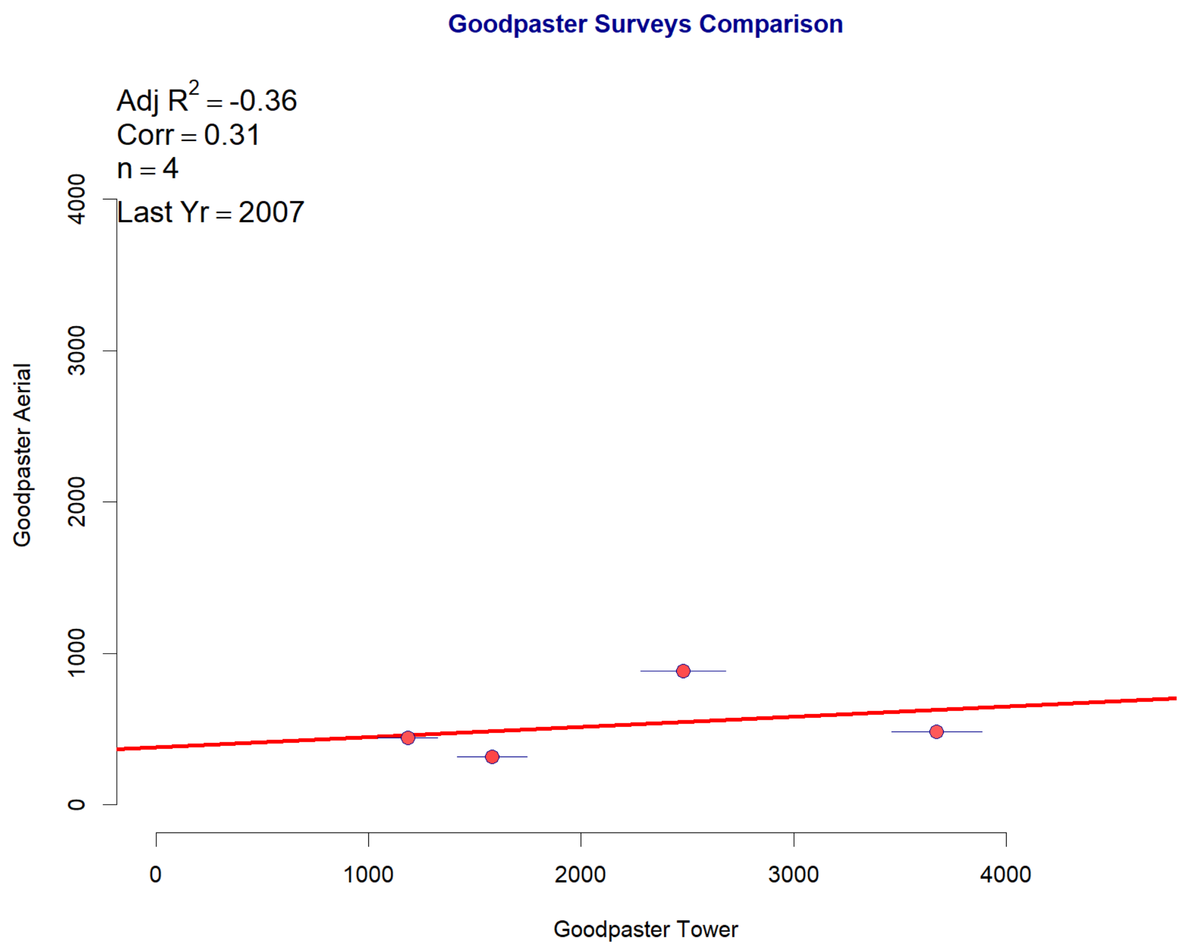

Figure A.35. Goodpaster Survey Comparison

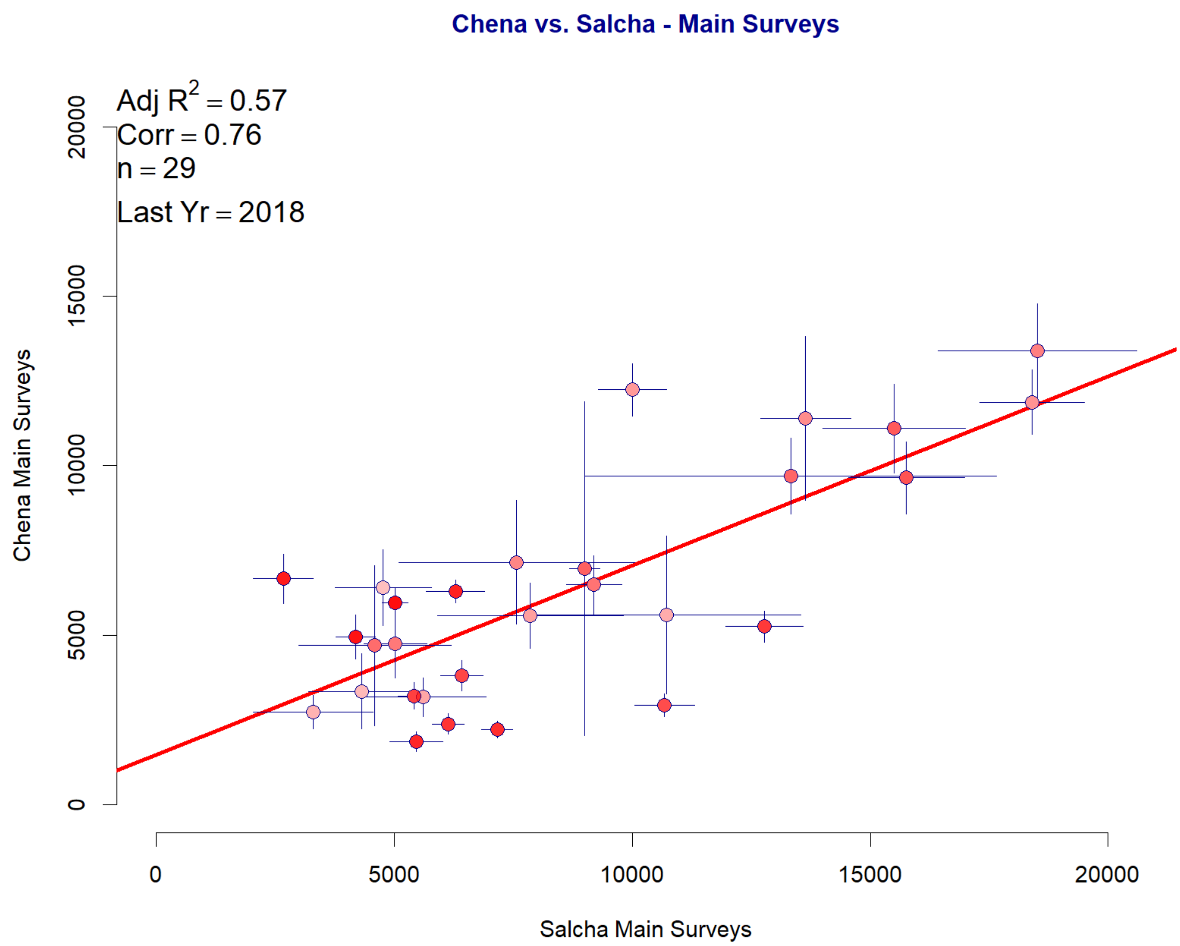

Figure A.36. Chena vs Salcha Main Survey Comparison

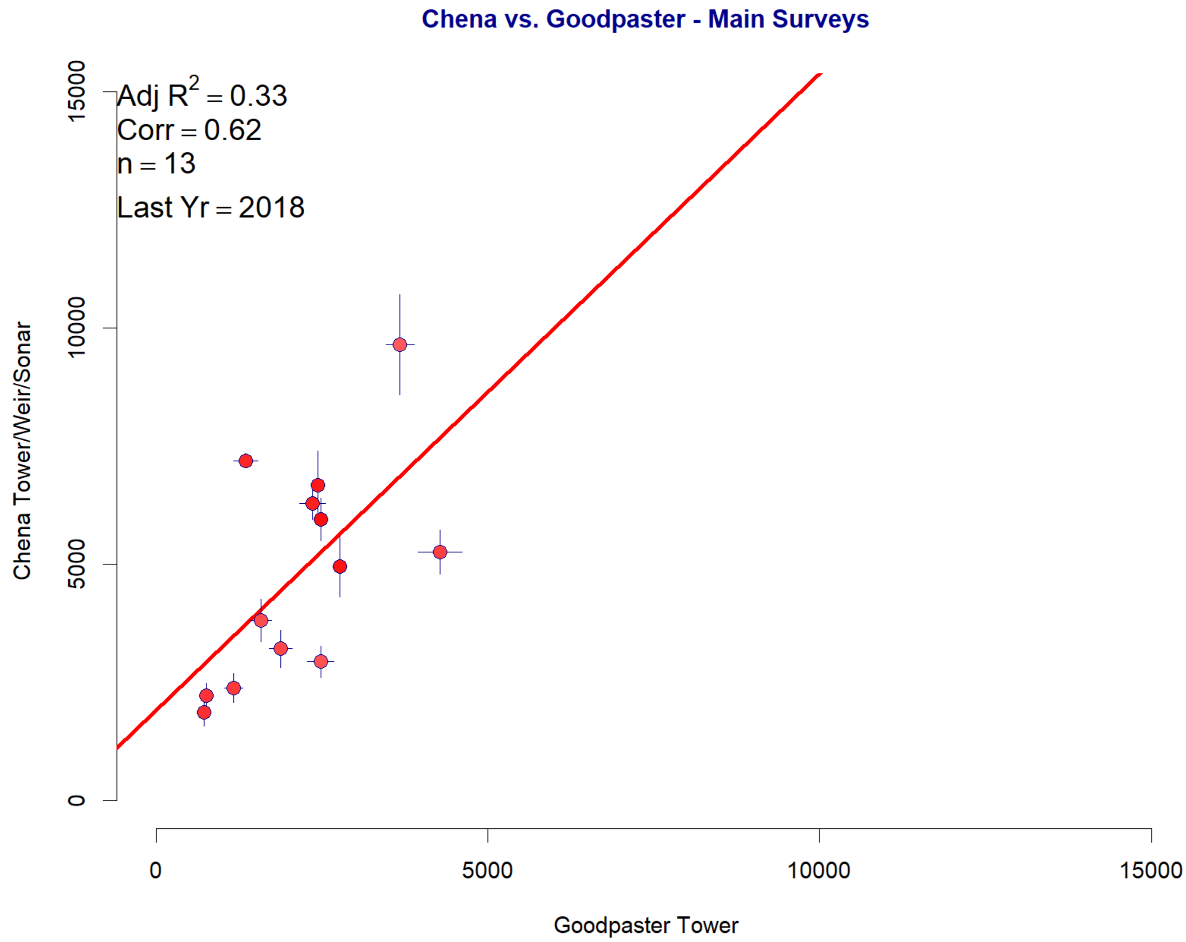

Figure A.37. Chena vs Goodpaster Main Survey Comparison

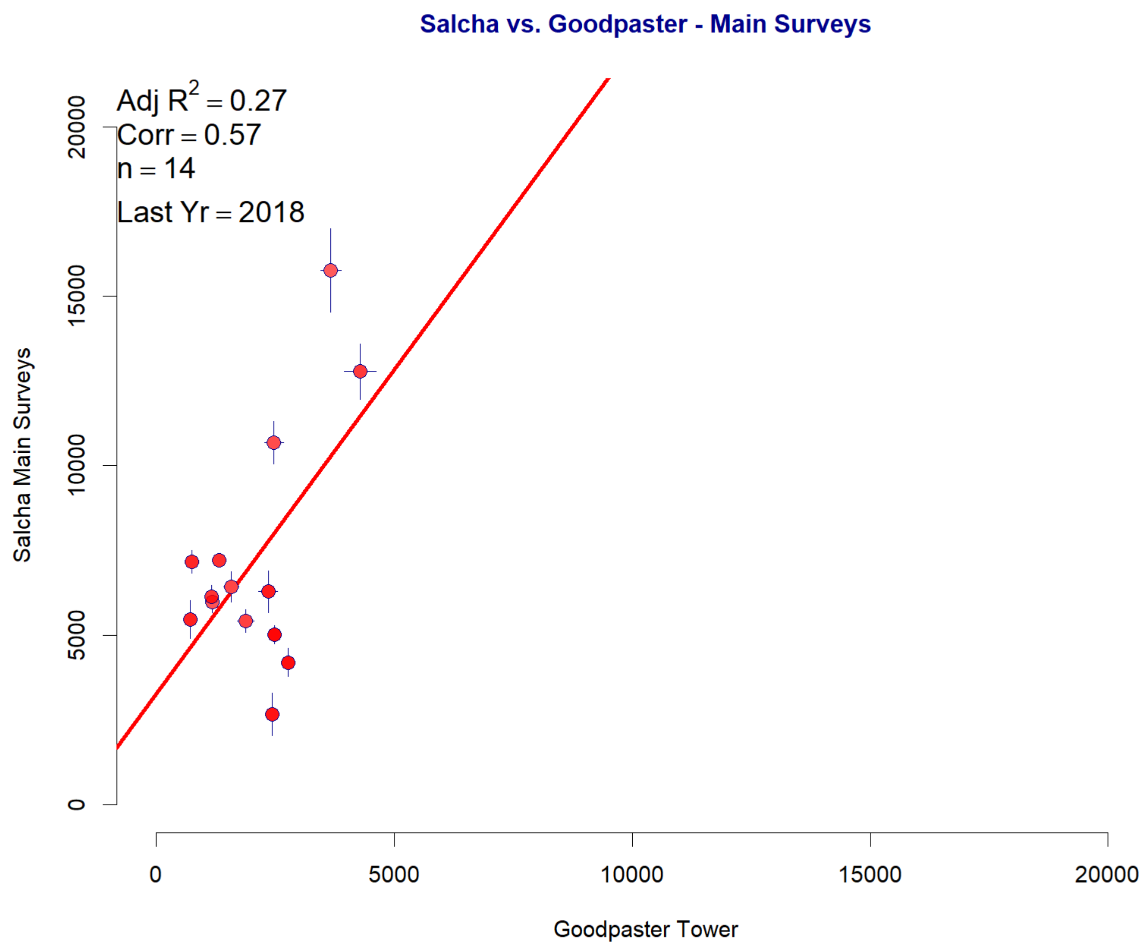

Figure A.38. Salcha vs Goodpaster Main Survey Comparison

Table A.18. *Annual Estimate Details and Escapement Estimate - Tanana Radio MR*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
2002	MR	33,167	28,638	37,696	Yes	Sum of large (>650) and small estimates
2003	MR	93,629	84,674	102,584	Yes	Sum of large (>650) and small estimates
2004	MR	97,615	87,907	107,323	Yes	Sum of large (>520) and small estimates

Table A.19. *Annual Survey Types and Escapement Estimate - Main Chena River Estimate (Tower/Weir/Sonar)*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1986	Mark–Recapture	9,065	6,905	11,225	Yes	
1987	Mark–Recapture	6,404	5,290	7,518	Yes	
1988	Mark–Recapture	3,346	2,234	4,458	Yes	
1989	Mark–Recapture	2,730	2,232	3,228	Yes	
1990	Mark–Recapture	5,603	3,275	7,931	Yes	
1991	Mark–Recapture	3,172	2,608	3,736	Yes	
1992	Mark–Recapture	5,580	4,624	6,536	Yes	
1993	Counting Tower	12,241	11,467	13,015	Yes	
1994	Counting Tower	11,877	10,919	12,835	Yes	
1995	Mark–Recapture	11,394	8,974	13,814	Yes	
1996	Mark–Recapture	7,153	5,327	8,979	Yes	
1997	Counting Tower	13,390	11,992	14,788	Yes	
1998	Counting Tower	4,745	3,739	5,751	Yes	
1999	Counting Tower	6,485	5,631	7,339	Yes	
2000	Mark–Recapture	4,694	2,326	7,062	Yes	
2001	Counting Tower	9,696	8,566	10,826	Yes	
2002	Mark–Recapture	6,967	2,035	11,899	Yes	
2003	Counting Tower	11,100	9,794	12,406	Yes	
2004	Counting Tower	9,645	8,581	10,709	Yes	
2006	Counting Tower	2,936	2,610	3,262	Yes	
2007	Counting Tower	3,806	3,354	4,258	Yes	
2008	Counting Tower	3,208	2,812	3,604	Yes	
2009	Counting Tower	5,253	4,791	5,715	Yes	
2010	Counting Tower	2,382	2,078	2,686	Yes	
2012	Counting Tower	2,220	1,966	2,474	Yes	
2013	Counting Tower	1,859	1,577	2,141	Yes	
2014	Sonar	7,192	7,046	7,338	Yes	
2015	Counting Tower/Sonar	6,291	5,953	6,629	Yes	
2016	Sonar/Bay. hier. model	6,665	5,939	7,391	Yes	
2017	Counting Tower/Sonar	4,949	4,307	5,591	Yes	
2018	Counting Tower/Sonar/Bay. hier. Model	5,947	5,495	6,399	Yes	

Table A.20. *Annual Survey Types and Escapement Estimate - Aerial Chena River Estimate*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1974	Aerial	723	NA	NA	Yes	
1975	Aerial	252	NA	NA		Poor
1976	Aerial	687	NA	NA	Yes	
1977	Aerial	639	NA	NA	Yes	
1979	Aerial	1,159	NA	NA		Poor
1980	Aerial	2,541	NA	NA	Yes	
1981	Aerial	600	NA	NA	Yes	
1982	Aerial	2,073	NA	NA	Yes	
1983	Aerial	2,808	NA	NA	Yes	
1984	Aerial	501	NA	NA	Yes	
1985	Aerial	2,553	NA	NA	Yes	
1986	Aerial	2,031	NA	NA	Yes	
1987	Aerial	1,323	NA	NA	Yes	
1988	Aerial	1,966	NA	NA	Yes	
1989	Aerial	1,280	NA	NA	Yes	
1990	Aerial	1,436	NA	NA	Yes	
1991	Aerial	1,277	NA	NA		Poor
1992	Aerial	825	NA	NA	Yes	
1993	Aerial	2,943	NA	NA	Yes	
1994	Aerial	1,570	NA	NA	Yes	
1995	Aerial	3,575	NA	NA	Yes	
1997	Aerial	3,495	NA	NA	Yes	
1999	Aerial	2,412	NA	NA	Yes	
2001	Aerial	1,813	NA	NA	Yes	
2005	Aerial	1,829	NA	NA	Yes	
2006	Aerial	671	NA	NA	Yes	
2007	Aerial	314	NA	NA	Yes	
2008	Aerial	512	NA	NA	Yes	
2011	Aerial	531	NA	NA	Yes	
2012	Aerial	559	NA	NA	Yes	
2014	Aerial	1,405	NA	NA	Yes	

Table A.21. *Annual Survey Types and Escapement Estimate - Main Salcha River Estimate (Tower/Weir)*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1987	Mark–Recapture	4,771	3,763	5,779	Yes	
1988	Mark–Recapture	4,322	3,210	5,434	Yes	
1989	Mark–Recapture	3,294	2,034	4,554	Yes	
1990	Mark–Recapture	10,728	7,920	13,536	Yes	
1991	Mark–Recapture	5,608	4,280	6,936	Yes	
1992	Mark–Recapture	7,862	5,912	9,812	Yes	
1993	Counting Tower	10,007	9,287	10,727	Yes	
1994	Counting Tower	18,399	17,301	19,497	Yes	
1995	Counting Tower	13,643	12,701	14,585	Yes	
1996	Mark–Recapture	7,570	5,094	10,046	Yes	
1997	Counting Tower	18,514	16,428	20,600	Yes	
1998	Counting Tower	5,027	4,365	5,689	Yes	
1999	Counting Tower	9,198	8,618	9,778	Yes	
2000	Counting Tower	4,595	2,991	6,199	Yes	
2001	Counting Tower	13,328	9,002	17,654	Yes	
2002	Counting Tower	9,000	8,680	9,320	Yes	
2003	Counting Tower	15,500	14,006	16,994	Yes	
2004	Counting Tower	15,761	14,537	16,985	Yes	
2005	Counting Tower	5,988	5,662	6,314	Yes	
2006	Counting Tower	10,679	10,049	11,309	Yes	
2007	Counting Tower	6,425	5,975	6,875	Yes	
2008	Counting Tower	5,415	5,077	5,753	Yes	
2009	Counting Tower	12,774	11,964	13,584	Yes	
2010	Counting Tower	6,135	5,795	6,475	Yes	
2011	Counting Tower	7,200	NA	NA		
2012	Counting Tower	7,165	6,839	7,491	Yes	
2013	Counting Tower	5,465	4,901	6,029	Yes	
2015	Counting Tower	6,287	5,669	6,905	Yes	
2016	Counting Tower/Sonar/Bayesian hierarchical model	2,675	2,049	3,301	Yes	
2017	Counting Tower/Sonar	4,195	3,785	4,605	Yes	
2018	Counting Tower/Sonar/Bayesian hierarchical model	5,021	4,747	5,295	Yes	

Table A.22. *Annual Survey Types and Escapement Estimate - Aerial Salcha River Estimate*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1960	Aerial	1,660	NA	NA	Yes	
1961	Aerial	2,878	NA	NA	Yes	
1962	Aerial	937	NA	NA	Yes	
1964	Aerial	450	NA	NA		Incomplete
1965	Aerial	408	NA	NA	Yes	
1966	Aerial	800	NA	NA	Yes	
1968	Aerial	739	NA	NA	Yes	
1969	Aerial	461	NA	NA		Poor
1970	Aerial	1,882	NA	NA	Yes	
1971	Aerial	158	NA	NA		Poor
1972	Aerial	1,193	NA	NA	Yes	
1973	Aerial	391	NA	NA	Yes	
1974	Aerial	1,857	NA	NA	Yes	
1975	Aerial	1,055	NA	NA	Yes	
1976	Aerial	1,641	NA	NA	Yes	
1977	Aerial	1,202	NA	NA	Yes	
1978	Aerial	3,499	NA	NA	Yes	
1979	Aerial	4,789	NA	NA	Yes	
1980	Aerial	6,756	NA	NA	Yes	
1981	Aerial	1,237	NA	NA	Yes	
1982	Aerial	2,534	NA	NA	Yes	
1983	Aerial	1,961	NA	NA	Yes	
1984	Aerial	1,031	NA	NA	Yes	
1985	Aerial	2,035	NA	NA	Yes	
1986	Aerial	3,368	NA	NA	Yes	
1987	Aerial	1,898	NA	NA	Yes	
1988	Aerial	2,761	NA	NA	Yes	
1989	Aerial	2,329	NA	NA	Yes	
1990	Aerial	3,744	NA	NA	Yes	
1991	Aerial	2,123	NA	NA	Yes	
1992	Aerial	1,484	NA	NA	Yes	
1993	Aerial	3,636	NA	NA	Yes	
1994	Aerial	11,823	NA	NA	Yes	
1995	Aerial	3,978	NA	NA	Yes	
1996	Aerial	4,866	NA	NA	Yes	
1997	Aerial	3,458	NA	NA		Poor
1998	Aerial	2,055	NA	NA		Poor
1999	Aerial	3,608	NA	NA	Yes	
2000	Aerial	2,562	NA	NA		Incomplete
2001	Aerial	3,989	NA	NA	Yes	
2002	Aerial	2,416	NA	NA	Yes	
2005	Aerial	5,489	NA	NA	Yes	
2006	Aerial	492	NA	NA	Yes	
2007	Aerial	1,257	NA	NA	Yes	
2008	Aerial	529	NA	NA		Poor
2011	Aerial	3,537	NA	NA	Yes	
2012	Aerial	647	NA	NA	Yes	
2014	Aerial	1,544	NA	NA		Poor
2015	Aerial	435	NA	NA	Yes	

Table A.23. *Annual Survey Types and Escapement Estimate - Main Goodpaster River Estimate (Tower/Weir)*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
2004	Tower	3,673	3,461	3,885	Yes	
2005	Tower	1,184	1,044	1,324	Yes	
2006	Tower	2,479	2,279	2,679	Yes	
2007	Tower	1,581	1,417	1,745	Yes	
2008	Tower	1,880	1,710	2,050	Yes	
2009	Tower	4,280	3,946	4,614	Yes	
2010	Tower	1,167	1,033	1,301	Yes	
2011	Tower	1,325	NA	NA	Yes	
2012	Tower	752	652	852	Yes	
2013	Tower	723	635	811	Yes	
2014	Tower	1,350	1,170	1,530	Yes	
2015	Tower	2,353	2,159	2,547	Yes	
2016	Tower	2,435	NA	NA	Yes	
2017	Tower	2,769	NA	NA	Yes	
2018	Tower	2,480	NA	NA	Yes	

Table A.24. *Annual Survey Types and Escapement Estimate - Aerial Goodpaster River Estimate*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1990	Aerial	510	NA	NA	Yes	
1991	Aerial	868	NA	NA		Poor
1992	Aerial	148	NA	NA		Poor
1993	Aerial	224	NA	NA	Yes	
1994	Aerial	1,392	NA	NA	Yes	
1995	Aerial	621	NA	NA	Yes	
1998	Aerial	477	NA	NA	Yes	
1999	Aerial	1,743	NA	NA	Yes	
2000	Aerial	2,175	NA	NA	Yes	
2001	Aerial	1,457	NA	NA	Yes	
2002	Aerial	1,440	NA	NA	Yes	
2003	Aerial	3,004	NA	NA	Yes	
2004	Aerial	480	NA	NA	Yes	
2005	Aerial	441	NA	NA	Yes	
2006	Aerial	884	NA	NA	Yes	
2007	Aerial	314	NA	NA	Yes	

A.3 Border and Canada

A.3.1 Correlations

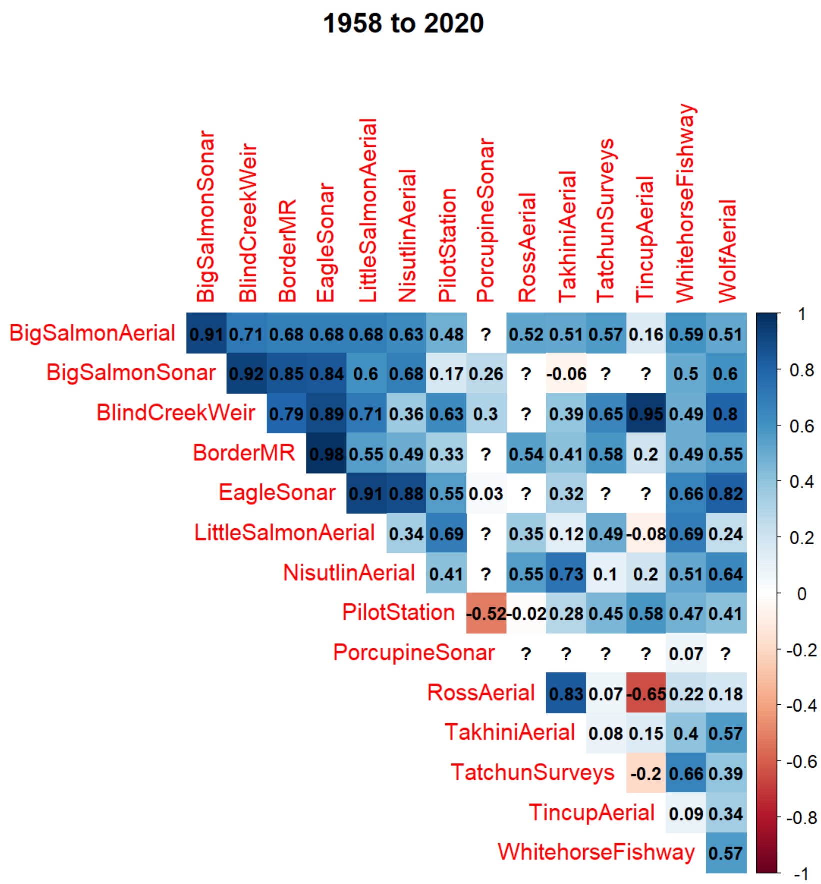

Figure A.39. *Correlation in Abundance Estimates - Border and Canadian Projects - All Years*. Plot shows pairwise correlations of all available data points for each pair of time series. Note that high correlations could be due to few paired obs (i.e. only few yrs where both projects had an estimate). Tables below list sample sizes. Figures in next sections show individual time series, and scatterplots for comparing key projects. The *?* identifies pairs with less than 5 data points for which correlations were not calculated.

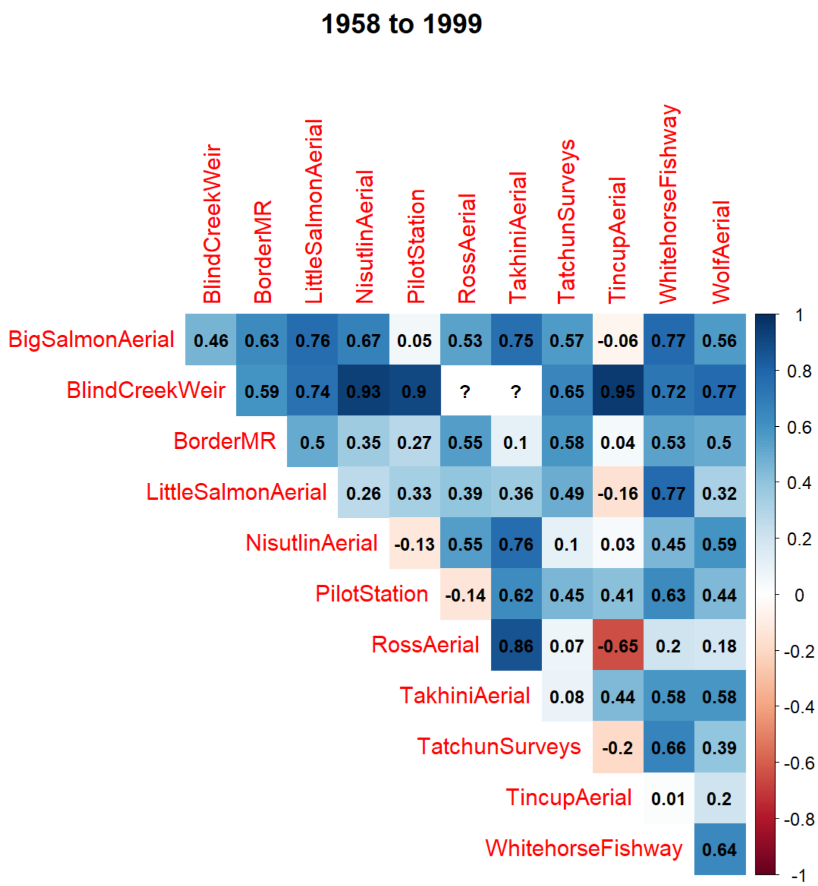

Figure A.40. *Correlation in Abundance Estimates - Border and Canadian Projects - Earlier Years*. Figure layout as per Figure A.39.

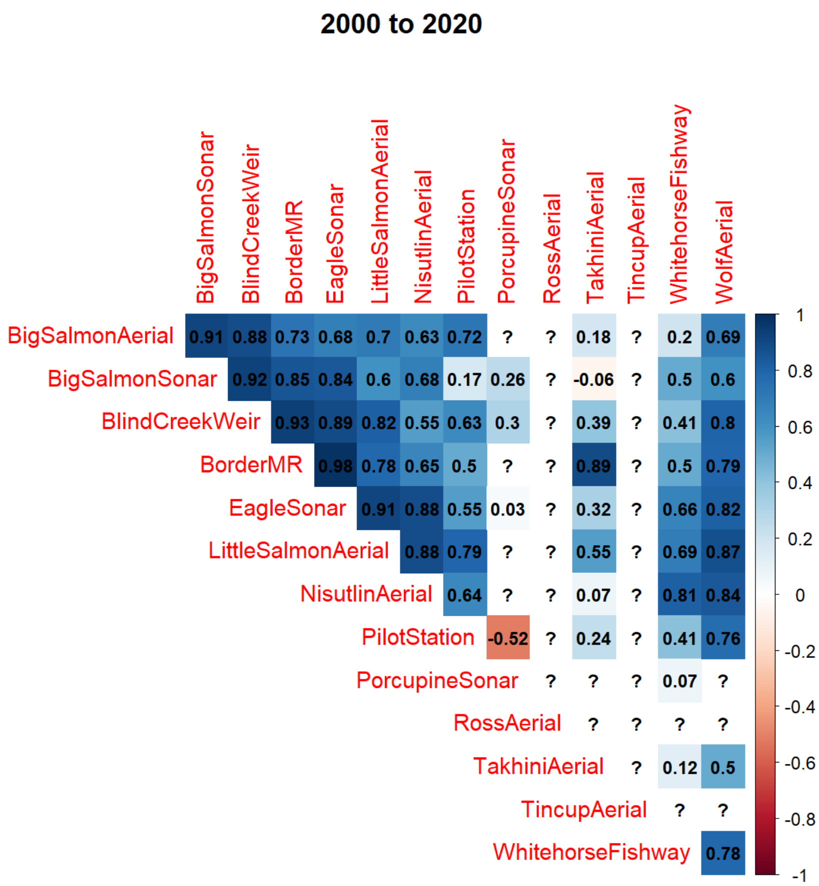

Figure A.41. *Correlation in Abundance Estimates - Border and Canadian Projects - Recent Years*. Figure layout as per Figure A.39.

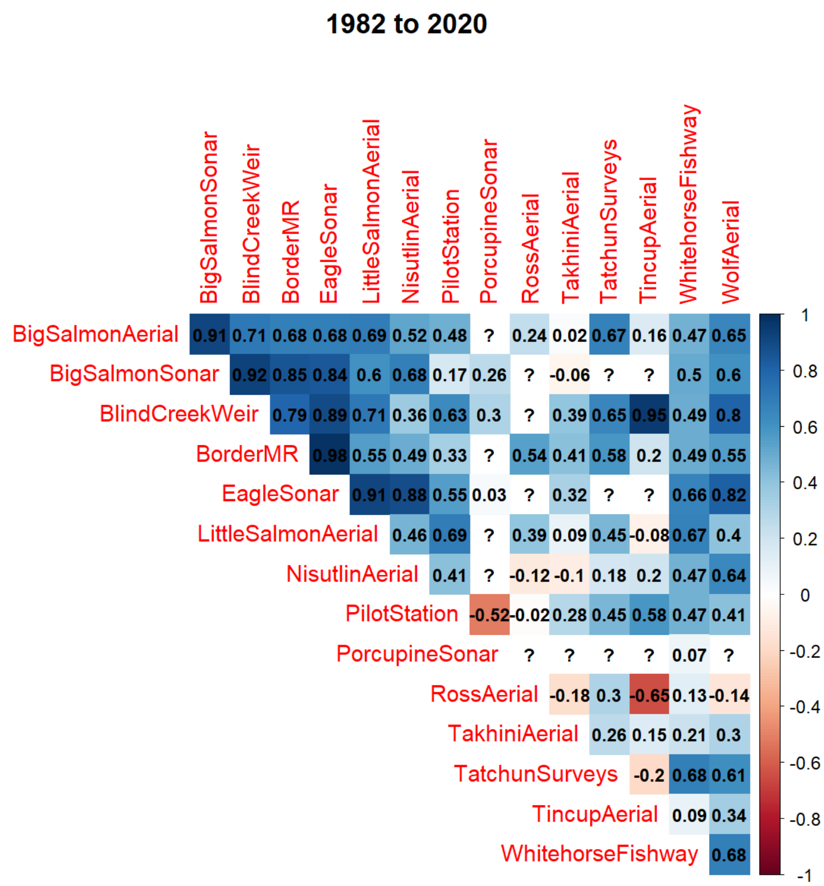

Figure A.42. *Correlation in Abundance Estimates - Canada Yukon Projects - Model Years (1982-2019)*. Covering the same time window as the integrated run reconstruction and spawner-recruit model by Connors et al. (2022). Figure layout as per Figure A.39.

Table A.25. *Correlation in Abundance Estimates - Border and Canada Projects*. Table lists all the pairwise correlations shown in Figures A.39 to A.41. Correlations larger than 0.4 are highlighted in light blue for positive correlations and orange for negative correlations. Correlations were not calculated for pairs with less than 5 data points.

		1958 to 2020		1958 to 1999		2000 to 2020		1982 to 2020	
Project1	**Project2**	**CorrAll**	**ObsAll**	**Corr1**	**Obs1**	**Corr2**	**Obs2**	**Corr3**	**Obs3**
BigSalmonAerial	BigSalmonSonar	0.91	7			0.91	7	0.91	7
BigSalmonAerial	BlindCreekWeir	0.71	13	0.46	4	0.88	9	0.71	13
BigSalmonAerial	BorderMR	0.68	27	0.63	18	0.73	9	0.68	27
BigSalmonAerial	EagleSonar	0.68	7			0.68	7	0.68	7
BigSalmonAerial	LittleSalmonAerial	0.68	40	0.76	28	0.7	12	0.69	30
BigSalmonAerial	NisutlinAerial	0.63	41	0.67	31	0.63	10	0.52	27
BigSalmonAerial	PilotStation	0.48	24	0.05	12	0.72	12	0.48	24
BigSalmonAerial	PorcupineSonar		0				0		0
BigSalmonAerial	RossAerial	0.52	18	0.53	17		1	0.24	16
BigSalmonAerial	TakhiniAerial	0.51	22	0.75	17	0.18	5	0.02	13
BigSalmonAerial	TatchunSurveys	0.57	28	0.57	28			0.67	16
BigSalmonAerial	TincupAerial	0.16	16	-0.06	14		2	0.16	16
BigSalmonAerial	WhitehorseFishway	0.59	44	0.77	32	0.2	12	0.47	30
BigSalmonAerial	WolfAerial	0.51	37	0.56	25	0.69	12	0.65	30
BigSalmonSonar	BlindCreekWeir	0.92	13			0.92	13	0.92	13
BigSalmonSonar	BorderMR	0.85	4			0.85	4	0.85	4
BigSalmonSonar	EagleSonar	0.84	15			0.84	15	0.84	15
BigSalmonSonar	LittleSalmonAerial	0.6	7			0.6	7	0.6	7
BigSalmonSonar	NisutlinAerial	0.68	7			0.68	7	0.68	7
BigSalmonSonar	PilotStation	0.17	15			0.17	15	0.17	15
BigSalmonSonar	PorcupineSonar	0.26	6			0.26	6	0.26	6
BigSalmonSonar	RossAerial		1				1		1
BigSalmonSonar	TakhiniAerial	-0.06	5			-0.06	5	-0.06	5
BigSalmonSonar	TatchunSurveys		0						0
BigSalmonSonar	TincupAerial		0				0		0
BigSalmonSonar	WhitehorseFishway	0.5	16			0.5	16	0.5	16
BigSalmonSonar	WolfAerial	0.6	8			0.6	8	0.6	8
BlindCreekWeir	BorderMR	0.79	10	0.59	4	0.93	6	0.79	10
BlindCreekWeir	EagleSonar	0.89	13			0.89	13	0.89	13
BlindCreekWeir	LittleSalmonAerial	0.71	13	0.74	4	0.82	9	0.71	13
BlindCreekWeir	NisutlinAerial	0.36	11	0.93	4	0.55	7	0.36	11
BlindCreekWeir	PilotStation	0.63	19	0.9	4	0.63	15	0.63	19
BlindCreekWeir	PorcupineSonar	0.3	4			0.3	4	0.3	4
BlindCreekWeir	RossAerial		2		1		1		2

Project1	Project2	CorrAll	ObsAll	Corr1	Obs1	Corr2	Obs2	Corr3	Obs3
BlindCreekWeir	TakhiniAerial	0.39	5		0	0.39	5	0.39	5
BlindCreekWeir	TatchunSurveys	0.65	3	0.65	3			0.65	3
BlindCreekWeir	TincupAerial	0.95	3	0.95	3		0	0.95	3
BlindCreekWeir	WhitehorseFishway	0.49	19	0.72	4	0.41	15	0.49	19
BlindCreekWeir	WolfAerial	0.8	13	0.77	4	0.8	9	0.8	13
BorderMR	EagleSonar	0.98	4			0.98	4	0.98	4
BorderMR	LittleSalmonAerial	0.55	27	0.5	18	0.78	9	0.55	27
BorderMR	NisutlinAerial	0.49	25	0.35	17	0.65	8	0.49	25
BorderMR	PilotStation	0.33	21	0.27	12	0.5	9	0.33	21
BorderMR	PorcupineSonar		0				0		0
BorderMR	RossAerial	0.54	16	0.55	15		1	0.54	16
BorderMR	TakhiniAerial	0.41	12	0.1	8	0.89	4	0.41	12
BorderMR	TatchunSurveys	0.58	16	0.58	16			0.58	16
BorderMR	TincupAerial	0.2	16	0.04	14		2	0.2	16
BorderMR	WhitehorseFishway	0.49	27	0.53	18	0.5	9	0.49	27
BorderMR	WolfAerial	0.55	27	0.5	18	0.79	9	0.55	27
EagleSonar	LittleSalmonAerial	0.91	7			0.91	7	0.91	7
EagleSonar	NisutlinAerial	0.88	6			0.88	6	0.88	6
EagleSonar	PilotStation	0.55	15			0.55	15	0.55	15
EagleSonar	PorcupineSonar	0.03	6			0.03	6	0.03	6
EagleSonar	RossAerial		1				1		1
EagleSonar	TakhiniAerial	0.32	5			0.32	5	0.32	5
EagleSonar	TatchunSurveys		0						0
EagleSonar	TincupAerial		0				0		0
EagleSonar	WhitehorseFishway	0.66	15			0.66	15	0.66	15
EagleSonar	WolfAerial	0.82	7			0.82	7	0.82	7
LittleSalmonAerial	NisutlinAerial	0.34	37	0.26	27	0.88	10	0.46	27
LittleSalmonAerial	PilotStation	0.69	24	0.33	12	0.79	12	0.69	24
LittleSalmonAerial	PorcupineSonar		0				0		0
LittleSalmonAerial	RossAerial	0.35	18	0.39	17		1	0.39	16
LittleSalmonAerial	TakhiniAerial	0.12	19	0.36	14	0.55	5	0.09	13
LittleSalmonAerial	TatchunSurveys	0.49	24	0.49	24			0.45	16
LittleSalmonAerial	TincupAerial	-0.08	16	-0.16	14		2	-0.08	16
LittleSalmonAerial	WhitehorseFishway	0.69	40	0.77	28	0.69	12	0.67	30
LittleSalmonAerial	WolfAerial	0.24	35	0.32	23	0.87	12	0.4	30
NisutlinAerial	PilotStation	0.41	22	-0.13	11	0.64	11	0.41	22
NisutlinAerial	PorcupineSonar		1				1		1
NisutlinAerial	RossAerial	0.55	17	0.55	16		1	-0.12	15

Project1	Project2	CorrAll	ObsAll	Corr1	Obs1	Corr2	Obs2	Corr3	Obs3
NisutlinAerial	TakhiniAerial	0.73	21	0.76	17	0.07	4	-0.1	12
NisutlinAerial	TatchunSurveys	0.1	28	0.1	28			0.18	16
NisutlinAerial	TincupAerial	0.2	16	0.03	14		2	0.2	16
NisutlinAerial	WhitehorseFishway	0.51	43	0.45	31	0.81	12	0.47	29
NisutlinAerial	WolfAerial	0.64	35	0.59	24	0.84	11	0.64	28
PilotStation	PorcupineSonar	-0.52	6			-0.52	6	-0.52	6
PilotStation	RossAerial	-0.02	10	-0.14	9		1	-0.02	10
PilotStation	TakhiniAerial	0.28	11	0.62	4	0.24	7	0.28	11
PilotStation	TatchunSurveys	0.45	10	0.45	10			0.45	10
PilotStation	TincupAerial	0.58	11	0.41	9		2	0.58	11
PilotStation	WhitehorseFishway	0.47	32	0.63	12	0.41	20	0.47	32
PilotStation	WolfAerial	0.41	24	0.44	12	0.76	12	0.41	24
PorcupineSonar	RossAerial		0				0		0
PorcupineSonar	TakhiniAerial		2				2		2
PorcupineSonar	TatchunSurveys		0						0
PorcupineSonar	TincupAerial		0				0		0
PorcupineSonar	WhitehorseFishway	0.07	6			0.07	6	0.07	6
PorcupineSonar	WolfAerial		0				0		0
RossAerial	TakhiniAerial	0.83	10	0.86	9		1	-0.18	9
RossAerial	TatchunSurveys	0.07	15	0.07	15			0.3	14
RossAerial	TincupAerial	-0.65	12	-0.65	12		0	-0.65	12
RossAerial	WhitehorseFishway	0.22	18	0.2	17		1	0.13	16
RossAerial	WolfAerial	0.18	17	0.18	16		1	-0.14	16
TakhiniAerial	TatchunSurveys	0.08	18	0.08	18			0.26	8
TakhiniAerial	TincupAerial	0.15	8	0.44	7		1	0.15	8
TakhiniAerial	WhitehorseFishway	0.4	29	0.58	22	0.12	7	0.21	15
TakhiniAerial	WolfAerial	0.57	18	0.58	13	0.5	5	0.3	13
TatchunSurveys	TincupAerial	-0.2	14	-0.2	14			-0.2	14
TatchunSurveys	WhitehorseFishway	0.66	29	0.66	29			0.68	16
TatchunSurveys	WolfAerial	0.39	23	0.39	23			0.61	16
TincupAerial	WhitehorseFishway	0.09	16	0.01	14		2	0.09	16
TincupAerial	WolfAerial	0.34	16	0.2	14		2	0.34	16
WhitehorseFishway	WolfAerial	0.57	38	0.64	25	0.78	13	0.68	31

A.3.2 Border - Mainstem

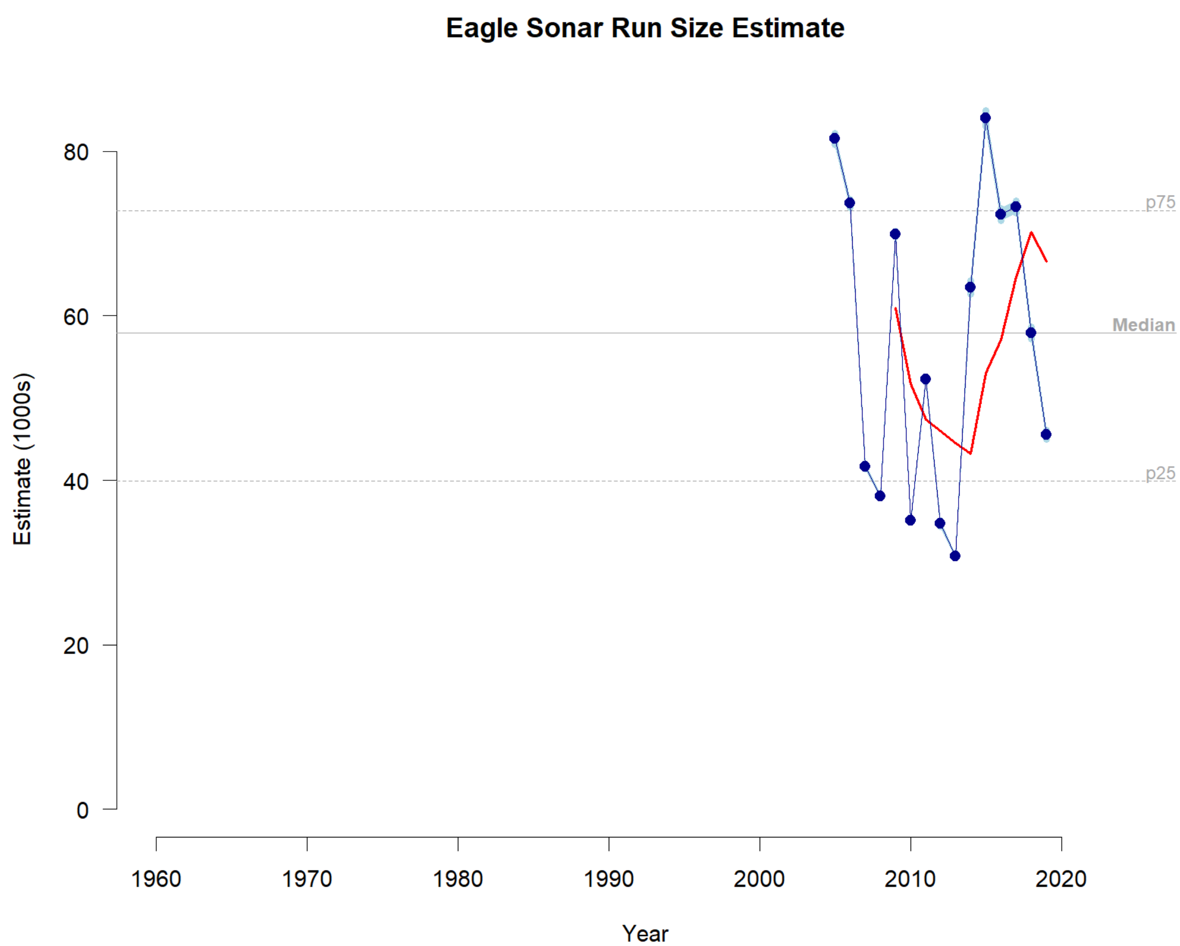

Figure A.43. *Available Estimates from Eagle Sonar*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

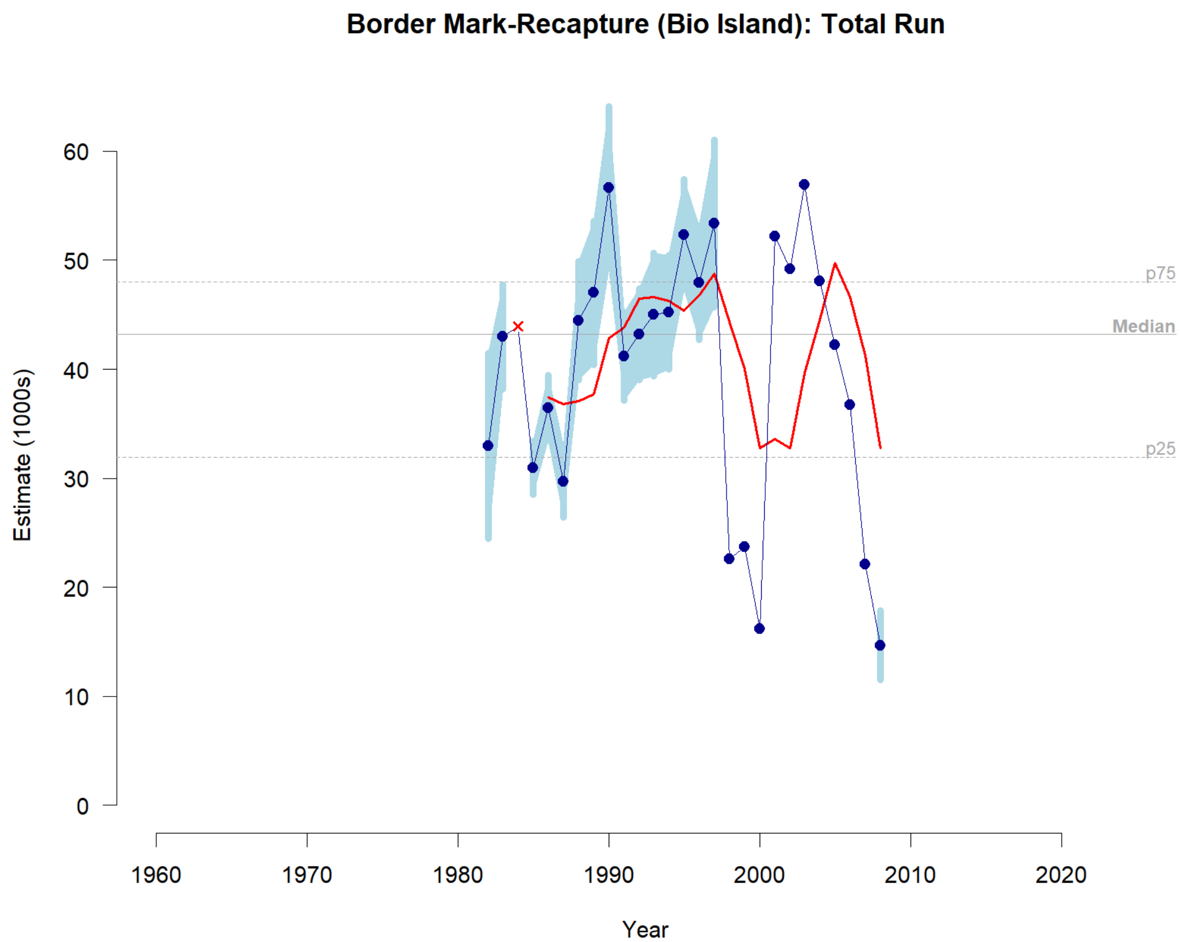

Figure A.44. *Available Estimates from Border Mark-Recapture (Bio Island)*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

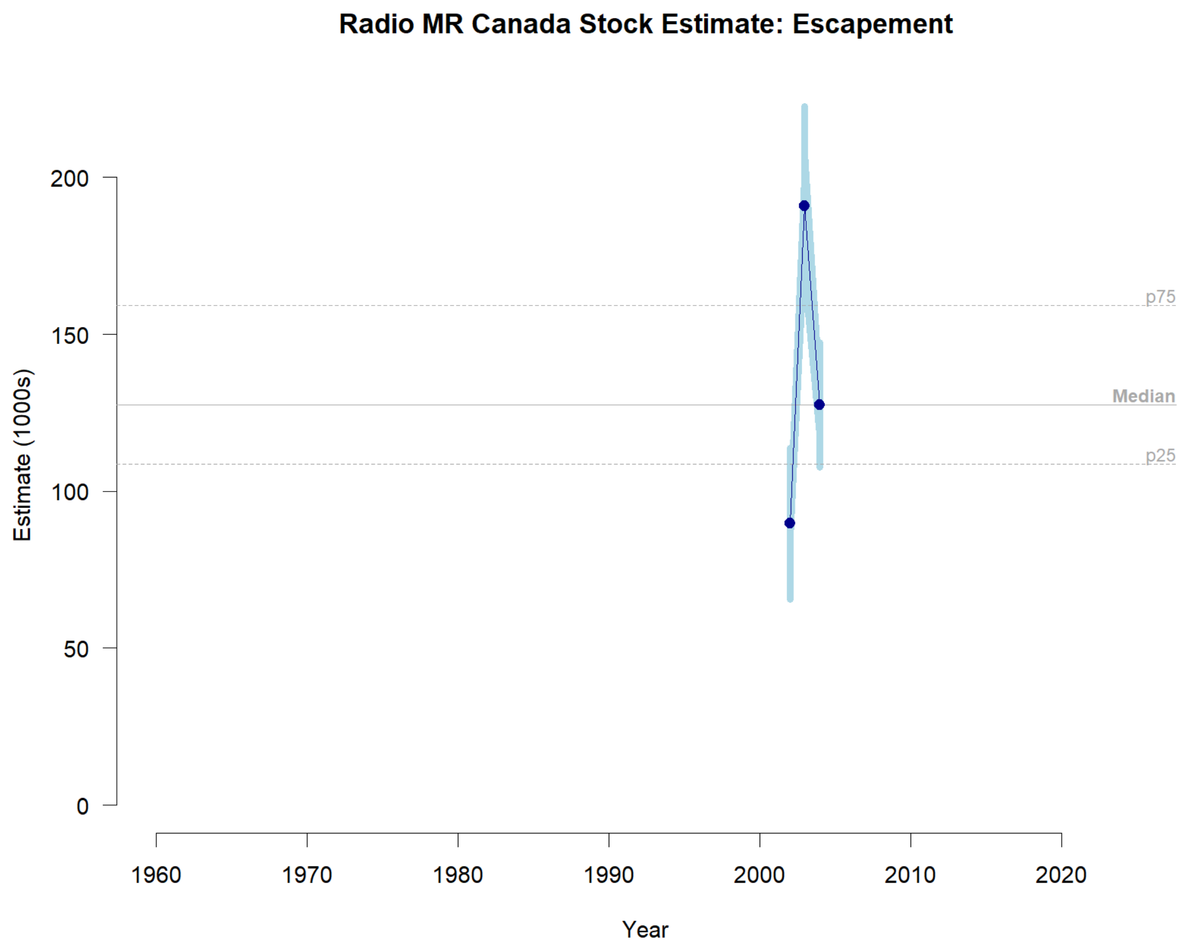

Figure A.45. *Available Estimates for Canadian Mainstem Chinook from Radio Mark Recapture Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

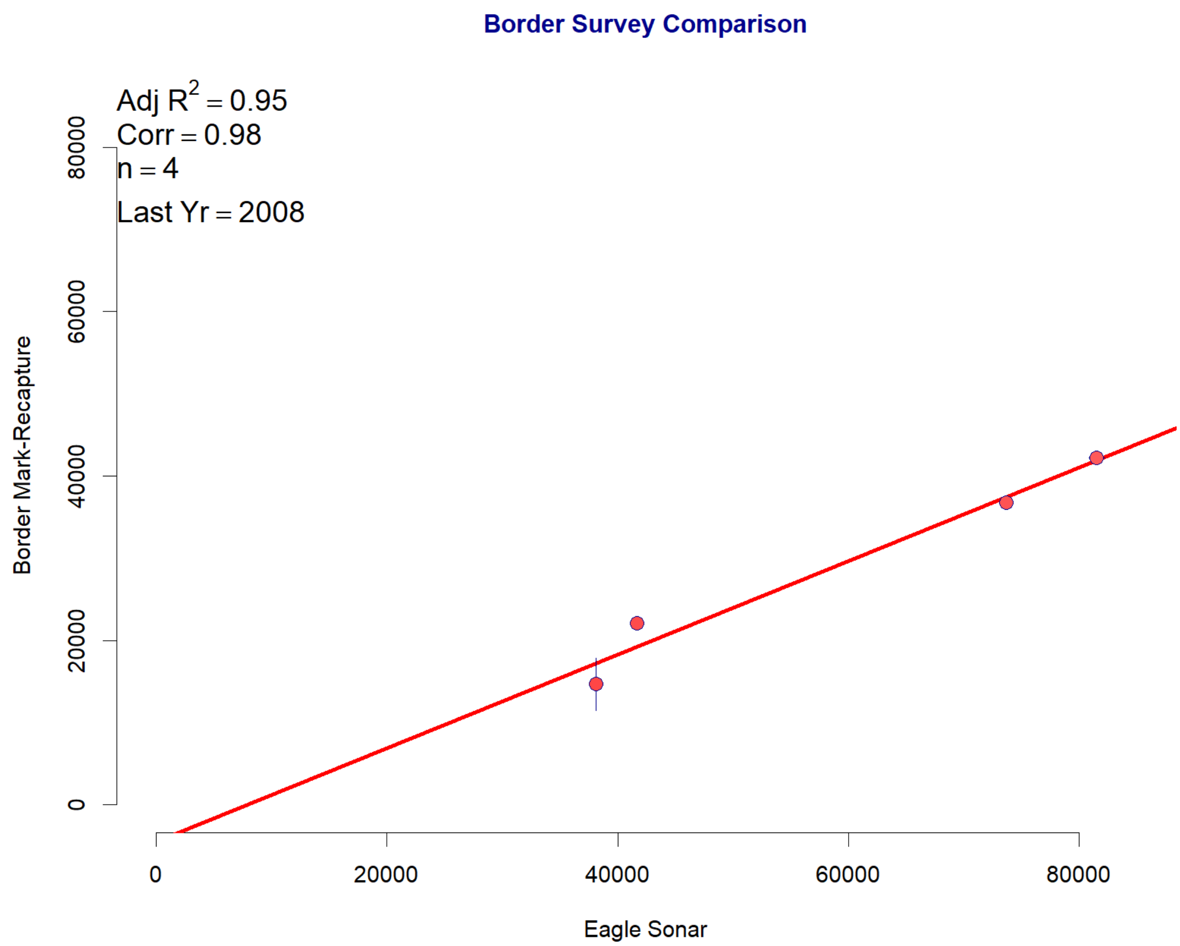

Figure A.46. Border Survey Comparison

Table A.26. *Annual Survey Types and Escapement Estimate - Eagle Sonar*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, and *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
2005	Sonar	81,528	80,822	82,234	Yes	
2006	Sonar	73,691	73,201	74,181	Yes	
2007	Sonar	41,697	41,411	41,983	Yes	
2008	Sonar	38,097	37,865	38,329	Yes	
2009	Sonar	69,957	69,613	70,301	Yes	
2010	Sonar	35,074	34,910	35,238	Yes	
2011	Sonar	52,271	52,001	52,541	Yes	
2012	Sonar	34,747	34,349	35,145	Yes	
2013	Sonar	30,725	30,561	30,889	Yes	
2014	Sonar	63,482	62,652	64,312	Yes	
2015	Sonar	84,015	83,039	84,991	Yes	
2016	Sonar	72,329	71,547	73,111	Yes	
2017	Sonar	73,268	72,522	74,014	Yes	
2018	Sonar	57,893	57,171	58,615	Yes	
2019	Sonar	45,560	45,012	46,108	Yes	

Table A.27. *Annual Survey Types and Escapement Estimate - Border Mark-Recapture (Bio Island)*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1982	MR	32,952	24,439	41,465	Yes	Chapman/Peterson
1983	MR	42,971	38,212	47,729	Yes	Chapman/Peterson
1984	Other	43,911	NA	NA		Not a MR estimate. Using CDN Harvest + Aerial Survey Index Expansion
1985	MR	30,933	28,490	33,376	Yes	Chapman/Peterson
1986	MR	36,479	33,497	39,460	Yes	Chapman/Peterson
1987	MR	29,685	26,413	32,956	Yes	Chapman/Peterson
1988	MR	44,445	38,994	49,896	Yes	Chapman/Peterson
1989	MR	47,013	40,408	53,618	Yes	Chapman/Peterson
1990	MR	56,679	49,243	64,115	Yes	Chapman/Peterson
1991	MR	41,187	37,113	45,261	Yes	Chapman/Peterson
1992	MR	43,185	38,992	47,379	Yes	Chapman/Peterson
1993	MR	45,027	39,396	50,658	Yes	Chapman/Peterson
1994	MR	45,231	40,026	50,435	Yes	Chapman/Peterson
1995	MR	52,353	47,306	57,399	Yes	Chapman/Peterson
1996	MR	47,955	42,718	53,192	Yes	Chapman/Peterson
1997	MR	53,400	45,740	61,060	Yes	Chapman/Peterson
1998	MR	22,588	NA	NA	Yes	Chapman/Peterson, source data for SE calculation not available.
1999	MR	23,716	NA	NA	Yes	SPAS
2000	MR	16,173	NA	NA	Yes	SPAS
2001	MR	52,207	NA	NA	Yes	SPAS
2002	MR	49,214	NA	NA	Yes	SPAS
2003	MR	56,929	NA	NA	Yes	SPAS
2004	MR	48,111	NA	NA	Yes	SPAS
2005	MR	42,245	NA	NA	Yes	SPAS
2006	MR	36,748	NA	NA	Yes	SPAS
2007	MR	22,120	NA	NA	Yes	SPAS
2008	MR	14,666	11,489	17,843	Yes	Chapman/Peterson

Table A.28. *Annual Survey Details and Escapement Estimate - Radio Mark-Recapture Estimate for Canadian Mainstem Chinook*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
2002	MR	89,692	65,564	113,820	Yes	Sum of large (>650) and small estimates
2003	MR	190,993	159,378	222,608	Yes	Sum of large (>650) and small estimates
2004	MR	127,593	107,766	147,420	Yes	Sum of large (>520) and small estimates

A.3.3 Canada - Klondike

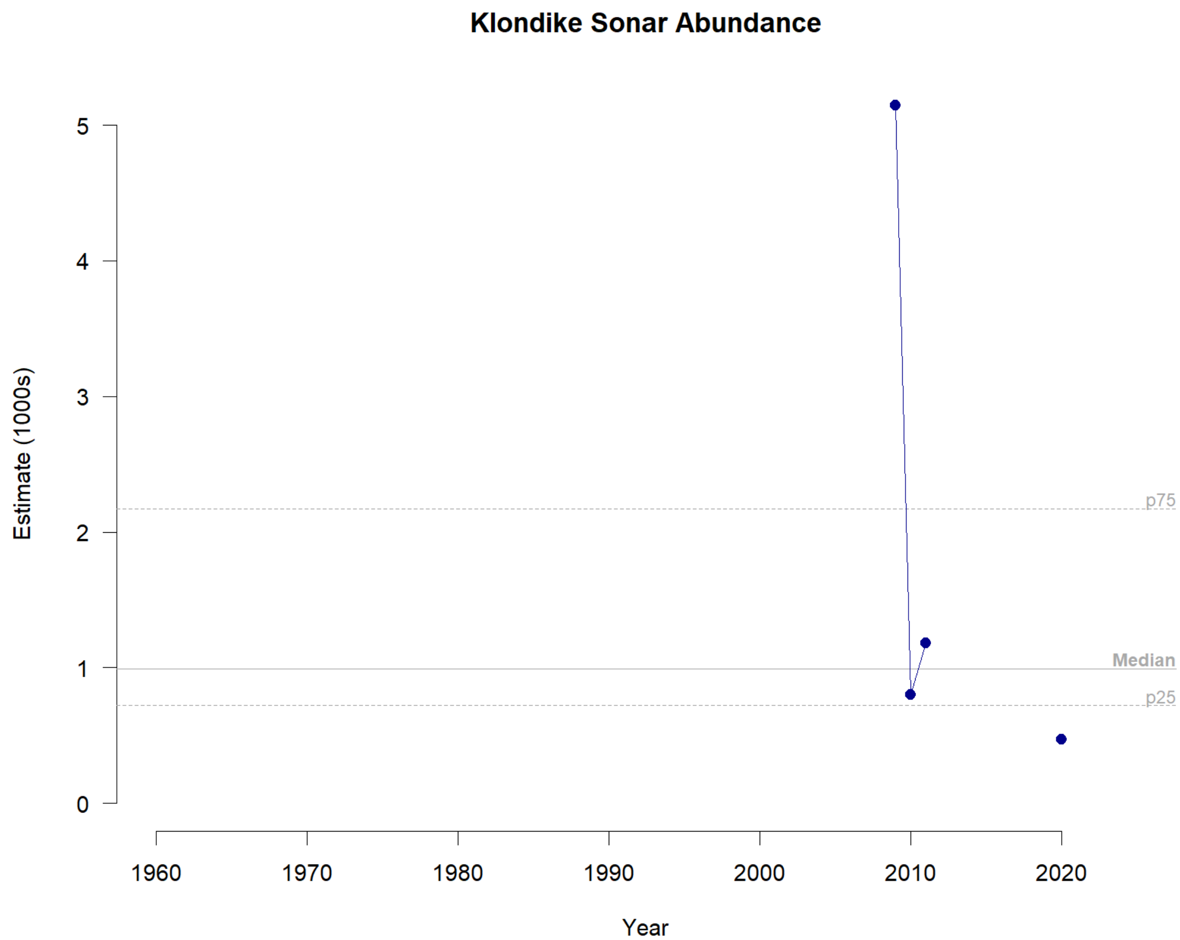

Figure A.47. *Available Estimates from Klondike Sonar*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

Table A.29. *Annual Survey Types and Escapement Estimate - Klondike Sonar*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
2009	Sonar	5,147	NA	NA	Yes	
2010	Sonar	803	NA	NA	Yes	
2011	Sonar	1,181	NA	NA	Yes	
2020	Sonar	470	NA	NA	Yes	

A.3.4 Canada - White

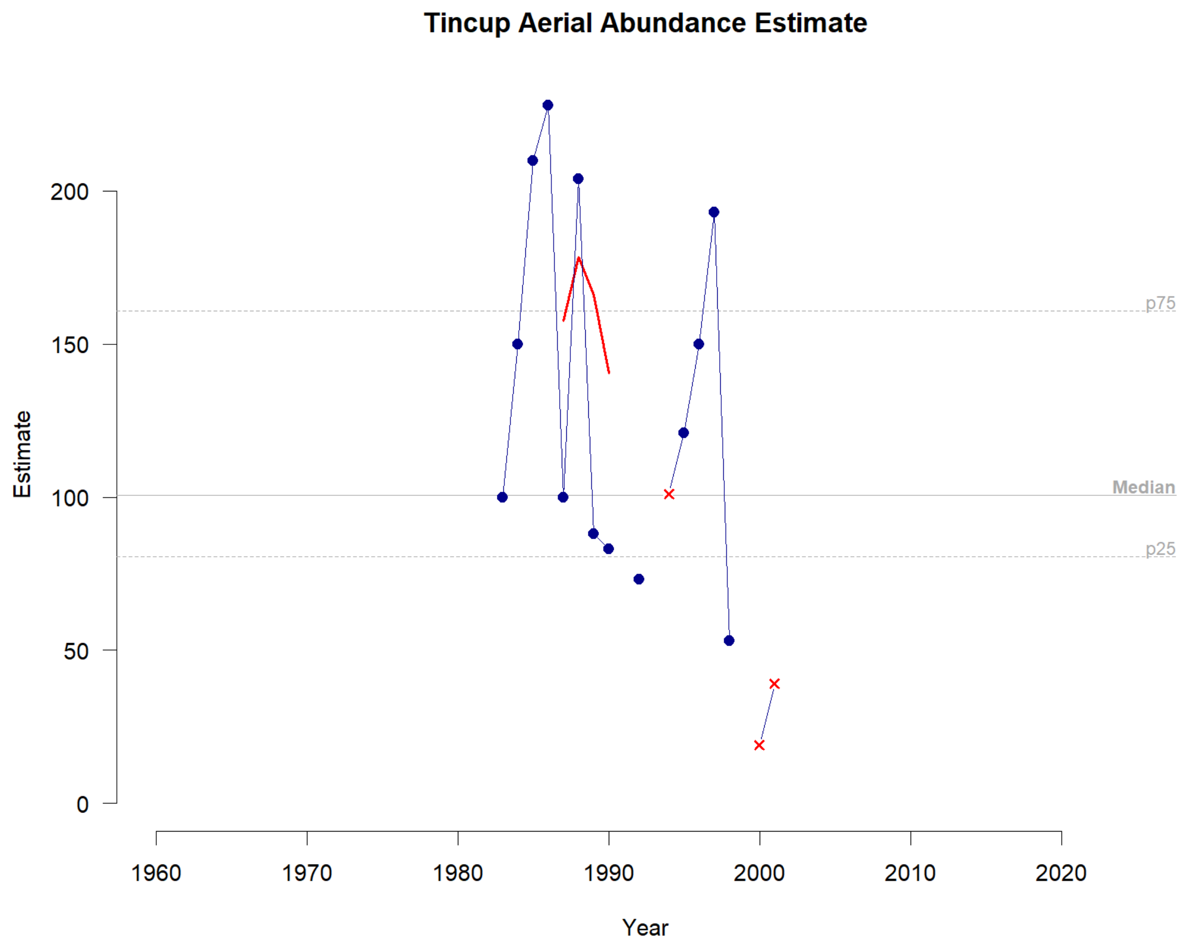

Figure A.48. *Available Estimates from Tincup Aerial Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

Table A.30. *Annual Survey Types and Escapement Estimate - Tincup Aerial*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1983	Aerial	100	NA	NA	Yes	
1984	Aerial	150	NA	NA	Yes	
1985	Aerial	210	NA	NA	Yes	
1986	Aerial	228	NA	NA	Yes	
1987	Aerial	100	NA	NA	Yes	
1988	Aerial	204	NA	NA	Yes	
1989	Aerial	88	NA	NA	Yes	
1990	Aerial	83	NA	NA	Yes	
1992	Aerial	73	NA	NA	Yes	
1994	Aerial	101	NA	NA		Poor quality rating
1995	Aerial	121	NA	NA	Yes	
1996	Aerial	150	NA	NA	Yes	
1997	Aerial	193	NA	NA	Yes	
1998	Aerial	53	NA	NA	Yes	
2000	Foot	19	NA	NA		Foot surveys
2001	Foot	39	NA	NA		Foot surveys

A.3.5 Canada - Pelly

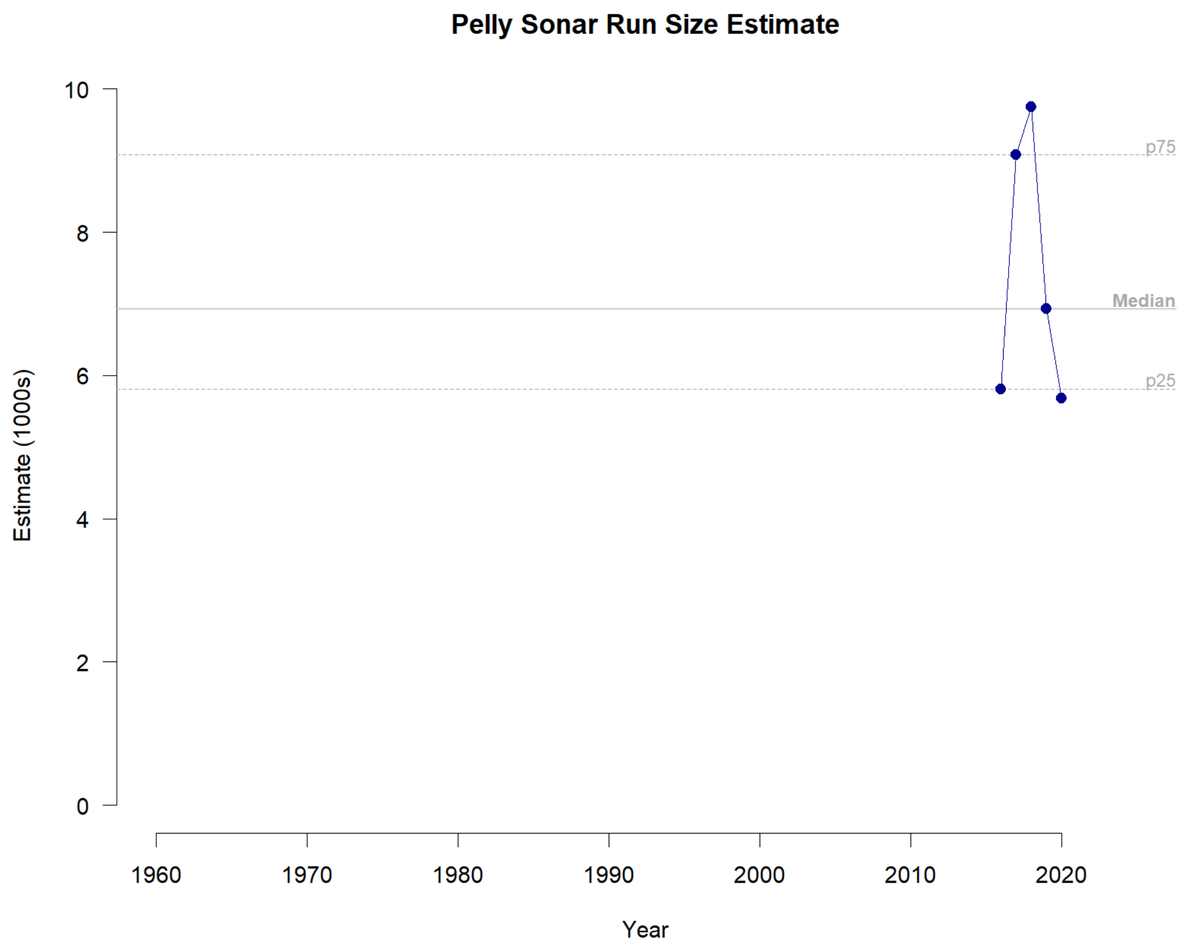

Figure A.49. *Available Estimates from Pelly River Sonar*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

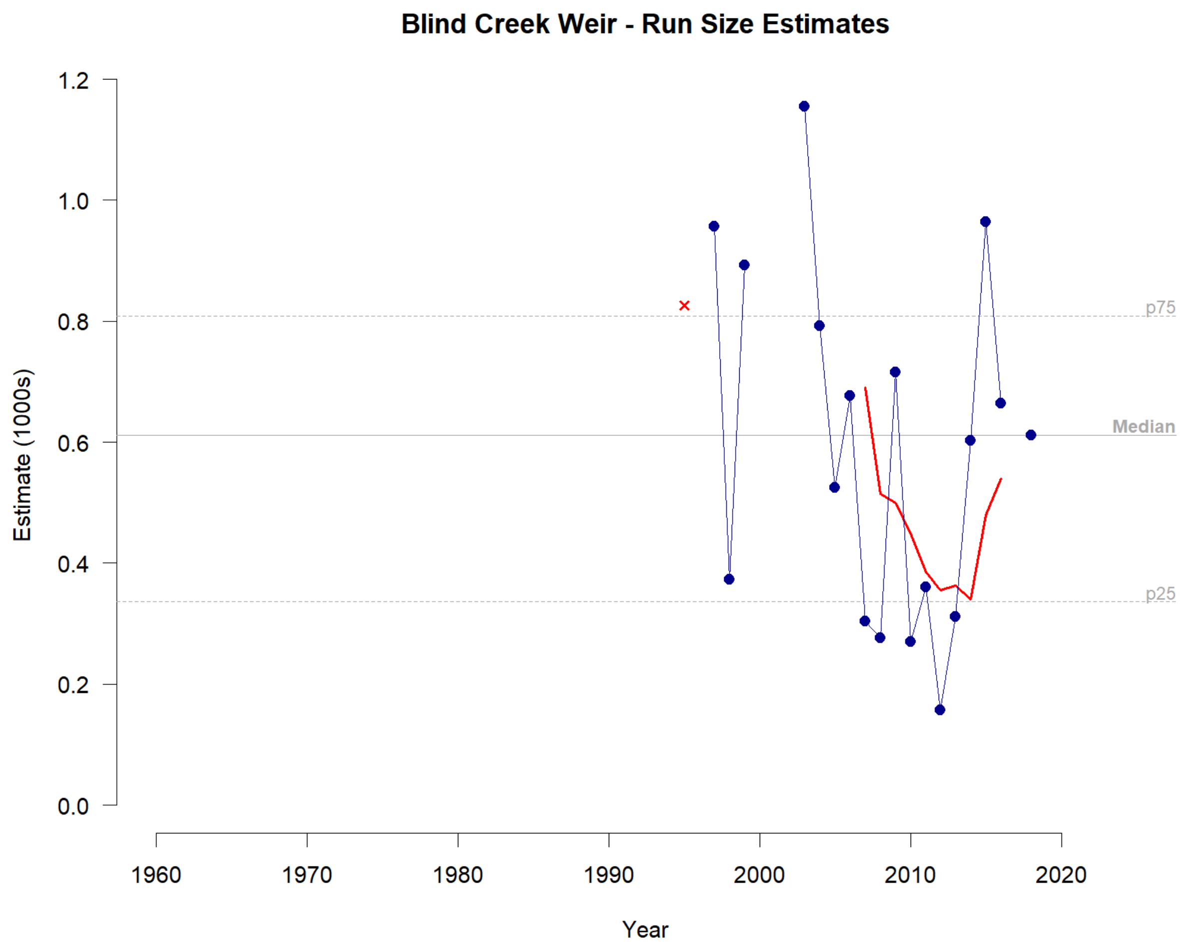

Figure A.50. *Available Estimates from Blind Creek Weir* Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

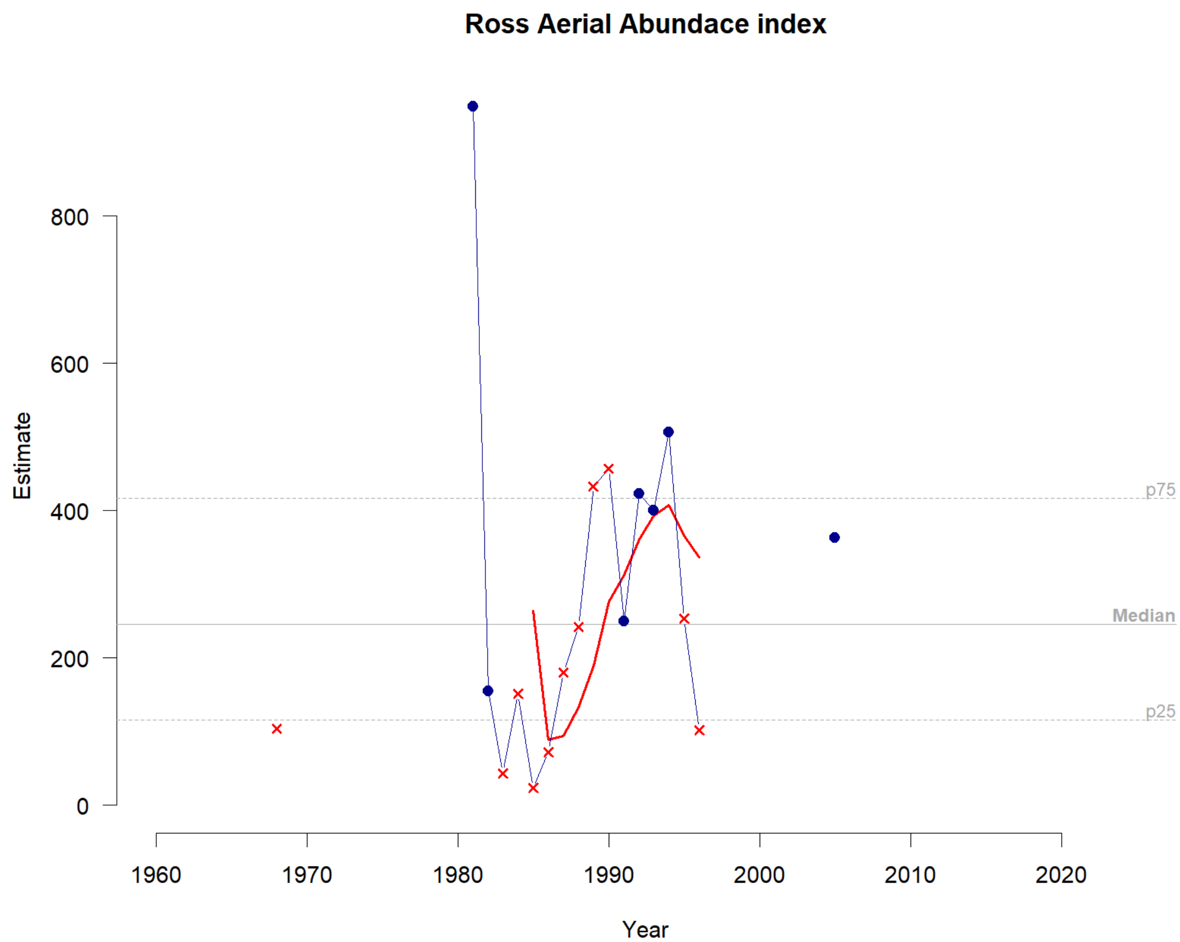

Figure A.51. *Available Estimates from Ross River Aerial Surveys.* Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

Table A.31. *Annual Survey Types and Escapement Estimate - Pelly Sonar*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
2016	Sonar	5,807	NA	NA	Yes	
2017	Sonar	9,081	NA	NA	Yes	
2018	Sonar	9,751	NA	NA	Yes	
2019	Sonar	6,927	NA	NA	Yes	
2020	Sonar	5,678	NA	NA	Yes	

Table A.32. *Annual Survey Types and Escapement Estimate - Blind Creek Weir*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1995	Weir	826	NA	NA		details lacking to support counts
1997	Weir	957	NA	NA	Yes	
1998	Weir	373	NA	NA	Yes	
1999	Weir	892	NA	NA	Yes	
2003	Weir	1,155	NA	NA	Yes	
2004	Weir	792	NA	NA	Yes	
2005	Weir	525	NA	NA	Yes	
2006	Weir	677	NA	NA	Yes	
2007	Weir	304	NA	NA	Yes	
2008	Weir	276	NA	NA	Yes	
2009	Weir	716	NA	NA	Yes	
2010	Weir	270	NA	NA	Yes	
2011	Weir	360	NA	NA	Yes	
2012	Weir	157	NA	NA	Yes	
2013	Weir	312	NA	NA	Yes	
2014	Weir	602	NA	NA	Yes	
2015	Weir	964	NA	NA	Yes	
2016	Weir	664	NA	NA	Yes	
2018	Weir	612	NA	NA	Yes	

Table A.33. *Annual Survey Types and Escapement Estimate - Ross Aerial*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1968	Aerial	104	NA	NA		Poor quality rating
1981	Aerial	949	NA	NA	Yes	
1982	Aerial	155	NA	NA	Yes	
1983	Aerial	43	NA	NA		Poor quality rating
1984	Aerial	151	NA	NA		Poor quality rating
1985	Aerial	23	NA	NA		Poor quality rating
1986	Aerial	72	NA	NA		Poor quality rating
1987	Aerial	180	NA	NA		Poor quality rating
1988	Aerial	242	NA	NA		Poor quality rating
1989	Aerial	433	NA	NA		Poor quality rating
1990	Aerial	457	NA	NA		Poor quality rating
1991	Aerial	250	NA	NA	Yes	
1992	Aerial	423	NA	NA	Yes	
1993	Aerial	400	NA	NA	Yes	
1994	Aerial	506	NA	NA	Yes	
1995	Aerial	253	NA	NA		Poor quality rating
1996	Aerial	102	NA	NA		Poor quality rating
2005	Aerial	363	NA	NA	Yes	

A.3.6 Canada - Carmacks Area Tributaries

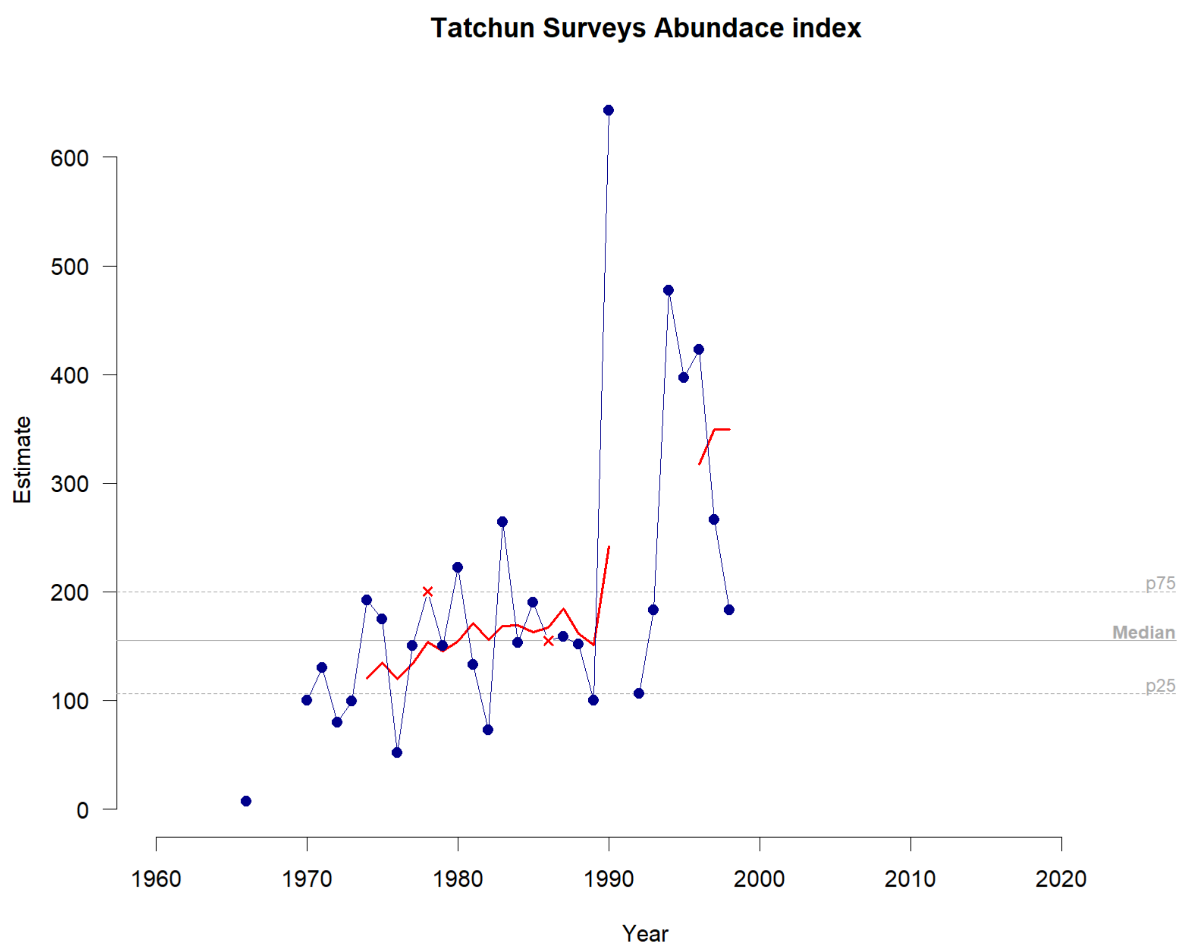

Figure A.52. *Available Estimates from Tatchun Surveys (Mostly foot surveys)*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

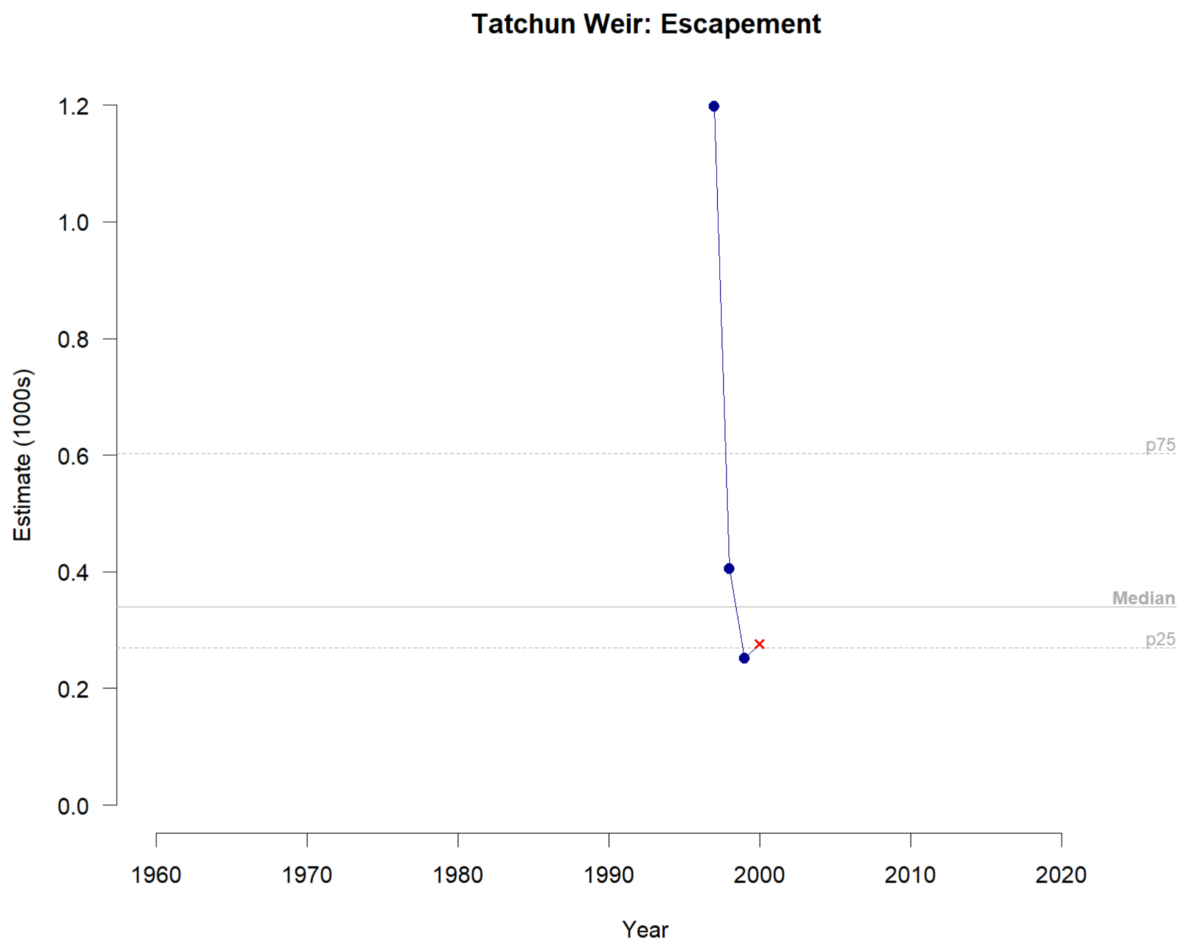

Figure A.53. *Available Estimates from Tatchun Weir*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

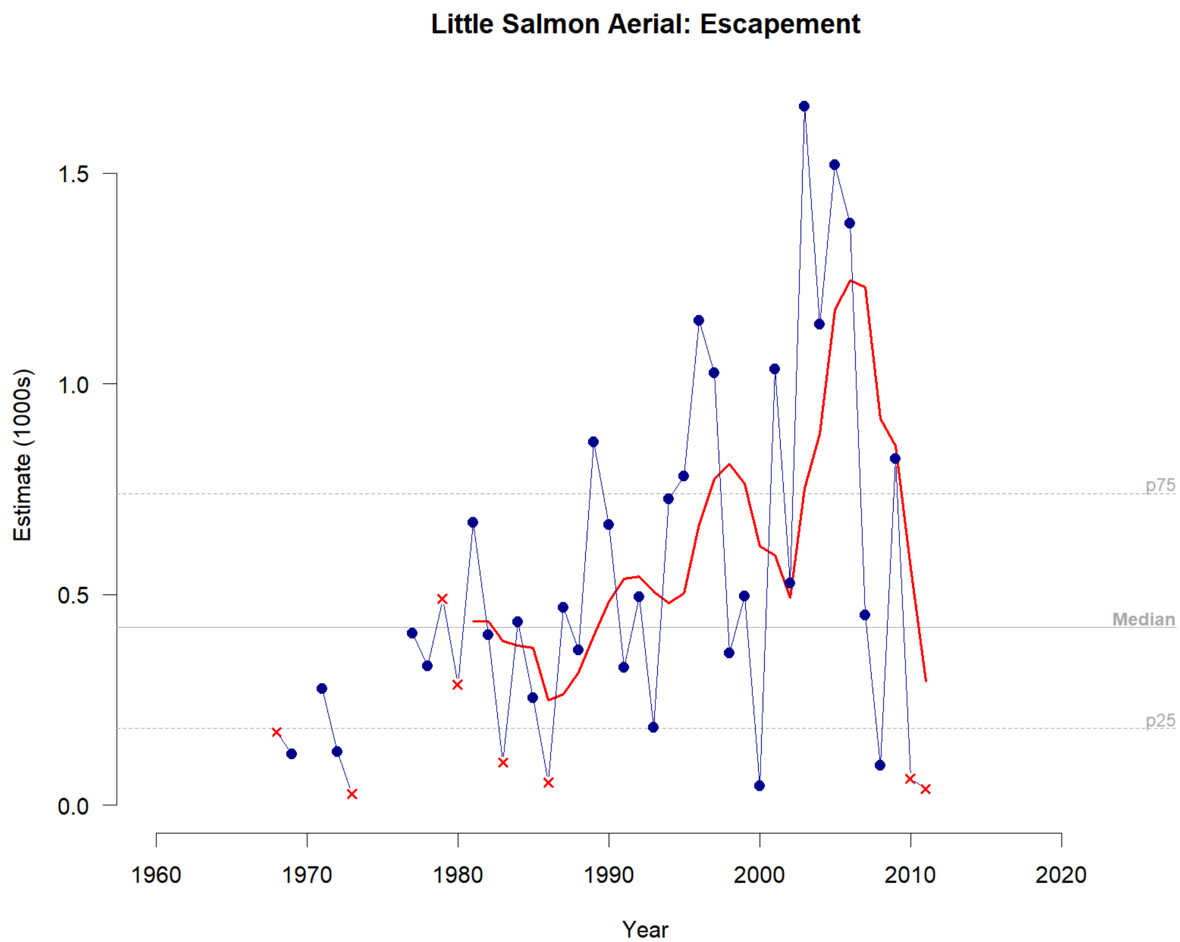

Figure A.54. *Available Estimates from Little Salmon Aerial Surveys.* Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

Table A.34. *Annual Survey Types and Escapement Estimate - Tatchun Surveys*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1966	foot	7	NA	NA	Yes	
1970	foot	100	NA	NA	Yes	
1971	foot	130	NA	NA	Yes	
1972	foot	80	NA	NA	Yes	
1973	foot	99	NA	NA	Yes	
1974	foot	192	NA	NA	Yes	
1975	foot	175	NA	NA	Yes	
1976	foot	52	NA	NA	Yes	
1977	foot	150	NA	NA	Yes	
1978	boat	200	NA	NA		different survey method
1979	foot	150	NA	NA	Yes	
1980	foot	222	NA	NA	Yes	
1981	foot	133	NA	NA	Yes	
1982	foot	73	NA	NA	Yes	
1983	foot	264	NA	NA	Yes	
1984	foot	153	NA	NA	Yes	
1985	foot	190	NA	NA	Yes	
1986	aerial	155	NA	NA		different survey method
1987	foot	159	NA	NA	Yes	
1988	foot	152	NA	NA	Yes	
1989	foot	100	NA	NA	Yes	
1990	foot	643	NA	NA	Yes	
1992	foot	106	NA	NA	Yes	
1993	foot	183	NA	NA	Yes	
1994	foot	477	NA	NA	Yes	
1995	foot	397	NA	NA	Yes	
1996	foot	423	NA	NA	Yes	
1997	foot	266	NA	NA	Yes	
1998	foot	183	NA	NA	Yes	

Table A.35. *Annual Survey Types and Escapement Estimate - Tatchun Weir*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1997	weir	1,198	NA	NA	Yes	
1998	weir	405	NA	NA	Yes	
1999	weir	252	NA	NA	Yes	
2000	weir	276	NA	NA		weir was removed early (August 24) due to flooding

Table A.36. *Annual Survey Types and Escapement Estimate - Little Salmon Aerial*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1968	Aerial	173	NA	NA		Poor quality rating
1969	Aerial	120	NA	NA	Yes	
1971	Aerial	275	NA	NA	Yes	
1972	Aerial	126	NA	NA	Yes	
1973	Aerial	27	NA	NA		Poor quality rating
1977	Aerial	408	NA	NA	Yes	
1978	Aerial	330	NA	NA	Yes	
1979	Aerial	489	NA	NA		Poor quality rating
1980	Aerial	286	NA	NA		Poor quality rating
1981	Aerial	670	NA	NA	Yes	
1982	Aerial	403	NA	NA	Yes	
1983	Aerial	101	NA	NA		Poor quality rating
1984	Aerial	434	NA	NA	Yes	
1985	Aerial	255	NA	NA	Yes	
1986	Aerial	54	NA	NA		Poor quality rating
1987	Aerial	468	NA	NA	Yes	
1988	Aerial	368	NA	NA	Yes	
1989	Aerial	862	NA	NA	Yes	
1990	Aerial	665	NA	NA	Yes	
1991	Aerial	326	NA	NA	Yes	
1992	Aerial	494	NA	NA	Yes	
1993	Aerial	184	NA	NA	Yes	
1994	Aerial	726	NA	NA	Yes	
1995	Aerial	781	NA	NA	Yes	
1996	Aerial	1,150	NA	NA	Yes	
1997	Aerial	1,025	NA	NA	Yes	
1998	Aerial	361	NA	NA	Yes	
1999	Aerial	495	NA	NA	Yes	
2000	Aerial	46	NA	NA	Yes	
2001	Aerial	1,035	NA	NA	Yes	
2002	Aerial	526	NA	NA	Yes	
2003	Aerial	1,658	NA	NA	Yes	
2004	Aerial	1,140	NA	NA	Yes	
2005	Aerial	1,519	NA	NA	Yes	
2006	Aerial	1,381	NA	NA	Yes	
2007	Aerial	451	NA	NA	Yes	
2008	Aerial	93	NA	NA	Yes	
2009	Aerial	821	NA	NA	Yes	
2010	Aerial	63	NA	NA		Poor quality rating
2011	Aerial	38	NA	NA		Poor quality rating

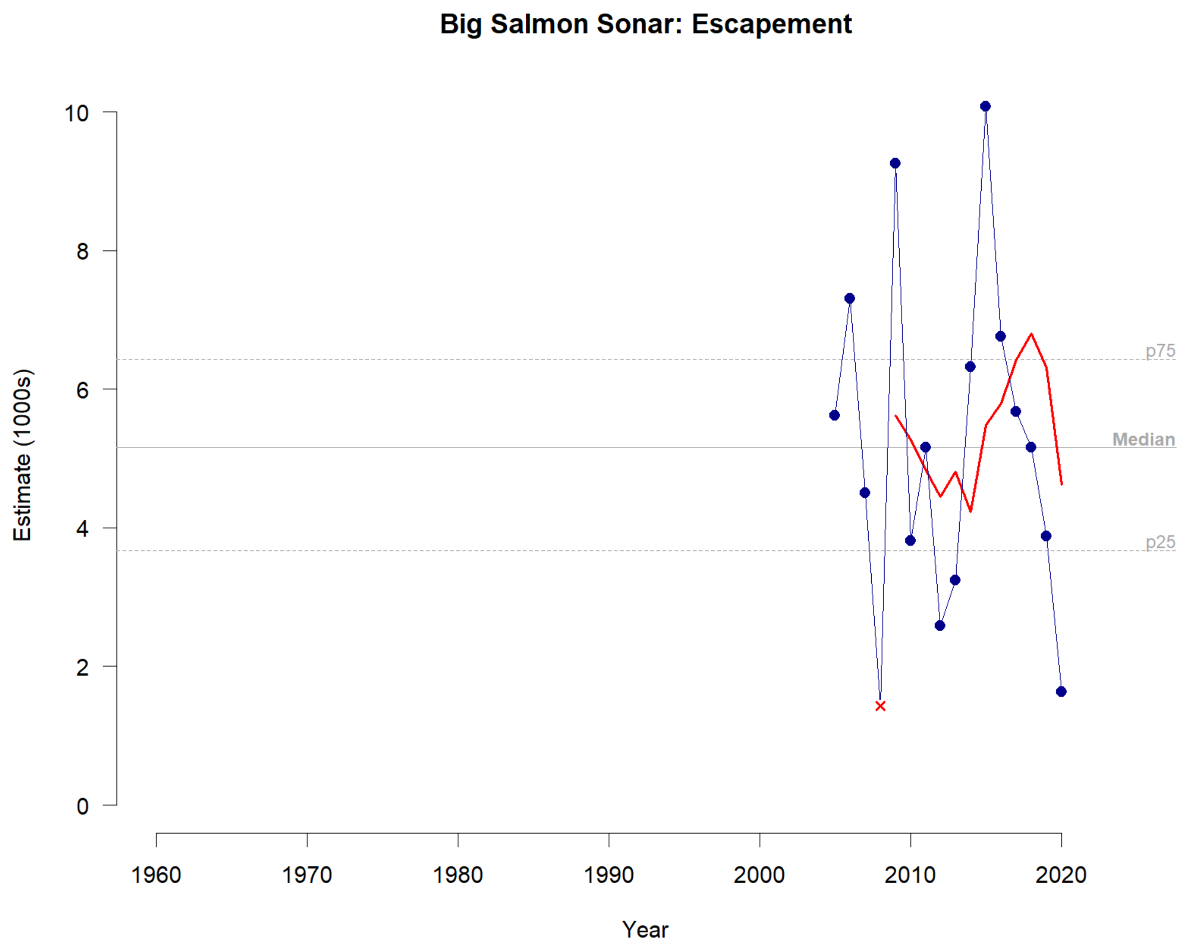

Figure A.55. *Available Estimates from Big Salmon Sonar*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

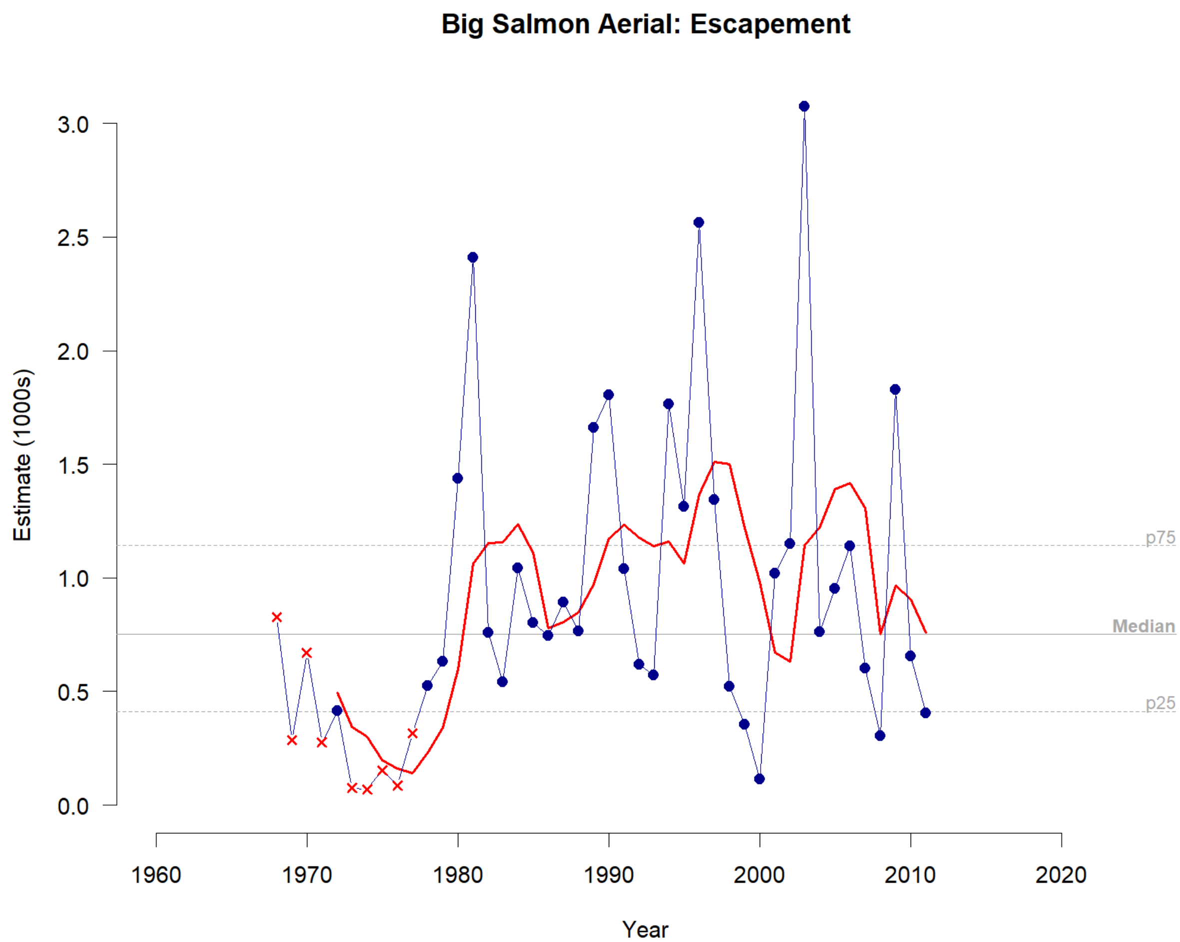

Figure A.56. *Available Estimates from Big Salmon Aerial Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

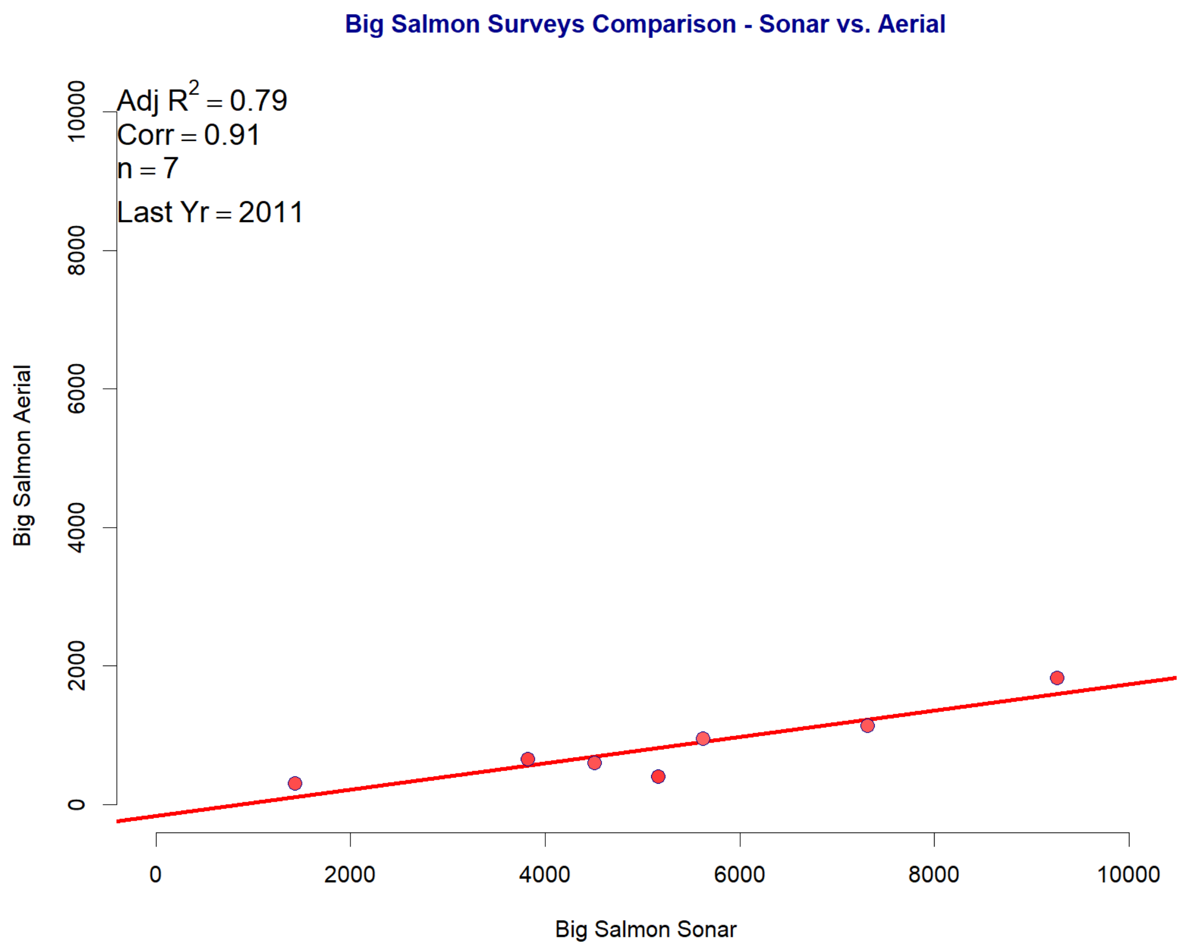

Figure A.57. Big Salmon Survey Comparison - Sonar vs. Aerial

Table A.37. *Annual Survey Types and Escapement Estimate - Big Salmon Sonar*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
2005	Sonar	5,618	NA	NA	Yes	
2006	Sonar	7,308	NA	NA	Yes	
2007	Sonar	4,506	NA	NA	Yes	
2008	Sonar	1,431	NA	NA		High water
2009	Sonar	9,261	NA	NA	Yes	
2010	Sonar	3,817	NA	NA	Yes	
2011	Sonar	5,156	NA	NA	Yes	
2012	Sonar	2,584	NA	NA	Yes	
2013	Sonar	3,242	NA	NA	Yes	
2014	Sonar	6,321	NA	NA	Yes	
2015	Sonar	10,078	NA	NA	Yes	
2016	Sonar	6,761	NA	NA	Yes	
2017	Sonar	5,672	NA	NA	Yes	
2018	Sonar	5,159	NA	NA	Yes	
2019	Sonar	3,874	NA	NA	Yes	
2020	Sonar	1,635	NA	NA	Yes	

Table A.38. *Annual Survey Types and Escapement Estimate - Big Salmon Aerial*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1968	Aerial	827	NA	NA		Poor quality rating, Survey extent not comparable
1969	Aerial	286	NA	NA		Poor quality rating
1970	Aerial	670	NA	NA		Survey extent not comparable
1971	Aerial	275	NA	NA		insufficient detail on survey area
1972	Aerial	415	NA	NA	Yes	
1973	Aerial	75	NA	NA		Poor quality rating
1974	Aerial	70	NA	NA		Poor quality rating
1975	Aerial	153	NA	NA		Poor quality rating
1976	Aerial	86	NA	NA		Poor quality rating
1977	Aerial	316	NA	NA		Poor quality rating
1978	Aerial	524	NA	NA	Yes	
1979	Aerial	632	NA	NA	Yes	
1980	Aerial	1,436	NA	NA	Yes	
1981	Aerial	2,411	NA	NA	Yes	
1982	Aerial	758	NA	NA	Yes	
1983	Aerial	540	NA	NA	Yes	
1984	Aerial	1,044	NA	NA	Yes	
1985	Aerial	801	NA	NA	Yes	
1986	Aerial	745	NA	NA	Yes	
1987	Aerial	891	NA	NA	Yes	
1988	Aerial	765	NA	NA	Yes	
1989	Aerial	1,662	NA	NA	Yes	
1990	Aerial	1,806	NA	NA	Yes	
1991	Aerial	1,040	NA	NA	Yes	
1992	Aerial	617	NA	NA	Yes	
1993	Aerial	572	NA	NA	Yes	
1994	Aerial	1,764	NA	NA	Yes	
1995	Aerial	1,314	NA	NA	Yes	
1996	Aerial	2,565	NA	NA	Yes	
1997	Aerial	1,345	NA	NA	Yes	
1998	Aerial	523	NA	NA	Yes	
1999	Aerial	353	NA	NA	Yes	
2000	Aerial	113	NA	NA	Yes	
2001	Aerial	1,020	NA	NA	Yes	
2002	Aerial	1,149	NA	NA	Yes	
2003	Aerial	3,075	NA	NA	Yes	
2004	Aerial	762	NA	NA	Yes	
2005	Aerial	952	NA	NA	Yes	
2006	Aerial	1,140	NA	NA	Yes	
2007	Aerial	601	NA	NA	Yes	
2008	Aerial	303	NA	NA	Yes	
2009	Aerial	1,827	NA	NA	Yes	
2010	Aerial	656	NA	NA	Yes	
2011	Aerial	405	NA	NA	Yes	

A.3.7 Canada - Yukon River Headwaters

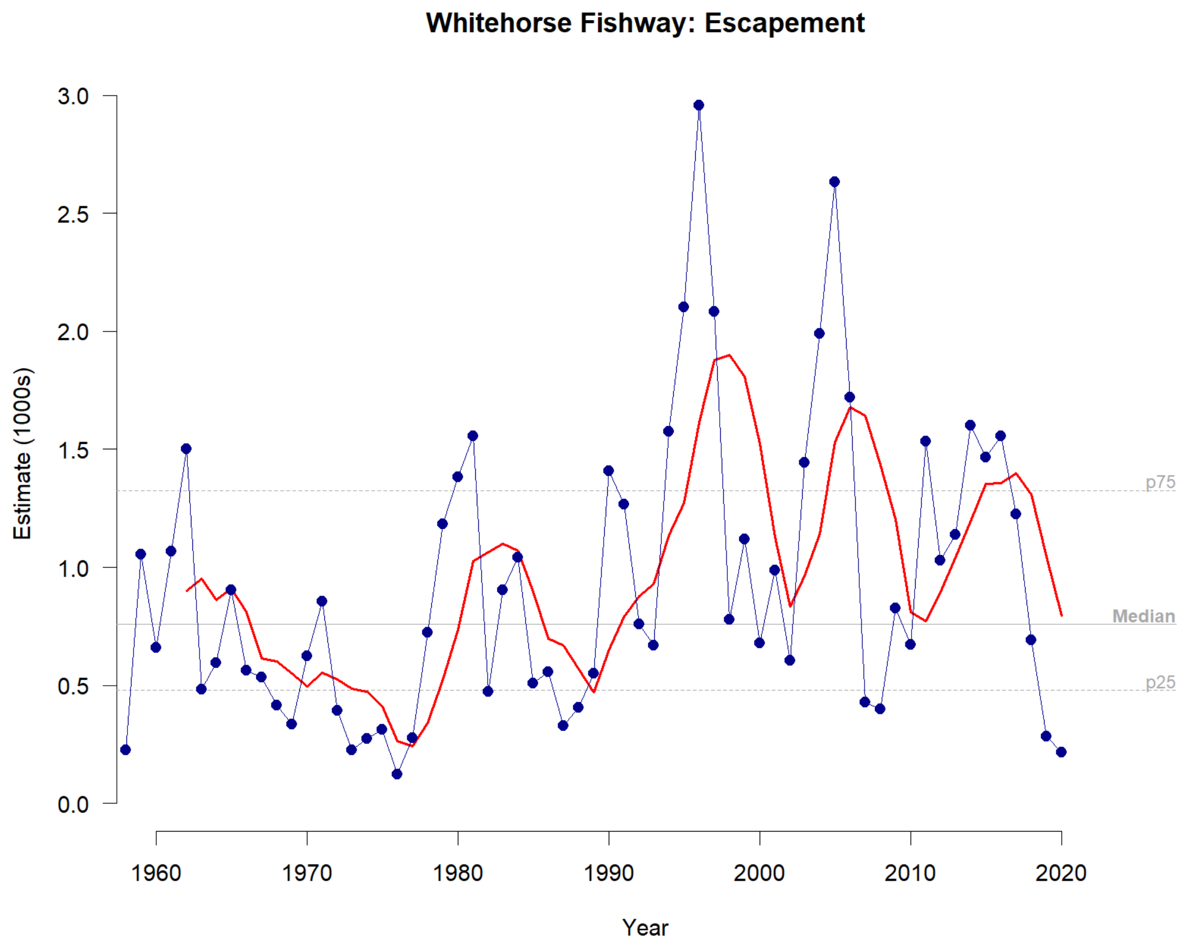

Figure A.58. *Available Estimates from Whitehorse Fishway*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

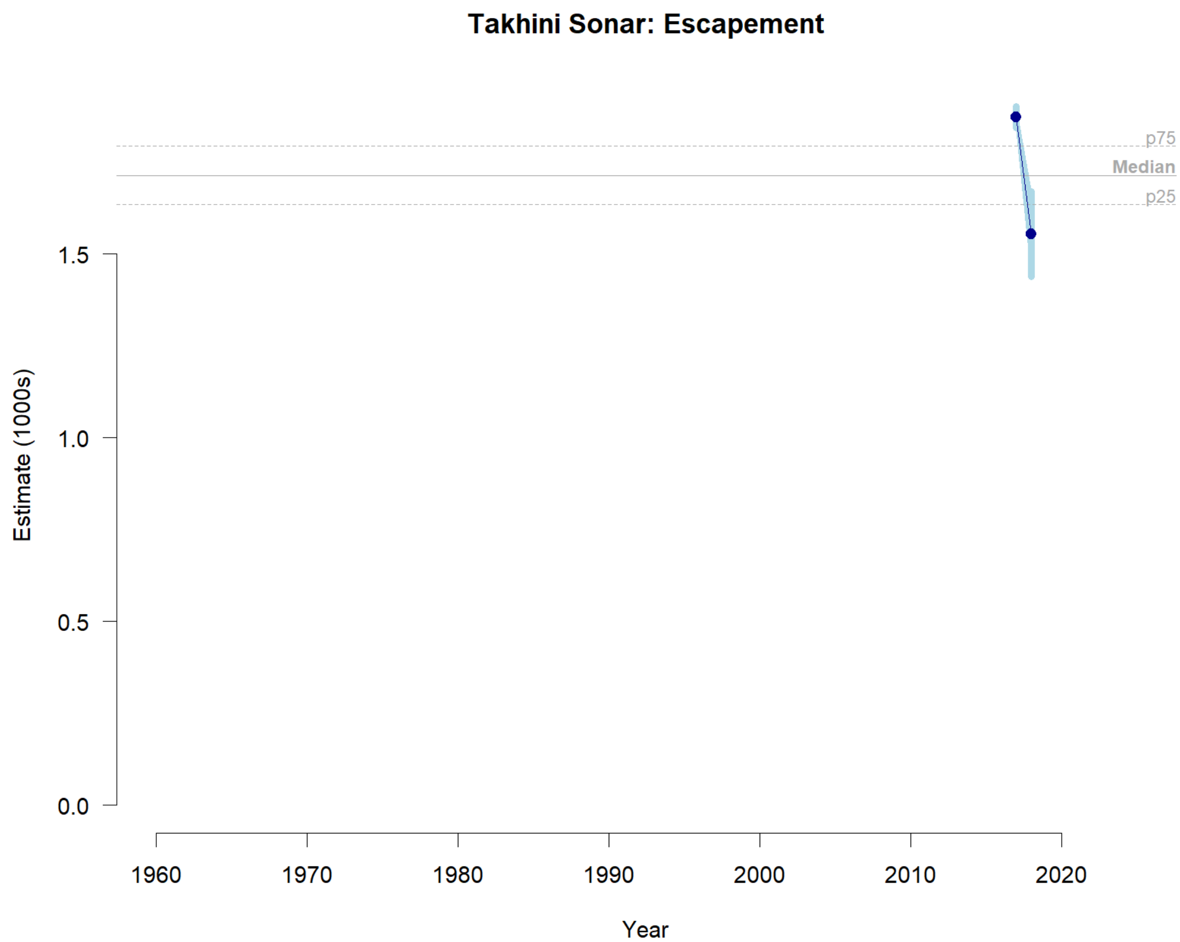

Figure A.59. *Available Estimates from Takhini Sonar*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

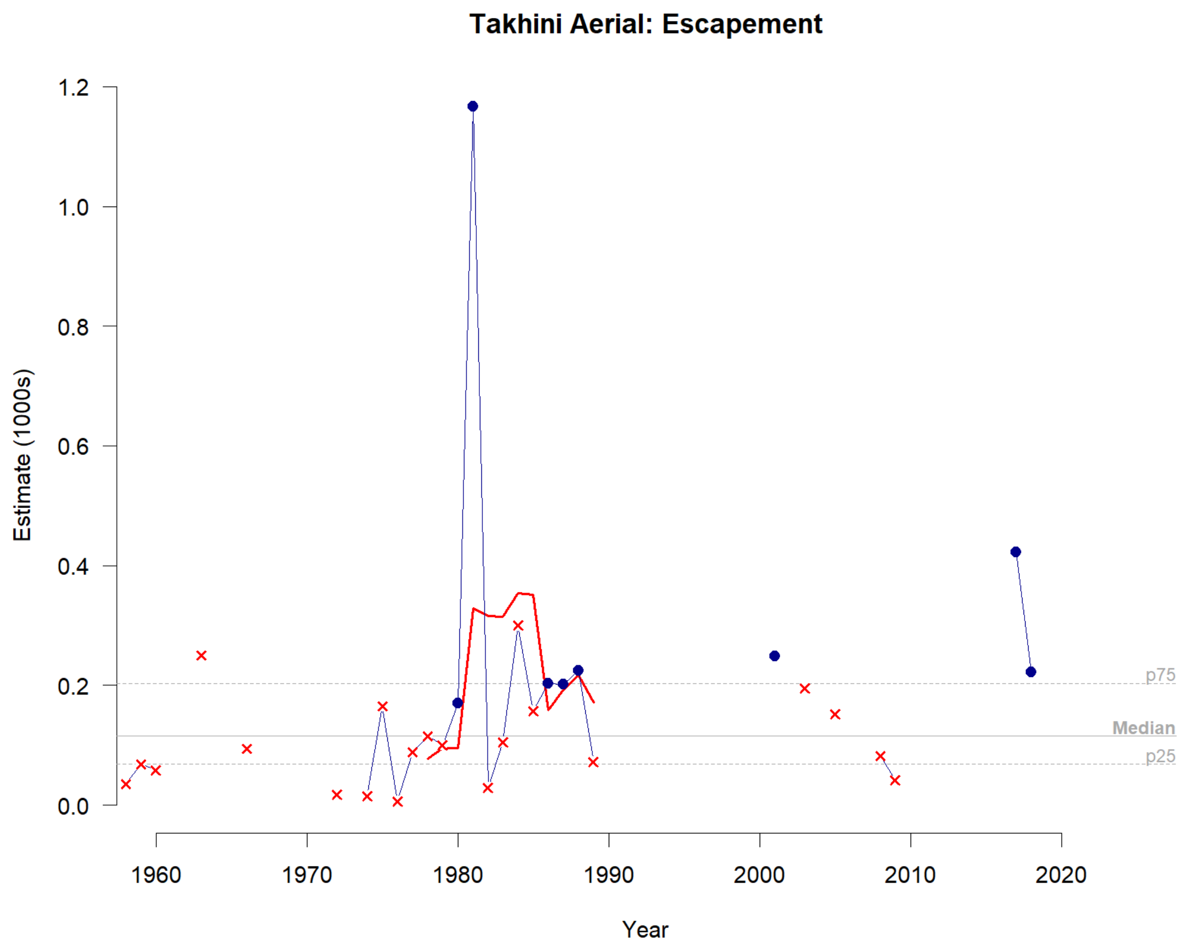

Figure A.60. *Available Estimates from Takhini Aerial Survey Program*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

Table A.39. *Annual Survey Types and Escapement Estimate - Whitehorse Fishway Estimate*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1958	Fishladder	224	NA	NA	Yes	
1959	Fishladder	1,054	NA	NA	Yes	
1960	Fishladder	660	NA	NA	Yes	
1961	Fishladder	1,068	NA	NA	Yes	
1962	Fishladder	1,500	NA	NA	Yes	
1963	Fishladder	483	NA	NA	Yes	
1964	Fishladder	595	NA	NA	Yes	
1965	Fishladder	903	NA	NA	Yes	
1966	Fishladder	563	NA	NA	Yes	
1967	Fishladder	533	NA	NA	Yes	
1968	Fishladder	414	NA	NA	Yes	
1969	Fishladder	334	NA	NA	Yes	
1970	Fishladder	625	NA	NA	Yes	
1971	Fishladder	856	NA	NA	Yes	
1972	Fishladder	391	NA	NA	Yes	
1973	Fishladder	224	NA	NA	Yes	
1974	Fishladder	273	NA	NA	Yes	
1975	Fishladder	313	NA	NA	Yes	
1976	Fishladder	121	NA	NA	Yes	
1977	Fishladder	277	NA	NA	Yes	
1978	Fishladder	725	NA	NA	Yes	
1979	Fishladder	1,184	NA	NA	Yes	
1980	Fishladder	1,383	NA	NA	Yes	
1981	Fishladder	1,555	NA	NA	Yes	
1982	Fishladder	473	NA	NA	Yes	
1983	Fishladder	905	NA	NA	Yes	
1984	Fishladder	1,042	NA	NA	Yes	
1985	Fishladder	508	NA	NA	Yes	
1986	Fishladder	557	NA	NA	Yes	
1987	Fishladder	327	NA	NA	Yes	
1988	Fishladder	405	NA	NA	Yes	
1989	Fishladder	549	NA	NA	Yes	
1990	Fishladder	1,407	NA	NA	Yes	
1991	Fishladder	1,266	NA	NA	Yes	
1992	Fishladder	758	NA	NA	Yes	
1993	Fishladder	668	NA	NA	Yes	
1994	Fishladder	1,577	NA	NA	Yes	
1995	Fishladder	2,103	NA	NA	Yes	
1996	Fishladder	2,958	NA	NA	Yes	
1997	Fishladder	2,084	NA	NA	Yes	
1998	Fishladder	777	NA	NA	Yes	
1999	Fishladder	1,118	NA	NA	Yes	
2000	Fishladder	677	NA	NA	Yes	
2001	Fishladder	988	NA	NA	Yes	
2002	Fishladder	605	NA	NA	Yes	
2003	Fishladder	1,443	NA	NA	Yes	
2004	Fishladder	1,989	NA	NA	Yes	
2005	Fishladder	2,632	NA	NA	Yes	
2006	Fishladder	1,720	NA	NA	Yes	
2007	Fishladder	427	NA	NA	Yes	
2008	Fishladder	399	NA	NA	Yes	
2009	Fishladder	828	NA	NA	Yes	

Year	Type	Estimate	Lower	Upper	Use	UseNotes
2010	Fishladder	672	NA	NA	Yes	
2011	Fishladder	1,534	NA	NA	Yes	
2012	Fishladder	1,030	NA	NA	Yes	
2013	Fishladder	1,139	NA	NA	Yes	
2014	Fishladder	1,601	NA	NA	Yes	
2015	Fishladder	1,465	NA	NA	Yes	
2016	Fishladder	1,556	NA	NA	Yes	
2017	Fishladder	1,226	NA	NA	Yes	
2018	Fishladder	691	NA	NA	Yes	
2019	Fishladder	282	NA	NA	Yes	
2020	Fishladder	216	NA	NA	Yes	

Table A.40. *Annual Survey Types and Escapement Estimate - Takhini Sonar Estimate*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
2017	Sonar	1,872	1,843	1,901	Yes	
2018	Sonar	1,554	1,439	1,669	Yes	

Table A.41. *Annual Survey Types and Escapement Estimate - Takhini Aerial Estimate*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1958	Unknown	35	NA	NA		method unknown
1959	Unknown	68	NA	NA		method unknown
1960	Unknown	58	NA	NA		method unknown
1963	Flight	250	NA	NA		extent minimal
1966	Flight	94	NA	NA		extent unknown
1972	Unknown	17	NA	NA		method unknown
1974	Unknown	15	NA	NA		method unknown
1975	Unknown	165	NA	NA		method unknown
1976	Unknown	6	NA	NA		method unknown
1977	Unknown	88	NA	NA		method unknown
1978	Flight	115	NA	NA		low quality
1979	Unknown	100	NA	NA		method unknown
1980	Heli	170	NA	NA	Yes	
1981	Heli	1,167	NA	NA	Yes	
1982	Ground	29	NA	NA		not comparable
1983	Ground	105	NA	NA		not comparable
1984	Unknown	300	NA	NA		method unknown
1985	Unknown	157	NA	NA		method unknown
1986	Heli	203	NA	NA	Yes	
1987	Heli	202	NA	NA	Yes	
1988	Heli	225	NA	NA	Yes	
1989	Heli	72	NA	NA		low quality
2001	Heli	249	NA	NA	Yes	
2003	Boat	195	NA	NA		extent short
2005	Boat	152	NA	NA		extent short
2008	Boat	82	NA	NA		extent short
2009	Boat	41	NA	NA		extent short
2017	Heli	423	NA	NA	Yes	
2018	Heli	222	NA	NA	Yes	

A.3.8 Canada - Teslin Headwaters

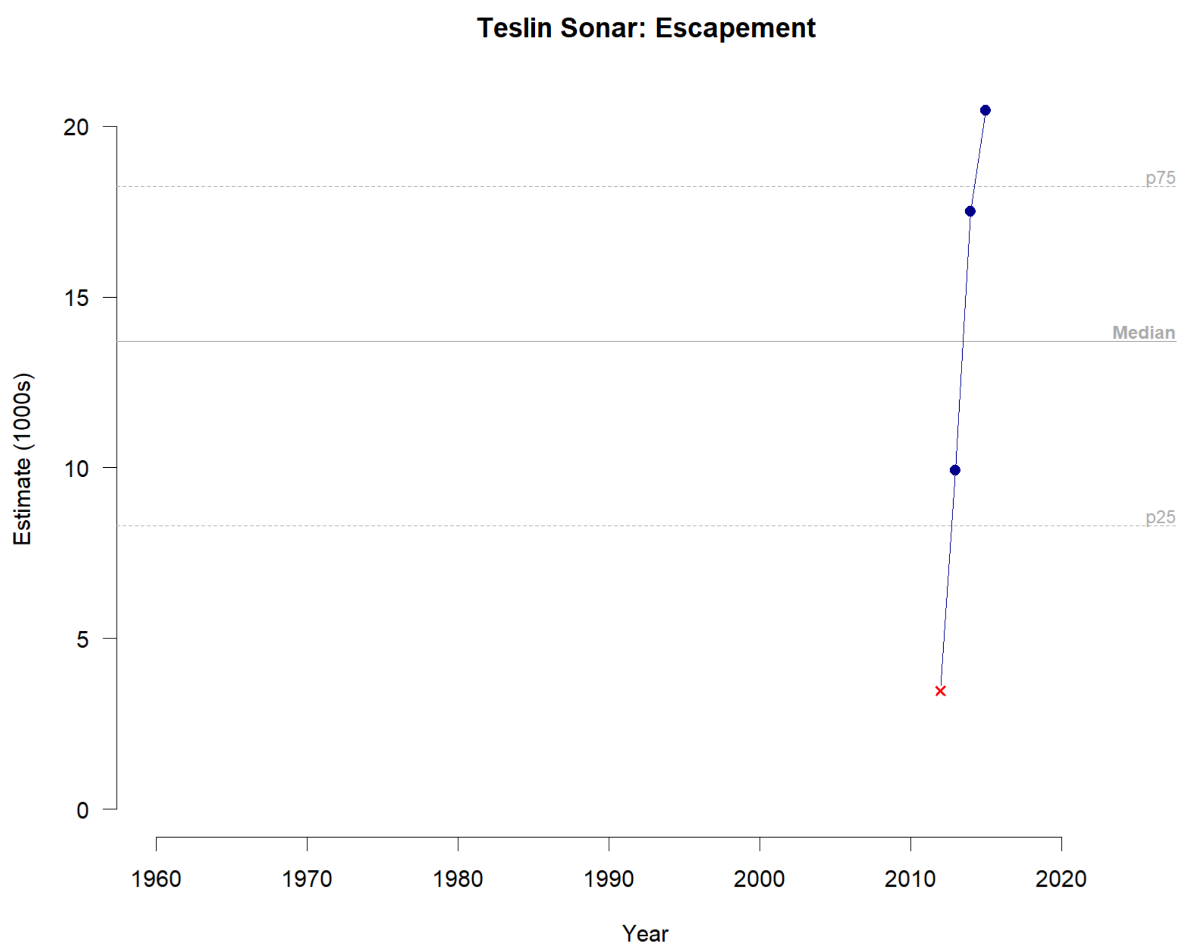

Figure A.61. *Available Estimates from Teslin Sonar*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

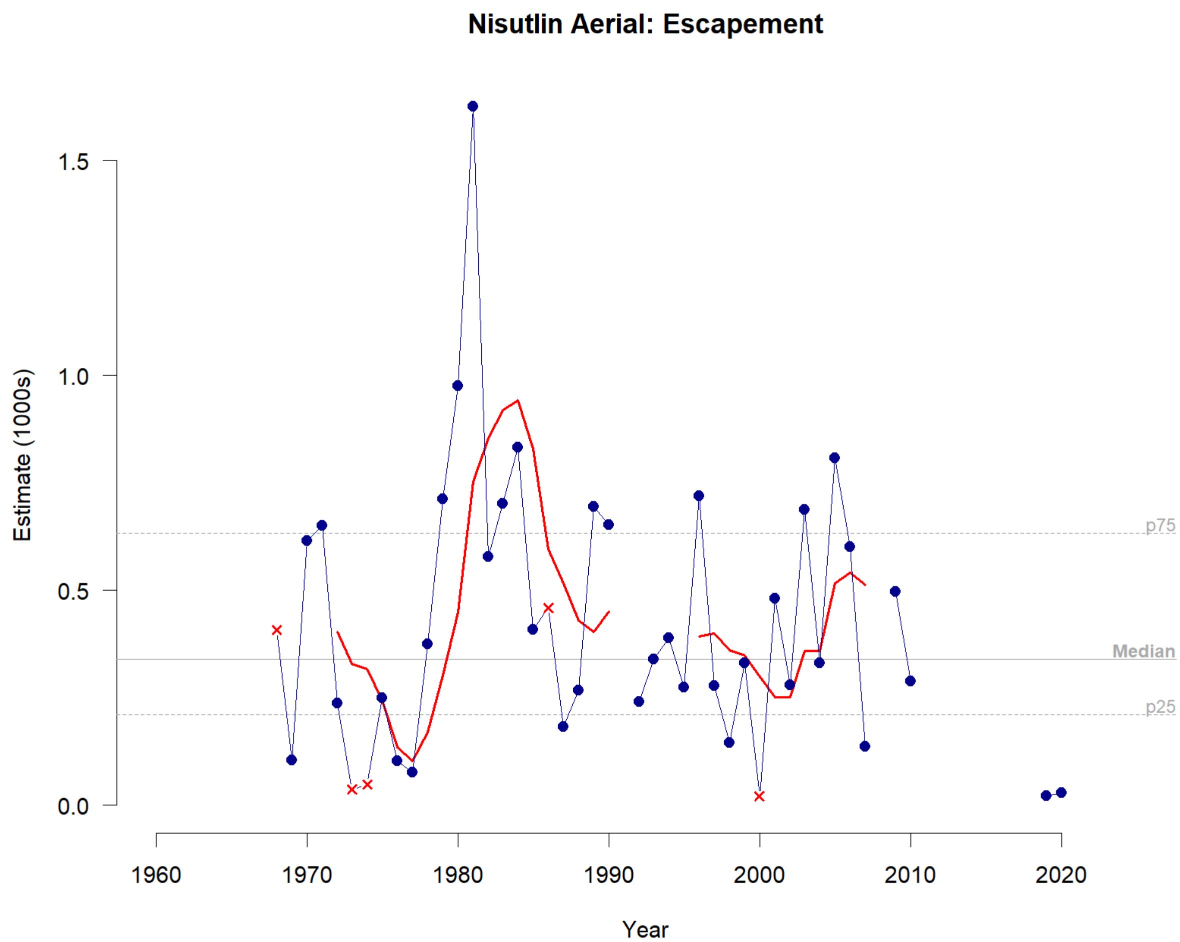

Figure A.62. *Available Estimates from Nisutlin Aerial Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

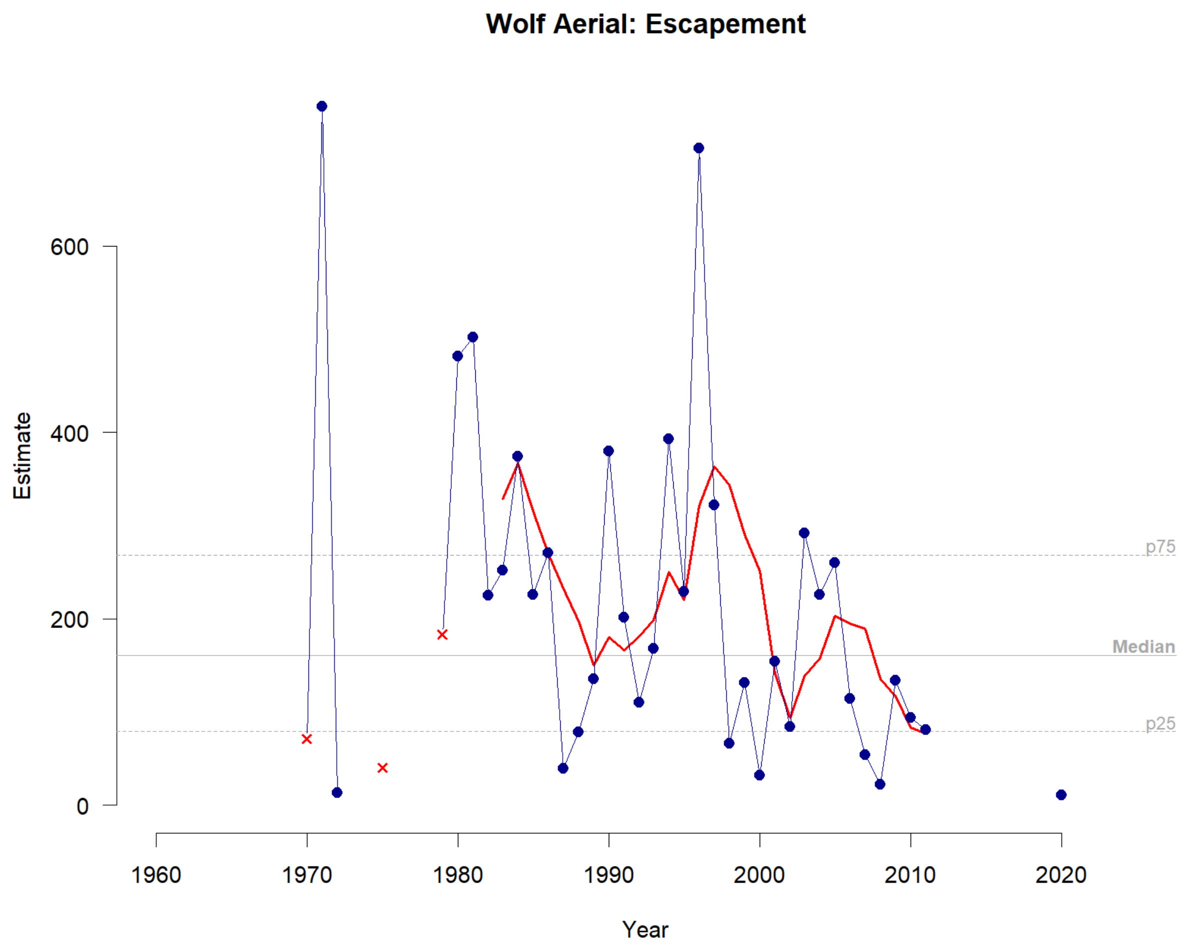

Figure A.63. *Available Estimates from Wolf Aerial Surveys* Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

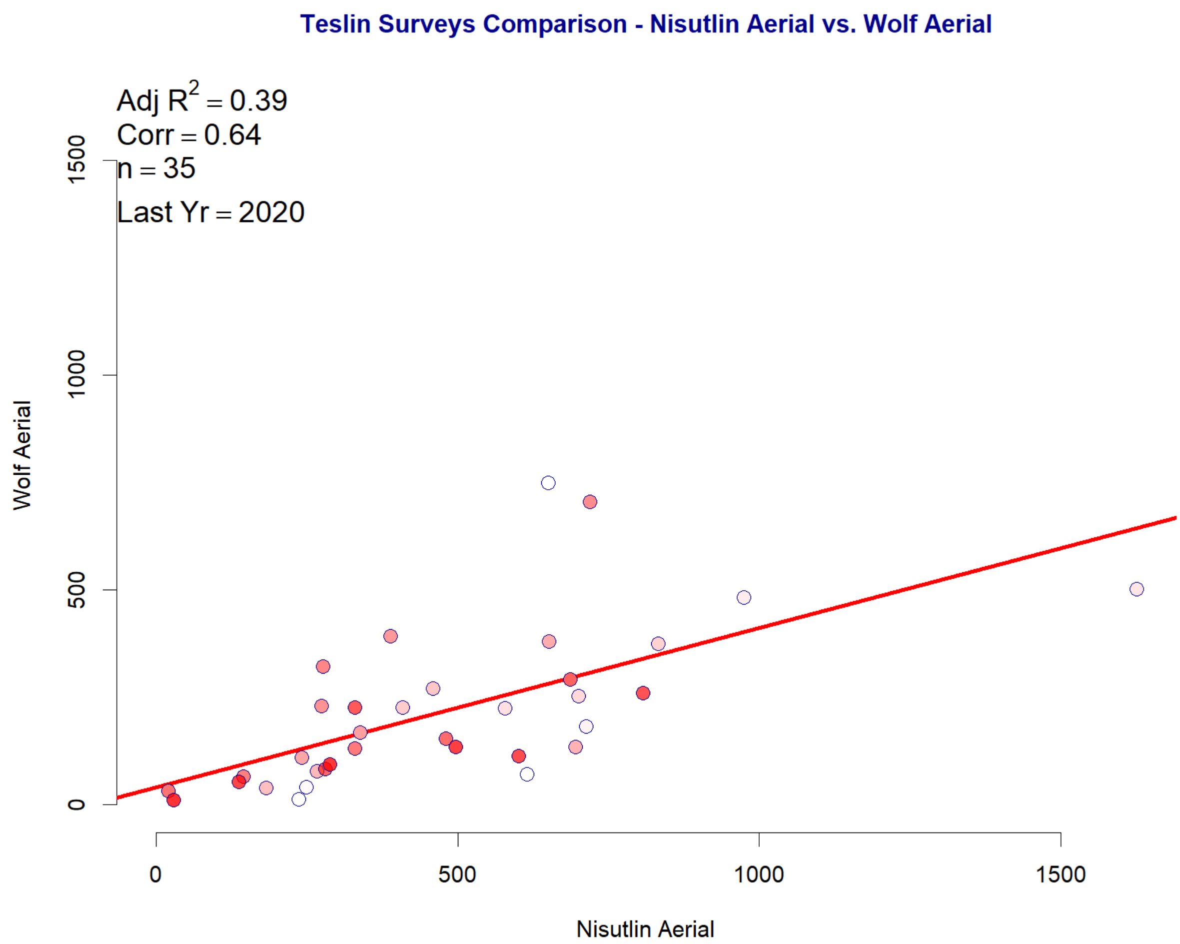

Figure A.64. *Teslin Survey Comparison - Nisutlin Aerial vs. Wolf Aerial*

Table A.42. *Annual Survey Types and Escapement Estimate - Teslin Sonar Estimate*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
2012	Sonar	3,454	NA	NA		No Chinook counted on left bank due to high water. Estimate considered a minimum.
2013	Sonar	9,916	NA	NA	Yes	
2014	Sonar	17,507	NA	NA	Yes	
2015	Sonar	20,463	NA	NA	Yes	

Table A.43. *Annual Survey Types and Escapement Estimate - Nisutlin Aerial Estimate*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1968	Aerial	407	NA	NA		Poor quality rating
1969	Aerial	105	NA	NA	Yes	
1970	Aerial	615	NA	NA	Yes	
1971	Aerial	650	NA	NA	Yes	
1972	Aerial	237	NA	NA	Yes	
1973	Aerial	36	NA	NA		Poor quality rating
1974	Aerial	48	NA	NA		Poor quality rating
1975	Aerial	249	NA	NA	Yes	
1976	Aerial	102	NA	NA	Yes	
1977	Aerial	77	NA	NA	Yes	
1978	Aerial	375	NA	NA	Yes	
1979	Aerial	713	NA	NA	Yes	
1980	Aerial	975	NA	NA	Yes	
1981	Aerial	1,626	NA	NA	Yes	
1982	Aerial	578	NA	NA	Yes	
1983	Aerial	701	NA	NA	Yes	
1984	Aerial	832	NA	NA	Yes	
1985	Aerial	409	NA	NA	Yes	
1986	Aerial	459	NA	NA		Poor quality rating
1987	Aerial	183	NA	NA	Yes	
1988	Aerial	267	NA	NA	Yes	
1989	Aerial	695	NA	NA	Yes	
1990	Aerial	652	NA	NA	Yes	
1992	Aerial	241	NA	NA	Yes	
1993	Aerial	339	NA	NA	Yes	
1994	Aerial	389	NA	NA	Yes	
1995	Aerial	274	NA	NA	Yes	
1996	Aerial	719	NA	NA	Yes	
1997	Aerial	277	NA	NA	Yes	
1998	Aerial	145	NA	NA	Yes	
1999	Aerial	330	NA	NA	Yes	
2000	Aerial	20	NA	NA		Poor quality rating
2001	Aerial	481	NA	NA	Yes	
2002	Aerial	280	NA	NA	Yes	
2003	Aerial	687	NA	NA	Yes	
2004	Aerial	330	NA	NA	Yes	
2005	Aerial	807	NA	NA	Yes	
2006	Aerial	601	NA	NA	Yes	
2007	Aerial	137	NA	NA	Yes	
2009	Aerial	497	NA	NA	Yes	
2010	Aerial	288	NA	NA	Yes	
2019	Aerial	22	NA	NA	Yes	
2020	Aerial	29	NA	NA	Yes	

Table A.44. *Annual Survey Types and Escapement Estimate - Wolf Aerial Estimate*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
1970	Aerial	71	NA	NA		Poor quality rating
1971	Aerial	750	NA	NA	Yes	
1972	Aerial	13	NA	NA	Yes	
1975	Aerial	40	NA	NA		Poor quality rating
1979	Aerial	183	NA	NA		Poor quality rating
1980	Aerial	482	NA	NA	Yes	
1981	Aerial	502	NA	NA	Yes	
1982	Aerial	225	NA	NA	Yes	
1983	Aerial	252	NA	NA	Yes	
1984	Aerial	374	NA	NA	Yes	
1985	Aerial	226	NA	NA	Yes	
1986	Aerial	271	NA	NA	Yes	
1987	Aerial	39	NA	NA	Yes	
1988	Aerial	78	NA	NA	Yes	
1989	Aerial	135	NA	NA	Yes	
1990	Aerial	380	NA	NA	Yes	
1991	Aerial	201	NA	NA	Yes	
1992	Aerial	110	NA	NA	Yes	
1993	Aerial	168	NA	NA	Yes	
1994	Aerial	393	NA	NA	Yes	
1995	Aerial	229	NA	NA	Yes	
1996	Aerial	705	NA	NA	Yes	
1997	Aerial	322	NA	NA	Yes	
1998	Aerial	66	NA	NA	Yes	
1999	Aerial	131	NA	NA	Yes	
2000	Aerial	32	NA	NA	Yes	
2001	Aerial	154	NA	NA	Yes	
2002	Aerial	84	NA	NA	Yes	
2003	Aerial	292	NA	NA	Yes	
2004	Aerial	226	NA	NA	Yes	
2005	Aerial	260	NA	NA	Yes	
2006	Aerial	114	NA	NA	Yes	
2007	Aerial	54	NA	NA	Yes	
2008	Aerial	22	NA	NA	Yes	
2009	Aerial	134	NA	NA	Yes	
2010	Aerial	94	NA	NA	Yes	
2011	Aerial	81	NA	NA	Yes	
2020	Aerial	11	NA	NA	Yes	

A.3.9 Canada - Porcupine

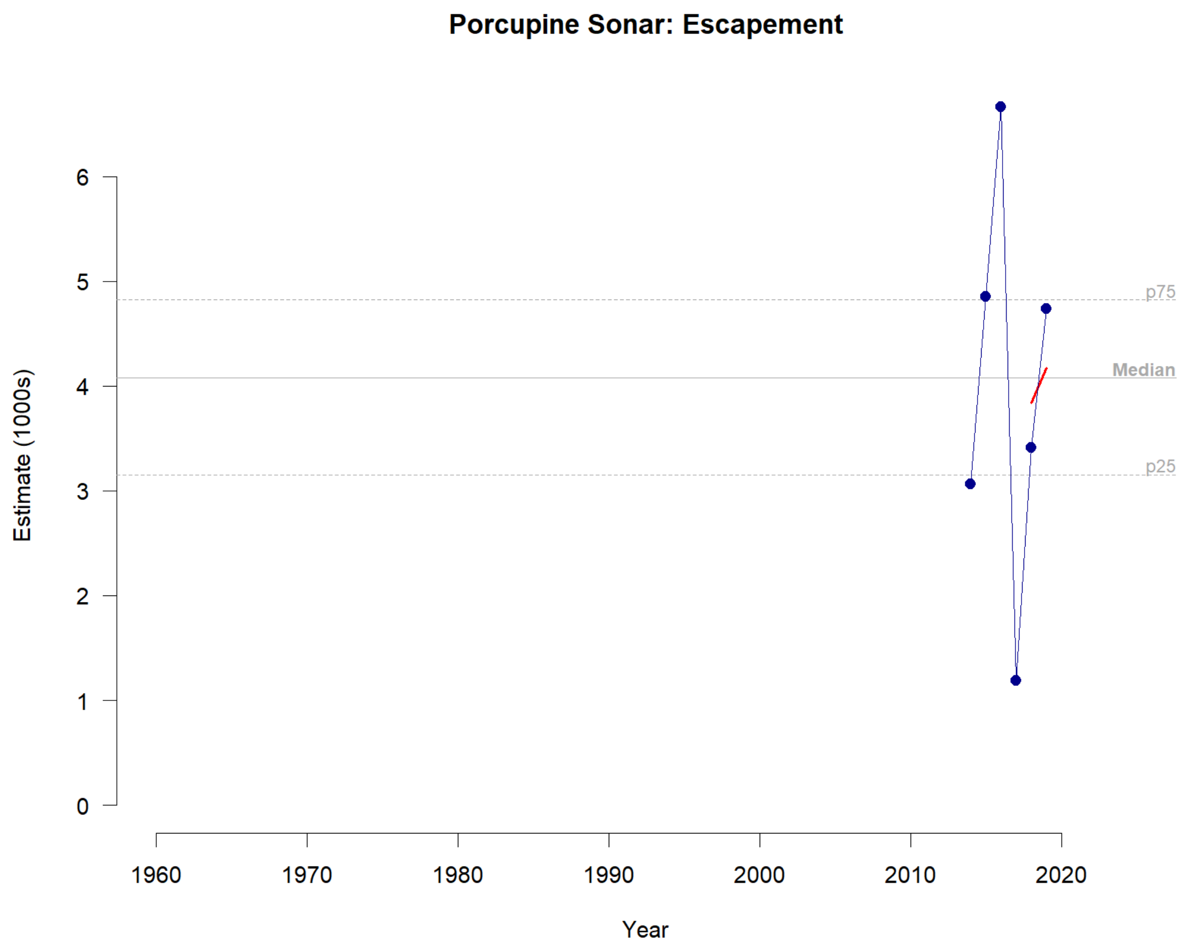

Figure A.65. *Available Estimates from Porcupine Sonar Surveys*. Figure was autogenerated using standardized code to facilitate changes to the input data in the future. As such only the relevant figure elements will appear. Figure shows annual estimates (points). When applicable, the figure identifies all annual estimates that are currently not used by agencies due to data concerns (red x), presents the 5-yr running average (red line), and confidence interval (±2 standard errors) based on reported coefficients of variation for the annual estimates.

Table A.45. *Annual Survey Types and Escapement Estimate - Porcupine Sonar Estimate*. *Lower* and *Upper* show estimate ± 2 SE. *Use* reflects whether the observation is currently being used by the agency that is collecting the data. If not, *UseNotes* provides a brief rationale.

Year	Type	Estimate	Lower	Upper	Use	UseNotes
2014	Sonar	3,066	NA	NA	Yes	
2015	Sonar	4,851	NA	NA	Yes	
2016	Sonar	6,665	NA	NA	Yes	
2017	Sonar	1,191	NA	NA	Yes	
2018	Sonar	3,414	NA	NA	Yes	
2019	Sonar	4,740	NA	NA	Yes	

APPENDIX B U.S. Harvest Estimates

B.1 Overview

U.S. harvests of Yukon Chinook occur in three types of fisheries:

- Commercial and test fisheries
- Subsistence and personal use fisheries
- Sport fisheries

B.2 U.S. Commercial and Test Fishery Harvest

B.2.1 Program Summary - U.S. Commercial and Test Fishery

Introduction

ADF&G collects fish tickets which contain:

- *record identifiers*: unique ticket number, ADF&G office stamped ID number, landing report ID, fisherman details and permit card info, processor information, port code
- *Catch value*: price per pound of catch, price per total of catch
- *fishery details*: period start date, time stamp or date delivered, gear type, statistical area, fishing period, number of fishermen, number of landings, harvest code (state managed fishery or confiscated fish), disposition code (sold, personal use, or live released used on Yukon River)
- *catch details*: harvested weight (lbs) by species, number of fish harvested by species, average weight of harvest by species, delivery condition (whole, headed and gutted, etc.). Some old data includes weight of roe (with or without the numbers of fish that produced the roe) and may not be contained in official fish ticket records.

All the data is available to ADF&G staff through the OceanAK database, but some of the data is considered confidential and not available to the public.

ADF&G manages commercial salmon fishing along the entire 1,200 mile length of the mainstem Yukon River in Alaska, the lower 225 miles of the Tanana River, and the lower 12 miles of the Anvik River. The Yukon Area is divided into 7 districts and 10 subdistricts for management and regulatory purposes. The Coastal District, which is divided into Southern and Northern areas, is the area from Naskonat Peninsula to Point Romanof, and includes all waters extending 3 nautical miles from any grassland (Estensen et al. 2018). Within districts and subdistricts are stat areas. The Coastal District is included in District 1 stat areas.

The program has been implemented annually since 1918. Commercial harvest data includes 1969 – 2019. Complete fish tickets are only available after 1985.

Methods

Commercial harvest includes all 5 species of Pacific salmon *Oncorhynchus* spp., with Chinook, Chum, Coho, and Pink salmon being the predominant species taken. In addition, Arctic Lamprey (*Lethenteron camtschaticum*) and whitefish (*Coregonus spp.*) are also harvested. The policy of ADF&G is to manage salmon runs to the extent possible for maximum sustainable yield, unless otherwise directed by state regulation (Policy for the Management of Sustainable Salmon Fisheries (SSFP; 5 AAC 39.222 .)). The Yukon River Chinook salmon run is managed according to the guidelines described in the Yukon River Chinook Salmon Management Plan (5 AAC 05.360)

The ADF&G fish ticket is the sales receipt provided to document commercial harvest from a public resource. As an alternative, many processors are using the eLandings system, which generates a printable ADF&G fish ticket. Both the ADF&G paper fish ticket forms and the eLandings system provide a method for accurately reporting of commercial fishing activity and comply with the Alaska Fish and Game Laws and Regulations. Fish tickets must be completed and submitted to the nearest ADF&G office within 7 days of the landing and/or first purchase of the fishery resource (adfg.alaska.gov).

Individual fish tickets are confidential, and while in general summaries of harvest for certain periods can be provided, this can also be confidential if a fishery has 3 or less participants. A request for the release of records can be made, but there is no guarantee of approval.

Additional sources of harvest, but still considered commercial harvest, are included as part of this summary. Other sources include test fish sales not included with commercial tickets, illegal harvest and sale, and commercial-related (estimated number of fish harvested for the commercial production of salmon roe). Most of these harvests are contained on fish tickets and in databases, but specific harvest codes are used to designate the harvest types. These varied harvest sources summed with records of normal commercial harvest by stat area provide the most accurate number of fish harvested commercially.

Discussion

Critical assumptions include:

- All commercially harvested fish are documented on a fish ticket.

Complete records and summaries of fish tickets exist back to 1985, records prior to 1985 are considered incomplete, as these data are not vetted, and discrepancies exist with accuracy and consistency. For example, roe fisheries were not always required to report the number of fish harvested, rather the pounds of roe. A variety of assumptions and reporting requirements were used to relate pounds of roe to numbers of chum and Chinook salmon (Brannian and Brady 1985). For example, in Subdistrict 4A, one pound of roe was assumed to be equal to one female and one male, while only females were reported in other districts.

The sources for fish ticket data are also not consistent. In the 1985 Arctic-Yukon-Kuskokwim

Salmon Fish Ticket processing manual (Brannian and Brady 1985), lead fisheries scientist Phil Mundy states in the Forword that prior to 1981 harvest information statewide was often incomplete. Records were often obtained through oral reports from processors, on-board observer reports, and other indirect measures of level of harvest. Furthermore, when digitizing old fish ticket records more recently, some records were incomplete or lost and these data gaps were filled in using old Area Management Reports (AMRs) or verbally from processors (Sabrina Larsen, ADF&G, Personal Communication). Other sources for potential error include inconsistencies or missing processor reports, and possible errors with changes to stat area reporting when fishery boundaries were moved (e.g. a fisher may have been used to recording a previously used stat area code when a new one had been applied).

B.2.2 Program Details - U.S. Commercial and Test Fish Harvest

Table B.1. US Commercial and Test Fish Use Harvest Estimates - Operational Timeline

Years	Change/Event
1918	First recorded commercial salmon harvest in the Alaska portion of the Yukon River drainage.
1919-1921	Large harvests of Chinook, chum, and coho salmon were taken in coastal waters beyond the mouth of the Yukon.
1925-1931	Closures in commercial fishing were implemented due to concerns for the inriver subsistence harvest
1961-present	Sustained commercial fishing for chum and/or coho salmon began
1961	Major commercial utilization of fisheries resources begins. Directed commercial fishing for fall run chum salmon begins.
1980s	Summer chum commercial harvests increased because of net changes, earlier openers, increased availability of processors, higher exvessel prices, development of Japanese markets, and increased run sizes. At the time, the economic value of Yukon River commercial fisheries was approximately 7.2 Million to fisherman and 18.3 Million wholesale value
1990	Starting in 1990 stat area 334-41 was broken into four new stat areas 334-44, 334-45, 334-46, 334-47.
2008	Chinook salmon-directed commercial fishing (defined by the use of large mesh gillnets larger than 7.5 mesh) is suspended due to poor runs.
2011	The 7.5 inch maximum gillnet mesh size restriction adopted by the BOF in 2010 went into effect in 2011. (Estensen et. al 2012).
2012-present	Selective gear types have been permitted to allow for the live release of Chinook salmon.
2010-Present	The sale of incidentally caught Chinook salmon in the summer chum salmon directed commercial fishery has been generally restricted except for years with high runs.

Table B.2. US Commercial and Test Fish Harvest Estimates - Potential Data Issues

Years Affected	**Potential Issue**
1969 – 1973	Commercial harvest data records are reported by district only. The commercial harvest data for this summary are coming from records found in the most recent published Yukon area annual management report (AMR).
1974-1984	Districts 1 – 3 commercial harvest data reported by stat area. Districts 4 – 6 reported by district. The commercial harvest data for this summary are being taken from records found in the most recent published AMR.
1985-2019	Commercial harvest data by stat area reported in the fish ticket database and summarized in various published reports. Similar to fish ticket records prior to 1985 some discrepancies exist between the database and published reports but the differences are minimal with most stat areas matching between datasets. In addition, fish ticket data has been vetted for accuracy and consistency. Discrepancies were noted in one or more stat areas in the following years; 1985 -1986, 1989-1991, 1997-1998 and 2002. All other year's records between the database and published reports matched. This report uses data contained in the fish ticket database, to ensure that analyses can be replicated. A select number of years will include additional harvest not included in the fish ticket database, as summarized in the table entries below.
1987, 1989-1992	Commercial harvest by statistical area in the ADF&G database does not include illegal sale of fish that occurred in 1987 and 1989-1992 (Whitmore et al. 1990, Schultz et al. 1993, Bergstrom et al. 1995). Illegal harvest is summarized by district in the data table.
1988 – 1990 and 1992	District 6 only. Test fish sales by stat area included with commercial harvest fish tickets data. 1992 district 6 test fish sale included with commercial harvest.
1991-2007	Test fish sales on fish tickets are reported separately from commercial harvest and included as a separate column in data table.
2008-2019	No test fish sales reported. All Chinook given away and reported as subsistence harvest.
1990-2002	Commercial Related – estimate of the number of salmon harvested for the commercial production of salmon roe (pounds of roe sold divided by average roe weight per female). Most, but not all, records are reported on fish tickets using special harvest designation code. Data are included in harvest summary tables by district in AMR. Included as a separate column by district in the data table.

B.2.3 References - U.S. Commercial and Test Fish

Data Sources

- Fish ticket harvest data: https://www.adfg.alaska.gov/CF_R3/external/sites/aykdbms_website/PublicReports/CommercialHarvestSummaryOBI.aspx
- Annual management reports (AMRs) http://www.adfg.alaska.gov/sf/publications/

Reports

Brannian, L. and J. Brady. 1985. Arctic-Yukon-Kuskokwim salmon fish ticket processing manual. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report No. 146, Juneau.

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Schultz, K. C., R. R. Holder, L. H. Barton, D. J. Bergstrom, C. Blaney, G. J. Sandone and D. J. Schneiderhan. 1993. Annual management report for subsistence, personal use, and commercial fisheries of the Yukon area, 1992. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A93-10, Anchorage.

Whitmore, C., D. J. Bergstrom, F. M. Anderson, G. Sandone, J. Wilcock, L. H. Barton, and D. Mesiar. 1990. Annual management report Yukon area, 1988. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A90-28, Anchorage.

B.3 U.S. Subsistence and Personal Use Harvest

B.3.1 Program Summary - U.S. Subsistence and Personal Use Harvest

Introduction

Using household surveys, ADF&G compiles annual estimates of subsistence and personal use harvest by community with additional data on number of fishing households and primary gear used.

The study area comprises the entire U.S. Yukon Area, which includes all waters of Alaska within the Yukon River drainage and all coastal waters of Alaska from Point Romanof southward to the Naskonat Peninsula. Postseason harvest interviews are conducted in 33 communities located off the road system. Harvests from the road accessible communities on the Yukon and Koyukuk rivers and all communities along the Tanana River are documented through permits and excluded from the household surveys.

The household surveys have been implemented annually since 1961. Subsistence harvest data are available in an ADF&G database starting 1992.

Methods

The total number of salmon harvested in subsistence and personal use fisheries is estimated using information collected from household surveys, subsistence and personal use permits, test fishery data supplied by projects, harvest calendars, and postcards. Total subsistence and personal use harvest includes fish harvested for direct personal or family use, fish distributed to households from various test fishery projects, and fish caught in commercial fisheries and retained (not sold) for household use. In surveyed communities, information was collected from selected households and expanded to estimate the harvest of the entire community. For communities in permit areas, harvest totals reported on returned permits were summed but not expanded to account for any harvest associated with unreturned permits.

Communities were surveyed roughly in order, from downriver to upriver, after most households finished harvesting salmon for subsistence. To maintain consistency in administration of the survey, household survey interviews were primarily conducted by the same 2 ADF&G technicians throughout the season.

The household harvest survey methodology was based on a stratified random sample design (Cochran 1977). In this design, a household within the community was the primary sampling unit. A household generally consists of 1 or more people living together in a dwelling and sharing the same phone or mailing address. Multiple generations living in 1 dwelling were considered 1 household. Individuals living in detached but physically related structures were considered part of a household if they participated as a unit in harvesting, processing, and distributing resources and shared contact information.

Subsistence fishermen are not required to have a fishing permit in most of the Yukon Area; however, permits are required for subsistence or personal use fishing in parts of the Koyukuk, Tanana and upper Yukon rivers that are accessible by road. Where permits are not required, voluntary household surveys are conducted in each community in order to estimate the subsistence harvest. In contrast, fishermen in areas where permits are required must submit their harvest records annually.

Personal use fishing is open to Alaskan residents only, and you must have a valid resident Sport Fishing License to participate in personal use fisheries. Personal use fishing permits and a resident sport fish license are required to fish within the Fairbanks non-subsistence area established in 1992. Non-subsistence areas are defined as areas where subsistence is not a principal characteristic of the economy, culture, and way of life (Alaska Statute 16.05.258(c)). Since 1995, personal use fishing has been open in non-subsistence areas to all Alaska residents regardless of where they reside.

Discussion

Critical assumptions include:

- All subsistence harvested Chinook salmon are documented as part of the household survey program, on subsistence permits, as test fish giveaway and commercial retained (not sold) for subsistence uses.
- All personal use harvested fish are documented on a personal use permit.
- Subsistence harvested fish documented as part of the survey have been expanded to account for households not surveyed.

Uncertainty Evaluation:

Subsistence household survey

- 1986: Standard Deviation
- 1991 – 2019: 95% confidence interval by community for expanded survey estimates.
- 2016-2020: CV by community for survey estimates

No uncertainty evaluation is available for Chinook harvest documented on subsistence and personal use permits, test fish giveaway, or commercial retained (not sold) fish for subsistence uses.

B.3.2 Program Details - U.S. Subsistence and Personal Use Harvest

Table B.3. U.S. Subsistence and Personal Use Harvest Estimates - Operational Timeline

Years	Change/Event
1958-1960	Since 1958, the state of Alaska has collected data on subsistence harvests of Yukon River salmon. Although information is available for 1958-60, the methodologies used in those years have not been documented.
1961	Since 1961 Alaska Department of Fish and Game (ADF&G) staff have conducted subsistence surveys. Subsistence salmon catch data has been collected through personal interviews, catch calendars, and mailed questionnaires. Survey methodologies prior to 1988 were varied, although the basic premise - that surveyors census all known fishing families (groups of households that fished together) in a village - was consistent. An extrapolation method was used to estimate total harvest of all known fishing families.
1970s	Subsistence fishing permits have been required in three sections of the Upper Yukon area since the early 1970s: (1) the Yukon River near the Yukon River Bridge between Hess Creek and the Dall River; (2) the upper portion of District 5 between the upstream mouth of Twenty-Two Mile Slough and the U.S./Canada border; and (3) the Tanana River near Fairbanks. Beginning in 1988 subsistence permits have been required for the entire Tanana River drainage.
1987	Prior to 1987 and in 1991, 1992, and 1994 personal use harvest was considered part of subsistence. Between 1987 and 1990, personal use fishing was defined by the fisherman's location of residence.
1988	New survey methodologies were developed in 1988. The basic methodology developed by the department's Subsistence Division in 1988 was to identify all households in each community and to break the updated community household lists into two strata: usually fish and usually not fished households (Walker et al. 1989). Substantially more fishing households were identified in 1988 than were listed previously. Because the historical survey lists evaluated households in a broader sense (family units working together to harvest and process salmon). there was no direct correlation between fishing family and fishing household. Subsistence catch data has been expanded for non contacted fishing families or households to provide an annual community estimate, and expanded community harvests have been summed for district and total drainage estimates.
1990-1991	The stratification system developed by the Subsistence Division was further refined in 1990 and 1991 to improve the accuracy and precision of the drainage-wide subsistence harvest estimate (Holder and Hamner 1991; Bromaghin and Hamner 1993). In 1990 households were classified into one of five catch strata based upon their level of subsistence harvest in 1988 and 1989; in 1991 the strata were based on harvests from 1988, 1989, and 1990. In 1990 fish that were commercially taken but provided both a subsistence and commercial use were assigned to a special category in the Annual Management Reports: the commercial-related salmon harvest.

Note that sources for estimates of U.S. subsistence and personal use harvest vary by time period, as listed in Table B.4.

Table B.4. U.S. Subsistence and Personal Use Harvest Estimates - Potential Data Issues

Years Affected	Potential Issue
1961-1987	Survey methodologies varied prior to 1988
1987 - 1990	Discrepancies exist between subsistence harvest database and permit harvest database. Summary uses data from historical AMR and subsistence harvest reports
1987 - 2019	District subtotals, Alaska Yukon River totals and Alaska Yukon area totals do not include personal use harvest. Personal Use harvest summarized by district only.
1977 - 1978	Coastal district harvest reported by district only and not community.
1961 – 1991	Harvest estimates from records found in historical published Yukon area annual management reports (AMR) and subsistence harvest reports.
1992-2019	Subsistence harvest from OceanAK database, personal use harvest from historical AMRs

B.3.3 References - U.S. Subsistence and Personal Use Harvest

Reports

Annual management reports (AMRs) http://www.adfg.alaska.gov/sf/publications/

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Holder, R. R. and H. H. Hamner. 1995. Estimates of subsistence salmon harvests within the Yukon River drainage in Alaska, 1992. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Technical Fishery Report No. 95-07 Juneau.

Jallen, D. M., S. K. S. Decker, and T. Hamazaki. 2017. Subsistence and personal use salmon harvests in the Alaska portion of the Yukon River drainage, 2015. Alaska Department of Fish and Game, Fishery Data Series No. 17-39, Anchorage.

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Walker, R. J., E. F. Andrews, D. B. Andersen, and N. Shishido. 1989. Subsistence harvest of Pacific salmon in the Yukon River drainage, Alaska, 1977-88. Alaska Department of Fish and

Game, Division of Commercial Fisheries, Regional Information Report 3A89-21, Anchorage

B.4 U.S. Sport Fish Harvest

B.4.1 Program Summary - U.S. Sport Fish Harvest

Introduction

Using mail surveys, ADF&G estimates annual sport fish catch (fish kept and released), harvest (fish kept), and participation.

The study area comprises the entire U.S. Yukon Area, which includes all waters of Alaska within the Yukon River drainage and all coastal waters of Alaska from Point Romanof southward to the Naskonat Peninsula

The mail surveys have been implemented since 1977. Harvest data are available publicly in a ADF&G database starting 1996. Data before 1996 are accessible electronically, but would require technical support to extract and process.

Methods

Since 1977, the Alaska Department of Fish and Game has conducted an annual mail survey to estimate sport fishing participation (number of anglers, days fished) and harvests (fish kept) statewide by Alaska fisheries, areas, regions, and species. The Statewide Harvest Survey (SWHS) is designed to provide estimates of effort, harvest, and catch on a site-by-site basis. Since 1990, catches (fish harvested plus fish released) have also been estimated. The primary object of this project is to estimate the number of anglers fishing in Alaska, days fished, and numbers of fish caught and kept by species, water type and fishing location.

A stratified random sample survey is conducted to estimate participation, catch, and harvest in Alaska sport fisheries. A self-administered mail-back questionnaire is mailed to households with at least 1 angler from that household was licensed to sport fish in Alaska during a particular year. On these pages, respondents are asked to write the name of the location where they fished using a map booklet as a guide. The survey booklet is designed to capture guided/non-guided activity within fisheries across Alaska.

Questionnaires are mailed to households from the sport fishing household database available in fall. Due to slowly declining total response rate, the total household sample was increased to 49,000 households in 2019, an increase of 2,000 households from the total sampled 2011-present. The 2019 sport fishing household database consists of identifying information for households with either:

1. at least one individual who purchased a sport fishing license, or
2. at least one individual holding a permanent identification (PID) card (a free card issued on request to Alaskan residents of at least one year who are 60 years or older) and who is no older than 82 years old, or
3. at least one individual holding a disabled veteran (DAV) license (a free license issued on request to Alaskan residents who are certified 50% disabled by the U.S. Veteran Administration).

Discussion

Critical assumptions include:

- All sportfish harvested fish are documented as part of the survey. Estimates produced from surveys of this type might be expected to suffer from one or more sources of respondent bias. For example, surveying anglers after the fishing season is over could result in recall bias. Some anglers might also be expected to overstate their success and therefore introduce prestige bias. On occasion it has been suggested that anglers might even underreport harvest in areas facing restrictions and thus introduce strategic bias. While the study does not assess the effects of bias, Mills and Howe (1992) and Clark (2009) examined the accuracy and precision of survey estimates and found they were consistent with onsite creel survey estimates for several fisheries.
- The utility of SWHS estimates depends on the number of responses received for a given site. In general, estimates from smaller fisheries with low participation are less precise than those of larger fisheries with high participation. Therefore, the following guidelines were implemented for evaluating survey data:
  - Estimates based on fewer than 12 responses should not be used other than to document that sport fishing occurred;
  - Estimates based on 12 to 29 responses can be useful in indicating relative orders of magnitude and for assessing long-term trends; and
  - Estimates based on 30 or more responses are generally representative of levels of fishing effort, catch, and harvest.

B.4.2 Program Details - U.S. Sport Fish Harvest

Table B.5. U.S. Sport Fish Harvest Estimates - Operational Timeline

Years	Change/Event
1977	Start of statewide sport fish harvest survey program. Recorded harvest only (fish kept)
1990	Started including Catch (fish kept and released)
1996 - present	Data available publicly in ADF&G database.
2011	The survey booklet was revised in 2011 and the new format has been used since. The revised booklet incorporates elements of the two different types of booklets used prior to 2011. Included in the survey booklet are pages that ask specifically about Kenai, Kasilof and Russian rivers freshwater fisheries and Cook Inlet saltwater fisheries. These pages will list specific sites within the Kenai Peninsula/Cook Inlet survey area. There will also be pages that ask about sport fishing activities at all other saltwater and freshwater sites in Alaska.
2019	Total household sample was increased to 49,000 households in 2019, an increase of 2,000 households from the total sampled 2011-present.

Table B.6. U.S. Sport Fish Harvest Estimates - Potential Data Issues

Years Affected	Potential Issue
1977-1995	Obtaining electronic data prior to 1996 would require ADFG tech support.
1996 – 2018	Most sportfish harvest within the Yukon drainage occurs within the Tanana River drainage. Survey data is available by survey area (Tanana River drainage (U) and Yukon River drainage (Y)). And further into location within the survey area. Below are tables breaking the harvest into survey area (Table 1) and specific location for the Yukon River drainage survey area (Table 2) from 1996-2018. Of the sportfish harvest in Yukon survey area most was documented downstream of the Koyukuk River. Unfortunately, the survey area is not broken down further to account for tributaries below the Koyukuk except the Anvik. Of the 23 years from 1996 through 2018, 1,972 or roughly 80 fish per year were harvested below the Koyukuk. Main tribs below the Koyukuk are the Anvik, Innoko and the Andreafsky. Most harvest below the Koyukuk is most likely from the Andreafsky. Option 1 - assume all the fish harvested below the Koyukuk is from the Andreafsky and therefore included in harvest below pilot. The remaining harvest would be broken into Yukon mainstem and Tanana. Option 2 - Assume all sportfish harvest is above Pilot and broken between Yukon mainstem and Tanana. Option 3 - Assume all sportfish harvest is above Pilot and from the Tanana. Although hook and line subsistence is allowed from the mouth of the Yukon River to the Nulato River, subsistence fishing does not require a sport fish license and therefore the SWHS does not record subsistence caught fish. Also, subsistence fishers using hook-and-line aren't subject to the bag and possession limits that sport fishers must adhere to. Consequently, harvest estimates of sport-caught fish from rural Alaska are generally low because local residents usually fish under subsistence regulations.

B.4.3 References - U.S. Sport Fish Harvest

Data Sources

Current harvest data for the summary was taken from the most recent JTC report and reported as Yukon River harvest: * Estimates prior to 1996 are available in historical publications. * Sportfish catch and harvest data from 1996-current are available online at the following link: https://www.adfg.alaska.gov/sf/sportfishingsurvey/ * Annual management reports (AMRs) are available at http://www.adfg.alaska.gov/sf/publications

Reports

Clark, R. A. 2009. An evaluation of estimates of sport fish harvest from the Alaska statewide harvest survey, 1996-2006. Alaska Department of Fish and Game, Special Publication No. 09-12, Anchorage.

Joint Technical Committee of the Yukon River U.S./Canada Panel). 2019. Yukon River salmon 2018 season summary and 2019 season outlook. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A19-01, Anchorage

Mills, M. J., and A. L. Howe. 1992. An evaluation of estimates of sport fish harvest from the Alaska statewide mail survey. Alaska Department of Fish and Game, Special Publication No. 92-2, Anchorage.

Romberg, W. J., I. Rafferty, and M. Martz. 2020. Alaska Statewide Sport Fish Harvest Survey, 2019. Alaska Department of Fish and Game, Division of Sport Fish, Regional Operational Plan ROP.SF.4A.2020.01, Anchorage.

APPENDIX C Canadian Harvest Estimates

C.1 Overview

There are four types of fisheries on the Yukon River, in Yukon Territory, Canada:

- First Nation subsistence fishery (formally known as First Nation Food, Social and Ceremonial Fishery)
- Public angling (i.e. recreational, sport)
- Commercial
- Domestic (non-aboriginal food fishery)

C.2 First Nation Fishery Harvest Information

The Government of Canada's legal and policy frameworks identify a special obligation to provide First Nations the opportunity to harvest fish for food, social and ceremonial (FSC) purposes. As such, Yukon River First Nation (YFN) Fishery is afforded the highest priority after conservation requirements are met. Currently there are 12 communal First Nation fishery licences issued annually to First Nations within the Yukon (including the Porcupine River) watershed, and harvest reporting to DFO is a condition of licence.

YFN governments direct and manage their respective First Nation fisheries which includes the responsibility to monitor and report harvest. DFO and YFN Land and Resources staff exchange management and assessment information throughout the season. DFO provides harvest calendars and reporting forms to YFN Governments to distribute to individual harvesters to support reporting. Lands and Resources staff collect the harvest information and provide the communal harvest data to DFO. Reporting can vary from a weekly basis to once at the end of the run. Occasionally harvest may not be reported. DFO only publicly reports the aggregate estimated harvest for the mainstem Yukon River, rather than harvest for specific First Nations.

Harvest Study (1996 to 2002)

A First Nation salmon harvest study was conducted from 1996 through 2002. Community members were hired and trained by DFO to conduct harvester interviews and sampling. The study provided a robust estimate of harvest and the proportion of total harvest carried out by each First Nation. Total harvest has decreased substantially from 1990s and earlier, but relative proportions are considered consistent.

Using Harvest Study and Current information to Estimate Harvest

Estimating the total First Nation harvest is informed by annually reported information and the First Nation Harvest Study as required. The availability of comprehensive harvest reports varies between years. Mainstem harvest is estimated using available harvest reports and the historical distribution for any unreported data. Adjustments are made as required based on YFN reported harvest, individual First Nation resolutions, salmon management and harvest strategies, Fish Camp activity (i.e. one family, multiple families, community camp etc.) and additional harvest activity reporting.

C.3 Public Angling Harvest Information

The first official public angling salmon licences in the Yukon were issued in 1949, shortly after the construction of the Alaska Highway (1942-1947). Angling harvest was estimated using a variety of methods, usually creel surveys, until the Yukon Salmon Conservation Catch Card (Catch Card hereafter) was introduced in 1999. Catch Cards are available online through DFO's National Recreational Licensing System to anglers with valid Yukon Territory Angling Licences

Immediately after landing a salmon (even if not retained) information including date, location, species, sex, presence of tags and adipose fins, and type of gear used must be recorded on the Catch Card.

Catch Card holders must submit their catch and harvest report (even if salmon fishing did not occur or if no salmon were caught) no later than November 30 of each year. This can be completed online or by mailing the Catch Card to the local office. This information is collected in a database shared with fishery managers

Failure to submit the Catch Card will result in a Conservation and Protection officer issuing a non-compliance notice and a fine. The angler will be ineligible to obtain a catch card until the report is submitted. If the issue persists they may lose the privilege indefinitely.

C.4 Commercial Fishery Harvest Information

The Canadian Yukon River commercial salmon fishery began in 1898. The commercial fishery involves up to 22 licensed fishers. Commercial harvesters must have a valid licence and are required to report their harvest. Commercial fishing gear consists of fish wheels and gillnets which must be used within conditions of license including fishing locations, gear types, and harvest periods. Effective as of 2021, the use of non-selective fishing gear (i.e. gill nets) is not permitted in the Yukon River commercial salmon fishery.

Licence Administration and compliance

Commercial licences are administered online via the National Online Licensing System (NOLS). Through this system, commercial harvesters/licence holders/vessel owners may view, pay for, and print their commercial fishing licences, licence conditions and receipts. Licence renewal and payment of fees is mandatory on an annual basis prior to the expiry date of each fishery, in order to maintain the eligibility to be issued the licence in the future. Licence eligibility will cease if it is not renewed annually.

While there are currently 22 Commercial licences, fewer than 10 are actively fished due to depressed Chinook runs (i.e. no commercial allocation for Chinook) and limited Chum markets. The most recent Commercial Chinook fishery occurred in 2009, when 364 Chinook were harvested.

Harvest Reporting

Catch Information must be reported to DFO's salmon information line for every 24 hour interval during a commercial fishery opening, within 8 hours of a commercial fishery closure and in accordance with the timelines described in the Conditions of the annual Yukon River Commercial Salmon Licence. Commercial harvesters are required to submit NIL report forms if they have not fished their licence.

C.5 References - Canadian Harvest Estimates

For additional information and context (including maps) please see the Yukon River 2020 Integrated Fisheries Management Plan at: http://publications.gc.ca/collections/collection_2020/mpo-dfo/Fs144-33-2020-eng.pdf

Licensing information for the Yukon Transboundary area https://www.pac.dfo-mpo.gc.ca/yukon/licence-permis-eng.html

APPENDIX D Stock Identification

D.1 Overview

Three sections:

- Overview of U.S. stock ID program (scale pattern analysis, genetic stock ID)
- Detailed description of GSI at Pilot Station from 2002 to 2019
- Eagle GSI program: used for Canadian domestic identification of conservation units, documented here, but not used for current IMEG analysis

Note: Throughout this appendix we have retained the stock labels used in the source reports, which are *Lower*, *Middle*, and *Upper*. In the rest of this report, the *Upper* stock is labelled the *Canada* stock.

D.2 U.S. Stock-at-Age Apportionment

D.2.1 Program Summary - U.S. Stock-at-Age Apportionment

Introduction

Since 1980, ADF&G has completed annual estimates of stock/age proportions and total harvests by stock/age, fishery, and district for Yukon River Chinook salmon.

Commercial and subsistence harvests are summarized by stock and age group for each fishing district Y1–Y6 and Canada.

Methods

Since 1980, Alaska Department of Fish and Game has implemented a Yukon River Chinook salmon stock and age harvest apportionment program and has published an annual harvest stock-of-origin report. This report series presents estimates of the percentage and number of Chinook salmon harvested in the Yukon River watershed by stock/age class, fishery, and fishing district.

The scope of annual sampling programs used to represent the harvests throughout the Yukon were adapted based on the expected size of the harvests, accessibility of harvested fish, staff capacity, and funding limitations. Chinook salmon scales and genetic tissue have been collected from subsistence, commercial, and test fishery monitoring projects throughout the Yukon and were used to characterize specific harvests and/or serve as proxies for unmonitored portions of the harvest. Scale age determination has followed standard methods. Stock identification methods have changed over time.

A total of 3 reporting groups (Lower, Middle, and Upper) have been used consistently to describe the harvest stock composition. The Lower stock group included Chinook salmon originating from Yukon River tributary streams from the Andreafsky River to near the confluence with the Tanana River and the lower Koyukuk River drainage. The Middle stock group included Chinook salmon from the upper Koyukuk River, the Tanana River, and the mainstem Yukon River and all tributaries upstream from the Tanana River confluence to the border with Canada. The Upper stock group consisted of Canadian–origin fish, including both mainstem and Porcupine River stocks. These stock reporting groups are consistent with reporting groups used for other programs where mixed stock analyses is performed (e.g., Pilot Station Sonar). Annual reports describe the approaches that were used to determine the most appropriate option for estimating harvest age and stock composition, given data availability. In general, the annual harvest was stratified by fishery and district, and scale/tissue collections were evaluated to determine the adequacy of information to estimate age/stock composition of harvested fish. For those harvests that were adequately sampled, the available data were used to apportion harvest by age and stock. For harvests that were not sampled, proxy information was used for the purpose of harvest apportionment, or harvested fish were assigned to a stock group based on geography. Estimation methodology, proxy usage, and geographic assignment changed over time commensurate with improvements in analytical methods, stock separation methods, understanding of harvest patterns, and scope of harvest sampling programs.

The scope of harvest sampling has varied considerably over time. Lingnau 2000 provides a summary of sample collections for years 1981–2006, and collection descriptions for other years are presented in annual reports. Sampling programs can be described generally for orientation. From 1982 through about 2000, Y1 and Y2 commercial samples provided most of the information used for stock apportionment. Lower river commercial samples were applied to Y1 and Y2 subsistence harvests based on the assumption that both fisheries overlapped in time, used similar gear, and harvested the same stocks/ages. Lower river samples were also applied to Y3 and Y4 commercial and subsistence harvests, unless those fisheries were adequately sampled (which was infrequent). Other harvests were assigned to a stock group based on geography. All fish harvested in District 5 were assigned to the upper group. All fish harvested in District 6 (Tanana) were assigned to the middle group. All sport harvest in the Alaska portion of the Yukon was assumed to be from the Tanana. Upper Koyokuk, Chandalar, and Black river subsistence harvest was assigned to the middle stock. Until 2004, harvests sampled from Y5 and Y6 were used for age composition analysis only. Beginning in 2004, Y5 harvests were apportioned to stock groups based on samples collected from fisheries in that area. Drainagewide (U.S. portion) subsistence sampling programs were established beginning 2001 and continued at some level through 2018.

The stock identification program is characterized by 2 distinct phases. Scale Pattern Analysis (SPA) was used for stock separation from 1980–2003. Genetic Stock Identification (GSI) was used for stock separation from 2004–2019. Simple reference to SPA and GSI may be misleading. During both eras multiple steps were required each with their own inherent uncertainties. Under SPA, scale patterns were only used to assign stock for a subsets of major age classes, minor ages were assigned based on escapement sample ratios, proxy information was used for unsampled harvests, and some harvests were assigned based on geographic location. Under GSI, stock proportions were only estimated for harvests that were adequately sampled, proxy information was used for unsampled harvests, and some harvests were assigned based on geographic location. There is considerable unaccounted uncertainty associated with reported stock-specific harvest estimates because each successive step in the process amplifies the uncertainties associated with prior steps and decisions.

Summary of Scale Pattern Analysis (SPA)

Schneiderhan 1997 provides a summary of the SPA analytical methods used from 1980–1996. Lingnau 2000 provides a detailed description of improved SPA analytical methods used to revise estimates from 1981–2006 and estimate stock of origin for years 1997–2003.

Years 1980 and 1981 evaluated the feasibility of using scale growth measurements to differentiate Chinook salmon run of origin for District 1 commercial fishery samples (McBride and Marshall, 1983). The authors concluded that "significant and persistent differences in the size of . . . growth zones measured on the scales of lower, middle, and upper Yukon runs . . . permit scale pattern analysis as a method for determining origins in the lower river fishery." During the feasibility years, available stock/age estimates are germane to the Y1 commercial harvest only. Beginning 1982 until 2003, SPA methods were used as the basis for determining run of origin for the entire Yukon River harvests by district.

The central component of SPA required a representative collection of scales from major spawning tributaries where stocks are assumed to be separated and stock-origin is known. These scales served as a baseline or reference for comparative purposes. Escapement scales collected from lower, middle, and upper tributaries were pooled proportional (when possible) to their source tributary contribution to the observed escapement as indicated by survey data. Escapement scales were aged, and age composition was determined for the lower, middle, and upper groupings. Major age classes were identified as those that were abundant and common to all geographic groups (typically age 1.3 and 1.4). Only scales with one freshwater annulus (age 1.x) were used. The subset of escapement scales that were major age classes were digitized, and specific growth measurements were recorded. Analytical methods were used to determine the combination of growth measurements with the highest potential for correctly assigning a scale to a geographic stock reporting group.

Annual baselines of escapement scales from known origin fish were typically collected from carcasses at the following locations:

- Lower Yukon – Andreafsky, Anvik, and Nulato Rivers
- Middle Yukon –Salcha and Chena Rivers (i.e., Tanana River drainage)
- Upper Yukon –Big Salmon, Little Salmon, Tatchun, Pelly, and Teslin Rivers; and escapement past the Whitehorse Dam (i.e., spawning tributaries in Canada's Yukon Territory).

In some years representative escapement samples from Canada were not available. In some cases, samples collected from the Dawson commercial harvest were used, but they were not preferred. In other cases, samples from the Department of Fisheries and Oceans border fish wheel tagging project were used, but a bias correction was applied to account for fish wheel selectivity of small fish.

SPA was only used to apportion major age classes of fish (typically age 1.3 and 1.4) harvested in mixed stock fisheries. This was accomplished by digitizing scales of harvested fish and statistically comparing annual harvest samples to the annual escapement baseline. Classification accuracy was determined from simulation. Stock proportions and standard error by age and fishery were estimated.

Minor age classes which were not classified by SPA were apportioned to run of origin based on escapement age composition ratios and assumptions about differential age-class proportions among stocks. For each stock (lower, middle, upper) the proportions of major and minor age classes were determined using escapement samples. Major age 1.3 was used to represent "young" minor ages (e.g., 1.1, 0.3, 1.2, and 0.4), because they were from a recent brood year and all tended to show a proportional decreasing trend with increasing distance upriver. Major age 1.4 was used to represent "old" minor age classes (e.g., 2.2, 2.3, 1.5, 2.4, 1.6, and 2.5), because they were the oldest fish in the return and all tended to show a proportional increase with increasing river distance. The ratio of proportional abundance (i.e., minor divided by major age class) was determined for each analog pair. These ratios were then used to estimate run/age-specific proportions and harvests.

Summary of Genetic Stock Identification (GSI)

From 2004–2019 stock composition of Yukon River fishery harvests was estimated using genetic methods. Laboratory methods used to estimate stock composition of the harvest are described in a series of reports covering the years 2004–2010. The genetic baselines used varied over time, but reporting groups were consistent. From 2004–2006, GSI was used to assign stock of origin for only the major age classes, and minor age classes were apportioned following the same methods used during the SPA era. Beginning in 2007, GIS was used exclusively to apportion harvest of all ages using samples collected directly from the fishery. For each harvest (e.g., fishery, district, period), the number of fish per stock group and age class was estimated by multiplying the total number of fish harvested by the corresponding stock proportion and age proportion.

Additional context about the broader GSI program can be found in the summary of Pilot Station GSI below (Appendix D.3).

Discussion

Critical assumptions include differ by method and time period.

General assumptions include:

- Sampling programs were adequate to represent the harvest(s).
- Proxy age and stock composition estimates were representative and appropriately applied to unsampled harvests.
- Stock of origin based on geographic assignment was appropriate. Typical assumptions included:
  - Y4 harvests the middle and upper stocks.
  - Y4, Koyokuk River subsistence harvests the middle stock.
  - Y4A and Y4B harvests primarily south-bank-oriented Tanana fish (middle stock).
  - Y5 harvest only the upper stocks. Note: This assumption was made annually from 1982–2003 and was demonstrated to be false based on GSI. From 2006–2018, Y5

harvests downriver from Fort Yukon were sampled in 11 of 13 years (1–2 locations per year), the lower stock comprised on average 4% (0–21%), and the middle stock comprised on average 20% (3–31%) of the harvest. Violations of this assumption would positively bias historical estimates of upper stock harvest.

  - Y5D (upriver from Fort Yukon) harvests the upper stock. Note: Genetic results indicate >90% of harvest is upper stock, based on 4 years of adequate samples.
  - Y5 Chandalar and Black River subsistence harvests the middle stock.
  - Y6 (Tanana) harvests the middle stock.
  - All Yukon sport harvest in Alaska occurs in the Tanana River, Y6.
  - Coastal District harvests Chinook in proportion to Y1 harvests.

Critical assumptions for the SPA include:

- Escapement samples used as baseline references adequately represent geographic stock groupings and proper weight or bias corrections were applied to account for disproportionate sampling or selection bias.
- Fishery selectivity does influence the spatial and temporal patterns in major and minor age classes (i.e., no disproportional harvest across stock and age groups).
  - Escapement patterns of major age 1.3 is representative of young minor age classes.
  - Escapement patterns of major age 1.4 is representative of older minor age classes.
- Variation in scale aging and digitizing experience does not influence classification accuracy using SPA. *Note: In 1986, the effects of subjective interpretation of scale patterns by digitizer on scale measurements and classification accuracies was investigated. Scale measurements by two independent digitizers resulted in similar model accuracies and catch proportion estimates by stock.*

Critical assumptions for the GSI include:

- Stock proportions from GSI are comparable to those from SPA. *Note: this assumption was found to be generally true based on 5 years of comparative work focused on Y1 commercial samples (Spearman and Wilmot 1995). The JTC (1997) Subcommittee on Stock Separation determined that "the two methods seem to produce comparable estimates of run composition for the stock groups defined as Lower, Middle, Upper runs." Comparable SPA and GSI estimates were positively correlated for both lower and upper runs, but there was no relationship between the methods for the middle stock group.*

Uncertainty evaluation:

- SPA (1981–2003):

- Classification accuracy of MLE estimates were determined from 500 bootstrap simulations drawing from escapement scale baseline samples of major age classes (e.g., Table 6 in Lingnau 2000). The average classification accuracy across all years 1981–2003 was 92%.
- Historically, estimation bias is most common between the Middle and Upper stock groups, and the Lower and Upper river stocks have been the easiest to separate.
- The 1997–2003 annual reports include the standard error of the estimated stock proportion for each major age class and fishery.
- No estimates of uncertainty were attempted for total Yukon River harvest by stock/age.

• GSI, 2004 - present

- For each baseline used, simulation studies based on the three reporting groups indicate that they are highly identifiable in mixtures. When simulated mixtures composed entirely from a single reporting group were treated as mixtures of unknown origin more than 90% of the mixture was correctly identified to geographic stock-of-origin.
- The 2004–2006 annual reports include the standard error of the estimated stock proportion for each major age class and fishery/period.
- Beginning in 2007, estimates of mean stock proportions, uncertainties, and posterior distributions are available for each sampled harvest (e.g., fishery, district, period, location).
- From 2004–2018, no estimates of uncertainty were attempted for total Yukon River harvest by stock/age.
- In 2019, the uncertainty associated with the estimated number of fish harvested by stock/age was calculated, such that estimation error from each of the 3 components was incorporated (harvest, age proportions, and genetic proportion). A total of 10,000 simulations was completed. At each sampling draw, harvest was drawn from normal distribution, age proportion was drawn from multinomial distribution of total age sample, and genetic proportion was drawn randomly from posterior distribution of 100,000 simulations provided by the ADF&G Gene Conservation Lab. This approach likely still underestimates true uncertainty, because if does not account for sampling error, unsampled harvests, proxy selection, and errors related to geographic assignment

D.2.2 Program Details - U.S. Stock-at-Age Apportionment

Table D.1. U.S. Stock-at-Age Apportionment - Operational Timeline

Years	Component	Change/Event
2014 - Current	All	Beginning in 2014, the Yukon Management Area's Coastal District was included to provide a more complete estimate of Yukon River Chinook salmon harvest by stock and age and to be consistent with information used by ADF&G for determining total run and harvest shares of the Canadian-origin stock component.
1982 - 2000	Subsist.	Sample collections occurred in Y4, Y5, and Y6 for estimating age composition. Y4 collections occurred in 14 of 18 years, Y5 in 8 years, and Y6 in 10 years.
2001 - 2018	Subsist.	Subsistence harvest sampling expanded to include lower river districts Y1–Y3. Y1 collections occurred in 15 of 18 years, Y2 in 6 years (since 2011), and Y3 in 9 years.
2011 - 2018	Subsist.	Subsistence sampling methods were refined beginning in 2011. Community members were recruited and trained on how to take age, sex, length, and genetic samples from their subsistence-caught Chinook salmon, and they were paid for each sample collected. Participants were asked to sample their entire Chinook salmon harvest. The study design assumed that a well distributed grab sample from volunteer participants resulted in a representative dataset that was "self-weighted" to the actual distribution of harvest across gear, time, and location of harvest. Sample collection and processing details are described in annual reports.
2018	Subsist.	Sample collections from the Coastal District were attempted, but largely unsuccessful.
1980 - 2003	SPA	SPA was used to apportion harvest to geographic stock of origin
1980 - 1996	SPA	Estimates of stock composition for major age classes used nearest neighbor analysis (NNA; 1980–1982)) or a linear discriminant function (LDF; 1983–1996) model. Each method was used in combination with observed age composition ratios among escapements to estimate stock composition of minor age classes. NNA was selected in early years because it was nonparametric and many of the scale characteristics used in the analyses were not normally distributed. LDF was used following a selection of new scale characteristics and data transformations which were approximately normally distributed. The two methods produced comparable results
1997 - 2003	SPA	A maximum likelihood estimation (MLE) model was developed to estimate stock composition more efficiently for major age classes. The MLE model was used in combination with observed age composition ratios among escapements to estimate stock composition of minor age classes.
2000	SPA	Historical estimates from 1982–1996 were revised using the MLE method (Lingnau 2000)
2004 - 2019	GSI	GSI methods replaced SPA for stock separation.

Years	Component	Change/Event
2004 - 2019	GSI	Stock composition of Y5 harvests were apportioned as a mixed stock using GSI methods instead of assuming the entire harvest was comprised of the upper stock group, as was done in prior years.
2004 - 2006	GSI	GSI methods were only used to estimate the stock composition of the major age classes harvested in mixed-stock fisheries. Like prior years, the proportions of minor age classes were estimated from age composition ratios among escapements, in combination with genetic estimates for analogous age classes.
2007 - 2018	GSI	GSI methods were used exclusively to estimate stock of origin from samples (i.e. regardless of age) collected directly from mixed-stock harvests.
2004 - 2014	GSI	genetic baselines varied, generally increasing the number of populations and markers: For details, refer to Pilot Station GSI Appendix

Table D.2. U.S.Stock-at-Age Apportionment - Potential Data Issues

Years Affected	Potential Issue
1980, 1981	Results are germane to Y1 commercial harvest.
1983	Inadequate sampling in Y4 to allocate harvest to stock of origin.
1990	Relatively low (less than 90 percent) stock-specific age-1.2 classification accuracy for at least one stock group.
1983, 1985–1987, 1991, 1994, 1995, 1997	Relatively low(less than 90 percent)) age-1.3 classification accuracy for at least one stock group.
1984, 1992, 1993, and 1996–1998	Relatively low (less than 90 percent) age-1.4 classification accuracy for at least one stock group.
2014, 2015, and 2019	Very limited sampling occurred. Nearly all harvest apportionment was based on proxy information from prior years, test fishery samples, and geographic assignment

D.2.3 References - U.S. Stock-at-Age Apportionment

Data Sources

Harvest by stock and age were sourced directly from annual project reports. *Note: Historical harvest estimates have been revised over time. As such harvests reported in annual stock-*

origin reports should be used to calculate stock/age proportions and applied to the best available harvest estimates.

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D.3 Pilot Station - Genetic Stock Identification

D.3.1 Program Summary - Pilot Station GSI

Introduction

ADF&G has completed genetic mixed stock analyses (MSA) for Chinook at Pilot Station for most years since 2002. Stock composition estimates, identifying Lower, Middle and Canadian Chinook are available for 2002–2003 and 2005–2019. The Canadian reporting group includes both mainstem and Porcupine River stocks.

Methods

Chinook salmon sample collection occurred in District 2 in the test fishery at the mainstem sonar project near Pilot Station for each year, 2002–2003 and 2005–2019. The test fishery was designed to apportion sonar counts by species and was assumed to be representative of the entire run of Chinook salmon that passed upriver from the sonar site. Tissue samples for genetic analysis were collected from all Chinook salmon caught in the test fishery. Samples were assumed to be collected in proportion to Chinook salmon passage, as estimated by the sonar. Within each year, samples were stratified to 3 strata to represent distinct pulses of Chinook salmon passing the test fishery (West and Dann 2019).

Genetic data were collected from the samples as individual multi-locus genotypes for 42 single nucleotide polymorphisms (SNPs; Table 1) and subject to several quality control checks following a well-established protocol (DeCovich and Howard 2011; West and Dann 2019). Stock compositions of each stratum were estimated using the program BAYES for mixed stock analysis (MSA) (Pella and Masuda 2001). This Bayesian method of MSA estimates the proportion of stocks using 4 pieces of information: 1) a baseline of allele frequencies for each population, 2) the grouping of populations into the reporting groups desired for MSA, 3) prior information about the stock proportions of the fishery, and 4) the genotypes of fish sampled from the fishery. The baseline for Chinook salmon in the Yukon River has evolved over time to include 42 SNPs (Table 1) genotyped in 36 populations (Table 2) throughout the Yukon River drainage. For MSA, 5 Markov Chain Monte Carlo (MCMC) chains were used to form the posterior distribution and tabulated means, medians, 90% credibility intervals, standard deviations, the probability that the group estimate is equal to zero (P=0), and coefficients of variation (CV) (West and Dann 2019). For each stratum and year, genetic stock composition estimates were reported to 3 reporting groups: Lower Yukon, Middle Yukon, and Canada (DeCovich and Howard 2011; West and Dann 2019), and the posteriors for each iteration were output to be combined with passage estimates.

Discussion

Critical assumptions include:

1. Samples collected at Pilot Station test fishery are representative of all stocks passing the sonar.

2. The ASL and stock compositions of samples were a function of the passage rate, gear, and time.

3. Strata choices are representative (i.e. variation within the strata is not significant).

Uncertainty evaluation:

- 2002 - 2003 uncertainty reported in standard error
- 2005 – 2019 uncertainty reported in standard deviation.

D.3.2 Program Details - Pilot Station GSI

Table D.3. Pilot Station GSI - Operational Timeline

Years	Change/Event
2002; 2003	Pilot Station genetic samples were taken from muscle and fin tissues. Initial investigations of Yukon River genetic population structure were based on information from allozyme data and reporting groups for stock composition estimates were defined using simulated and actual mixtures of Chinook salmon from the Yukon River with the program SPAM (Debevec et al. 2000). Genetic data were collected in the form of individual genotypes inferred from phenotypes observed for 16 enzymes indicating variation at 22 enzyme-encoding loci for an allozyme baseline. Years 2002 and 2003 are original stock composition estimates based on allozymes (Templin et al. 2005).
2004	Alternatives to the allozyme baseline and methods were explored (Smith et al. 2005; Templin et al. 2006b; Templin et al. 2006c). No Pilot Station genetic analysis was performed, but Y2 harvest estimates are available in Templin et al. 2006b using a Single Nucleotide Polymorphism (SNP) baseline of 23 Chinook salmon populations in the Yukon River drainage and 18 SNPs
2005	Two types of genetic markers were explored as a replacement to the allozyme baseline: SNPs and microsatellites (Smith et al. 2005; Templin et al. 2006b; Templin et al. 2006c). Genetic data were collected from the fishery samples as individual multi-locus genotypes for the 13 microsatellite loci included in the Pacific Salmon Commission standardized database at the time. Stock composition estimates were generated using a baseline of 19 populations and 13 microsatellites using the program SPAM (Debevec et al. 2000; Templin et al. 2006b). 2005 are original estimates based on microsatellites.
2006	Genetic data were collected from the fishery samples as individual multi-locus genotypes for the 13 microsatellite loci a using a baseline of 19 populations and 13 microsatellites (same methods as 2005). 2006 are original estimates based on microsatellites.In 2006, the SNP baseline was augmented and consisted of 25 populations and 26 SNP markers (Templin et al. 2008). Three additional populations were added for analysis, the Sheenjek and Kantishna rivers from Alaska and the Little Salmon River from the Yukon Territory, Canada. One Canada population was removed from the baseline based on DFO recommendation, Stoney Creek.

Years	Change/Event
2007-2018	2007-2018 Pilot Station test fishery samples were restratified and reanalyzed using the methods and 2014 baseline (36 populations and 42 SNPs) as described above (D. Prince, Fishery Geneticist, ADF&G, Anchorage, personal communication). Original methods and baselines used for a given year are summarized here for context.
2007	In 2007, the SNP baseline was augmented to include additional markers and consisted of 25 populations and 51 SNP markers (DeCovich and Templin 2009). Genetic data were collected from the fishery samples as individual multi-locus genotypes for the 26 SNPs used for stock composition estimates in 2006. This reduced set of SNPs, when compared to the original set of 51 SNPs, was determined to provide acceptable levels of accuracy and precision while enabling substantial cost savings (DeCovich and Templin 2009). Fishery stock composition estimates were produced using a baseline of 25 populations and a subset of 26 SNPs.
2008	Genetic data were collected from the fishery samples as individual multi-locus genotypes for 48 SNPs. However, the same version of the baseline with 26 SNPs used in 2006 and 2007 (DeCovich and Templin 2009; Templin et al. 2008) was used in 2008, and only genotypes from 26 SNPs were used to analyze the fishery samples in 2008 (DeCovich et al. 2010).This reduced set of SNPs, when compared to the original set of 51 SNPs assayed in 2006, was determined to provide acceptable levels of accuracy and precision while providing substantial cost savings (DeCovich and Templin 2009).Fishery stock composition estimates were produced using a baseline of 25 populations and a subset of 26 SNPs.
2009	In 2009, the SNP baseline was augmented and consisted of 27 populations and 52 SNPs. Two additional populations were added to the baseline; the Chatanika River in the Tanana River drainage and a mainstem spawning population collected near Minto. Genetic data were collected from the fishery samples as individual multi-locus genotypes for a subset of 42 SNPs from the baseline. More SNPs were assayed in 2009 than in 2008 (26 SNPs) because with advancements in laboratory technology it was no longer cost effective to run only 26 SNPs (DeCovich and Howard 2010). Fishery stock composition estimates were produced using a baseline of 27 populations and a subset of 42 SNPs.
2010	Genetic data were collected from the fishery samples as individual multi-locus genotypes for a subset of 42 SNPs from the 2009 baseline of 27 populations and 52 SNPs (DeCovich and Howard 2011). Fishery stock composition estimates were produced using a baseline of 27 populations and a subset of 42 SNPs.
2011	In 2011, the SNP baseline was augmented and consisted of 31 populations and 43 SNPs. Four additional populations were added to the baseline: Morley River, Teslin River, Tincup Creek, and Kandik River. Genetic data were collected from the fishery samples as individual multi-locus genotypes for the 43 SNPs from the baseline.
2012	Genetic data were collected from the fishery samples as individual multi-locus genotypes for the 43 SNPs from the 2011 baseline of 31 populations and 43 SNPs.

Years	Change/Event
2013	In 2013, the SNP baseline was augmented and consisted of 36 populations and 43 SNPs. Five additional populations were added to the baseline: the Nulato River, the Kateel River, the Goodpaster River, the Colleen River, and the Porcupine River. Genetic data were collected from the fishery samples as individual multi-locus genotypes for the 43 SNPs using the baseline of 36 populations and 43 SNPs.
2014-2018	In 2014, the SNP baseline was revised to 36 populations and 42 SNPs. This baseline allows 5 reporting groups (Lower Yukon, Koyokuk River, Tanana River, Upper U.S. Yukon, and Canada) to be identified in mixture samples when sample sizes are at least 200 fish (West and Dann 2019). Genetic data were collected from the fishery samples as individual multi-locus genotypes for the 42 SNPs and stock compositions of fishery mixtures were estimated using the program BAYES (Pella and Masuda 2001).
2019	Samples from 2019 were summarized using the current 2014 baseline (36 populations and 42 SNPs) and current methods (West and Lee In prep).

Table D.4. Pilot Station GSI - Potential Data Issues

Years Affected	Potential Issue
2002-2003	original estimates based on different methods which prevented reanalysis using the 2014 baseline
2004	Alternative estimate available.
2005-2006	original estimates based on different methods which prevented reanalysis using the 2014 baseline (INCLUDE A BIT MORE DETAIL RE: SPECIFIC ISSUE)
2010	Large uncertainty on stock comp due to sonar issue and test fish mesh size changes.

D.3.3 References - Pilot Station GSI

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D.4 Border Stock Identification

D.4.1 Program Summary - Border GSI

Since the early 1980s an average of 1,300 Chinook salmon scale samples have been collected annually from the fish wheels at White and Sheep rocks (most years from 1982–2008). The gill net test fishery at Eagle (2005 to 2019) has collected an average of about 600 Chinook samples. The samples collected are from the mainstem Canadian-origin stocks only and do not include the portion of Canadian-origin fish returning to the Porcupine River. Samples are taken throughout the run, and are generally in proportion to the run, given fishing effort. However in some years of fish wheel operation, scale sampling would end before the run ended (Biolsand) and in other years genetic analysis occurred on a proportional subsample (Eagle test fishery). Since 2006, 293 to 1026 tissue samples per year from individual fish in the Eagle Sonar test fishery have been used to extract genetic material and assign each fish to one of eight genetically distinct population groups via microsatellite markers (2006-2016; Beacham et al. 2006; JTC 2017) or Single Nucleotide Polymorphisms (SNPs) since 2017 (SNPs; Beacham et al. 2018; JTC 2018). In addition, a research project (Siegle and Connors 2021) has recently extended these population composition estimates back to 1985 by extracting genetic material from archived scale collections maintained at Fisheries and Oceans Canada's Pacific Biological Station. This has resulted in approximately 250 individual fish per year (1985–2007) being assigned to one of the eight populations based on allelic variation at 15 microsatellite loci.

Collectively these genetic stock assignments can help provide insight into variation in Canadian origin Yukon Chinook salmon stock composition over space and time, though raw stock assignments and annual composition need to be interpreted with caution given variation in sampling effort and coverage within and among years as well as changes in sampling methodology (e.g., fish wheels vs gill nets).

A key assumption is that scales are collected proportionally to the run, throughout the entire run. This is not always true as some years BioIsland ran out of scale cards and stopped collecting scales before the end of the run.

Also note that BioIsland pooled GSI samples while Eagle collects them individually. Samples are not all analyzed and only about 1,000 samples are processed each year.

D.4.2 References - Border GSI

Most recent project report

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APPENDIX E Lower Yukon Assessment Project Descriptions

E.1 Overview

Stock assessment on the lower Yukon River includes;

- Mainstem sonar at Pilot Station
- Radiotag Mark-Recapture in the lower River Mainstem
- Lower Yukon Test Fishery
- Weir and aerial surveys on the Andreafsky River (east fork, west fork)
- Aerial surveys on the Anvik River and Nulato River (north fork, south fork)
- Tower/weir and aerial surveys on the Gisasa River in the Koyukuk watershed
- Weir on the Tozitna River

The sonar provides an estimate of total Chinook abundance entering the basin, covering most years since the late 1980s. The tributary surveys cover the main known spawning sites.

E.2 Pilot Station Sonar

E.2.1 Project Summary - Pilot Sonar

Introduction

The Pilot Station Sonar program is implemented by ADF&G.

The project estimates salmon passage by species based on sonar (i.e. sound-based detection of size and direction of passing objects). Age-Sex-Length (ASL) data are also collected from Chinook sampled in a test fishery using drift gill nets.

The project is located at river km 197, in a single channel environment near the village of Pilot Station (61° 56' 59.79" N, 162° 51' 37.76" W)

The sonar program at Pilot Station has been operated annually since 1980, except for 1984, 1992, and 1996. Note, however, that the sonar operation was substantially modified in 1995, and because of these changes, data collected from 1995 to current are not directly comparable to previous years (Tables E.1 and E.2).

Methods

The approach for collecting the data necessary to achieve the objectives for this project involve stratified systematic sampling of fish passage using hydroacoustic equipment and a drift gill net fishery to determine daily species composition. Sampling procedures are designed to obtain relative proportional sampling of fish passage within the entire sampling range of the sonars. Both banks are stratified by range in order to improve detection by optimizing the aim and ping rates within each strata. Temporally, sampling is systematic to best ensure changes to passage rates over the day are captured while reducing expenses by not operating 24-hours per day.

Apportionment of fish species is determined by test fishery catches using catch per unit effort (CPUE) as well as gill net selectivity. To compensate for the differential probability of capture, the project employs gill nets of varying mesh sizes (2.75 to 8.5 inches) and test fishing at multiple zones along the river in front of the sonars. In 2004, the selectivity model used in species apportionment was refined through biometric review and analysis of historical catch data from the project's test fishery. The model providing the best overall fit to the data was a Pearson model with a tangle parameter (Bromaghin 2004). Probability of capture was determined by net selectivity for each species (for details see Maxwell et al. 1997; Carol and McIntosh 2008; Lozori and McIntosh 2014) using selectivity parameters from the most current catch data prior to the field season. Since initiation of the project, statistical methods for estimating species apportionment have been reviewed and revised several times. Additional information regarding historical changes in species apportionment methodologies see Pfisterer et al. 2017.

Discussion

Critical assumptions include:

- Most fish pass within range of the sonar and are detected.

- No diurnal changes to fish passage and that the sampling plan is sufficient to estimate passage over a full day.
- There is minimal to no milling at the site so that fish are not counted multiple times.
- All fish are equally likely to be captured by test fish nets, i.e. no species specific net avoidance.
- The catches in the test nets reflects the true species composition in the river.* Uncertainty evaluation

Many of these project assumptions have been tested since the project's inception. Initial feasibility studies did not identify any diurnal passage patterns (Nickerson and Gaudet, 1983). Additionally, the project operated sonar 24 hours a day periodically during the season from 1997-2008 with no consistent diurnal patterns detected (Carroll and McIntosh, 2011). The project leaders monitor target distribution during the season to observe if a large percentage are offshore which could suggest significant passage beyond the detection range. The split-beam and imaging sonar make it possible to detect direction of travel so milling fish would be observed in the data.

Chinook salmon avoiding (25 fathom) test net was examined by using longer (50 fathom) net; however, this did change estimates of Chinook passage (Lozori 2020).

Sidescan sonar found no significant passage beyond the detection range

It is very difficult to ascertain whether species apportionment assumptions are met, however, the estimates of some species have been compared to other independent studies.

Chinook salmon passages were lower than that by radio-telemetry mark-recapture (Spencer et al. 2009) and genetic mark-recapture (Hamazaki and DeCovich 2014). However, after the updates of species apportion methodology (Pfisterer et al. 2017), Chinook salmon passage estimate became comparable to genetic mark recapture (i.e., ratio estimator ~ 1.0).

The Chinook salmon estimates when compared to a total river estimate derived using the Canadian border escapement estimate and genetic data collected at Pilot Station appear unbiased (F. West, Commercial Fisheries Biologist, ADF&G, Anchorage; personal communication). Pilot Station summer chum salmon estimates have compared reasonably with a total run mark-recapture estimates produced using data from a radio telemetry study (Larson et al., 2017) and Pilot Station fall chum salmon estimates appear unbiased relative to the post season run reconstruction estimates (B. Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication). Given these comparisons to independent studies, we feel the project produces a reasonably unbiased estimate of salmon passage at the site (with the exception of pink salmon which are actively avoided at high passage).

E.2.2 Project Details - Pilot Sonar

Table E.1. Pilot Station - Operational Timeline

Years	Component	Change/Event
1980-1983	All	Project feasibility studies conducted.
1985	Sonar	Initial set up using BioSonics 420 kHz with 20 min sampling duration with a -32 dB detection threshold. Report periods were 3-9 days to obtain minimum sample of 120 fish at each site. Transducers were aimed 15 deg downstream to determine direction of travel. Counts within sectors were expanded for the proportion of the water column covered. Left bank strata required 2 transducers deployed at different ranges.
1985	Test Fishery	Used 4 mesh sizes: 101.6 mm (4.0 in), 139.7 mm (5.5 in), 162.0 mm (6.38 in), and 215.9 mm (8.5 in) 45.7 m (150 ft) . Sampled 4 strata, (left bank nearshore, left bank offshore, right bank bottom, right bank surface),
1986	Test Fishery	6 Mesh sizes utilized 101.6 mm (4.0 in), 127.0 mm (5.0 in), 139.7 mm (5.5 in), 165.1 mm (6.5 in), 190.5 mm (7.5 in), and 215.9 mm (8.5 in). All were 45.7 m (150 ft) long and 7.6 m (25 ft) deep.
1988	Test Fishery	Did not adjust catches for selectivity (this was 1988 only).
1989	Test Fishery	Methodology consistent with 1986.
1990	Test Fishery	Spatial expansion based on the proportion of the water column ensonified was discontinued. 8.5in and 7.5indrifted twice per bank per period, other nets drifted once per bank. Stopped fishing 8.5in and 7.5in nets after July 25. Net selectivity methodology improved from previous, used McCombie and Fry method (1960) for Chinook and chum salmon and Holt (Peterson 1966) for coho salmon, pink salmon, and whitefish. Began computing sample variance for the estimates. SAS used to generate estimates.
1991	Test Fishery	First year 70 mm (2.75 in) net fished
1992	Sonar	Project only operated a partial season and savings used to purchase 120kHz equipment
1993	Sonar	Sonar frequency changed from 420 kHz to 120 kHz to detect fish at greater ranges. Individual sonar stratum were sampled in 15 min periods (was 20 min previously). Sonar operated 24 hrs/day 4 times during the season. No expansion for fish beyond the counting range using down looking fathometer Log-normal curves used to describe selectivity.

Years	Component	Change/Event
1995	Test Fishery	Utilized a single stratum on the right bank. The project has always utilized a single stratum (or test fish zone) for the apportionment of the sonar counts on the right bank. Although there were a couple years (2008 and 2009) where another test fish zone was fished to bolster Chinook catches for GSI, this data was not used in the apportionment of sonar counts.
1995	Sonar	No longer used the angle of traces to distinguish downstream from upstream fish. All traces were considered upstream.
1996	Sonar and TF	Project did not produce estimates and operated for training purposes only.
1997	Test Fishery	140 mm (5.5 in) mesh added in the fall when 7.5 in and 8.5 in discontinued.
1998	Sonar	Sampled 3 sonar strata on right bank.
1998	Test Fishery	Discontinued the 127.0 mm (5.0 in) and 165.1 mm (5.5 in) nets, used 133 mm (5.25 in).
1999	Test Fishery	In the fall season, discontinued 215.0 mm (8.5 in) and 133 mm (5.25 in) nets and added 146 mm (5.75 in) and 127 mm (5.0 in).
2001	Sonar	Transitioned to HTI split-beam equipment. Frequency kept at 120 kHz and still marked fish using paper charts.
2004	Sonar	Changed selectivity model to use Pearson-T curve.
2005	Sonar	Incorporated the DIDSON into left bank sampling for the first 20 m.
2009	Sonar	Transitioned from marking fish on paper charts to electronic echograms.
2010	Test Fishery	Tested 50 fathom nets during summer season. Alternated 25 fathom and 50 fathom by test fishing period.
2010	Sonar	Preliminary testing of side-scan sonar for use offshore during periods of extreme turbidity.
2011	Test Fishery	Discontinued the 50 fathom nets and resumed normal test fishing operations.
2011	Sonar	Final year of side-scan testing.
2015	Sonar	Switched from DIDSON to ARIS on the left bank sampling the entire stratum 3 (0-50 m).
2016	Sonar	Updated selectivity parameters for all species and implemented a minimum selectivity threshold of 0.1.

Table E.2. Pilot Station - Potential Data Issues

Years Affected	Potential Issue
1980-1994	Prior to 1993, the project used dual-beam sonar equipment that operated at 420 kHz. Prior to 1995, the project attempted to identify direction of travel of detected targets by aiming transducers at an upstream or downstream oblique angle relative to fish travel. Because of these changes, data collected from 1995 to current are not directly compatible to previous years.
Mid 1990s	Sandbar issue on the right bank plagued the project for several years. Detection through the silt band created by the bar while depositing or vacating made counts difficult in those years.
1996	The Pilot Station sonar project did not operate at full capacity in 1996 and there are no passage estimates for this year.
2001	High water levels were experienced at Pilot Station therefore, passage estimates are considered conservative. Extreme high water during the bulk of the summer season (May, all of June and part of July). Water remained slightly above average throughout the fall.
2005	Estimates include extrapolations for the dates June 10 to June 18 to account for the time before the DIDSON was deployed. Otherwise, the estimates should be good.
2009	High water levels were experienced at Pilot Station therefore which limited detection. Passage estimates are considered conservative. Extremely high in May but then just above average the rest of the summer season. In the fall, water dropped to record low causing all kinds of unique issues for those species.

E.2.3 References

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No. 17-46, Anchorage.

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E.3 Lower Yukon Mark-Recapture

E.3.1 Project Summary - Lower Yukon Mark-Recapture

Introduction

Alaska Department of Fish and Game (ADF&G) and the U.S. National Marine Fisheries Service (NMFS) operated a radiotag mark-recapture program, tagging adult Chinook in the Lower Yukon.

The program generated various abundance estimates, as well as data on final fates of tagged fish, migration rates, spawning distribution, and age, sex, and length of tagged fish.

Adult Chinook salmon were captured and marked near the village of Marshall (2000–2002) and Russian Mission / Dogfish Village field camp (2000–2004), 22 km upriver from Russian Mission. At each location numerous fishing sites were established along the north and south banks.

Adult Chinook salmon were examined for marks at a range of tributary monitoring locations and in fishery harvests in the U.S. and Canada.

Project objectives varied slightly throughout this 5-year study. Primary objectives included: 1) estimate the stock composition (proportional distribution) of the total Yukon River Chinook salmon escapement among major tributaries; 2) estimate the stock specific run timing, migration rate, and movement patterns; and 3) estimate the abundance of Chinook salmon in major Yukon River tributaries and the entire Yukon River drainage upriver of Russian Mission with relative precision (coefficient of variation) less than 20%.

Although the basin-wide telemetry study was designed to provide other types of information, the data collected were used to develop mark–recapture abundance estimates of the Chinook salmon return. The methods summarized here describe those used to address abundance estimation. Methods included two-sample mark-recapture and telemetry.

Methods

- *First Sample Event*: The first sample event used drift gill net methods to capture, sample, and tag Chinook salmon. Various net configurations were fished in 2000 and 2001 to determine the most appropriate gill net characteristics for this study. From 2002-2004, the gill nets used were 8.5” mesh size (# 21 seine twine, length 46 m, depth 7.6 m, with a hang ratio of 2:1). Fish were tagged with an external 14” long spaghetti tag and an appropriately sized internal pulse-encoded esophageal radio tag. The axillary process was removed from each tagged fish as a secondary external mark and used for genetic analysis. Age, sex, and length (mm MEF) was determined for all captured Chinook salmon. Efforts were made to distribute tags throughout the entirety of the run past the tag sites in proportions to abundance. Fishing started in early June and ended in mid-July. Each day, fishing occurred for two 7.5 or 8-hour shifts; one each scheduled during the day (0900–1700) and night (1800–0200). Standardized capture and handling methods were implemented to reduce the potential for negatives impacts on tagged fish. At each gill net operation, net was retrieved as soon as fish was captured, and only first three fish that were free of serious injury were tagged and released immediately.

- *Second Sample Event*: used primarily escapement monitoring projects operated in the lower, middle, and Canadian portions of the Yukon, upriver from the first event tag sites. The escapement monitoring projects used to calculate the mark–recapture estimates varied each year based on the number of tags recovered, directed tag recovery efforts associated with numbers of fish, and completeness of information.

- *Telemetry tracking*: Telemetry methods were used to monitor the upriver movement of tagged fish. The spatial extent of tracking efforts varied annually, but in each year a combination of boat tracking, aerial tracking, and fixed ground-based receiver stations were used. Mobile tracking surveys (primarily aerial) were conducted along the mainstem Yukon River from Marshall to the Canadian headwaters and in selected tributaries. Ground based tracking stations (Eiler 1995) were placed along the Yukon River mainstem and major tributaries. In 2000 and 2001, telemetry tags were only applied to a subset of the total tagged fish

- *Fates of tagged fish*: A combination of telemetry data and voluntary tag reporting was used to determine the fate of tagged fish. Radiotagged fish that passed the first set of tracking stations at Paimiut, located approximately 62 km upriver from Russian Mission, were considered to have resumed upriver movements. Fish tracked to terminal reaches of the drainage were classified as distinct spawning stocks. Tagged fish found in communities or fish camps during tracking surveys were assumed harvested even if not reported by fishers. Voluntary returns were important in determining the fate of “unknown” fish (e.g., not detected using telemetry). Commercial and subsistence fishers in the U.S. and Canada were asked to report any marked fish they captured. Steps were taken to facilitate voluntary return of tags.

- *2000-2004 abundance estimation of large fish upriver from Russian Mission*: Chapman’s closed population two-sample, mark–recapture estimator (Seber 1982) was employed to estimate the drainagewide population abundance. In all years, the abundance estimate was germane to the number of fish passing upstream of Russian Mission. The marked population was equal to the number of tags that successfully went upstream of Russian Mission. The number of fish examined during the second event was curtailed to only large fish (generally over 650 mm).Tagging targeted larger fish, so the second event was also limited to large fish. The number of recaptures was only those marked fish observed, among all fish inspected, at the upriver recovery sites. Methods for estimating variance changed over time. Mark-recapture estimates are listed on Table 11 of Spencer et al. (2009)

- *2000-2004 abundance estimation of small fish upriver from Russian Mission*: An abundance estimate for small Chinook salmon (generally less than 650 mm) was generated based on frequency distribution of age classes obtained from the inspected fish at the recovery projects. The method used to classifying small fish compared length with age class to censure out 2 ocean fish. This resulted in different length criteria for small fish between years. That method could not be done in 2004 when very few small fish were marked, examined, or recaptured upstream and there was no clear division between age classes.

- *2000-2004 drainagewide abundance estimation*: In each year, the abundance of all Chinook salmon returning to the Yukon River was reconstructed. Reconstructed estimates were the sum of 1) estimates of large Chinook salmon upriver from Russian Mission; 2) estimates of small Chinook salmon (generally less than 650 mm) upriver from Russian Mission (based on frequency distribution of age classes observed at escapement projects); and 3) all fish that were harvested or escaped downriver from the tag site. Downriver Chinook salmon included fish harvested in test, subsistence, and commercial fisheries as well as fish that escaped to the Andreafsky River. Drainagewide estimates are listed in Table 13 of Spencer et al. (2009). Note that for the total estimates, which are the sum of separate estimates for large and small fish, the standard error is calculated as $\sigma_{total} = \sqrt{\sigma^2_{large} + \sigma^2_{small}}$, which implies the assumptions that the two estimates are independent.

Methods - 2002-2004 estimates of abundance in the Tanana River and Canada

Beginning in 2002, Chinook salmon passage into the Tanana River and passage into Canada were estimated separately with two methods based on marked fish. The abundance of fish migrating into the Tanana River (or into Canada) was estimated by multiplying the drainage abundance estimate by the fraction of tagged fish that were tracked to each terminal location. This method was referred to as the “proportional experiment.” The second method was based on a two-event mark–recapture experiment. In this “local experiment,” marked fish from the first event were only those tagged fish known to have entered the Tanana River (or Canada) based on remote tracking station data, and fish inspected during the second event are only taken in samples in the combined Salcha and Chena rivers (or from the Canadian subsistence fishery). Variances in these competing estimates were calculated within the drainagewide variance estimation framework. Tanana and Canada estimates are listed in Table 12 of Spencer et al. (2009).

Discussion

Critical assumptions include:

- To use the Chapman closed population estimator, the following assumptions must be met:
    1) recruitment of untagged fish does not occur between the tagging and recapture events;
    2) tagging does not affect the fate of a fish;
    3) tagged fish do not lose their marks and all marks are recognized; and
    4) all fish have an equal probability of capture at the capture sites, or all fish have an equal probability of capture at the recapture locations, or marked fish mix completely with unmarked fish between capture locations.
- Due to limited telemetry information in 2000 and 2001, all tagged fish were assumed to have continued upriver migration.
- The 2002-2004 estimates of abundance for the Tanana River and Canada required that tags were distributed in proportion to abundance passed the tag site.

Evaluation of critical assumptions suggested that estimates of abundance were unbiased. The length frequency of the tagged sample was not representative of the run due to the selectivity of the gill nets for larger fish. Untagged fish examined upstream were decidedly smaller than those captured downstream for most years. As a result, small fish were culled from the experiment and estimates are for large fish (generally greater than 650 mm). Only those large fish that successfully resumed upriver migration post-tagging were included in the experiment. Radiotelemetry data indicated most all tagged fish in 2002–2004 were successfully tracked upstream and exhibited swimming rates suggestive of normal movements. Comparison of marked fractions across lower river (upstream of the tagging site), mid-river, and upper river pooled sampling locations indicated that all large fish, regardless of their spawning location, had an equal chance of being marked at the tagging sites. The similarity of the marked fractions of tagged fish across the different recovery locations suggests that sampling was representative, thus avoiding bias in estimates of abundance when considering the large-fish component of the run. In each year, tag deployment was approximately proportional to abundance passed the tag site. Statistical bias was estimated in 2002-2004 using bootstrap procedures and the average bias was 3.13%, 2.86%, and 3.03% respectively for the drainage upriver from Russian Mission, Canada, and Tanana River.

Drainagewide mark-recapture estimates of large Chinook salmon abundance were compared to independent estimates of large Chinook salmon based on a sonar at Pilot Station (note: the comparable sonar estimates were revised in 2016; Pfisterer 2016) . Sonar estimates in 2000, 2001, and 2004 were notably smaller and not contained within the 95% CI of the mark-recapture estimates. Sonar estimate in 2002 was contained within the 95% CI of the mark-recapture estimate, near the lower bound. Sonar estimate in 2003 was larger than the upper bound of mark-recapture estimate.

Proportional and local estimates of the number of Chinook salmon passage into Canada can be compared to border fish wheel mark-recapture estimates from Canada Department of Fishery and Oceans. The border fish wheel estimates are known to be biased low. As such, the 2002-2004 proportional and local experiments should yield larger estimates. In 2002, the proportional estimate was 22% smaller than the estimate based on fish wheel data, while the local estimate was 4% larger. In 2003, the proportional and local estimates were respectively 77% and 58% larger, while in 2004 they were 42% and 23% larger than the fish wheel estimate.

E.3.2 Project Details - Lower Yukon Mark-Recapture

Feasibility years (2000, 2001)

- Additional project objectives included: 1) evaluate if adequate numbers of fish can be captured to conduct a full-scale radio telemetry program; 2) determine the capture method most effective for Chinook salmon and in a condition suitable for tagging; 3) evaluate the effects of handling and tagging on the migratory behavior of fish; and 4) determine the feasibility of tracking radiotagged fish in the lower Yukon River mainstem.
- An alternative method was explored to estimate abundance based on tagged fish released at the Marshall tag site and recaptured at the Russian Mission (Dogfish) tag site. Few tag recaptures prevented testing critical assumptions, and this method was discontinued in future years. For this reason, these published estimates were not considered further.

- External spaghetti tags were the primary tag type. Only a small subset of spaghetti tagged fish were also given a radio tag.
- Mobile tracking efforts were conducted in the lower river to evaluate movement of tagged fish after release. Surveys extended 10 km downriver to 70 km upriver from the Russian Mission tagging site.
- In 2000, five telemetry towers were operated, with the most upriver tower located at Rampart Rapids.
- In 2001, 10 tracking stations were used and included towers located on the mainstem Yukon and Porcupine rivers at the U.S./Canada border.
- In 2000, the following locations served as recapture sites: Gisasa and Henshaw weirs (lower Yukon; Koyokuk River assessment), Nenana test fish wheel and Beaver Creek weir (middle Yukon); and six locations in Canada (White Rock fish wheel, Sheep Rock fish wheel, Dawson test fishery, Tatchun Creek weir, Rapids subsistence fish wheel, and Whitehorse fishway)
- In 2001, the following locations served as recapture sites: Gisasa and Henshaw weirs (lower Yukon; Koyokuk River assessment), Nenana test fish wheel (middle Yukon); and four locations in Canada (White Rock fish wheel, Sheep Rock fish wheel, Dawson test fishery, and Whitehorse fishway)
- Recapture sample sizes limited the ability to test for equal mark to unmarked ratios across the geographic range of recapture locations. Recapture data were pooled for lower, middle, and upper groups.
- Variance estimation used a standard closed-form equation for two-sample mark-recapture experiments.

Full operational years (2002-2004)

- Radio tags were the primary tag type used. External spaghetti tags served as a secondary mark.
- Mobile tracking surveys were conducted on the Yukon River mainstem from Marshall to the Canadian border, upriver of stations on terminal tributaries, and in other selected reaches.
- 2002-2004, 39 telemetry towers were operated.
- Radiotagged fish that did not resume upriver migration were censored from the experiment.
- Fates of tagged fish were standardized and assigned to eight mutually-exclusive categories: 1) disappeared; 2) moved upstream to Tanana but not to Chena or Salcha; 3) moved upstream to remain in a U.S. tributary, but not in the Tanana River; 4) moved upstream to Canada, but not inspected; 5) moved upstream through the weir on the Gisasa River (R1); 6) moved upstream past towers on the Salcha River (R2); 7) moved upstream over a dam on the Chena River (R3); and 8) were caught in a Canadian subsistence fishery (R4).

- Tag recaptures occurred at four standardized locations representing the lower Yukon (Gisasa River; R1), middle Yukon (Salcha River [R2] and Chena River [R3]), and Canada (subsistence fishery [R4]). For lower and middle Yukon, tag recaptures were equal to the number of radio tags recorded upriver from the assessment programs, and the number of fish examined for marks at each location was an estimate.
- The primary problem encountered was the lack of recovery projects where adequate numbers of fish representing large proportions of the return could be accurately enumerated, limiting the confidence in the abundance estimates obtained. As such, recapture sample sizes limited the ability to test for equal mark to unmarked ratios across the geographic range of recapture locations. Recapture data were pooled for lower, middle, and upper groups.
- The fate of some radiotagged fish was not determined. Possible causes include tag malfunction, unreported fishery harvest, and movements to tributaries where aerial surveys were not conducted, or recovery projects were not operated. A portion of these fish may have died while in transit to spawning areas further upriver, which could bias estimates.
- From 2002-2004, parametric bootstrap methods were used to estimate variance. In this study, up to four variates were simulated: 1) number of marked fish (year 2002 only); 2) number of marked fish that resumed upriver migration; 3) numbered recaptured fish; and 4) number of large fish examined at the recapture sites. For each of 1,000 simulations, a new estimate of abundance was calculated.

Data Concerns - 2000

- Of the six net configurations used in 2000, the 8.5" mesh size with 2: 1 hanging ratio net had the highest Chinook to chum salmon catch ratio and was used again in 2001.
- Telemetry tower located at Baldhead Mountain, immediately upriver from the Russian Mission tag site, was compromised by poor signal reception and atmospheric interference. Limited data was available to evaluate upriver movement of radiotagged fish after release.
- Abundance estimation relied on a relatively small number of marked fish.
- A total of 675 Chinook salmon were tagged. Only 91 (13%) were radiotagged, and 11 of those (12%) were experimental and not monitored beyond the tagging site. A total of 669 of 675 (99.1%) were assumed to have resumed upriver migration.
- Although spaghetti tagging was conducted throughout the season, radiotagging was conducted for only 20 days, from 11 June to 30 June. Distribution of radiotagged fish is not representative of the entire population.
- Fish smaller than 630 mm were censored from the population abundance estimate (approximately 3% of first sample and 5% of second sample).

Data Concerns - 2001

- Of the three net configurations used in 2001, the 8.5" mesh size with # 21 seine twine (length 46 m, depth 7.6 m, with a hang ratio of 2:1) was considered most effective at targeting Chinook salmon and minimizing incidental catch of other species. The #21 seine twine type did impose higher rates of minor injuries compared to monofilament, but there was no evidence the injuries substantially affected behavior of fish post-tagging.
- The Baldhead Mountain tower site was replaced with a new site located at Paimiut Hills. Beginning in 2001, this new site was used to determine if tagged fish continued upriver migration after release.
- To increase the number of marked fish, all fish (except the most seriously injured) were marked with a spaghetti tag. Tagging fish in potentially marginal condition likely biased the abundance estimate high, due to the likelihood that a disproportionate number of fish may have failed to complete their upriver migration compared to the untagged fish.
- A total of 2,010 Chinook salmon were tagged. Of those only 117 (6%) were radiotagged, and 9 of those (8%) were experimental and not monitored beyond the tagging site. 100% of tagged fish were assumed to have continued upriver migration.
- Although spaghetti tagging was conducted throughout the season, radiotagging was conducted for only a 7-day period from 18 June to 24 June. Distribution of radiotagged fish is not representative of the entire population.
- Fish smaller than 640 mm were censored from the population abundance estimate (approximately 2% of first sample and 13% of second sample).
- Mark-recapture estimate of 2001 is considered unusually high, even though all assumptions were met.

Data Concerns - 2002

- Fish smaller than 650 mm were censored from the population abundance estimate (approximately 6% of first sample and 23% of second sample).
- When tagging began at Marshall, fish were already present and had been passing the site for a week, suggesting the abundance estimates may be biased low, especially the upper basin component.
- Fishing effort at the Marshall and Dogfish sites was adjusted inseason to increase catches. This resulted in an increased probability of catching fish later in the run and introduced the potential for unequal catch probabilities among the different stocks. In response, a subset of tags was culled from the study to remove that source of sampling error from the marking procedure and produce similar marked fractions of inspected fish across recovery sites.
- Only 768 of the available 1,000 radio tags were deployed. Of those, 303 (40%) were culled to address disproportionate fishing effort. A total of 465 were considered to have resumed upriver migration. The number of marked fish was treated as a variate in the bootstrap simulation used to estimate variance.
- Tagging effort was standardized following the 2002 season to address these issues.

Data Concerns - 2003

- Fish smaller than 650 mm were censored from the population abundance estimate (approximately 1% of first sample and 7% of second sample).
- When tagging began at Dogfish and Russian Mission, fish were already present, suggesting the abundance estimates may be biased low.
- A total of 1,081 of 1,097 (98.5%) were considered to have resumed upriver migration. 2004
- No Chinook salmon were caught at the start of fishing at Dogfish tag site, indicating that the marking event coincided with the start of the run.
- A total of 958 of 995 (96.3%) were considered to have resumed upriver migration.
- Few small fish were marked, examined, or recaptured. Fish were not censored for length, so abundance is equal to all Chinook salmon (i.e., $\geq$ 520 mm).

E.3.3 References

Data Sources

Spencer, T. R., R. S. Chapell, T. Hamazaki, and J. H. Eiler. 2002. Estimation of abundance and distribution of Chinook salmon in the Yukon River using mark recapture and radio telemetry in 2000 and 2001. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A02-37, Anchorage.

Spencer, T. R., T. Hamazaki, and J. H. Eiler. 2005. Mark–recapture abundance estimates for Yukon River Chinook salmon in 2002. Alaska Department of Fish and Game, Fishery Data Series No. 05-75, Anchorage.

Spencer, T. R., T. Hamazaki, and J. H. Eiler. 2006. Mark-recapture abundance estimates for Yukon River Chinook salmon in 2003. Alaska Department of Fish and Game, Fishery Data Series No. 06-31, Anchorage.

Spencer, T. R., T. Hamazaki, and J. H. Eiler. 2007. Mark-recapture abundance estimates for Yukon River Chinook salmon in 2004. Alaska Department of Fish and Game, Fishery Data Series No. 07-30, Anchorage.

Spencer, T. R., J. H. Eiler, T. Hamazaki. 2009. Mark–recapture abundance estimates for Yukon River Chinook salmon in 2000–2004. Alaska Department of Fish and Game, Fishery Data Series No. 09-32, Anchorage.

Other References

Eiler, J. H. 1995. A remote satellite-linked tracking system for studying Pacific salmon with radio telemetry. Transactions of the American Fisheries Society 124:184-193.

Pfisterer, C. T., T. Hamazaki, and B. C. McIntosh. 2017. Updated passage estimates for the Pilot Station sonar project, 1995-2015. Alaska Department of Fish and Game, Fishery Data Series No. 17-46, Anchorage.

Seber, G. A. F. 1982. On the estimation of animal abundance and related parameters. second edition Charles Griffin and Sons, Ltd., London. 654 p.

E.4 Lower Yukon Test Fishery

ADF&G has conducted annual test fisheries since 1963 to estimate catch-per-unit-effort and collect ASL data. Directed Chinook Drift gill net operations started in 2001.

The Big Eddy and Middle Mouth test fisheries combined make up what is known as the Lower Yukon Test Fishery (LYTF). The Big Eddy test fishery is located on Kwikluak Pass (South Mouth) near the village of Emmonak. This project originally began in 1963 as a set gill net test fishery on Flat Island and in 1979 was relocated to its current location near the village of Emmonak. The Middle Mouth test fishery is located on Kwikpak Pass, upstream of Kawanak Pass (Middle Mouth). The location and number of set gill net sites have changed over the years but have been in their general locations since 1989. Most test set net sites are well established and provide data through the entire season. However; due to changing water levels building sandbars and eroding cutbanks, the effectiveness of a set net can be altered through the course of the season.

Catch per unit effort (CPUE) is calculated to standardize the catch in each net based on the amount of time they are fished and are summarized by day. The daily and cumulative CPUE are used to index the relative abundance and timing of salmon entering the various mouths of the Yukon River and can be compared to the Pilot Station sonar passage estimates. Age, sex and length and genetics samples are also collected from the catch to characterize the return relative to the selectivity of the gear fished. The changes in abundance, species composition, and age/sex composition are used in fishery management decisions.

No formal data review of the LYTF project was undertaken since the data was considered of low priority and is not currently included in the run reconstruction model. The test fishery has been used in recent years by the department to help identify pulses as they enter the river but not as an overall representation of total run size. Additionally, the number of sites and number of nets fished have not been consistent between years. Therefore, annual index values may not be comparable between years.

All historical test fish CPUE data by site and year are not currently available in the ADF&G database but efforts are currently underway to enter the data. More background on the LYTF can be found in the following publications:

Bergstrom, D. J. 1986. Lower Yukon River salmon test fishing studies 1984. Alaska Department of Fish and Game, Division of Commercial Fisheries AYK Region, Yukon Test Fish Report No. 21, Anchorage.

Crawford, D. 1979. Lower Yukon River salmon test fishing studies, 1979. Alaska Department of Fish and Game, Division of Commercial Fisheries AYK Region, Yukon Test Fish Report No. 12, Anchorage.

Newland, E. J., and S. J. Hayes. 2008. Summer season cooperative salmon drift gill net test fishing in the Lower Yukon River, 2006. Alaska Department of Fish and Game, Fishery Data Series No. 08-39, Anchorage.

E.5 Andreafsky River

- Have weir program and aerial survey program on the East Fork, and and aerial survey on the West Fork. The weir program is described in this section, the aerial survey program is described in Section G.5 *Lower River Aerial Surveys*.

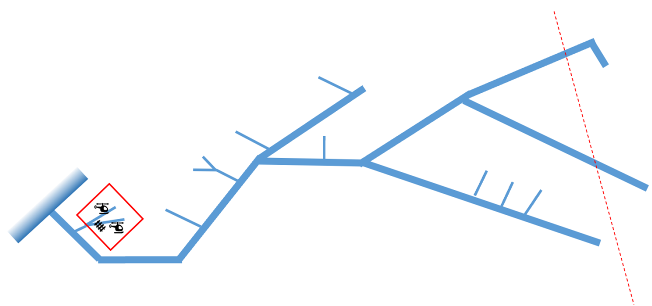

Figure E.1. Location of Andreafsky Surveys in the Lower Yukon

E.5.1 Project Summary - East Fork Weir

Introduction

The East Fork Andreafsky River weir program is implemented by USFWS - Fairbanks.

The project estimates daily salmon passage and collects age, sex, length (ASL) data.

The weir program on the Andreafsky River has generated annual estimates since 1994, except for 2001.

Methods

A modified resistance board weir (Tobin 1994; Tobin and Harper 1995) was installed annually in the EF Andreafsky River from 1994 – 2019. Weir panel picket spacing was designed to remain functional during higher water flow, but allowed smaller Pink Salmon and resident fish to pass through the weir undetected (Zabkar and Harper 2003). Two passage chutes were installed, one approximately one-third of the way across from the left bank, and the other centered between the banks, in water deep enough to allow fish passage in the vent of low water conditions. A fish trap was installed to facilitate biological sampling, and the weir was cleaned and its integrity visually checked daily. All fish were enumerated and identified to species as they passed through the live trap. Fish were counted 24 hours per day and the numbers were recorded hourly.

A stratified random sampling design was used to collect age, sex, length (ASL) data for Chinook Salmon and summer Chum Salmon. Biological sampling of Chinook Salmon and summer Chum Salmon occurred each week, with a sampling goal spread throughout each week, and daily sampling spread throughout each 24-hour period. All target species within the trap were sampled to prevent bias. Non-target species were identified and counted, but not sampled for age, length, and sex. Sampling consisted of identifying salmon to species, determining sex, measuring fish lengths, collecting scales, and releasing fish upstream of the weir. Secondary characteristics were used to determine sex. Lengths were measured from mid-eye to fork of the caudal fin to the nearest 1 mm. Scales were removed from the area above the lateral line and posterior to the dorsal fin. Four scales were collected from each Chinook Salmon sampled, and one scale was collected from each summer Chum Salmon sampled. Daily sex ratios were collected by visually examining each fish for external morphological features when sampling for age and length. The escapement counts and sex ratios were reported daily to the USFWS Fairbanks Fish and Wildlife Field Office and forwarded to ADF&G staff.

The original count data for Chinook and Chum Salmon runs were revisited for both the EF Andreafsky and Gisasa River weir projects to standardize the methodology for reconstructing missed segments of the runs (Brown et al. 2020). These complied and standardized data will be made available as supplemental materials for the manuscript: Population Trends for Chinook and Summer Chum Salmon in Two Yukon River Tributaries in Alaska (Brown et al. 2020) that was recently accepted for publication in the Journal of Fish and Wildlife Management.

Discussion

Critical assumptions include:

- All fish within a spawning tributary are counted and accurately identified to species by observers.
- The ASL data are accurately reported and that age-sex proportion estimates of subsampled individuals are reflective of the broader spawning population.

Uncertainty Evaluation

The extended seasons of the EF Andreafsky River weir during the years 1995 through 2005 revealed that a small fraction of the Chinook and Chum Salmon runs continue trickling in for days or weeks after the main body of the run passes. Additionally, during some years, high flow events and associated turbidity following large rains have interfered with counting for a few hours to a few days during the runs. Over the course of this weir project, the early and late gaps in counts have generally been considered insignificant and were not reconstructed. However, the mid-season gaps were estimated using the history of run proportions from specific date ranges in other years to reconstruct gaps in the current year's count record (Zabkar and Harper 2003). Passage in the ascending and descending tails and in mid-run gaps were estimated by applying the statistical arrival models introduced by Sethi and Bradley (2016). In a few cases, however, the models did not draw the passage counts to zero in the declining tails of the runs and the results were considered to be implausible and high influential of other run parameters. In those cases, a declining function was used (Brown et al. 2020).

Upon conversion to an electronic video weir system in 2014, all hourly video files from selected dates were reviewed as a quality control measure. The two of three days of highest fish passage were selected for review because counting and species identification errors would be more likely when fish were crowded in the passage chute and view window. Additional video files were reviewed as necessary to follow up on significant discrepancies between field and office counts. Fish identification discrepancies were assessed qualitatively to determine the nature of the errors, look for differences between individual observers, and track whether accuracy improved over time. Discrepancies in counts were also assessed quantitatively for presence of systematic bias (i.e., consistent under- or over-counting) and magnitude of error compared with total species counts. Visual fish counts at weirs by direct observation are generally assumed to be a complete census of the species passage during the operating periods, and error is assumed to be negligible. Therefore, formal variance statistics and not generally reported and we do not report them in this project.

E.5.2 Project Details - East Fork Weir

Table E.3. Andreafsky Weir - Operational Timeline

Years	Component	Change/Event
1994	Location	The EF Andreafsky River weir was originally installed at latitude 62.12996° and longitude -162.79793 (WGS84 datum; Tobin and Harp 1995), approximately 40 km upstream from the confluence with the main stem.
1995	Location	Weir moved about 2 km downstream, at latitude 62.11673 and longitude -162.80761, which had a wider and shallower channel profile thought to be better able to handle high flow periods (Tobin and Harper 1996; Mears and Morella 2017).
1996	Design	Second fish passage chute added (Tobin and Harper 1997).
1994, 2006 to 2016	Duration	Count stop dates ranged from July 27 to August 3, based on diminishing counts of Chinook and summer Chum Salmon.
1995 to 2005	Duration	Effort to count later arriving Coho Salmon and the weir remained operational until a fall stop date that ranged from September 11 to September 23.
Before 2014	Counting Method	An observer sat on the chute counting fish from above whenever the doors on the chute were open.
Since 2014	Counting Method	Motion activated, high resolution video systems were developed and since that time fish have been counted by observing video images of migrating fish (Mears 2015).
Early Years	Sample Size	In the early years of the EF Andreafsky (Tobin and Harper 1996), there was an effort to achieve weekly sampling goals during a 1–4 day period at the start of each weekly stratum to maximize demographic contrasts among strata, a strategy discussed by Geiger et al. (1990).
Later Years	Sample Size	Later, the weir project adopted a daily sampling plan with effort distributed across different hourly time periods each day (Mears and Morella 2017). To ensure sampling was distributed throughout the run roughly in proportion to escapement, the season was divided into 4 periods having approximately equal fish passage numbers based on historical fish passage counts. The sample target was 55 – 60 fish of each species within each period. The same size goal for each species was 220-240 fish for the season. This goal was based on a statistical calculation indicating a minimum desirable sample size of 180 fish with readable scales (Contiz 2019).
Recent	Biological Sampling	A recent problem in biological sampling at the EF Andreafsky River weir is the increasing frequency of high water temperatures (see next table).

Table E.4. Andreafsky Weir - Potential Data Issues

Years Affected	Potential Issue
2001	Missing about half of the annual passage because high water prevented counting until July 15 (Zabkar and Harper 2003). However, the 2001 escapements of Chinook and Chum Salmon into the EF Andreafsky River have been reconstructed for production analyses by Siegel (2017) and Fleischman and Evenson (2010).
2019	Biological sampling was temporarily suspended 2019 as mandated by current protocol when water temperatures exceeded specified thresholds identified by the Environmental Protection Agency (17 C for three consecutive days or any time water temperature measurement 20 C°; Shink 2020). This protocol was established in an effort to minimize the cumulative impact of handling/sampling and heat stress on adult salmon preparing to spawn. Due to persistent high water temperatures exceeding thresholds for safe fish handling no sampling was conducted for two weeks (July 7–20) in 2019. As a result, biological sample sizes were not only below target ranges, but were not distributed in proportion to the roughly equal passage numbers in each of the 4 periods.

E.5.3 References

Most Recent Project Published Operational Plan and Report

The original count data for Chinook and Chum Salmon runs were revisited for both the EF Andreafsky and Gisasa River weir projects to standardize the methodology for reconstructing missed segments of the runs (Brown et al. 2020). These complied and standardized data will be made available as supplemental materials for the manuscript: Population Trends for Chinook and Summer Chum Salmon in Two Yukon River Tributaries in Alaska (Brown et al. 2020) that was recently accepted for publication :

Brown, R. J., C. Bradley, and J. L. Melegari. 2020. Population Trends for Chinook and Summer Chum Salmon in two Yukon River Tributaries in Alaska. Journal of Fisheries and Wildlife Management. In press.

Data Sources

Conitz, J. 2019. Abundance and Run Timing of Adult Pacific Salmon in the East Fork Andreafsky River, Yukon Delta National Wildlife Refuge, Alaska. U.S. Fish and Wildlife, Alaska Fisheries Data Series Number 2019-02, Fairbanks.

Fleischman, S. J., and D. Evenson. 2010. Run reconstruction, spawner-recruit analysis, and escapement goal recommendation for summer Chum Salmon in the East Fork of the Andreafsky River. Alaska Department of Fish and Game, Fishery Manuscript Series No. 10-04, Anchorage.

Geiger, H. J., J. E. Clark, B. Cross, S. McPherson. 1990. Report from the work group on sampling. Pages 3-12 in Geiger, H. J., R. L. Wilbur, editors. Proceedings of the 1990 Alaska stock separation workshop. Alaska Department of Fish and Game, Special Fisheries Report No. 2, Juneau, Alaska.

Mears, J. D. 2015. Abundance and run timing of adult Pacific salmon in the East Fork Andreafsky River, Yukon Delta National Wildlife Refuge, Alaska, 2014. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series Number 2015-5, Fairbanks.

Mears, J. D., and J. Morella. 2017. Abundance and run timing of adult Pacific salmon in the East Fork Andreafsky River, Yukon Delta National Wildlife Refuge, Alaska, 2015. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series Number 2017-2, Fairbanks.

Sethi, S. A., and C. Bradley. 2016. Statistical arrival models to estimate missed passage counts at fish weirs. Canadian Journal of Fisheries and Aquatic Sciences 73:1251-1260.

Siegel, J. E., M. D. Adkison, M. V. McPhee. 2018. Changing maturation reaction norms and the effects of growth history in Alaska Chinook Salmon. Marine Ecological Progress Series 595:187-202.

E.6 Anvik River

- Have aerial survey program, described in Section G.5 *Lower River Aerial Surveys*.
- There is also a sonar program, briefly summarized below, which focuses on summer Chum and does not provide useful estimates of Chinook abundance.

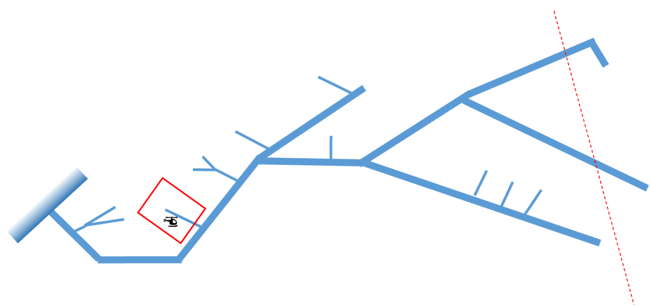

Figure E.2. Location of Anvik Surveys in the Lower Yukon

E.6.1 Project Summary - Anvik Sonar

Introduction

ADF&G has used a sonar and sampling program on the Anvik River to estimate Chum and pink salmon passage, as well as collect ASL data.

The purpose of the Anvik River sonar project is to monitor escapement of adult summer Chum salmon *Oncorhynchus keta* and pink salmon *O. gorbuscha* to the Anvik River drainage, one of the largest producers of summer Chum salmon in the Yukon River drainage. Chinook salmon *O. tshawytscha* and pink salmon spawn in the Anvik River concurrently with summer Chum salmon, with high abundance of pink salmon occurring on even years in the Yukon River drainage.

Dual-frequency identification sonar (DIDSON) was used to estimate adult summer Chum salmon and pink salmon passage in the Anvik River. Tower counts were used to apportion during even years the number of summer Chum and pink salmon migrating past the sonar. Because of the low proportion of Chinook and sockeye salmon migrating past the sonar site, these species were not proportioned in the daily estimates.

A formal data review of the Anvik River sonar project was not included in this data summary, because the primary focus of the project is to count summer Chum salmon. Estimates of Chinook salmon are not available because of their low proportion migrating past the sonar.

Most recent published report:

Brodersen, N. B. 2019. Sonar estimation of summer Chum and pink salmon in the Anvik River, Alaska, 2018. Alaska Department of Fish and Game, Fishery Data Series No. 19-23, Anchorage.

E.7 Nulato River

- Have tower/weir program, described in this section, and aerial survey program described in Section G.5 *Lower River Aerial Surveys*.

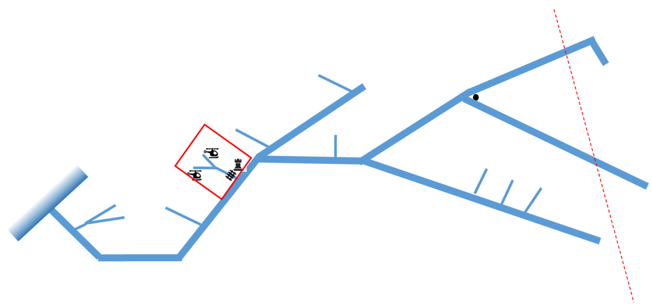

Figure E.3. Location of Nulato Surveys in the Lower Yukon

E.7.1 Project Summary - Nulato Tower/Weir

Introduction

Tower and weir counts on the Nulato River were implemented jointly by the Alaska Department of Fish and Game (ADF&G), Tanana Chiefs Conference (TCC) and Nulato Tribal Council. ASL samples are also collected.

Before 1994, salmon escapements to the Nulato River were previously indexed only by aerial surveys. Beginning in 1994, a cooperative tower counting project was formed by the Tanana Chiefs Council, Nulato Tribal Council and the Alaska Department of Fish and Game. The tower project operated from 1994 through 2002 and was mainly used to assess escapement of summer Chum salmon and few Chinook salmon were captured in beach seines for ASL information. Official abundance of spawning Chinook salmon was still based on aerial survey. A weir was established in 2003 to hopefully improve quality of abundance estimates and ASL data of both Chinook and Chum salmon.

The Nulato river is formed from two main branches, the North Fork and South Fork., which converge approximately 9 kilometer (km) above its mouth. Both forks of the Nulato River originate at an elevation of approximately 600 meter (m). The Nulato River tower site is located approximately 5 km up stream of the confluence of the Nulato and Yukon Rivers. The weir site was about 1.5 km upstream from the 1994-2002 tower site.

The tower was active from 1994 to 2002, and the weir in 2003.

Note: The tower was mainly used to count Chum so estimates of Chinook are considered conservative. Aerial survey index counts are used for the official count for escapement goal evaluation.

Methods - Tower

Tower counting operations were conducted 7 days a week, 24 hours a day, for a 15-minute period each hour on each bank. The left bank counting period began at the top of the hour and the right bank began at the bottom of the hour. The observer counted fish passage by species and noted the direction of movement (upstream or downstream). Hand-held tally counters were used to record the observed tower counts. These counts were then transferred to data forms immediately after completion of a shift. Each count was expanded for each hour and each bank by dividing the count by the proportion of the hour counted. Missed counts were estimated by averaging the counts for the hours before and after the missed hourly count. When salmon were not counted for a portion of a day, the expanded total daily count for that day was estimated by dividing the expanded partial daily count by the mean proportion of the count, for the corresponding hours for the day before and day after having full 24-hour counts. When counting was not conducted for a full day, the salmon passage estimate for that day was calculated as the mean salmon passage for the day before and after. When counting was not conducted for more than one full day, the passage for those days were estimated by interpolating between the last full day and first full day of counts after counting resumed.

The daily passage for each bank was calculated by summing the expanded hourly counts for each species, for each bank. The total daily passage estimate for each species was the sum of the expanded count for each bank.

Methods - Weir

All fish passing upstream through the passage chute / trap were enumerated by species. Each day the entrance of the trap was opened by 0700 hours to allow fish to enter the holding pen. The hinged gate was adjusted to ensure that fish could be identified by species, but without causing an undue obstacle for the fish. The technician was positioned above the exit gate and enumerates passage with zeroed multiple tally counters. Enumeration continues for 30 min, or until passage wanes to near zero, then the exit gate was closed. The technician immediately recorded the fish passage into a Rite-in-the-Rain notebook. This procedure was repeated five times throughout the day; even when passage was slow, to allow fish to pass upstream. The five scheduled 30-min counting periods each day were at 0700 hours, 1100 hours, 1530 hour, 1800 hours, and 2100 hours.

Where possible, counts that were missed were interpolated by taking the average of the count for the same hour on the day before and the day after the missed count.

Discussion

Critical assumption for the tower estimates include:

- All Chinook passage is visible from the tower.
- Passage of Chinook salmon is consistent within the hour
- There is minimal to no milling at the site so that fish are not counted multiple times.

Critical assumption for the weir estimates include:

- Once the weir is installed all adult salmon are unable to pass without going through the passage chute and being counted.

- ASL sampling is unbiased/representative of the fish population passing the weir at that point in time.

Tower and Weir operations are pretty straight forward and uncertainty is normally very low. No uncertainty was evaluated for these counts.

E.7.2 Project Details - Nulato Tower/Weir

The main operational change was the 2003 change from a tower counting project to using a floating panel weir.

Table E.5. Nulato Tower/Weir - Potential Data Issues

Years Affected	Potential Issue
1997	Last day of tower count not included in database as compared to daily count data in Crawford and Lingnau 2004. Including last day of count to season total estimate found in database.
1998	Not all daily tower counts in OceanAK database match those in Crawford and Lingnau 2004. Interpolation for missed counts updated in database. Using season total from database
1999	Not all daily tower counts in OceanAK database match those in Crawford and Lingnau 2004. Interpolation for missed counts updated in database. Using season total from database
2002	Daily counts on July 25 and 26 from the database do not match those in Crawford and Lingnau 2004. Looks to be data entry error in database. Using season total from Crawford and Lingnau 2004. (i.e. Not all daily tower counts in OceanAK database match those in Crawford and Lingnau 2004 but season total matches. Using season total from database.)
2003	Not all daily weir counts in OceanAK database match those in Crawford and Lingnau 2004. Counts expanded through postseason analysis and considered partial count due to high water. Using season total count from Crawford and Lingnau 2004.

E.7.3 References

Data Sources

Crawford, D. L., and T. L. Lingnau. 2004. Nulato River salmon escapement project, 2003. Alaska Department of Fish and Game, Division of Commercial Fisheries Regional Information Report 3A04-08, Anchorage.

Lingnau, T. L. 2002. Nulato River salmon escapement project, 2002. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A02-42, Anchorage

Sandone, G. J. 1995. Nulato River salmon escapement study, 1994. Alaska Department of Fish and Game, Regional Information Report 3A95-19, Anchorage.

E.8 Koyukuk River Watershed - Lower Yukon Stock Components

- On the Gisasa River, have tower/ weir program , described in this section, and aerial survey program described in Section G.5 *Lower River Aerial Surveys*.
- Note that Henshaw Creek, in the upper part of the Koyukuk watershed, is part of the Middle Yukon stock based on genetics. Henshaw Creek assessment is summarized in Section F.2.

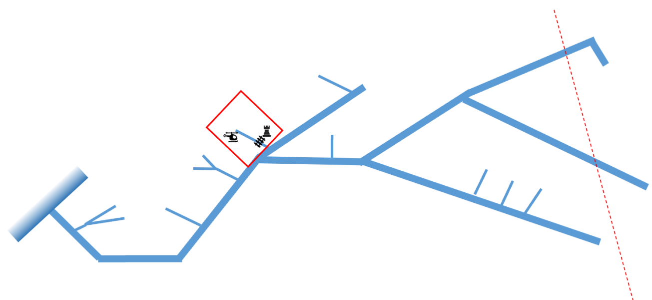

Figure E.4. Location of Gisasa Surveys in the Lower Yukon

E.8.1 Project Summary - Gisasa Tower/Weir

Introduction

The Gisasa River weir program is implemented by USFWS.

The project estimates salmon passage by species based on sonar (i.e. sound-based detection of size and direction of passign objects). Age-Sex-Length (ASL) data are also collected from fish sampled in a test fishery using drift gill nets.

The Gisasa River headwaters originate in the Nulato Hills, and the river flows northeast as it passes through the Koyukuk National Wildlife Refuge. Approximately 112 km from its source, the Gisasa River enters the Koyukuk River (**INSERT COORDINATES**, USGS 1:63,360 series, Kateel River B-4 quadrangle), 90 km upriver from the mouth of the Koyukuk River. The weir site is located approximately 4 km upriver from the mouth of the Gisasa River.

The weir program on the Gisasa River has generated annual estimates since 1995, except for 2014 and 2018.

Methods

A resistance board weir was used to enumerate and collect biological data from adult salmon as they migrated up the Gisasa River to spawn. The Gisasa River weir has been installed at the same site since the project was initiated in 1994, following the construction and installation methods described by Tobin (1994). Weir integrity checks were conducted daily to ensure weir remained “fish tight.” Age- Sex-Length (ASL) samples were collected from Chinook Salmon and Chum Salmon. More detailed description of methods can be found in Melegari and Wiswar (1995) and Carlson and Olson (2018).

Prior to 2014 fish were counted in real time from the top of the trap box as they passed through the counting chute. Beginning in 2014 a video counting system was integrated into the project. The video system was installed on the upstream side of the weir trap box to capture video footage of migrating salmon and other species. Fish are funneled into a narrow passage chute in front of the video camera box that allowed for the continual movement of fish through the weir, and video recording of all fish passing through the weir. Once video counting began, motion capture features were enabled, and all counting was conducted from individual motion capture files. Motion capture files were saved to a hard drive and reviewed hourly. Fish were identified to species and total hourly counts were entered into an electronic data sheet daily. The video box was equipped with LED lights so that fish could be observed 24 hours per day. Adjustments to video settings and equipment were made as necessary to optimize image quality and performance of the system. During the first week of weir operation, motion capture performance was closely observed to verify that settings were adjusted properly and all fish passing the camera were detected.

Discussion

Critical assumptions include:

- Once the weir is installed all adult salmon are unable to pass without going through the passage chute and being counted.
- The video system is capturing all passing fish.
- ASL sampling is unbiased/representative of the fish population passing the weir at that point in time.

E.8.2 Project Details - Gisasa Tower/Weir

Table E.6. Gisasa Tower/Weir - Operational Timeline

Years	Component	Change/Event
2014	Counter	Integration of video counter.
Various	ASL	Minor changes in ASL sampling schedules have occurred over the years, but these are assumed to have negligible impact on the data.

Table E.7. Gisasa Tower/Weir - Potential Data Issues

Years Affected	Potential Issue
2014	High water interrupted counting during a considerable portion of the peak of the run.
2017	Warm water temperatures caused delays in sampling procedures at various times on different days (including one 38-hour block of time between 7/14 at 1700 and 7/16 at 0700).
2019	First extended block of time (6 full days) July 10 to July 15 that could not be sampled due to high water temperatures.

E.8.3 References

Most Recent Project Published Operational Plan and Report

Carlson, J.G. and M.L. Olson 2018. Abundance and run timing of adult salmon in the Gisasa River, Koyukuk National Wildlife Refuge, Alaska, 2017. U.S. Fish and Wildlife Service, Fairbanks Fishery Resource Office, Alaska Data Series 2018-7, Fairbanks, AK.

Data Sources

Melegari, J.L. and D.W. Wiswar. 1995. Abundance and run timing of adult salmon in the Gisasa River, Koyukuk National Wildlife, Alaska, 1994. U.S. Fish and Wildlife Service, Fairbanks Fishery Resources Office, Fishery Data Series Number 95-1, Fairbanks, Alaska.

Tobin, J. H. 1994. Construction and performance of a portable resistance board weir for counting migrating adult salmon in rivers. U.S. Fish and Wildlife Service, Kenai Fishery Resource Office, Alaska Fisheries Technical Report Number 22, Kenai, Alaska.

E.9 Tozitna River

On the Tozitna River, have weir program , described in this section, and aerial survey program described in Section G.5 *Lower River Aerial Surveys*.

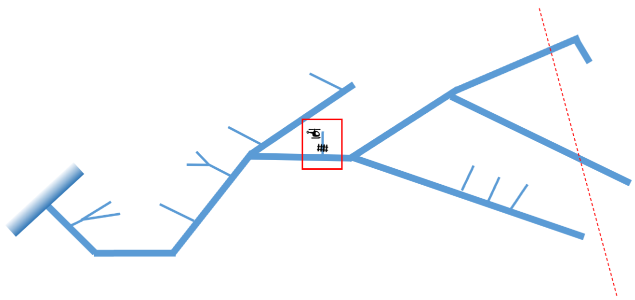

Figure E.5. Location of Tozitna Surveys in the Lower Yukon

E.9.1 Project Summary - Tozitna Weir

Introduction

In 2001 the Bureau of Land Management began a cooperative project with the Tanana Tribal Council to evaluate the feasibility of enumerating adult salmon escapement within the Tozitna River drainage using a counting tower and partial weir. Salmon escapement and run timing were assessed by visually identifying and counting fish from a 7.3 m high viewing platform on the North side of the river, for at least 30 minutes of every hour, 24 hours a day and seven days a week. Age, sex and length (ASL) data were also collected.

The project was active from 2001 to 2009.

The weir site was located at lat 65º 31.0980' N, long 152º 12.8622' W, approximately 80 km upstream from the mouth of the Tozitna River and approximately 0.5 km upstream from the Tozitna River's confluence with Dagislakhna Creek.

Methods

Salmon escapement, run timing, and composition were assessed from 2002-2009 by counting and sampling fish as they passed through the resistance board weir fitted with a live trap. The weir was 60 m wide and typically operational by the end of June. The weir was cleaned and inspected on a daily basis to remove debris and ensure that the trap provided the only avenue for fish passage.

All salmon passing through the weir and live trap were counted and identified to species. Observers wore polarized sunglasses to facilitate in fish identification. Counting occurred 24 hours per day, 7 days per week and consisted of four 6-hour shifts. During daily sampling efforts the trap could be closed for up to 45 minutes. On average, salmon were able to pass through the trap within 15 minutes after entering. Hourly counts were summed to achieve a daily count

(0000 – 2359 hours). Run timing was calculated by the proportion of daily to cumulative passage to determine quartile (25%, 50%, and 75%) dates, peak, and median date of passage.

Discussion

Critical assumptions include:

- Once the weir is installed all adult salmon are unable to pass without going through the passage chute and being counted.
- ASL sampling is unbiased/representative of the fish population passing the weir at that point in time.

No formal evaluation of uncertainty was conducted for escapement counts. Some years missed days were interpolated and included in the final estimate. Standard Error (SE) was calculated for the ASL data.

E.9.2 Project Details - Tozitna Weir

Table E.8. Tozitna Weir - Operational Timeline

Years	Change/Event
2001	Feasibility of enumerating adult salmon escapement within the Tozitna River drainage using a counting tower and partial weir. Salmon escapement and run timing were assessed by visually identifying and counting fish from a 7.3 m high viewing platform on the North side of the river, for at least 30 minutes of every hour, 24 hours a day and seven days a week.
2002	Tower was discontinued and all counting and sampling of fish took place as they passed through a resistance board weir fitted with a live trap.
2005	The weir was relocated 200 m downstream of its original (2002-2004) location due to a change in channel morphology. The Tozitna River weir remained in the same location for the duration of the project (2005-2009).

Table E.9. Tozitna Weir - Potential Data Issues

Years Affected	Potential Issue
2002 - 2004, 2006 - 2008	Increased discharge in 2002, 2003, 2004, 2006, 2007, and 2008 affected operation of the weir, either forcing the crew to let fish pass undetected for a matter of hours or days and interpolate data later or to pull the project completely before salmon escapement had been satisfactorily enumerated. Only in 2005 and 2009 were complete counts of both summer chum and Chinook salmon achieved.

Years Affected	Potential Issue
2003	No interpolation was done for missing days of counts.
2004	High stream discharge from the period of 1 to 3 August prevented counting and biological sampling; counts were interpolated for this period.
2006	Count is considered incomplete due to a 6 day period of missing counts during high stream discharge.
2008	In 2008 heavy rain in the upper Tozitna River watershed forced closure of the fish trap at 2100 on 2 August after the weir panels became submerged until 1030 on 5 August.

E.9.3 References

Data Sources

S.R. Beaudreault, J.W. Post, C.F. Kretsinger, and B.R. Karlen, 2010. Abundance and Run Timing of Adult Salmon in the Tozitna River, Alaska, 2001-2009. U.S. Fish and Wildlife Service, Office of Subsistence Management, Fisheries Resource Monitoring Program, Final Report (Study No. 07-208), Anchorage, Alaska.

APPENDIX F   Middle Yukon Assessment Project Descriptions

F.1   Overview

Stock assessment on the middle Yukon River includes;

- Weir on the Henshaw River in the upper Koyukuk watershed. Note that surveys on the Gisasa River, in the lower Koyukuk watershed, are grouped with the Lower Yukon assessment projects, but Henshaw Chinook are genetically grouped with the Middle Yukon stock, and so are included here.
- Various surveys on three tributaries of the Tanana watershed:
  - Radio Mark-Recapture estimates for Tanana
  - Chena River with various ground surveys over time (mark-recapture, weir/tower, sonar) and an aerial program
  - Salcha River with various ground surveys over time (mark-recapture, tower, sonar) and an aerial program
  - Goodpaster River with a tower and and aerial program

These tributary surveys cover the main known spawning sites.

Note that there is also data from a fish wheel CPUE program at Rampart Rapids on the mainstem, which we briefly summarize in this appendix, but did not include in the main results, due to the poor match between Rampart Rapids CPUE and other estimates of border passage (See summary in Table 8, and details in Section F.6).

F.2 Henshaw Creek

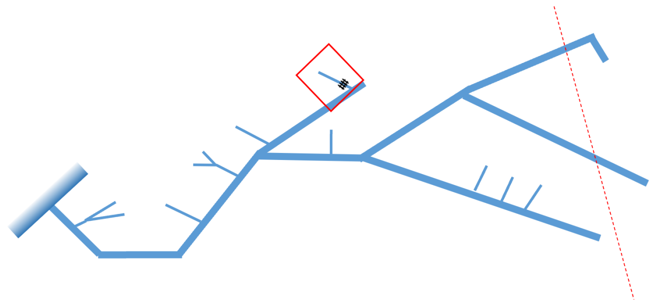

Figure F.1. Location of Henshaw Surveys in the Middle Yukon

F.2.1 Project Summary - Weir

Introduction

Henshaw Creek Weir is located in the Kanuti National Wildlife Refuge (66° 33'N, 152° 14' W). weir operations collect daily passage counts and age, sex, length (ASL) data. The weir has been operated by various organizations since 2000: United States Fish and Wildlife Service (USFWS)-Fairbanks Fish and Wildlife Conservation Office (FFWCO) from 2000-2004, USFWS-FFWCO and Tanana Chiefs Conference (TCC) from 2005-2007, and TCC from 2008 – present.

Methods

The weir has been at the same location every year since the project's inception (2000 – 2019), which is approximately 1.5 km upstream from the mouth of Henshaw Creek.

A resistance board weir was used to collect escapement counts and biological information from adult salmon as they migrated into Henshaw Creek to spawn. The start date was based on previous years' run timing data. The end date of the project was determined inseason when the daily count of each species dropped to less than 1% of the seasonal passage to date and continued at this low level for three or more consecutive days. The construction and installation of resistance board weirs was described by Tobin (1994). Each picket of the weir was made of schedule-40, polyvinyl chloride electrical conduit with 2.5 cm inside diameter and individual pickets spaced 3.2 cm apart. During daily visual inspection, the weir was cleaned of debris, fish carcasses, and gravel dislodged by spawning fish. A live trap installed near mid-channel allowed salmon and resident fish species to be recorded as they passed through the weir.

A stratified random sampling scheme was used to collect age, sex, and length ratio information from both adult salmon species. Sampling started at the beginning of each week and generally was conducted over a 3-4 day period, targeting 160 salmon/species/week. Scales were used for ageing salmon with age class information being reported using the European technique (Foerster 1968). Three scales were collected from Chinook salmon and one scale from chum salmon. Scales were sampled from the area located on the left side of the fish and two rows above the lateral line on a diagonal from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin. Scales from both adult salmon species were sent to ADF&G for processing. Lengths of Chinook and chum salmon were measured to the nearest 5 mm from mid-eye to fork of the caudal fin. Sex ratio data were collected during age and length sampling. Sex of each fish was visually determined by secondary sex characteristics. Daily escapement counts and sex rations were reported to USFWS-FFWCO in Fairbanks.

Discussion

Critical assumptions include:

- All fish within a spawning tributary are counted and accurately identified to species by observers.
- The ASL data are accurately reported and that age-sex proportion estimates of subsampled individuals are reflective of the broader spawning population.

Uncertainty evaluation:

- No formal estimate of error bounds.
- When daily counts were missed due to high water, the missing daily counts were estimated by linear interpolation between the daily count before and after the high water event.
- Incomplete 24-h counts due to high water were adjusted for a 24-h period.

F.2.2 Project Details

Table F.1. Henshaw Creek Weir Surveys - Potential Data Issues

Years Affected	Potential Issue
2000, 2003	The weir was only operational for part of the season due to high water for most of the season, which caused the counting schedule to be interrupted at times. On occasions when water level rose high enough to impede the counting schedule the weir remained intact but weir panels were submerged allowing fish to pass undetected.
2006	The first summer chum salmon was counted on June 30. Daily escapement counts, hydrological and weather information were reported seven days a week by satellite phone to the FFWFO. Due to heavy rains, the Henshaw Creek weir flooded on July 1 and remained flooded for the rest of the field season. By July 27, the water level had dropped sufficiently to remove the weir.

Years Affected	Potential Issue
2007	The first Chinook and summer chum salmon were counted on July 2. Due to heavy rains, the Henshaw Creek weir flooded on July 16 through 1430 on July 21 and again on August 6. The preliminary escapement count was 569 Chinook salmon, and 32,085 summer chum salmon. Missed counts were interpolated postseason and annual estimate updated.
2010	The weir was operational beginning on June 23 and ending August 8. Two interruptions to weir operations occurred due to high water events: July 7 – 9 and July 22. Daily estimates of Chinook and summer chum salmon passage were estimated for the days that were missed due to high water by using linear interpolation as outlined in the methods section of the annual report.
2013	The weir was operational beginning on June 30 and ending on August 5. One high water event interrupted weir operations and suspended enumeration efforts for nearly four and a half days, beginning at 22:45 hours on July 9 and ending at 12:00 hours on July 14. The partially enumerated days of July 9 and 14 were adjusted to provide full day passage estimates. However, no interpolation was made to estimate the passage for the complete missed days, July 10 – 13. No interpolation was made due to the timing of the high water event coupled with the size of the escapement on July 9 and July 14. The first day of escapement for both species was July 9. Estimated escapement on July 9 was one Chinook salmon and 42,528 chum salmon. During the period of interruption, the trap door on the weir was left closed, blocking passage of salmon for 3.5 days of the 4.5 day period. The trap door was opened to allow for unimpeded migration for the last 24 hours of the 4.5 day period. While the trap door was closed, it is assumed that the majority of both salmon species were unable to migrate upstream of the weir. However, it is possible that a portion of both salmon species were able to migrate over the weir as the weir was underwater during this high water event.
2014	The weir was not installed nor operated due to sustained flooding in Henshaw Creek. High water persisted from mid-June through July 29, at which point in time the decision was made to forgo weir installation as the majority of the run had already passed through the weir site.
2016	Two high water events interrupted weir operations. The first high water event occurred between 09:00 hours on July 5 and 23:59 hours on July 8. This event temporarily suspended ASL sampling, but did not suspend escapement enumeration. The second high water event occurred between 19:30 and 22:00 hours on July 11. This event suspended escapement enumeration. The trap door was left open during this event as to not block passage through the weir. The partially enumerated day of July 11 was adjusted to a full day count using linear interpolation as outlined in the methods sections of the annual report.

Years Affected	Potential Issue
2018	The weir was not installed nor operated due to sustained flooding in Henshaw Creek. High water persisted from mid-June through July 21, at which point in time the decision was made to forgo weir installation as the majority of the run had already passed through the weir site.
2019	The weir was operational with enumeration beginning on June 30 and ending on August 2. Smoke from a nearby wildlife interrupted weir operations for six hours on July 13. Enumeration was suspended between midnight and 5:59am, with normal weir operation resuming at 6:00am. The door on the trap of the weir was left open during the 6-hour interruption to allow for salmon and other resident fish species to migrate freely up and down river. The partially enumerated day of July 13 was adjusted to a full day count using linear interpolation as outlined in the methods sections of the annual report
2020	The weir was not installed nor operated due to the COVID-19 pandemic.

F.2.3 References

Data Sources

Data was compiled from previous reports from USFWS-FFWCO and TCC.

Reports

Fairbanks Fish and Wildlife Field Office. 2005. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2000. Alaska Fisheries Data Series Number 2005-1, Fairbanks.

VanHatten, G. K. 2002. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2001. U.S. Fish and Wildlife Service Office of Subsistence Management Annual Report No. FIS00-025-2, Fairbanks.

VanHatten, G. K. 2003. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2002. U.S. Fish and Wildlife Service, Office of Subsistence Management, Annual Report No. FIS00-025-3, Fairbanks.

VanHatten, G. K. and M. Voight. 2005. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2000-2003. Alaska Fisheries Data Series Number 2005-11, Fairbanks.

O'Brien, J. P. and B. L. Berkbigler. 2005. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2004. Alaska Fisheries Data Series Number 2005-15, Fairbanks.

Berkbigler, B. and K. Elkin. 2006. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2005. Alaska Fisheries Data Series Number 2006-9, Fairbanks.

Berkbigler, B. and T. McLain. 2007. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2006. U.S. Fish and Wildlife Service Fisheries Information Services Annual Report FIS-05-211, Fairbanks.

Berkbigler, B. L. 2010. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2007. U.S. Fish and Wildlife Service, Office of Subsistence Management, Annual Report No. FIS 05-211, Fairbanks.

Dupuis, A. W. and B. L. Baker. 2008. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2008. Tanana Chiefs Conference, Fisheries Program, Annual Report FIS 08-201.

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Dupuis, A. W. 2010. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2010. Tanana Chiefs Conference, Fisheries Program, Annual Report FIS 08-201.

Dupuis, A. W. 2011. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2008 – 2011. Tanana Chiefs Conference, Fisheries Program, Annual Report FIS 08-201.

McKenna, B. and A. Frothingham. 2012. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2012. Tanana Chiefs Conference, Fisheries Program, Annual Report FIS 12-202.

McKenna, B. 2013. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2012 – 2013. Tanana Chiefs Conference, Fisheries Program, Annual Report FIS 12-202.

McKenna, B. 2014. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2014. Tanana Chiefs Conference, Fisheries Program, Annual Report FIS 14-209.

McKenna, B. and N. Farnham. 2016. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2015. Tanana Chiefs Conference, Fisheries Program, Annual Report FIS 14-209.

Farnham, N. and B. McKenna. 2017. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2014 – 2016. Tanana Chiefs Conference, Fisheries Program, Annual Report FIS 14-209.

Farnham, N. 2018. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2017. Tanana Chiefs Conference, Fisheries Program, Annual Report FIS 16-204.

Farnham, N. 2019. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2018. Tanana Chiefs Conference, Fisheries Program, Annual Report FIS 16-204.

Rowe, R. E. and B. McKenna. 2020. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2017 – 2019. Tanana Chiefs Conference, Fisheries Program, Annual Report FIS 16-204.

F.3 Chena River

- The main assessment program has used different surveys types for different years (mark-recapture program, weir/tower program, sonar), and is supplemented by an aerial survey program. The main program is described in this section, the aerial survey program is described in Section G.6 *Middle River Aerial Surveys*.

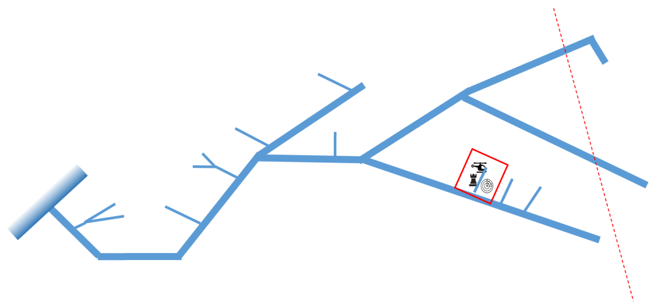

Figure F.2. Location of Chena Surveys in the Middle Yukon

F.3.1 Project Summary - Chena Surveys

Introduction

The Chena River is a 160km tributary of the Tanana River. Tower/Sonar location is on the upstream side of the Moose Creek Dam on the Chena River.

Annual Chinook salmon escapement on the Chena River has been calculated various ways. The project started in 1986 as a standard Mark-recapture project. Chinook salmon were electroshocked in the lower river and marked. Then carcass surveys were conducted on and below the spawning grounds as the second event. Counting tower techniques were put into place around 1993. Mark-recapture experiments were still undertaken when an estimate from tower count methods was not possible. Enumeration with sonar was added starting in 2007 to supplement visual tower counts during high and turbid water events.

In summary, the following data are available:

- Annual Chinook Escapement data (1986-2019)
- Raw age, sex and length data from carcass samples (1975-2019)
- Aerial survey data completed by Alaska Department of Fish and Game, Sport Fish Division (1971-2014)

Methods - Mark-Recapture

The experiment was designed to estimate the abundance of Chinook salmon escaping to spawn in the Chena River using two-sample mark-recapture techniques for a closed population:

- Marking Event: A river boat equipped for electrofishing was used to capture adult Chinook salmon. The approximately 80 km reach of the Chena River where the majority of the Chinook salmon spawning occurs was divided into two sections that were roughly equal in length. The first section began at the Chena River dam and spanned river km 72 – 115; the second section spanned river km 116 –150. All fish were individually tagged with a uniquely numbered jaw tag and measured to the nearest 5 mm from mid-eye to fork of the tail (MEF). In addition to the jaw tag, a secondary fin clip was applied which varied according to the week and river section of tagging.
- Recapture Event/Carcass Survey: After the marking events, carcasses were collected and inspected for tags and fin clips during two complete surveys of the study area.

Methods - Tower

Daily escapements of Chinook and chum salmon were estimated using counting towers on the Chena River. White fabric panels were laid on the river bottom on the upstream side of the Moose Creek Dam on the Chena River. Over the course of the salmon run, personnel stood on scaffolding towers and counted all salmon moving upstream and downstream across the white panels for 20-minute intervals beginning at the top of every hour. Lights were suspended over the panels to provide illumination during periods of low ambient light.

The numbers of Chinook and chum salmon passing up- and downstream across the panels were recorded on field forms at the end of each 20-min count. Only counts with an associated water clarity rating of 1–3 were used in the estimate of escapement. A count with an associated water clarity rating of 4 or 5 was considered as not counted. Five technicians were assigned to each river to enumerate the salmon escapement. Each day was divided into three 8-hour shifts: Shift I began at 0000 (midnight) and ended at 0759, Shift II began at 0800 and ended at 1559, and Shift III began at 1600 and ended at 2359.

Methods - Sonar

In conjunction with the counting towers, 2 sonars were deployed upstream of the white fabric panels on the Chena River to estimate the number of migrating salmon during periods of low visibility. One dual-frequency identification sonar (DIDSON) and one adaptive resolution imaging sonar (ARIS) were deployed on opposite sides of the river, upstream of the Chena counting tower. Images were recorded 24 hours a day, 7 days a week for the project duration. Both the DIDSON and ARIS units were mounted to portable aluminum stands that could be moved manually to adjust for changing water depth. Additionally, all units incorporated rotators that enabled remote adjustment and focusing. Weir structures were deployed behind each unit to ensure migrating salmon passed through the sonar beam. When daily visual counts were available and water clarity ratings were greater than 3, the paired estimates were used to evaluate the effectiveness of the sonar.

Inseason and postseason, all fish >450 mm in length in the DIDSON sonar images were measured and recorded using Echotastic, a software program developed to process sonar images. Historical length distributions of chum and Chinook salmon from the Chena and Salcha Rivers have illustrated that no salmon are less than 450 mm in length. The estimated lengths from the sonar images, along with the associated dates of tower passage, were later used in a Bayesian mixture model that also incorporated historical length and run-timing data to apportion and estimate numbers of Chinook and chum salmon from the total sonar count.

Methods - Age/Sex/Length Data

Age, sex and length data has been collected from returning live Chinook salmon via electrofishing and spawned-out, dead Chinook salmon. Sex is determined by primary or secondary sexual characteristics or by external palpitation for eggs or milt. Length data is measured in mm as mid-eye to fork of tail. Scales are collected and age is determined from scale patterns as described by Mosher. Gear for collecting ASL data has changed over the years but sampling techniques have not. Uncertainty is not calculated for this data because it is simply a census of all raw data collected.

Discussion

For the mark-recapture estimate of abundance to be unbiased, certain assumptions must be met (Seber 1982). These assumptions, expressed in the circumstances of this study, along with their respective design considerations and test procedures will be that:

- Assumption I: The population is closed to births, deaths, immigration and emigration.
- Assumption II: Marking and handling did not affect the catchability of Chinook salmon in the second event.
- Assumption III: Tagged fish did not lose their tags between the two sampling events.
- Assumption IV: One of the following three conditions needed to be met: (1) All Chinook salmon had the same probability of being caught in the first event; (2) All Chinook salmon had the same probability of being captured in the second event; or, (3) Marked fish mixed completely with unmarked fish between samples.

Critical assumptions for the Tower/Sonar surveys include: * Most fish pass within range of the sonar and are detected. All Chinook passage is visible from the tower. * Passage of chinook salmon is consistent within the hour. * No diurnal changes to fish passage and that the sampling plan is sufficient to estimate passage over a full day. * There is minimal to no milling at the site so that fish are not counted multiple times.

Uncertainty Evaluation

Estimates of Chinook salmon escapement were stratified by day and daily estimates were summed to estimate total escapement. Daily escapement was estimated and put into 1 of 5 categories, depending on the frequency of successful counts:

- Two or more 8-hour shifts per day were considered complete (i.e., a minimum of 4 counting periods per shift were sampled)
- Only one 8-hour shift per day was considered complete but at least 4 counting periods are sampled.
- No 8-hour shifts were considered complete on a given day, interpolation techniques were used to estimate escapement. This approach was used when no 8-hour shifts for 1 or 2

consecutive days of counting were considered complete. Postseason escapements for these dates were estimated using the mixture model that apportions the sonar counts of salmon by species.

- When all 8-hour shifts on 3 or more but fewer than 10 consecutive days were considered incomplete, no inseason daily escapement values were reported and postseason daily escapement values were assessed using a mixture model that apportioned the sonar counts of salmon by species.
- When visual counting could not be conducted for an excessive number of days during the run (e.g., more than 10 consecutive days or more than 20 total days), or when neither visual counts nor sonar counts could be conducted for 3 or more consecutive days (i.e., high water and inoperative sonar equipment), a Bayesian hierarchical model was used to estimate escapement for the missed days (if <25% of the total run) using characteristics of the run-timing.

Uncertainty is calculated as the standard error for the final escapement estimate. Specific detailed methods can be found in the reports listed in the Reference section.

F.3.2 Project Details - Chena Surveys

Table F.2. Chena Main Surveys - Operational Timeline

Years	Component	Change/Event
1986 to 1992	Method	Escapement estimated using a Petersen mark-recapture experiment. This type of experiment required two events. During the first event, a sample of the population was captured, marked, and released back into the population. During the second event, after allowing time for the marked and unmarked fish to mix, another sample was collected and examined for marks.
1993	Method	First year using visual counting techniques. Chinook and chum salmon were counted during 20 min periods each hour as they passed beneath the Moose Creek Dam on the Chena River. Chinook salmon were captured and tagged near Manley on the Tanana River to estimate the migration time to the Salcha and Chena rivers. Four-hundred thirteen chinook salmon were captured and 403 were tagged and released from 12-15 July. The tagged salmon were counted as they passed the counting sites on each river and as they were caught in the commercial and subsistence fisheries.
1993 to 2006	Method	Tower counts were the main method of assessment but a Mark-Recapture experiment was undertaken when an estimate wasn't possible from tower count methods
2007 to present	Method	Starting in 2007, Dual-frequency Identification Sonar (DIDSON) was used to enumerate migrating fish during periods of high-water. A DIDSON was deployed and a mixture model based on length was used to allocate the total count of salmon passing the sonar into numbers of Chinook and chum salmon. Results were compared to actual tower counts and suggested this methodology is an appropriate means to estimate passage when conditions prohibit tower counts.
2014	Challenge	No visual counts from towers were possible. two DIDSON (Model 300 short range) transducers were used to enumerate migrating fish and were deployed just upstream of the counting panels. Chinook and chum salmon were estimated using a mixture model with fish length being the discriminating information, weakly informed by run timing. The sonar enumeration methodology was developed and added onto the tower enumeration project as a means to estimate escapement when visual counts were not possible.

Years	Component	Change/Event
2019	Method	Starting in 2019, changes were implemented in how sport fish reported the Chinook and Chum salmon numbers for the Chena and Salcha Rivers inseason. They continued to report the expanded visual counts as usual for Chinook and chum salmon. For days when no visual counts, the top-of-the-hour sonar files will be completed and any fish over 650mm (cutoff chosen based on historic length compositions) was considered a Chinook salmon. Fish that fell below the 650mm cutoff value will be considered a mix of kings and chum. The sonar counts were treated like visual counts and expanded for the full hour. The expanded sonar counts for both fish over 650 and fish under 650 were reported on the daily update spreadsheet. These changes dramatically reduced workload and allowed for more immediate data particularly when visual counts are not available. Additionally, final estimates were available shortly after the season ended instead of several months later.

Table F.3. Chena Main Surveys - Potential Data Issues

Years Affected	Potential Issue
1993	First year using visual tower count operations to estimate escapement.
1994	Extreme high water during late June and early July postponed installation of flash panels five days in the Salcha River and eight days in the Chena River from the planned start date of 1 July. Chinook salmon were observed on the first day of counting, (8 July) in the Chena River, but not until the second day of counting (6 July) in the Salcha River.
1995	Because of the large number of missed tower counts on the Chena River due to high water and poor counting conditions, the estimate of total chinook salmon passage was deemed inadequate, and a two-sample mark-recapture experiment was conducted to estimate abundance.
1996	Large number of missed counts on both the Salcha and Chena rivers due to high water and poor counting conditions, estimates of total chinook salmon passage were deemed inadequate, and two-sample mark-recapture experiments were conducted as the sole estimate of abundance for each system.
1997	A Mark/recapture experiment was conducted but the tower count was used as the official estimate of passage.
1998	Poor counting conditions prevented counts from being conducted on 9, 10, 15, 18, and 25-28 July. Missed counts were interpolated.
2000	Heavy rain and subsequent high water and poor visibility prevented counting from 11 through 16 July. An escapement estimate based on tower counts was not possible. Consequently, a mark-recapture experiment was conducted in order to acquire an estimate of total abundance.
2001	Poor counting conditions prevented counts from being conducted during 8-9 July and on 15 July. Total count includes interpolated estimates for the missed days.
2002	Complete tower counts were only accomplished during 10 of the 28 days of the run, and the peak of the run was not included. The decision was made to proceed with a mark-recapture experiment to estimate escapement abundance.
2003??	No interpolation for missed counts, represents a minimum estimate of escapement.
2004	Because fish were known to have passed upriver during the high smoke conditions, and counting tower operations ceased before the end of the chum salmon run, the 2004 escapement estimates of 9,645 Chinook salmon (SE=532) and 15,162 chum salmon (SE=648) are biased low and considered minimums. Because more than 12 consecutive shifts were missed during the high smoke conditions; the days when counting could not occur were not interpolated for.

Years Affected	Potential Issue
2005	High water events prevented an annual escapement estimate. No mark-recapture experiment was performed in 2005 because although the tower count was a failure, none of the criteria for performing a mark-recapture experiment as described in the methods were met.
2006	Counts are biased low and considered minimums. Because more than 12 consecutive shifts were missed during the high water conditions; the days when counting could not occur were not interpolated for.
2011	Unable to provide an annual estimate with both the tower and sonar due to high water events.
2012	Majority of daily estimates came from visual tower counts except for July 21 – July 26th which were estimated from sonar.
2013	Recorded DIDSON images of migrating salmon were collected from 8 July through 4 August. A high water event from 22 July through 23 July prevented tower counts, but this data gap was less than 2 days, and the moving average estimator was used to estimate the daily escapements
2014	No visual counts. Estimates based on Didson mixture model.
2015	Escapement estimate based on both visual and sonar counts.
2017	High water events caused an extended period of poor visibility that required the use of sonar technology to estimate fish passage. Postseason, a length-based mixture model was used to apportion sonar targets during the low visibility period and the total was added to expanded visual counts and single days of interpolated data.

F.3.3 References - Chena River Assessment

- Data sources: AYK database management system. AYKDBMS Home Page (alaska.gov)
- ADF&G Publication Database: Publications Search - Sport Fish - ADF&G (alaska.gov)

Most Recent Project Published Operational Plan and Report

Matter, A. N., and M. Tyers. 2020. Chinook salmon escapement in the Chena and Salcha Rivers and coho salmon escapement in the Delta Clearwater River, 2017. Alaska Department of Fish and Game, Fishery Data Series No. 20-01, Anchorage.

Matter, A. N., and M. Tyers. 2019. Chinook salmon escapement in the Chena and Salcha Rivers and Coho salmon escapement in the Delta Clearwater River, 2019-2023. Alaska Department of Fish and Game, Regional Operational Plan ROP.SF.3F.2019.03, Anchorage.

Data Sources

Huang, J. 2012. Sonar-based Chena River salmon assessment 2008. Alaska Department of Fish and Game, Fishery Data Series No. 12-39, Anchorage.

Savereide, J.W. 2012. Salmon studies in the Chena, Salcha, Goodpaster, and Delta Clearwater rivers, 2010. Alaska Department of Fish and Game, Fishery Data Series No. 12-05, Anchorage.

Savereide, J. W. 2012. Salmon studies in the Chena, Delta Clearwater, Goodpaster and Salcha rivers, 2007-2009. Alaska Department of Fish and Game, Fishery Data Series No. 12-03, Anchorage.

Stuby, L., and M. Tyers. 2016. Chinook salmon escapement in the Chena, Salcha, and Goodpaster rivers and coho salmon escapement in the Delta Clearwater River, 2015. Alaska Department of Fish and Game, Fishery Data Series No. 16-45, Anchorage.

Stuby, L., and M. Tyers. 2018. Chinook salmon escapement in the Chena and Salcha rivers and coho salmon escapement in the Delta Clearwater River, 2016. Alaska Department of Fish and Game, Fishery Data Series No. 18-13, Anchorage.

F.4 Salcha River

- The main assessment program has used different surveys types for different years (mark-recapture program, tower program, sonar), and is supplemented by an aerial survey program. The main program is described in this section, the aerial survey program is described in Section G.6 *Middle River Aerial Surveys*.

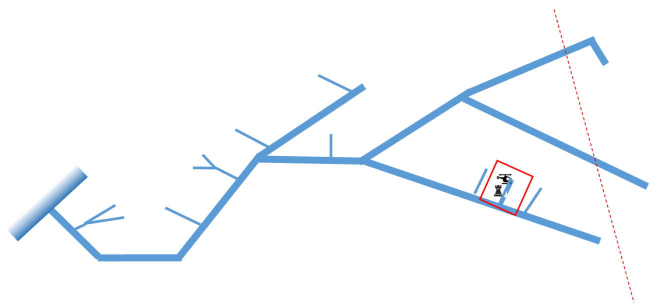

Figure F.3. Location of Salcha Surveys in the Lower Yukon

F.4.1 Project Summary - Salcha Main Surveys

The Salcha River is a 201 km tributary of the Tanana River. Tower/Sonar location is approximately 1 km upriver of the Richardson Highway Bridge on the Salcha River.

The program has been implemented by Alaska Department of Fish and Game Sport Fish Division since the 1970s, with changes in implementation:

- Annual Chinook Escapement data (1987-2019)
- Raw age, sex and length data from carcass samples (1975-2019)
- Aerial survey data completed by sportfish (1971-2014)

Annual Chinook salmon escapement on the Salcha River has been calculated various ways. ADF&G Sport Fish Division conducted mark-recapture abundance estimates on the Salcha River between 1987 and 1992 and again in 1996. Chinook salmon were electroshocked in the lower river and marked. Then carcass surveys were conducted on and below the spawning grounds as the second event. Tower-count estimates began in 1993 and continued through 1998. After 1998, Sport Fish Division discontinued efforts to estimate chinook salmon abundance in the Salcha River. Bering Sea Fisherman's Association (BSFA) contracted with a Fairbanks fisheries consultant to conduct tower counts from 1999 to 2015. ADF&G Sport Fish Division took over the tower project again in 2016 through present and supplemented tower counts with a sonar to enumerate passage when visual counts were not possible due to high and turbid water.

In summary, the following data are available:

- Annual Chinook Escapement data
- Raw age, sex and length data from carcass samples
- Aerial survey data completed by sportfish
- Age composition data
- Run data including harvest

Methods - Mark-Recapture

- *Marking Event*: A river boat equipped for electrofishing was used to capture adult Chinook salmon. All fish were measured to the nearest 5 mm (mid-eye to fork-of-tail), marked by attaching an individually numbered jaw tag and by removing a fin, and released alive. Fish were marked during two complete passes through the study section. Each pass required four days to complete. The timing of the marking events were centered around the short period after completion of immigration and spawning and before fish began to die. The study areas were divided into three sections roughly equal in length. Due to potential loss of tags, a unique fin clip was given corresponding to time (first or second pass) and location (river section) of tagging.
- *Recapture Event/Carcass Survey*: After the marking events, carcasses were collected and inspected for tags and fin clips during two complete surveys of the study area.
- *Estimation of Abundance* : The experiment was designed to estimate the abundance of Chinook salmon escaping to spawn in the Chena River using two-sample mark-recapture techniques for a closed population.

Methods - Tower

- Daily escapements of Chinook and chum salmon were estimated using counting towers on the Salcha River. White fabric panels were laid on the river bottom on the upstream side approximately 1 km upriver of the Richardson Highway Bridge on the Salcha River. Over the course of the salmon run, personnel stood on scaffolding towers and counted all salmon moving upstream and downstream across the white panels for 20-minute intervals beginning at the top of every hour. Lights were suspended over the panels to provide illumination during periods of low ambient light.
- The numbers of Chinook and chum salmon passing up- and downstream across the panels were recorded on field forms at the end of each 20-min count. Only counts with an associated water clarity rating of 1–3 were used in the estimate of escapement. A count with an associated water clarity rating of 4 or 5 was considered as not counted. Five technicians were assigned to each river to enumerate the salmon escapement. Each day was divided into three 8-hour shifts: Shift I began at 0000 (midnight) and ended at 0759, Shift II began at 0800 and ended at 1559, and Shift III began at 1600 and ended at 2359.

Methods - Sonar

- In conjunction with the counting towers, 2 sonars were deployed upstream of the white fabric panels on the Salcha to estimate the number of migrating salmon during periods of low visibility. Two adaptive resolution imaging sonars (ARIS) were deployed on opposite sides of the river, upstream of the Salcha River counting tower. Images were recorded 24 hours a day, 7 days a week for the project duration. ARIS units were mounted to portable aluminum stands that could be moved manually to adjust for changing water depth. Additionally, all units incorporated rotators that enabled remote adjustment and focusing. Weir structures were deployed behind each unit to ensure migrating salmon passed through the sonar beam. When daily visual counts were available and water clarity ratings were greater than 3, the paired estimates were used to evaluate the effectiveness of the sonar.
- Inseason and postseason, all fish >450 mm in length in the DIDSON sonar images were measured and recorded using Echotastic, a software program developed to process sonar images. Historical length distributions of chum and Chinook salmon from the Chena and Salcha Rivers have illustrated that no salmon are less than 450 mm in length. The estimated lengths from the sonar images, along with the associated dates of tower passage, were later used in a Bayesian mixture model that also incorporated historical length and run-timing data to apportion and estimate numbers of Chinook and chum salmon from the total sonar count.

Methods - Age/Sex/Length Data

Age, sex and length data has been collected from returning live Chinook salmon via electrofishing and spawned-out, dead Chinook salmon. Sex is determined by primary or secondary sexual characteristics or by external palpitation for eggs or milt. Length data is measured in mm as mid-eye to fork of tail. Scales are collected and age is determined from scale patterns. Gear for collecting ASL data has changed over the years but sampling techniques have not. Uncertainty is not calculated for this data because it is simply a census of all raw data collected.

Discussion

For the mark-recapture estimate of abundance to be unbiased, certain assumptions must be met (Seber 1982). These assumptions, expressed in the circumstances of this study, along with their respective design considerations and test procedures will be that:

- Assumption I: The population is closed to births, deaths, immigration and emigration.
- Assumption II: Marking and handling did not affect the catchability of Chinook salmon in the second event.
- Assumption III: Tagged fish did not lose their tags between the two sampling events.
- Assumption IV: One of the following three conditions needed to be met: (1) All Chinook salmon had the same probability of being caught in the first event; (2) All Chinook salmon had the same probability of being captured in the second event; or, (3) Marked fish mixed completely with unmarked fish between samples.

Critical assumptions for the Tower/Sonar surveys include:

- Most fish pass within range of the sonar and are detected. All Chinook passage is visible from the tower.
- Passage of chinook salmon is consistent within the hour.
- No diurnal changes to fish passage and that the sampling plan is sufficient to estimate passage over a full day.
- There is minimal to no milling at the site so that fish are not counted multiple times.

Uncertainty Evaluation - Tower/Sonar/MR

Estimates of Chinook salmon escapement were stratified by day and daily estimates were summed to estimate total escapement. Daily escapement was estimated and put into 1 of 5 categories, depending on the frequency of successful counts:

- Two or more 8-hour shifts per day were considered complete (i.e., a minimum of 4 counting periods per shift were sampled)
- Only one 8-hour shift per day was considered complete but at least 4 counting periods are sampled.
- No 8-hour shifts were considered complete on a given day, interpolation techniques were used to estimate escapement. This approach was used when no 8-hour shifts for 1 or 2 consecutive days of counting were considered complete. Postseason escapements for these dates were estimated using the mixture model that apportions the sonar counts of salmon by species.
- When all 8-hour shifts on 3 or more but fewer than 10 consecutive days were considered incomplete, no inseason daily escapement values were reported and postseason daily escapement values were assessed using a mixture model that apportioned the sonar counts of salmon by species.
- When visual counting could not be conducted for an excessive number of days during the run (e.g., more than 10 consecutive days or more than 20 total days), or when neither visual counts nor sonar counts could be conducted for 3 or more consecutive days (i.e., high water and inoperative sonar equipment), a Bayesian hierarchical model was used to estimate escapement for the missed days (if <25% of the total run) using characteristics of the run-timing.
    - Specific detailed methods can be found in the cited reports.
    - Uncertainty is calculated as the standard error for the final escapement estimate.

F.4.2 Project Details - Salcha Main Surveys

Table F.4. Salcha Main Surveys - Operational Timeline

Years	Component	Change/Event
1987 to 1992	MR	Escapement estimated using a Petersen mark-recapture experiment. This type of experiment required two events. During the first event, a sample of the population was captured, marked, and released back into the population. During the second event, after allowing time for the marked and unmarked fish to mix, another sample was collected and examined for marks.
1987-1994	Other	Potential Egg Production was calculated as a byproduct from the carcass surveys. Fecundity of chinook salmon that returned to the Salcha River was estimated using parameters from a linear regression model that described the relation between fecundity and length (Skaugstad and McCracken 1991).
1993	Tower, MR	First year using visual tower counting techniques. Chinook and chum salmon were counted during 20 min periods each hour as they passed beneath the Richardson Highway bridge on the Salcha River. Chinook salmon were captured and tagged near Manley on the Tanana River to estimate the migration time to the Salcha and Chena rivers. Four-hundred thirteen chinook salmon were captured and 403 were tagged and released from 12-15 July. The tagged salmon were counted as they passed the counting sites on each river and as they were caught in the commercial and subsistence fisheries
1993 to 2006	Tower	Tower counts were the main method of assessment but a Mark-Recapture experiment was undertaken when an estimate wasn't possible from tower count methods
1999 to 2015	Tower	BSFA began contracting with a Fairbanks fisheries consultant to conduct tower counts in 1999. Project mobilization, escapement enumeration, and data analysis procedures for the Salcha River counting tower are virtually identical to those used for the Chena River.
2004 to 2005	Tower	In 2004, one 12 foot tall tower was erected on the left bank (looking upriver) of the Salcha River approximately 0.25 mile downstream from the Richardson Highway Bridge. In 2005 that site was abandoned due to a deepening channel and increased sport fishing activity. The tower was moved approximately 0.50 mile upstream of the Richardson Highway Bridge and switched to the right bank (looking upriver).
2015	Tower	BSFA operated the tower. A binomial mixed-effects model was used to interpolate the first two weeks of missed counts. No sonar was used
2016	Tower	ADF&G took over operation of the project from BSFA. In addition to the counting tower, one DIDSON and one adaptive resolution imaging sonar (ARIS) with a telephoto lens were deployed on the west side near the Salcha River counting tower. Ranges up to 30 m were needed to ensonify the entire river sections

Years	Component	Change/Event
2019	Tower	Starting in 2019, changes were implemented in how Division of Sport Fish reported the Chinook and Chum salmon numbers for the Chena and Salcha Rivers inseason. They continued to report the expanded visual counts as usual for Chinook and chum salmon. For days when no visual counts, the top-of-the-hour sonar files were completed and any fish over 650mm (cutoff chosen based on historic length compositions) was considered a Chinook salmon. Fish that fell below the 650mm cutoff value were considered a mix of kings and chum. The sonar counts were treated like visual counts and expanded for the full hour. The expanded sonar counts for both fish over 650 and fish under 650 were reported on the daily update spreadsheet. These changes dramatically reduced workload and allowed for more immediate data particularly when visual counts are not available. Additionally, final estimates were available shortly after the season ended instead of several months later.

Table F.5. Salcha Main Surveys - Potential Data Issues

Years Affected	Potential Issue
1993	First year using visual tower count operations to estimate escapement.
1994	Extreme high water during late June and early July postponed installation of flash panels five days in the Salcha River and eight days in the Chena River from the planned start date of 1 July. Chinook salmon were observed on the first day of counting, (8 July) in the Chena River, but not until the second day of counting (6 July) in the Salcha River.
1996	Large number of missed counts on both the Salcha and Chena rivers due to high water and poor counting conditions, estimates of total chinook salmon passage were deemed inadequate, and two-sample mark-recapture experiments were conducted as the sole estimate of abundance for each system.
1997	Missed counts were interpolated
1998	High water due to rainfall prevented counts on 8, 19, 24-26, and 30 July. Missed counts were interpolated.
1999	High water due to rainfall prevented counts on 27-31 July and 9-12 August. Missed counts were interpolated.
2000	The Salcha River, similar to the Chatanika and Chena rivers, experienced high water and subsequent poor visibility from 11-16 July. Because only five periods were counted during the graveyard shift on 11 July and no counts were conducted during 12-16 July, an expanded estimate for the missing days was calculated using past, complete tower estimates from 1993- 1995 and 1997-1999. The uncertainty of the missing counts is reflected in the relatively large standard error.
2001	Documented escapement through July 23 (day 19) was estimated to be 9,300 (SE = 322) chinook salmon for the Salcha River (adjusted for three days of missing counts due to high, turbid water). After July 23, an additional 119 chinook salmon were counted. Total escapement, estimated to be 13,328 (SE = 2,163) chinook salmon, was calculated by summing the estimate from count data through 23 July with an estimate of escapement after 23 July based on historical run timing information.
2002	The gaps and questionable counts during the run-up to the probable peak and after make it extremely difficult to develop a point estimate of abundance. Count expanded at a later date.
2003	High water events impacted counts. Tower count expanded at a later date.
2007 to 2008	High water events impacted counts. Estimates should be considered minimum estimates of escapement.
2009	BSFA is reporting total estimates of escapement in their annual summary of projects that expand interrupted tower counts greater than 4 days based on different techniques than ADF&G; therefore, total estimates of escapement may differ when the number of days with no counts exceeds 4 days.

Years Affected	Potential Issue
2011	Multiple high water events prevented complete counts of the salmon run so estimates were interpolated.
2014	In 2014, the Salcha River counting tower was not in operation due to multiple high-water events; there are no estimates of Chinook and chum salmon escapement
2015	A binomial mixed-effects model was used to interpolate the first two weeks of missed counts. No sonar was used.

F.4.3 References

Most Recent Project Published Operational Plan and Report

Matter, A. N., and M. Tyers. 2019. Chinook salmon escapement in the Chena and Salcha Rivers and Coho salmon escapement in the Delta Clearwater River, 2019-2023. Alaska Department of Fish and Game, Regional Operational Plan ROP.SF.3F.2019.03, Anchorage.

Data Sources

- Data sources: AYK database management system. AYKDBMS Home Page (alaska.gov)
- ADF&G Publication Database: Publications Search - Sport Fish - ADF&G (alaska.gov)

Tower/Sonar/MR Report Citations

Matter, A.N., and M. Tyers. 2020. Chinook salmon escapement in the Chena and Salcha rivers and coho salmon escapement in the Delta Clearwater River, 2017. Alaska Department of Fish and Game, Fishery Data Series No. 20-01, Anchorage.

Skaugstad, C. 1993. Abundance, egg production, and age-sex-length composition of the chinook salmon escapement in the Salcha River, 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-23, Anchorage, Alaska, USA

Skaugstad, C. 1994. Salmon studies in Interior Alaska, 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-14, Anchorage, Alaska, USA. Stuby, L., and M. Tyers. 2016. Chinook salmon escapement in the Chena, Salcha, and Goodpaster rivers and coho salmon escapement in the Delta Clearwater River, 2015. Alaska Department of Fish and Game, Fishery Data Series No. 16-45, Anchorage.

Stuby, L., and M. Tyers. 2018. Chinook salmon escapement in the Chena and Salcha rivers and coho salmon escapement in the Delta Clearwater River, 2016. Alaska Department of Fish and Game, Fishery Data Series No. 18-13, Anchorage.

F.5 Goodpaster River

- Have a tower survey supplemented by an aerial survey program. The tower program is described in this section, the aerial survey program is described in Section G.6 *Middle River Aerial Surveys*.

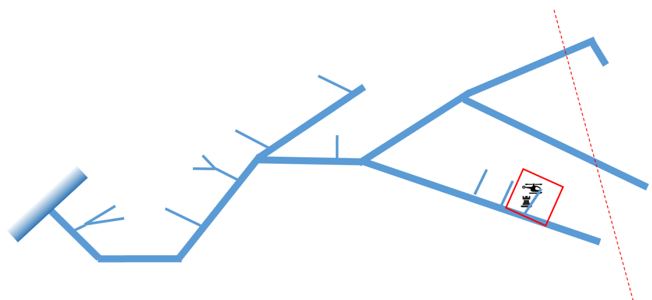

Figure F.4. Location of Goodpaster Surveys in the Middle Yukon

F.5.1 Project Summary - Goodpaster Tower

Introduction

A counting tower was operated on the Goodpaster River from 2004 to 2018, implemented by various organizations: Alaska Department of Fish and Game (ADF&G), Tanana Chiefs Conference (TCC), Bering Sea Fishermen's Association (BSFA), Northern Ecological Services (NES)

The tower site is about 8 miles above the Goodpaster River North and South fork confluence and approximately 30 miles downriver from the Tech-Pogo mining project site. The tower site is downstream of the 15-mile long stretch of Goodpaster River documented by Northern Ecological Services in 1999-2003 to be the primary Chinook salmon spawning locations. The tower is located at latitude N64.13.40, and longitude W145.08.30. The entire river passes the tower site in a single channel with run type features (flat surface, low turbulence) for excellent observation characteristics.

Methods

Standardized counting tower enumeration protocols were employed to count fish in all years of this project. Crew consisted of 3 to 4 people over the duration of the project that counted fish during 8-hour shifts. Counts were conducted for 20 minutes per hour, 24 hours a day from July through early August as weather (flooding stream issues) allows. Fish counts are written into a logbook at the end of each 20-minute count and subsequently entered into an Excel spreadsheet. To estimate the total hourly passage, the number of salmon counted during a 20-minute period is multiplied by three. The daily Chinook salmon escapement estimate is the sum of the 24 expanded hourly estimates.

Tower count estimates conducted by ADF&G and TCC, estimates are expanded postseason by the methods described in Stuby et al. (2015). For counts operated by BFSA, estimates of Chinook salmon passage for those days with inadequate data (due flooding) are rough estimates based on present year uncompromised daily total data (good counts from the days before and after the compromised counts) and historic passage portions (date specific portion of total historic annual passage). In general these made up data points should 'fit' a into a bell shaped curve, which is consistent with historic run timing patterns from uncompromised Goodpaster River Chinook salmon escapement data sets (2004, 2006, 2009, 2010, 2012, and 2014) as well most all salmon run timing return data world wide (C. Stark, project biologist, BSFA, Fairbanks, personal communication).

Discussion

Critical assumptions include:

- All Chinook passage is visible from the tower.
- Passage of chinook salmon is consistent within the hour
- There is minimal to no milling at the site so that fish are not counted multiple times.

Uncertainty Evaluation

ADF&G calculates uncertainty as the standard error for the final escapement estimate to account for missed days of counts. No uncertainty was available for all aerial survey estimates and tower estimates from 2011, and 2016 – 2018.

Variability in accuracy of tower counts and surveys dependent upon several factors. Weather (e.g., wind, cloud cover), water conditions (e.g., turbidity, surface turbulence), river morphology (e.g., depth, sinuosity), substrate color, and bank vegetation can contribute substantially to an observers ability to see fish in the survey area.

F.5.2 Project Details - Goodpaster Tower

Table F.6. Goodpaster Main Surveys - Operational Timeline

Years	Component	Change/Event
All years	Tower	Daily tower counting methods were similar between years and agencies responsible. Methods for expanding the count post season for missed hours or days varied between agencies and years.
2004 to 2010 and 2012 to 2015	Estimation	The formulas necessary to calculate escapement from counting tower data were taken directly or modified from those provided in Cochran (1977).
2011, 2016 to 2018	Estimation	BFSA methods for calculating post season expanded tower count for missed days described above

Table F.7. Goodpaster Main Surveys - Potential Data Issues

Years Affected	Potential Issue
2014	project only operated 18 days because of high water. Estimate was expanded for missed days. After reviewing the raw data for this summary a transcription error was found in Stuby et. al Appendix C2. Number reported in published report was 1,305 but should read 1,350. SE of 90 is correct.
2018	Estimate has not been published but the data is on file with ADF&G, Division of Commercial Fisheries, Yukon Area Management Group, Fairbanks).

F.5.3 References

Tower and Aerial survey estimates are available in the ADF&G AYKDBMS database. https://www.adfg.alaska.gov/CF_R3/external/sites/aykdbms_website/Default.aspx

References

Barton, L. H. 1987b. Yukon area salmon escapement aerial survey manual. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fairbanks. Arctic, Yukon, and Kuskokwim Region, Yukon River Salmon Escapement Report No. 33

Estensen, J. L., H. C. Carroll, S. D. Larson, C. M. Gleason, B. M. Borba, D. M. Jallen, A. J. Padilla, and K. M. Hilton. 2018. Annual management report Yukon Area, 2017. Alaska Department of Fish and Game, Fishery Management Report No. 18-28, Anchorage.

Stuby, L., and M. Tyers. 2016. Chinook salmon escapement in the Chena, Salcha, and Goodpaster rivers and coho salmon escapement in the Delta Clearwater River, 2015. Alaska Department of Fish and Game, Fishery Data Series No. 16-45, Anchorage.

F.6 Rampart Rapids Fish wheel CPUE

F.6.1 Introduction

The Rapids Research Center represents several projects and data collection efforts that utilized a set of fish wheels at an area known as “The Rapids.” The Rapids is a narrow canyon located 730 miles from the mouth of the Yukon River and 40 miles upriver of the village of Tanana. Due to the unique currents in the area, fish wheels can be operated and used to catch good numbers of fish across a wide range of water levels (including high water and heavy debris).

The program was active from 1996-2014, and estimated CPUE for Chinook, Chum, and whitefish. Associated biological data were also collected.

F.6.2 Methods

From 1996-2014, this site has been used for various fishery assessment projects. Initially, this site provided a platform for tag deployment for Rampart/Rapids mark-recapture project by USFWS on fall chum salmon which operated through 2005 and provided daily fish wheel CPUE of fall chum salmon. Monitoring of Chinook salmon passage began in 1999, and in 2000 a video fish wheel project was developed to provided daily catch rates for Chinook salmon, as well as chum salmon, sheefish, humpback and broad whitefish, and least and Bering cisco.

The video fish wheel was operated until 2014. During that time, it was the only assessment project in the U.S. portion of the mainstem Yukon River above Pilot Station, and it was used for inseason management providing relative abundance and run timing of upper Yukon River stocks. The video fish wheel was located on the left bank of the river, and its location and operation were maintained in a consistent manner from year to year so meaningful comparisons and interpretations could be made from the data collected. In addition to fish wheel catch rates, there is also subsistence catch sampling that is conducted by members of the Research Center, and biological data (e.g., age-sex-length-weight and *Ichthyophonus* infection) has been collected from both fish caught in the video fish wheel and from fish harvested by subsistence fishermen in the surrounding area.

F.6.3 Discussion

No formal review of the video fish wheel Chinook salmon CPUE data was conducted. Fish wheel catches are suspected to be biased toward small, male, bank-orientated, and potentially compromised (e.g., weak or diseased) Chinook salmon compared to the total population passing the Rapids area. However, the consistent standards used to operate the video fish wheel from year-to-year would suggest that the catches may provide a reliable relative index of the Chinook salmon timing, abundance, and composition. Initial analyses, however, suggested there was no clear relationship between the Rapids fish wheel CPUE and Chinook salmon passage estimates from the Eagle sonar located near the U.S./Canada border (Table F.8, Figure F.5). As such, the

Rapids CPUE dataset was not considered as an additional model input to inform the Canadian-origin stock component.

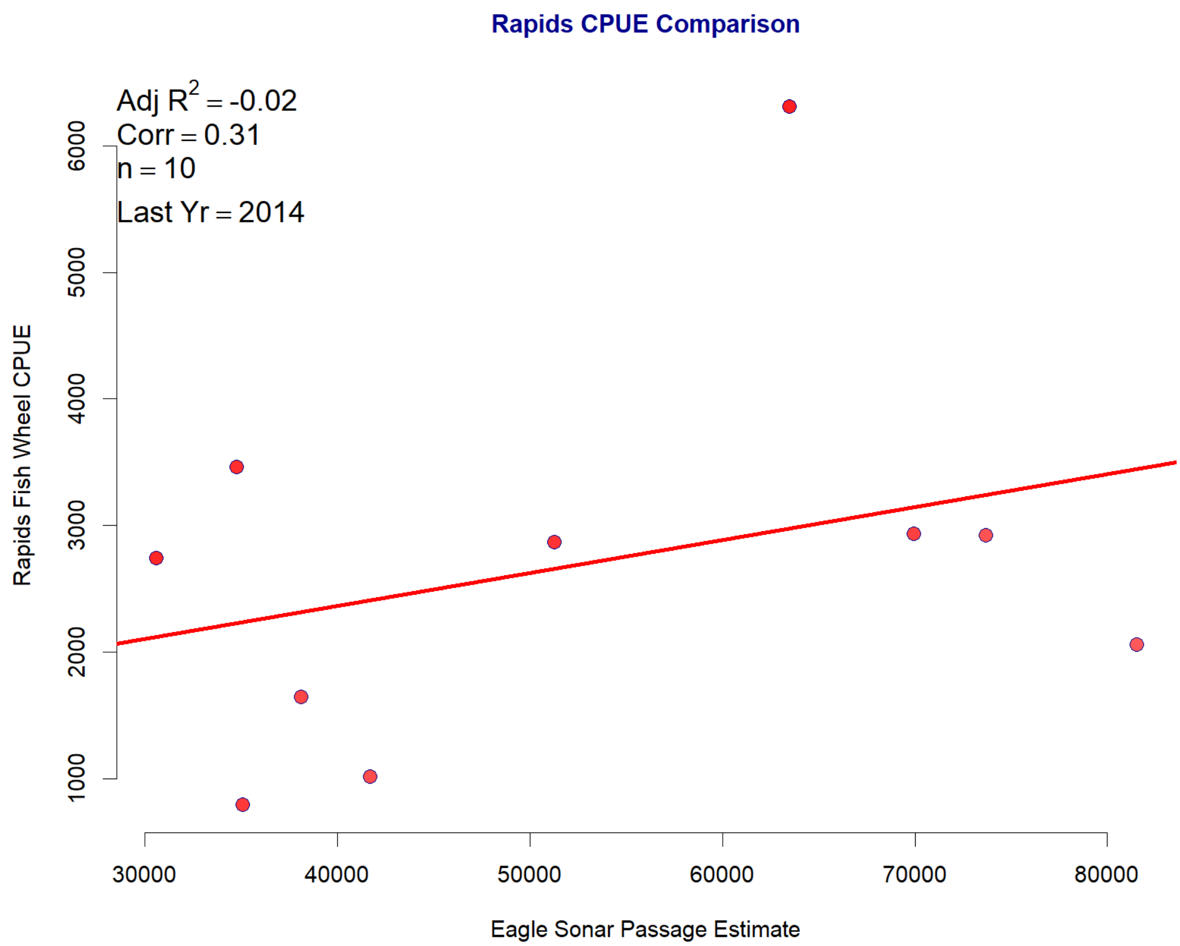

Figure F.5. *Comparison of Chinook CPUE in Rampart Rapids Fish Wheel vs. Eagle Sonar Passage Estimate*.

Table F.8. *Rampart Rapids Fish Wheel Chinook CPUE*.

Year	RapidsCPUE	EagleSonar
2000	1,743	NA
2001	5,477	NA
2002	1,652	NA
2003	1,631	NA
2004	2,890	NA
2005	2,061	81,527
2006	2,923	73,691
2007	1,014	41,697
2008	1,645	38,097
2009	2,937	69,957
2010	793	35,074
2011	2,872	51,271
2012	3,465	34,747
2013	2,742	30,578
2014	6,313	63,462

APPENDIX G U.S. Aerial Surveys

G.1 Overview

Aerial surveys of Lower and Middle Yukon tributaries have been used for visual counts since the early 1950s. Surveys were mostly implemented by ADF&G, but intermittent survey were also flown by USFWS or other agencies.

Lower and Middle Yukon aerial survey records include:

- Visual counts
- Survey method
- Date
- Quality rating
- Environmental quality ratings: Water, wind, weather, river bottom, bottom effects and spawning stage
- Observer comments

G.2 Methods

Aerial survey techniques are used to index Chinook salmon escapement throughout multiple spawning tributaries draining into the Lower Yukon River. Surveys counts are typically conducted one time each year corresponding with the presumed peak spawning activity. Peak counts are treated as indices of relative abundance. Resulting indices can be used for monitoring abundance trends over years, informing estimation of total escapement from base year data by established expansion factors, or apportioning a total escapement estimate obtained from other methods to specific portions of the tributary based on spawning distribution.

To the extent practical, survey methods are standardized to improve accuracy and comparability of the one-time peak index counts. Surveys are conducted using either two or four-seat fixed-wing aircraft with unobstructed views out of both sides of the plane (note: helicopters are rarely used due to their high cost). Surveys are flown during date ranges suspected to correspond with peak spawning activity, informed by historical survey timing and available current-year information. Effort is made to conduct surveys on days when weather conditions are adequate to observe fish and facilitate safe aircraft operations. Surveys are typically conducted at elevations between 300 and 500 feet and at low airspeeds appropriate for the selected aircraft (typically 50-60 mph). Standardized survey areas have been established for West Fork Andreafsky River, Anvik River, and Nulato River to ensure the index counts are comparable over time. Survey areas have not been standardized for East Fork Andreafsky River or Gisasa River.

Available data were summarized in several ways. Only counts obtained from aerial methods (fixed-wing or helicopter) were used. Counts were the sum of live Chinook salmon and carcasses. Total annual count was provided, by tributary, for each year in which a survey was conducted. The spatial extent of “total counts” varied broadly and may not be comparable. The total count was presented regardless of survey rating; however, only surveys rated as “fair” or “good” should be used. If more than one survey was flown in a specific year, the count from the survey with the most favorable rating (i.e., “poor” versus “fair/good”) was presented. If more than one “fair/good” survey was available, the survey with largest count was used. Standardized counts were also presented for the subset of tributaries with standardized index reaches. A standardized count was only presented if the survey rating was “fair/good” and all standardized index reaches were successfully surveyed. For the Anvik River, a “mainstem index” count was also presented following the same criteria as the standardized count, albeit the spatial extent was limited to select mainstem reaches. Discretion is required to determine which count type is most appropriate for the intended use.

G.3 Discussion

Critical assumptions include:

- Counts observed from all models of fixed-wing and helicopter were assumed to be comparable.
- Survey pilots were appropriately skilled to maneuver the aircraft along all portions of assigned survey reaches in a manner suitable for observing fish.
- Survey observers accurately identified and reported all Chinook salmon and carcasses that were observed in each survey reach.
- Timing of surveys correspond to peak-spawning activity.
- Survey rating was an adequate representation of the reliability of the index count.
- Single (or multiple) aerial surveys do not count the entire escapement within an aerial index area as runs are usually protracted with the early spawning fish disappearing before the late ones arrive. Weather and water conditions, the density of spawning fish, as well as observer experience and bias also affect survey accuracy. Index surveys are rated according to survey conditions

Uncertainty in aerial estimates has been evaluated as follows:

- No formal evaluation of survey accuracy is undertaken.
- Peak counts are an underestimate of the true inriver abundance at the time of survey. In addition, aerial counts may demonstrate a wide range in the proportion of fish enumerated from year to year in each river.
- Variability in accuracy is dependent upon several factors. Weather (e.g., wind, cloud cover), water conditions (e.g., turbidity, surface turbulence), river morphology (e.g., depth, sinuosity), substrate color, and bank vegetation can contribute substantially to an

observers ability to see fish in the survey area. Timing of surveys with respect to peak spawning is a very important factor, with both early and late-timed surveys resulting in reduced counts relative to the peak. The type of aircraft, survey altitude, experience of both pilot and observer also contribute substantially to the accuracy of the counts. Each of these factors is carefully considered and a subjective survey rating of “poor,” “fair,” or “good” is assigned by the observer.

G.4 Project Details - General

- Historically, survey methods have included a range of fixed-wing aircraft (e.g., PA18 super cub, C-180, C-185, other) and helicopter models. Boat and foot surveys have also been conducted in some locations but were not considered comparable to aerial methods and were not used.
- The spatial extent of annual surveys has varied considerably. Users must look closely at raw survey data and observer comments to determine the spatial extent and comparability of annual survey counts. As such, extensive knowledge of the historical aerial survey program, geography of the survey areas, and local landmarks are needed to interpret observer comments.
- Within the AYKDBMS there is considerable variation in how surveyed areas are grouped and described. For example, in some years counts are reported separately for discrete portions of the total survey area, and in other years all counts are reported as a single entry in the database.
- The AYKDBMS contains survey “section number” assigned to each entry. Historically, the section numbers were not standardized and in many cases were assigned sequentially to each successive count recorded by the observer. Therefore, survey numbers do not necessarily represent the same geographic area for all years. There have been efforts to standardized section numbers in more recent years.

G.5 Lower Yukon River Aerial Surveys

G.5.1 Project Summary

On the Lower Yukon, data have been summarized for 6 consistent surveys covering 4 tributary watersheds since 1961:

- Andreafsky River (East and West Forks)
- Anvik River
- Nulato River (North and South Forks)
- Gisasa River (in the lower part of the Koyukuk watershed)
- Tozitna River (tributary to the mainstem, downstream of Tanana, but genetically linked to Lower Yukon stock)

G.5.2 Project Details - Operational Changes

Andreafsky

- East Fork and West Fork Andreafsky surveys were grouped together in AYKDBMS through 1999 and referred to Andreafsky River Aerial Survey. Forks were distinguished by survey comments and section numbers. Beginning in 2000, East Fork survey counts were entered into the AYKDBMS separate from West Fork counts as Andreafsky (East Fork) Aerial Survey.
- In 2018, air survey data were evaluated, and standardized survey areas were established for West Fork Andreafsky River (Liller and Savereide 2018).
  - The West Fork of the Andreafsky River should be assessed using index reaches 101 (community of St. Mary's upriver to the confluence of Allen Creek) and 102 (confluence of Allen Creek upriver to approximately 62.958715 N, 162.124570 W).
  - The standardized reaches account for nearly 100% of historical counts.

Anvik

- Anvik aerial survey counts have been recorded and entered in the AYKDBMS in multiple ways. In most years, a query for "Anvik River Aerial Survey" will return counts for all surveyed mainstem and tributary sections. In a subset of years, surveyed tributaries of the Anvik River were entered separately as follows, with varying implications for Chinook salmon counts:
  - Beaver Creek (Tributary Anvik River) Aerial Survey, 2001 and 2004
  - Beaver Creek Aerial Survey, 2013
  - Canyon Creek Aerial Survey, 1985
  - McDonald Creek (Anvik) Aerial Survey, 2001 and 2004
  - Otter Creek Aerial Survey, 2001, 2004, 2007, and 2013
  - Swift River (Anvik River) Aerial Survey, 1985, 2004, and 2007
  - Swift River Aerial Survey, 2013
  - Yellow River Aerial Survey, 1985 and 2001
- Historically, the Anvik River survey counts have been reported in multiple ways. "Drainagewide" counts represent the sum of all observed live and dead Chinook salmon from all surveyed reaches. The geographic extent of the "drainagewide" count may vary considerably across years and may not be comparable. Alternatively, a mainstem "index count" has been produced in most years since 1980 and is the sum of counts from reaches 104, 105, and 106 (i.e., Yellow River to McDonald Creek). Prior to 1980, survey reach descriptions allow for producing mainstem index counts for four additional years (i.e., 1972, 1973, 1975, and 197), but the 1973 survey received a poor rating. Huttenen and Bergstrom 1999 recommended using the mainstem index counts for escapement goal evaluation purposes, because the index count is a standardized subset of the total count and numerically drainagewide count in most years.

- In 2018, air survey data were evaluated, and new standardized survey areas were established for the Anvik River for use in escapement goal evaluations (Liller and Savereide 2018).
  - Anvik River should be assessed using the cumulative count of live and dead Chinook salmon within 4 mainstem index reaches 103–106 (sonar site to McDonald Creek) and 3 tributary reaches 108 (Beaver Creek), 110 (Swift River), and 111 (Otter Creek).
  - The standardized areas selected represented more than 96% of the total Chinook salmon escapement to the Anvik River and was the group of index reaches flown most often since 1960.

Nulato

- North Fork and South Fork Nulato surveys were grouped together in AYKDBMS through 1997 and referred to as Nulato River Aerial Surveys. Forks were distinguished by survey comments and section numbers. In the following years, South Fork survey counts were entered into the AYKDBMS separate from North Fork counts as Nulato River (South Fork) Aerial Survey: 1998, 2001, 2002, 2004, 2005, 2013, 2015, and 2017–2019.
- In 2018, air survey data were evaluated, and new standardized survey areas were established for the Nulato River for use in escapement goal evaluations (Liller and Savereide 2018).
  - The Nulato River should be assessed using 4 index reaches representing the North and South forks of the Nulato River. North Fork reaches include 101 (mouth to the confluence of North and South Forks) and 102 (mouth of North Fork upriver to Kalasik Creek). South Fork reaches include 101 (mouth of South Fork upriver to Drill Hole) and 102 (Drill Hole upriver to Township Line).
  - The standardized reaches account for nearly 100% of historical counts. Historical survey descriptions were often inadequate to parse counts beyond the upper extent of the standardized reaches. Surveys descriptions that suggest the entire fork was flown were considered comparable to the subset of years when only the standardized reaches were surveyed.

Tozitna

- Standard survey index areas are Dagishlakhna Creek to McQuesten Creek and McQuesten Creek to Fleshlanana Creek

G.5.3 Project Details - Potential Data Issues

Table G.1. Andreafksy East Fork Aerial - Potential Data Issues

Project	Years Affected	Potential Issue
Andreafsky East Fork Aerial	All	Survey reaches are not standardized.
Andreafsky East Fork Aerial	1969, 1970, 1980, 1984, 2000, and 2015	Use designation differs from JTC reporting
Andreafsky East Fork Aerial	1970	“Fair” survey rating was overturned based on “poor” survey comments.
Andreafsky East Fork Aerial	1974	A reconnaissance survey was flown on July 4 and 50 Chinook were observed. No follow-up peak survey was flown.
Andreafsky East Fork Aerial	1992	Multiple surveys were flown. Peak survey count of 1,030 on July 17 was rated as poor and incomplete (75% of survey area flown). A follow-up survey on July 29 was rated fair, comments indicated the survey was past peak, and the count of 756 Chinook salmon was not used.
Andreafsky East Fork Aerial	1997	Survey reach description says “East Fork”; however, survey comments reference Allen Creek which is West Fork. Assigned the counts to East Fork to be consistent with JTC reporting.

Table G.2. Andreafksy West Fork Aerial - Potential Data Issues

Project	Years Affected	Potential Issue
Andreafsky West Fork Aerial	1969, 1975, 1988, 2000, 2007, and 2015	Use designation differs from JTC reporting
Andreafsky West Fork Aerial	1975, 1992	AYKDBMS total count differs from JTC reporting
Andreafsky West Fork Aerial	1970	“Fair” survey rating was overturned based on “poor” survey comments.
Andreafsky West Fork Aerial	1975	Multiple surveys were flown. Peak survey count of 301 on July 22 was rated as poor. A follow-up survey on July 26 was rated good but only 120 Chinook were observed. The smaller count was used but is consistent with JTC reporting.
Andreafsky West Fork Aerial	1984	Standardized count differs from JTC reporting. A total of 5 fish observed in an unnamed tributary (not normally surveyed) was excluded from the total count to improve comparability with other years.
Andreafsky West Fork Aerial	1987	Standardized count differs from JTC reporting. A total of 140 fish observed in Allen Creek (not normally surveyed) was excluded from the total count to improve comparability with other years.
Andreafsky West Fork Aerial	1988	Only 60 river miles were flown.

Table G.3. Anvik Aerial - Potential Data Issues

Project	Years Affected	Potential Issue
Anvik Aerial	1973, 1993, 2000, 2006, 2018	Use designation differs from JTC reporting
Anvik Aerial	1975 to 1979, 1985, 1987, 2000, 2007, 2013	AYKDBMS total count differs from JTC reporting
Anvik Aerial	1983, 1991, 1996, 2000, 2006	AYKDBMS mainstem index count differs from JTC
Anvik Aerial	1967	poor survey rating based on observer comments.
Anvik Aerial	1972 to 1979	Anvik tower counts are included in the air survey portion of the AYKDBMS. JTC reporting appear to have incorrectly summed tower and air survey counts in a subset of years.
Anvik Aerial	1978	Multiple survey dates (July 11 – July 15) effectively covered the full standardized area and mainstem index area. Daily survey extents overlapped, and it was not possible to ensure fish were not double counted. The sum from all days and survey areas was 198 Chinook salmon.
Anvik Aerial	1981	Poor survey based on observer comments.
Anvik Aerial	1983	Section 106 was not flown. Mainstem index count (376) reported by JTC is incomplete.
Anvik Aerial	????	Observer comments “good” conditions above Yellow River overrides undefined survey rating.
Anvik Aerial	1993	Rating is undefined, and comments indicate “fair” or “poor”. JTC reports count as usable.
Anvik Aerial	1996	JTC mainstem index count incorrectly included reaches 101 and 102
Anvik Aerial	2000	Original survey form is missing. No detail regarding spatial extent of survey.
Anvik Aerial	2006	Mainstem index reported by JTC includes approximately 8 miles of counts from section 103. Reported counts cannot be parsed to develop a comparable index.
Anvik Aerial	2008	Survey rating listed as “Surveyed too early”. Recommendation not to use count is consistent with JTC reporting.

Table G.4. Nulato and Gisasa Aerial - Potential Data Issues

Project	**Years Affected**	**Potential Issue**
Nulato Aerial Both Forks	1974	Survey rated as “fair”, but comment includes “counts considered 25% low” likely due to early survey timing of July 13.
Nulato Aerial Both Forks	1983	Good survey rating as per comments.
Nulato Aerial Both Forks	2004, 2005	North Fork count excludes section 101 which was flown but grouped with South Fork count and cannot be parsed. Likely 5% of total Nulato annual survey is misallocated between forks, based on average contribution of North Fork reach 101.
Nulato Aerial Both Forks	2012	Helicopter survey
Nulato Aerial North Fork	1991	Survey was conducted over a two-day period with no overlap in survey areas.
Nulato Aerial South Fork	1981	Use designation differs from JTC reporting
Nulato Aerial South Fork	1985	Survey description of “South Fork Drill Hole to 15 miles upstream” suggests most of the standardized area was flown
Gisasa Aerial	All	Survey reaches are not standardized.
Gisasa Aerial	1994	Two surveys were flown. The 8/10/94 survey counted 2,888 fish but no survey rating was given. The 7/26/94 survey counted fewer fish (2,775) but was rated “fair”. The rated survey should be used.
Gisasa Aerial	2001	Use designation differs from JTC reporting
Gisasa Aerial	2013	Poor survey based on comment “Surveyed too late”.

Table G.5. Tozitna Aerial - Potential Data Issues

Project	Years Affected	Potential Issue
TozitnaAerial	2008	survey focused on counting redds not live salmon
TozitnaAerial	2009	includes unknown count upriver from survey area

G.6 Middle Yukon River Aerial Surveys

G.6.1 Project Summary

On the Middle Yukon, data have been summarized for 3 consistent surveys covering 3 tributaries of the Tanana watershed:

- Chena River since the 1970s
- Salcha River since the 1960s
- Goodpaster River since the 1990s

G.6.2 Project Details - Operational Changes

Chena

Aerial surveys were conducted in various years by sport fish and commercial fish staff. Surveys were conducted by flying low and counting fish as described in Barton (1987b).

- Surveys counts are typically conducted one time each year corresponding with the presumed peak spawning activity. Peak counts are treated as indices of relative abundance.
- To the extent practical, survey methods are standardized to improve accuracy and comparability of the one-time peak index counts. Surveys are conducted using either two or four-seat fixed-wing aircraft with unobstructed views out of both sides of the plane (note: helicopters are rarely used due to their high cost). Surveys are flown during date ranges suspected to correspond with peak spawning activity, informed by historical survey timing and available current-year information. Effort is made to conduct surveys on days when weather conditions are adequate to observe fish and facilitate safe aircraft operations. Surveys are typically conducted at elevations between 300 and 500 feet and at low airspeeds appropriate for the selected aircraft (typically 50-60 mph).
- Available data were summarized in several ways. Only counts obtained from aerial methods (fixed-wing or helicopter) were used. Counts were the sum of live Chinook salmon and carcasses. Total annual count was provided, by tributary, for each year in which a survey was conducted. The spatial extent of “total counts” varied broadly and may not be comparable. The total count was presented regardless of survey rating; however, only surveys rated as “fair” or “good” should be used. If more than one survey was flown in a specific year, the count from the survey with the most favorable rating (i.e., “poor” versus “fair/good”) was presented. If more than one “fair/good” survey was available, the survey with largest count was used.

Sections that were sampled during that event were categorized as follows:

- Section 1: Below Moose Creek Dam
- Section 2: Dam to Grange Hall Rd/Bluffs/Mullen Slough
- Section 3: Grange Hall Rd/Bluffs/Mullen Slough to South Fork
- Section 4: South Fork to Middle Fork
- Section 5: South Fork
- Section 6: North Fork (upstream of Middle Fork mouth)
- Section 7: Middle Fork mouth to Munson Creek
- Section 8: Middle Fork above Munson Creek

Salcha

Aerial surveys were conducted in various years by sport fish and commercial fish staff. Surveys were conducted by flying low and counting fish as described in Barton (1987b):

- Surveys counts are typically conducted one time each year corresponding with the presumed peak spawning activity. Peak counts are treated as indices of relative abundance.
- To the extent practical, survey methods are standardized to improve accuracy and comparability of the one-time peak index counts. Surveys are conducted using either two or four-seat fixed-wing aircraft with unobstructed views out of both sides of the plane (note: helicopters are rarely used due to their high cost). Surveys are flown during date ranges suspected to correspond with peak spawning activity, informed by historical survey timing and available current-year information. Effort is made to conduct surveys on days when weather conditions are adequate to observe fish and facilitate safe aircraft operations. Surveys are typically conducted at elevations between 300 and 500 feet and at low airspeeds appropriate for the selected aircraft (typically 50-60 mph).
- Available data were summarized in several ways. Only counts obtained from aerial methods (fixed-wing or helicopter) were used. Counts were the sum of live Chinook salmon and carcasses. Total annual count was provided, by tributary, for each year in which a survey was conducted. The spatial extent of “total counts” varied broadly and may not be comparable. The total count was presented regardless of survey rating; however, only surveys rated as “fair” or “good” should be used. If more than one survey was flown in a specific year, the count from the survey with the most favorable rating (i.e., “poor” versus “fair/good”) was presented. If more than one “fair/good” survey was available, the survey with largest count was used.

G.6.3 Project Details - Operational Changes

Chena and Salcha

The AYKDBMS contains survey “section number” assigned to each entry. Historically, the section numbers were not standardized and in many cases were assigned sequentially to each successive count recorded by the observer. Therefore, survey numbers do not necessarily represent the same geographic area for all years. There have been efforts to standardized section numbers in more recent years.

Goodpaster

Various agencies were responsible for conducting surveys. Surveys were conducted by flying low and counting fish as described in Barton 1987b. Fixed wing aircraft and or helicopters were used to conduct surveys . NES conducted surveys between 1999 – 2004 and helicopters were used. Surveys are considered mostly complete with most sections surveyed each year during that time period.

G.6.4 Project Details - Potential Data Issues

Table G.6. Middle Yukon Aerial - Potential Data Issues

Project	Years Affected	Potential Issue
ChenaAerial	All Years	Survey reaches are not standardized. Section number and section descriptions were not consistent between years but total surveys seem to cover a similar spatial area.
SalchaAerial	All Years	Survey reaches are not standardized. Section number and section descriptions were not consistent between years but total surveys seem to cover a similar spatial area.
SalchaAerial	1991	Discrepancy between database and summary of published estimates (Brase 2012). Published value incudes sections 101 and 102 from survey conducted on 7/20 in addition to 7/21.
SalchaAerial	2000	Published estimates (Brase 2012) includes only sections 104 - 109 and no count of dead fish. Database value includes additional sections 102- 103 and dead fish observed.
SalchaAerial	2001 to 2006	Published estimates (Brase 2012) includes only sections 103 - 108. Database includes additional sections 101-102.
SalchaAerial	2005	Published estimates (Brase 2012) only includes sections 104 - 107. Database includes sections 101 - 107.
GoodpasterAerial	Before 1990	Aerial survey reaches surveyed inconsistent between years and agency responsible. Surveys conducted prior to 1990 were not done consistently and sections surveyed limited. Aerial Survey sections surveyed, and naming conventions varied between years and not consistent. ADF&G conducted surveys with fixed wing aircraft between 1954, 1960, 1961, 1965,1970 – 1977, 1983 – 1985, 1990 – 1995, 2005 – 2007 and sections surveyed varied. NES conducted surveys with helicopter between 1998 – 2004 and most sections were surveyed.

G.7 References

Data Sources

- Survey data were retrieved from the ADF&G AYK Database Management System.
- Database results were cross referenced with published JTC tables and unpublished ADF&G

Other References

Barton, L. H. 1987b. Yukon area salmon escapement aerial survey manual. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fairbanks. Arctic, Yukon, and Kuskokwim Region, Yukon River Salmon Escapement Report No. 33

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Huttunen D. and D. Bergstrom. 1999. ADF&G Memo: Yukon River BEG Review and Recommendations.

APPENDIX H Border and Above Assessment Project Descriptions

H.1 Overview

Stock assessment at the Border and in the Canadian portion of the Yukon basin includes;

- Mainstem sonar at Eagle
- Border mark-recapture
- Yukon River North Mainstem: Klondike Sonar
- White: Tincup Aerial
- Pelly: Pelly Sonar, Blind Creek Weir, Ross Aerial
- Carmacks Area Tributaries: Tatchun Surveys, Little Salmon Aerial, Big Salmon Sonar and Aerial
- Upper Yukon River: Whitehorse Fishway, Takhini Sonar, Takhini Aerial
- Teslin Headwaters: Teslin Sonar, Nisutlin Aerial, Wolf Aerial
- Porcupine: Porcupine Sonar

Additional projects were considered for inclusion in this data report, but data could not be consolidated within the scope of the current project:

- *Chandindu Weir*: This project was not included in the data review due to the short time span and difficulties with the project and the system which can experience variable conditions, and as a result incomplete counts to assess the full return. Accordingly, chandindu weir counts are not used in the run reconstruction by Connors et al. (2022). Note that this is a change from the run reconstruction in Hamazaki (2021), which included Chandindu weir counts.
- *McQuesten Aerial*: This program in the Stewart watershed is discussed briefly in Section I, which summarizes the Canadian aerial surveys. However, the data are not included in this report.

H.2 Eagle Station Sonar

H.2.1 Introduction

Eagle Sonar has been implemented annually since 2005 by ADFG and DFO.

Feasibility studies were done in 2003 and 2004. In both years, site suitability was explored by collecting bottom profiles in different sites and short durations of exploratory sonar operations. The feasibility studies did not enumerate through the entire run and are not an adequate measure of total salmon passage. Sonar explorations were conducted in the vicinity of the U.S./Canada border in a few years during the 1990s, but data collection efforts were not associated with the existing Eagle Sonar program and are not discussed in this review.

The study area is located on the mainstem of the Yukon River at Six Mile Bend (64.8732N, 141.0792W), approximately 11.5 km downriver from Eagle, Alaska. Six Mile Bend was selected as the preferred site because it is just 18 miles downstream of Alaska's border with Canada and has an ideal riverbed profile for using sonar to detect fish. The river at the site has a linear bottom profile on both sides without large obstructions and flows through a single, approximately 400-meter-wide channel.

The project estimates Chinook salmon passage using sonar (sound-based detection). Age, sex and length (ASL) of Chinook and freshwater species is collected mainly from the extensive drift-net sampling program, but there have been some set-nets deployed in the early years.

H.2.2 Methods

Chinook salmon passage estimation involves stratified systematic sampling of salmon passage using hydroacoustic equipment to estimate daily passage. The total width of the Yukon River at the Eagle Sonar site is approximately 400 meters. Split beam sonar is deployed along the left bank, and the ensonified area along the left bank extends approximately 150 meters offshore. Aeris sonar is deployed along the right bank, and the ensonified area along the right bank extents approximately 40 meters offshore. There is no evidence that large numbers of Chinook salmon migrate upriver beyond the sonar beams. Throughout the duration of this project, the right bank counts have been stratified to include nearshore and offshore counts. Stratified counts along the right bank began in 2014. The sonar operates 24 hours per day throughout the season, but fish passage is counted 30 minutes out of each hour per spatial strata. Standard statistical methods are employed to expand the sample to the entire day and to estimate passage during limited times when sonar operations are impeded. Operational downtime at this location has been infrequent, and high-water conditions are not thought to affect the quality of the daily estimates.

A drift gillnet test fishery is operated for the purpose of ASL data collection and determining the transition between Chinook and fall chum salmon. A total of four different mesh sizes (5.25, 6.5, 7.5, and 8.5 inches) were drifted, during daylight hours, in a rotating schedule throughout the Chinook salmon sample fishery to effectively capture all size classes present. The suite of mesh sizes used likely underrepresents the smallest and largest individuals, but the aggregate of ASL samples are believed to be representative of the total passage (Hamazaki 2018; MacDonald and Labelle 2012). Throughout the entire Chinook salmon run, gillnets are drifted along the nearshore and offshore zones along the left bank and the nearshore right bank zone. Later in the Chinook salmon run, a separate inshore (i.e., beach walk) drift is added to assist with capturing fall chum salmon. The species crossover date (Chinook to fall chum salmon) varies annually and is determined by test fishery species-specific catch per unit effort. Prior to the crossover date, all fish traces are assumed to be Chinook salmon, and all fish traces after the crossover date are assumed to be fall chum salmon.

Table H.1. Eagle Sonar - Operational Timeline

Years	Component	Change/Event
2003-2004	All	Project Feasibility
2005	Duration	Project operated only during Chinook salmon migration from July 1 -August 13.
2005	Sonar	Kongsberg Simrad EK60 digital echo sounder which included a general-purpose transceiver and a 4° by 10° 120 kHz transducer (left bank). DIDSON long-range unit manufactured by Sound Metrics Corp. operated at 0.70 MHz (right bank). Sampled 3 strata: single left bank strata (60 min sampling duration); right bank nearshore 1-20 m (30 min sampling duration), and right bank offshore 20-40 m (30 min sampling duration).
2005	Test Fishery	6 Mesh sizes utilized in the drift gillnet fishery 2.75 in (70 mm), 4.0 in (102 mm), 5.25 in (133 mm), 6.5 in (165 mm), 7.5 in (191mm), and 8.5 in (216 mm). 6.5-inch mesh gillnet was set from shore on August 4 for 48 hours to explore the possibility of using set nets at the site in future.
2006	Duration	Project ran full season from July 8 to October 6.
2006	Sonar	The range of the left bank split beam sonar was reduced on Aug 18 from 150 m to 75 m to allow faster ping rates and improved detection of chum salmon nearshore. From September 8 to October 4 a DIDSON long-range unit was operated side-by-side with the split-beam sonar on the left bank. The purpose was to collect data to examine whether small, non-salmon species were misclassified as salmon on the split-beam echogram. Inseason cutoff date for Chinook salmon was determined using sonar data, gillnet catches, local subsistence harvest, and Canadian mark–recapture fish wheel estimates.

Years	Component	Change/Event
2006	Test Fishery	Four different mesh sizes were drifted over the course of the season: 7.5 in (191 mm), 5.25 in (133 mm), 4.0 in (102 mm), and 2.75 in (70 mm). In addition to the standard drifts, the 2.75 in (70 mm) , 4.0 in (102 mm), and 5.25 in (133 mm) nets were used to investigate the presence of fish close to shore (shore to the inshore extent of the nearshore drift). On the days that the 2.75 in and 4.0 in nets were used, they were also drifted once within the nearshore zone. The inshore drifts were referred to as "beach walks". Two set gillnets of mesh sizes 7.5 in (191 mm) and 5.75 in (147 mm) were fished periodically throughout the season. The nets were 25 fm in length and approximately 3-fm deep. The setnet site was approximately 100 meters upstream from the split-beam sonar on the left bank.
2007	Sonar	July 31 to August 9, 2007, DIDSON long-range unit was operated side-by-side with the split-beam sonar on the left bank. Inseason cutoff date for Chinook salmon was determined using reverse-cumulative Chinook catches and cumulative chum catches.
2007	Test Fishery	Test fishing for species composition was conducted once daily on the left bank. During the sampling period, both the 5.25 in (5.75 in for the inshore) and the 7.5-in nets were drifted twice within each of 3 zones (inshore, nearshore and offshore). An additional fishing period was conducted once daily between July 9 and August 15 after the normal test fishing period, Three different mesh sizes (6.5 in, 7.5 in and 8.5 in) were fished daily over the course of the Chinook salmon run to effectively capture all size classes present.
2008	All	5.75 inch mesh was discontinued from the species composition test fishery (The 5.75 net was replaced with a 5.25 net. 5.75 was only used because a 5.25 couldn't be purchased for the inshore drift in 2007). Non salmon study using side by side comparison of split beam and DIDSON sonars on left bank discontinued.
2009-2012	All	Sonar methodology consistent with 2008. Around 2010 the driftnetting switched from drifting through the beam for the inshore and offshore LB sets to drifting below the sonar. Prior to this fish could have been captured above the sonar and released below the sonar.
2013	All	CPUE from the species composition test fishery replaced the methodology of using reverse cumulative of chinook and fall chum salmon catch to determine inseason cut-off date for Chinook salmon.
2014	All	Left bank split-beam sampling range was divided into 2 strata (30 min sampling duration) during the Chinook migration to increase the number of echoes received by fish traveling closer to the transducer (S1 0-50 m and S2 50-150 m). The use of Excel to calculate daily passage was eliminated, and passage estimation was calculated using an R script.

Years	Component	Change/Event
2015	All	Replaced DIDSON with ARIS sonar. Split-beam sampling range was divided into 2 strata (30 min sampling duration) during the fall chum migration to increase the number of echoes received by fish traveling closer to the transducer (S3: approximately 0–25 m and S4: approximately 25–75 m)
2016-2020	All	Methodology consistent with 2015.

Table H.2. Eagle Sonar - Potential Data Issues

Years Affected	Potential Issue
None	None Identified

H.2.3 Discussion

Critical assumptions include:

- Most fish pass within range of the sonar and are detected. The sampling plan is sufficient to estimate passage over a full day.
- There is minimal to no milling at the site so that fish are not counted multiple times.
- Sonar fish trace size and pattern (i.e., behavior) is adequate to distinguish small resident fish species from migratory salmon.
- Chinook and fall chum salmon migrations are discrete in time with very little temporal overlap.
- No salmon migrated behind the sonar or out of field of view and were thus, not accounted for

Project assumptions have been tested since the project's inception. Bathymetry profiles are conducted annually to determine optimal sonar placement. The project leaders monitor target distribution during the season to observe if a large percentage are offshore which could suggest significant passage beyond the detection range. The split-beam and imaging sonar make it possible to detect direction of travel so milling fish would be observed in the data. The sampling plan samples each strata for a half hour out of every hour, which is more than the typical 10 minutes out of every hour sampled at tower projects. The sampling is more than adequate to address any diurnal changes to migration patterns.

The Chinook salmon estimates when compared to a total river estimate derived using the Canadian border escapement estimate and genetic data collected at Pilot Station appear unbiased (F. West, Commercial Fisheries Biologist, ADFG, Anchorage; personal communication). The Big Salmon sonar project began operating in 2005 and has a historical timespan nearly identical to the Eagle sonar project. In general, the timing and relative magnitude of the annual estimates is consistent with estimates of Chinook salmon observed at the Eagle sonar project.

H.2.4 References

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H.3 Border Mark-Recapture

H.3.1 Project Summary

Introduction

The fishwheel program was implemented by Fisheries and Oceans Canada (DFO). It is often referred to as “Bio Island” as well as variations on this along with “border fishwheels” and “mark-recapture.” The program estimated passage by capturing salmon in fishwheels located on the mainstem Yukon River, close to the Canadian side of the Yukon - Alaska border. Salmon were tagged and released, with the commercial fishery upstream serving as the main recapture event.

The two main fishwheel capture locations were downstream of all commercial fishing:

- White Rock fishwheel located approximately 10 river kilometers upstream of the international border on the north (river right) bank (64.628, -140.876)
- Sheep Rock fishwheel located approximately 17 river kilometers upstream of the international border on the north (river right) bank (64.62075, -140.7575)

Note that both fishwheels were on the same side of the river. Moose Creek(?) fish wheel was attempted on the other side but it was not a suitable location. No suitable location was found on the other side.

Other fishwheels and occasionally other capture methods are described in Table H.3.

The fishwheel program was operated annually by DFO in 1982-83 and 1985-2008. Some similar projects undertaken in 1973, 1974, 1978, and 2010-2012 are summarized in Table H.3.

The main objectives of the mark-recapture program (as described in Johnson et al. 2002) were to determine:

1. in-season abundance estimates for use by fishery managers in monitoring catch and escapement objectives;
2. final estimates of border passage abundance;
3. estimates of Canadian drainage spawning escapements;
4. harvest rates in Canadian fisheries;
5. migration timing and migration rates;
6. sex, length and age composition profiles of chinook salmon captured for mark application and recaptured in the commercial fishery.

Fishwheel Operations

The White Rock and Sheep Rock fishwheel sites were downstream of all Canadian commercial fishing activity. Fishwheels had two baskets which fished to a 3m x 3m depth and width. Placed at the upstream limits of eddies where mainstem currents were sufficient to tum them, rotation speed was typically 3-4 RPM depending on water velocity. Speed was adjustable by adding or removing plywood sections of the fishwheel paddles. As water level fluctuated fishwheel position would be adjusted to prevent paddles from hitting bottom and achieve maximum efficiency. Lowering or raising the axle additionally allowed about 1m of depth adjustment without major repositioning of the fishwheel. Fishwheels were kept in place by steel cables, polypropylene ropes, and logs cut on site. Salmon holding pens were constructed to allow a continuous flow of fresh water, for the fish which were held prior to multiple daily checks. Specific details on fishwheel design can be found in Appendix 1, Milligan et al. 1985.

Fishwheels were operated in order to sample the entire run, generally starting to fish during the second or third week of June each year, and continued to operate through the fall chum run when a similar DFO chum mark-recapture program was undertaken. Effort was generally constant and with the exception of short periods for maintenance or repair, fishwheels were operational 24 hours daily (Johnson et al 2002).

Sampling and Marking

Fishwheels were checked a minimum of two or three times per day with more frequent checks during peak migration or if conditions required (to minimize overcrowding and holding time). Fish would be held for 6 – 12 hours depending on the frequency of checks. Captured Chinook were sampled for age (scales; 2-5 taken depending on the year), sex (external morphological characteristics or expelled sex products), and fork length to the nearest centimetre. Scale samples were collected with a total sample goal, so were not always collected in proportion to the run.

A spaghetti tag with consecutive non-repeating numbering information went through the dorsal musculature (approximately 1.3 cm below the dorsal surface and between the pterygiophore bones of the dorsal fin – Cronkite and Johnson 1988) with a 15 cm long needle like applicator, and tied with an overhand knot. Approximate tag size was 2 mm in diameter and 30 cm in length. Salmon were tagged in a tray with their heads kept in frequently changed water. As they were done concurrently, sampling and tagging generally took less than 30 seconds before fish were released back into the river.

For a subset of years examined, recaptures of fish tagged at a lower wheel was between 0 and 2% of all wheel catches

Recapture (Commercial Fishery)

The Canadian commercial fishery zone begins upstream of Sheep Rock and continues up the mainstem of the Yukon River to a point just downstream of Dawson City. There is a short, closed area here before resuming upstream of Dawson City on the Yukon Mainstem. The waters open to commercial fishing continue up the mainstem Yukon River, stopping just below Tatchun Creek. The first portions of the Pelly and Stewart Rivers, which enter the mainstem between Dawson City and Tatchun are also part of the commercial fishing zone.

Due to the bulk of fishing effort being between Dozen Islands (~5km upstream of Sheep Rock, a local name for a group of islands around 64.60427, -140.68246 ; Yukon River Heritage Reference) and Sixty Mile River (below the upstream boundary of commercial fishing) (Johnson et al. 2002) the (re)capture event was contained to Chinook caught before the confluence of the Stewart River with the mainstem, covering approximately 210 river km (Johnson et al. 2002).

Tags were recovered through both mandatory catch reporting and tag return incentives such as a small payment per tag or each tag return being an entry into a prize draw. Mandatory catch reporting was also the source of information on total number of salmon captured (with or without tags).

Although there are multiple other fisheries in Canada, the commercial fishery was the primary recapture event. In some years in season other fisheries were used, but with commercial (and then test fisheries in times of low returns) having the strictest reporting requirements in terms of location and tag return this was the focus of the recapture event.

Mark-Recapture Population Size Estimate

The main method of completing the mark-recapture estimate was with Chapman's estimation procedure (also known as the modified Peterson procedure). In some years other estimation methods were considered (detailed in Table 1), sometimes retroactively applied (post season) to the border passage estimate published in the Joint Technical Committee reports.

Tag loss (inclusive of tag loss from the fish, mortality, or return downstream) was estimated to be 10% of all tags applied at the fishwheels from 1985 on. The revised dataset included here has had 10% tag loss applied to all years consistently.

Additional Information Collected

Relative to the project objectives, additional information was also collected from the commercial fishery and from spawning grounds. From the commercial fishery, salmon harvested could be subsampled for length, weight, sex, scales etc. (see Table 1 for details)

From spawning grounds, the recovery of tags to inform distribution and abundance took place along with sampling for fork and hypural length, 10 scales from each fish for ageing. and carcasses dissected to determine spawning success.

Information on salmon sex, length, and age from both the fishery and spawning grounds was also used with fishwheel samples of the same to compare the run composition by location and capture method.

Discussion

The BioIsland project was a significant undertaking which provided with direct inseason estimates for Canadian fisheries, and the primary method of determining Canadian origin run size and escapement for several decades, until the implementation of the Eagle Sonar in 2005 and transition to full use for in season and post season estimates by 2008.

Although using the best methods available at the time, it was observed/generally known that the fishwheels were proportionally capturing smaller Chinook (i.e. the fish wheel caught larger Chinook than what was captured in the nets at Eagle), and consequently more males than the run was composed of. The Eagle sonar also revealed the mark-recapture abundance estimates for Chinook seemed to be biased low for the years in which the two projects overlapped in operations. Separate work is ongoing to determine how differences in catch composition between the marking event and the recapture event occurred, as well as other assumptions about the project design that may have caused a lower estimate than observed through sonar enumeration.

Mark recapture assumptions: given the large amount of literature which deals with the critical assumptions of MR (e.g., Krebs 1999) and several publications which discuss these assumptions specific to this fishwheel program (Johnson et al. 2002, Brannian 1990, Cronkite and Johnson 1989), this review will focus on a few consideration specific to BioIsland which affect the ongoing use of the data and the impacts of changes to operations over time.

The biggest known issue is that abundance estimates are biased low due to the selective nature of the fishwheel captures (REFS). Other issues which might affect how these estimates are used in the run reconstruction include:

- *different methods of calculation between years*: Most years are a simple Chapman. Later years involved consideration of run timing and stratified / SPAS estimate / max likelihood models mixed in there. 1984 isn't based on fishwheels but escapement indexes plus harvest.
- *Selection of fish for marking*: In early years more fishwheels ran and some gillnetting took places. Additionally, a change in the minimum size of fish selected for marking may have an impact. Some years not all fish were marked, in the mid 1990s a specific decision was made not to mark fish under 450 mm fork length although this likely had a minimal impact as few fish of this size caught / marked prior.
- *recapture fishery varied*: changes over time in effort and gear of the commercial fishery; then a reduction in the commercial fishery due to low runs required a test fishery either for the entire recapture event or to supplement recaptures in the commercial fishery (1998, 2000-2004, 2007, 2008).
- *Other unexamined possibilities for bias in recapture event*. These include timing of openings related to releases of marked fish, locations of fishing related to bank orientation of salmon, and potential selection of smaller fish kept for personal use (not reported in commercial catches),
- *fish wheels moved/changed*: over time, additional effort (netting, additional fishwheels) were operated to increases catches / variety of catches, but numbers were minimal compared to the annual catches of the two main fish wheels, Sheep Rock and White Rock. Construction of fishwheels also evolved over time, with significant changes noted in Table H.3. However both primary fishwheels being on the same bank, while recapture events were more varied may have an unexamined impact if causing bias in the capture event.
- *effect of water levels and clarity*: higher catches in higher water years (until the point where high water and debris caused removal of fishwheels). Water clarity in low water years, (typically an issue during the end of the fall season).

The data compiled as part of this review intends incorporate estimates from 1982 on, all published or reproducible confidence intervals, and standardize assumptions where possible (e.g., tag loss).

H.3.2 Project Details

Table H.3. Border Mark-Recapture - Operational Timeline

Years	Component	Change/Event
1973	All	One fishwheel 48km downstream from Dawson City. Basic fish wheel construction. Petersen disc tags were placed behind the dorsal fin as a mark. A range of recapture events used including four locations with multipanel gillnets, a subset of commercial fishwheels, commerical gillnets, and First Nation fish camps. Only fish captured upstream of Dawson were used in the mark-recapture estimation. Data not used, considered preliminary work. Details in Sweitzer (1974).
1974	All	Similar methods to 1973, with the addtion of spaghetti tags to roughly one third of salmon and Peterson discs to the rest. Recapture data from commercial, domestic, and First Nation fisheries. Initially recapture data focused on fisheries above the Stewart River, but was recalculated to focus on the Dawson area (Milligan et al. 1985). Data not used, considered preliminary work. Details in Brock (1976).
1982 to 1983	All	Fishwheel MR study focused on border passage. Multiple fishwheels and locations. In 1982: fishwheels 7 and 12 river km upstream from the border, in 1983: in locations 12, 15, and 89 km above border. Tagging with spaghetti tags and recaptures in all fisheries, but commercial fishery below Stewart used for estimates as it had the most reliable information. 1983 included radio tagging to estimate tag loss and spawnig distribution. Radio tagging also done at commercial fishwheel 142km above border. Study observed erratic post-tagging behaviour, proximity to spawning ground, handling and holding effects, vulnerability to recapture (possibly related to stress, proximity to fishery) and effect of water level.
1984	All	No mark-recapture program. See "Data Issues" table for alternate estimate description.
1985	Location	Program resumed. 3 fishwheel locations; 10 km (White Rock), 13 km (Moose Rock), and 17 km (Sheep Rock) upstream of the border – this is an overlap of locations with earlier years (differences in river distance measurement methods).
1994-1995	Tagging	Only Chinook salmon over 450 mm in fork length were tagged at the fishwheels. Likely small effect as minimal fish under 450 mm caught.
2000, 2007 and 2008	Recapture Fishery	Test Fishery only. Low run size and limited to no commercial fishing oppurtunies led to a test fishery in the Dawson area taking place to serve as the recapture event.
1998, 2001-2004	Recapture Fishery	Commercial fishery and test fishery.

Years	Component	Change/Event
1999-2002	Tag Loss	Investigation of tag loss, looking for secondary marks . No fish with only secondary mark found in subset of fish examined in upstream fisheries.
1999-2007	Population Size Calculation	Temporally stratified analysis (SPAS, Arnason et al. 1996) undertaken retrospectively for 1999-2007 to produce final published estimates for the JTC report and this dataset.
2008	Population Size Calculation	As the primary in-season and post-season assessment was switched to the Eagle Sonar, the estimate produced from this project in 2008 was never updated from the preliminary estimate using standard one event mark recapture.
2001	Fishwheel construction	Fishwheel pontoons were upgraded to aluminium floats, with an undetermined effect on fish catchability.
2004	Marking Event	Gillnetting was undertaken from around the second week of July to the first week of August to increase Chinook captures. Nets were fished in three locations on river left, in four combinations as follows: (1) Mesh size 5.5”, length 120 feet, 30 meshes deep, 2.5:1 hang ratio, (2) Mesh size 5.5”, length 150 feet, 35 meshes deep, 4:1 hang ratio, (3) Mesh size 7.25”, length 120 feet, 30 meshes deep, 4:1 hang ratio, (4) Nets #1 and #3 together. The first three individual nets were only used briefly at the beginning, followed by the combined net. Soak time was generally between one and three hours. In total, 139 Chinook were captured (135 tagged, 87% were male).
2008	All	Final year of fish wheel operation, as JTC recommended using the Eagle sonar project in 2008 as the primary assessment tool for the border passage estimate. Was going to operate in 2009 for another comparative year of data, but flood damaged.
2010-2012	ASL Collection	One fishwheel (White Rock, 10 rkm from border) operated as an R and E project to collect ASL and genetic data from Chinook for the purpose of comparision with Eagle test fishery.

Table H.4. Border Mark-Recapture - Potential Data Issues

Years Affected	Potential Issue
1973 and 1974	Fishwheel locations and recapture methods not comparable to 1983 and on.
1984	No fishwheel program. Border passage estimate based on mainstem harvest plus 5-area escapement index relationship.
1988	Extremely high water and debris affected start date of fishwheel catches and commercial recapture fishery at the early part of the run.
1992	Only one fishwheel (White Rock) was in operation for most of the Chinook season, with Sheep Rock not running until August 8 (affecting number of tags applied).
2002	In 2002, the distribution of the run only allowed an SPAS estimate to be calculated for part of the season, so an expansion was applied based on mean run timing for 2000-2001 and 2003-2005.
2007	Very limited Chinook catch and tag recovery data after the first week of August affected recaptures avalible for estimate.
2008	Low run size created challenges with implementing full suite of test fishing. Non-stratified estimate used, but flagged as likely biased low at the time. Stratified SPAS estimate not completed.

H.3.3 References

Most Recent Project Published Operational Plan and Report

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H.4 Yukon River North Mainstem

The Klondike River is a tributary to the Yukon River, with the confluence at Dawson City and the watershed primarily in Tr'ondëk Hwëch'in's Traditional Territory. One of the first major (Brown et al). spawning tributaries after the border, the Klondike River an early component of the Canadian mainstem Chinook salmon run.

Chinook abundance in the tributaries to the Yukon North mainstem have been assessed in a few recent years with a sonar program on the Klondike near the confluence with the Yukon River.

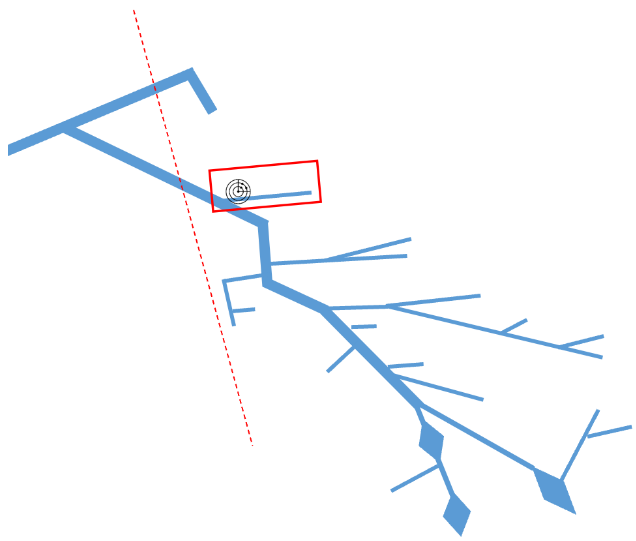

Figure H.1. Location of Klondike Sonar in the Yukon North Mainstem

H.4.1 Project Summary - Klondike Sonar

Introduction

The Klondike River Sonar program initially ran for three years. It was operated by a consultant with R&E funding from 2009-2011. It was re-implemented in 2020 by Tr'ondëk Hwëch'in in partnership with a private consultant.

The project estimated Chinook salmon passage into the Klondike River using a DIDSON high resolution sonar (2009-2011) and an ARIS unit (2020 on). . In the first year (2009), visual counts were used to verify the precision of the sonar counts. Age, sex and length (ASL) data was collected in 2010 and 2011. DNA samples were collected in 2011 (n=36).

For the 2009-2011 assessment, the project was located on the south bank of the Klondike River (river right), about 3.5 km upstream of the confluence of the Klondike and Yukon Rivers (64.044921N, -139.400196W).

The 2020 assessment was located on the north bank (river left) of the Klondike River, ~1 km upstream of the confluence of the Klondike and Yukon Rivers (64.0423557N, -139.4138556W).

Methods

- Each year one sonar used to enumerate passing Chinook salmon, ensonifying the full width of the Klondike River with a deflection weir on both sides.
- Each year sonar enumeration began in early July and ended in mid-August
- In 2009 and 2010 a linear regression model was used to extrapolate the number of passing Chinook for an additional nine days after the sonar operations stopped. In 2011 an exponential regression model was used to extrapolate the number for an additional nine days after the sonar operations stopped.
- In 2009 visual counts, from an elevated river bank, were used to verify the precision of the sonar counts.
- In 2009, gaps in daily sonar counts were corrected using expanded observer visual counts during the gap period.
- In 2010 and 2011, gaps in daily sonar counts were corrected using expanded counts based on the number of fish per hour derived from the mean 24 hour counts before and after the sonar outage.
- In 2010 and 2011, four days were spent, each year, in early to mid-August searching for carcasses and sampling for ASL data. 2010 n=20. 2011 n=48.
- 2020 no test fishing or carcass sampling occurred

Discussion

Critical assumptions include:

- All salmon that migrate past the sonar are accounted for.
- Counts from DIDSON and ARIS units are comparable across years.
- The linear and exponential regressions are the most appropriate models for extrapolating post-season passage.
- No salmon migrated behind the sonar or out of field of view and were thus, not accounted for.
- All fish measured to be greater than 50cm were counted as Chinook salmon.
- Need to check 2020 length thresholds if applicable to counting method.

Note that these critical asusmptions were not reviewed in-depth for this project, because it is not currently used on the run reconstruction by Connors et al. (2022).

Uncertainty Evaluation:

- When used properly, sonar can provide accurate counts of passing salmon. The method still produces an estimate however, not a hard count.
- Based on the experience of the operators and authors of the reports, the uncertainty behind the results obtained can be considered minimal. The operator has extensive experience with enumerating salmon using the methods outlined, and can be relied on to produce a passage estimate of the highest accuracy possible, with the equipment available.

H.4.2 Project Details - Klondike Sonar

Table H.5. Klondike Sonar - Operational Timeline

Years	Component	Change/Event
2009	Cross-Check	Visual counts, from an elevated river bank, were used to verify the precision of the sonar counts
2010 & 2011	Cross-Check	Four days were spent, each year, in early to mid-August searching for carcasses and sampling for ASL data. 2010 n=20. 2011 n=48.
2009	Gap Correction	Gaps in daily sonar counts were corrected using expanded observer visual counts during the gap period
2010 & 2011	Gap Correction	Gaps in daily sonar counts were corrected using expanded counts based on the number of fish per hour derived from the mean 24 hour counts before and after the sonar outage
2009 & 2010	Coverage Correction	Linear regression model used to extrapolate the number of passing Chinook for an additional nine days after the sonar operations stopped.
2011	Coverage Correction	Exponential regression model was used to extrapolate the number for an additional nine days after the sonar operations stopped

Table H.6. Klondike - Potential Data Issues

Years Affected	Potential Issue
2010 & 2011	Sonar counts were not cross- verified with visual counts.

H.4.3 References

Data Sources

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H.5 Pelly Watershed

The Pelly Watershed is a large watershed which has an average return of ~14% of the Canadian mainstem Chinook run (JTC 2016-17). The drainage has a number of traditional territories; Selkirk, Na-cho-Nyak Dun, Little Salmon Carmacks, and Kaska Dena.

Two historically long running assessment projects in this watershed are the Blind Creek weir on a small spawning tributary to the Pelly Mainstem, and aerial surveys of Ross River, a larger tributary to the Pelly River, and further upstream (south-east) than Blind Creek. Closer to the mouth, the Pelly River sonar is a more recent project which enumerates the return to the entire watershed.

The sonar and weir programs are described in this section. The Ross River aerial program is covered in Section I, which summarizes the Canadian aerial surveys.

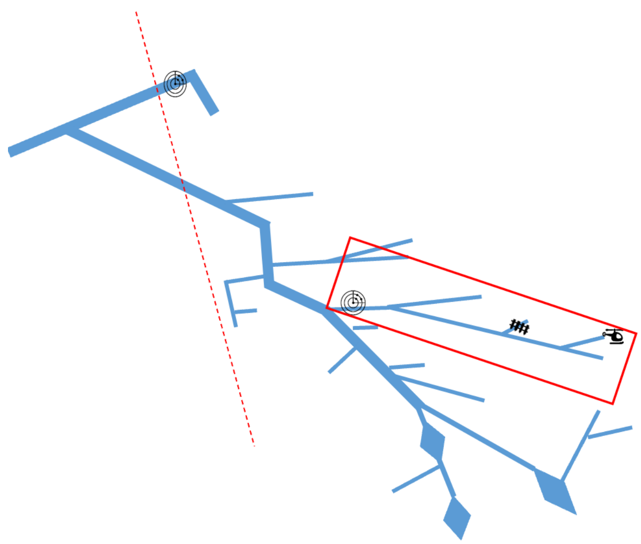

Figure H.2. Location of Pelly Surveys

H.5.1 Project Summary - Pelly Sonar

Introduction

Pelly River Sonar has been implemented annually by Selkirk First Nation and a consultant as a Restoration and Enhancement Funded project.

The project estimates Chinook salmon passage using sonar. Some age, sex and length (ASL) of Chinook is collected via minimal test fisheries.

Sonars and camp are situated ~24km downstream of Pelly Crossing and ~24km upstream of the confluence of the Pelly and Yukon Rivers (62.833963N, -137.079965W).

Methods

- Each year sonar enumeration began between July 1-10, and ended between August 3-26.
- Gaps in sonar counts were corrected, post-season, using the same techniques each year. Three different interpolation methods were used depending on the amount of data to be interpolated. Formulas can be found on pg. 10 in Lust (2017).
- A second order polynomial equation was used to extrapolate Chinook passage rate to the estimated end date. This technique was used each year.
- The same second order polynomial equation was used to extrapolate Chinook passage to a start date of July 1 in 2018 and 2019.
- Set netting started between July 3-20 each year, and ended August 2-18 each year.
- Drift netting was more irregular; 2016 July 21-August 2, 2017 July 4-August 14, 2018 August 6 and 8, 2019 none.
- Significant decrease in drift netting effort from 2016 to 2019.
- Transition from Simrad EK60 sonars to ARIS 1200/1800 sonars from 2016-2019.
- Increase in sonar and netting season duration after the 2016 season.

Discussion

Critical assumptions include:

- All salmon that migrate past the sonar are accounted for.
- No salmon migrated behind the sonar and were thus, not accounted for.
- no salmon migrated behind the sonar or out of field of view and were thus, not accounted for
- Counts from Simrad EK60 and ARIS units are comparable across years
- Should address salmon who go up and then out (referred to as ‘straying’ salmon in the Big Salmon section)
- The method of extrapolating are the most appropriate models for extrapolating post-season passage

Uncertainty Evaluation

- The post-season expansion formula for Pelly sonar relies on the assumption that the post-season expansion at Eagle sonar is accurate. And that the distance between Eagle and Pelly (456km) is travelled in 7.5 days.

- The characteristics used to distinguish migrating Chinook from other fish on the echogram are vague (eg: crescent shape, parallel to river current, salmon traces are generally brighter and larger than freshwater fish, large salmon create a shadow on the echogram when passing in front of the sonar). Total length is not used.
- if target testing/yearly bathymetry is not completed, it is more likely fish could be missed.
- there is a side channel that is accessible during high water. Efforts are made to block it but during high water events, but this might not always be possible.

H.5.2 Project Details - Pelly Sonar

Table H.7. Pelly Sonar - Operational Timeline

Years	Component	Change/Event
Various	Sonar	Drift netting was attempted to confirm that there was no fish passage in the middle of the river. This could not be confirmed due to difficulties drifting on a sharp bend in a relatively small river (current pushed boat/net onto shore).
2016	Sonar	2 Simrad EK60 split-beam sonars were positioned on the right and left bank. The right bank sonar was able to ensonify 100m of the river channel and the left bank sonar was able to ensonify 50m of the river channel resulting in full sonar coverage across the full width of the Pelly River.
2017	Sonar	1 Simrad EK60 split-beam sonar was positioned on the right bank, and one ARIS Explorer 1800 multi-beam sonar was positioned on the left bank. The right bank sonar ensonifed 75m of the river channel, while the left bank sonar ensonified 35m of the river channel.
2018+	Sonar	1 ARIS Explorer 1200 multi-beam sonar and 1 ARIS Explorer 1800 multi-beam sonar were positioned on the left and right banks, respectively. The left bank sonar ensonified 60m of the river channel, while the right bank sonar ensonified 30m of the river channel.

Table H.8. Pelly Sonar - Potential Data Issues

Years Affected	Potential Issue
All	Lack of yearly target testing/bathymetry, so unknown whether fish may pass in the middle of the river where it is not ensonified (couldn't be confirmed through test fishery due to river characteristics).
2016	In the first year, the sonars were removed from the water very early (August 3) thus missing a significant later portion of the Chinook run. A post-season expansion formula was used to extrapolate the counts for 21 days (a relatively long time).
2017	30m of river not ensonified
2018, 2019	50m of river not ensonified

H.5.3 Project Summary - Blind Creek Weir

Introduction

The Blind Creek weir program was initially operated by the Ross River Dena Council annually between 1995 and 2000 (AFS Funding), and then run annual by a consultant (R&E Funding) from 2003 to 2018 (except in 2017 due to high water).

Weir counts are available for all operational years, but ASL sampling started in 2003. Other information (e.g. fish condition, water temperatures) is also collected.

The weir is located on Blind Creek, a tributary to the Pelly River near the community of Ross River. The weir has been at the same location for all years of operation, approximately 1 km upstream of the creek mouth (62.183847N, -133.200422W).

Methods

The site consists of a weir installed across the width of the creek, in a fairly standard tripod and weir panel setup, in an upstream pointing V, with a pen and gate for fish passage, an observation/sampling platform, and a recovery area. The weir has generally operated from mid-July to mid-August, exact yearly dates provided in Appendix 2, Wilson (2018). Counting takes place at a minimum of an hourly basis during daylight hours, and the gate is closed unless salmon are being counted through.

From 1997 – 1999, daily and total weir counts are available, no sampling was conducted. From 2003 – 2018 ASL sampling was conducted, mainly from live dip netting but including carcasses in some years. In the earlier years, there were challenges with sampling causing fish to move back from the weir, or concerns regarding handling of fish (particularly 2004 and 2005). Any observed spaghetti tags from downstream research projects were reported, and through the mid 2000s, genetic tissue samples were collected from handled fish for baseline use. Beginning in 2013, some Broodstock collection for school programs has occurred, as well as small amounts of egg collection for thiamine testing (2015-16). Various other information has been collected over time including egg retention in carcasses, observations of fish condition, observations of net marks, water level and temperature records.

Weir and pen construction has been relatively consistent through the years, with some notable updates as listed in Table H.9. Overall, the weir counts at Blind Creek should be considered reliable and robust. There are minimal years with specific issues that should be considered in context (Table H.10).

Discussion

Related to a weir on a smaller system, the two critical assumptions are that all passage is accounted for, and that spawning below the weir is minimal.

Generally the weir has been in place several days prior to any observed passage (Appendix 2, Wilson 2018). Potential exceptions to this are 1997, 2003, and 2012. In 1997 there was high passage on the first day of counts, in 2003 a small number of Chinook had been observed in the area four days before weir construction, and in 2012 high water delayed the installation of the weir although it may also have delayed upstream Chinook migration. Any missed passage was likely minimal, and the weir is only removed when passage has diminished to no or minimal passage. During the operational season, the weir is checked regularly for any holes, and has been considered fish tight over the seasons. Occasionally, high and/or silty water have obstructed the ability to count, however with the upstream gate closed Chinook would be dip netted over the weir (2007, 2013, 2014).

While fish have been observed below the weir, these are considered minimal compared to the spawning areas above the weir in the remainder of the system. A handful of aerial surveys which took place in the late 1980s and 1990s found the majority of spawning occurred above the future weir location, especially in km 12 – 30 (Harder and Associates, 1996).

Uncertainty Evaluation:

Visual fish counts at weirs by direct observation are generally assumed to be a complete census of the species passage during the operating periods, and error is assumed to be negligible. Therefore, formal variance statistics have not been calculated.

H.5.4 Project Details - Blind Creek weir

Table H.9. Blind Creek Weir - Operational Timeline

Years	Component	Change/Event
2004	Trial	Holding / recovery area upstream of weir was not successful. Counting chamber operational
2007+	Weir Design	New weir tripods were installed which increased angle of weir panels
2015+	Weir Design	Specific gate was built, rather than removing a few pieces of individual conduit to allow fish to pass

Table H.10. Blind Creek Weir - Potential Data Issues

Years Affected	Potential Issue
1995	Although a final count is reported by the JTC, detail on daily counts and weir construction and timing is lacking" [not recommended for use at this time]
1996 and 2000	Weir was installed however operational challenges precluded a complete count, no data.
1996	Record of a weir operating, but no further detail is available.
1997	The weir went in on a later date compared to the following years, and the count on the first day of operation (July 25) was high (12% of the total run). However the total run size of this year was within the range of following years' data.

Years Affected	Potential Issue
2017	Weir was breached during a flood event resulting in the collapse of the weir structure. There is no passage count or estimate.”
2013	Delay in complete weir installation after large debris interfered.

H.5.5 References

Pelly Sonar

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Blind Creek Weir

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Wilson, J. 1997. Blind Creek Chinook Salmon Enumeration Weir, 1997. Prepared for Ross River Dena Council and DFO, Aboriginal Fishery Strategy.

Wilson, J. 1997. Blind Creek Chinook Salmon Enumeration Weir, 1996. Prepared for Ross River Dena Council and DFO, Aboriginal Fishery Strategy.

H.6 Carmacks Area Tributaries

This area represents tributaries which flow directly into the Yukon River, as opposed to being large drainages with a single confluence with the Yukon River. A number of systems are known as important Chinook migration, spawning, and rearing habitat. The main traditional territories in this region are that of Little Salmon Carmacks First Nation and Selkirk First Nation. Tatchun creek is a small lake-headed system draining directly into the Yukon River, and a long standing area of harvest for the Little Salmon Carmacks First Nation. Given its importance, as well as modern accessibility by road, it has had a variety of assessments undertaken. Moving upstream on the Yukon River, the Little Salmon River, then the Big Salmon river are tributaries to the Yukon River which have historical aerial assessments, as well as a long running sonar project on the Big Salmon River.

The Tatchun surveys and Big Salmon sonar program are described in this section. The Little Salmon and Big Salmon aerial surveys are covered in Section I, which summarizes all the Canadian aerial surveys.

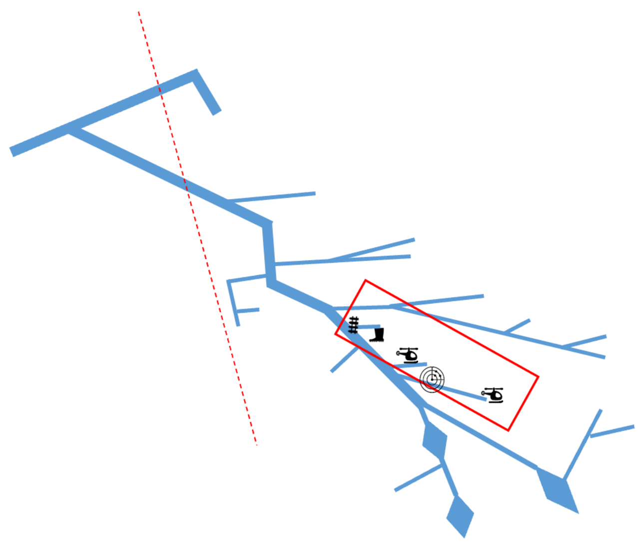

Figure H.3. Location of Surveys on Carmacks Area Tributaries

H.6.1 Project Summary - Tatchun River Chinook Surveys (Mostly Foot, 4 years of weir)

Introduction

Tatchun surveys were implemented by different organizations over the years:

- Alaska Department of Fish and Game: 1966, 1970-1972
- Environment Canada Fisheries Service: 1973-1983
- Department of Fisheries and Oceans Canada: 1984-1990, 1992-1996

- Quixote Consulting - R&E funded: 1997-2000

Methods

Survey types and implementation varied over time:

- Spawner counts by foot survey (1966, 1970-1977, 1979-1985, 1987-1990, 1992-1996): Over the course of one day, an observer walked the creek and counted spawning salmon. Stream walks happened some time between as early as 15-Aug to as late as 8-Sep.
- Spawner counts by boat survey (1978): Observer drifted the stream and counted spawning salmon.
- Spawner counts by aerial survey (1986): Implementation as per the descriptions in Section I.
- Escapement count by weir (1997-2000): Weir was in place from as early as July 15 to as late as September 5. Total weir operational period ranged from 24-55 days.

Survey coverage varied between years

- 1966, 62.281792N, -136.308703W (300m upstream of highway bridge).
- 1970, 62.281202N, -136.303408W (300m upstream of campground).
- 1972, entire stream surveyed.
- 1975, lake outlet to highway bridge surveyed.
- 1980, entire stream surveyed.
- 1995 and 1996, entire stream surveyed.
- 1997-2000 (weir location), 62.284567, -136.321509W
- Location details unknown for years not listed above

Discussion

Critical Assumptions:

- Spawner index numbers from 1966 to 1996 are comparable.
- All spawning Chinook were counted as they passed the weir during 1997-2000 seasons.

Uncertainty Evaluation:

- From 1966 to 1996, it is unknown if the survey effort (survey duration and stream distance/area surveyed) was consistent between years, thus compromising the strength of the indices.

- The spawning stage, when the foot/boat surveys were conducted between 1966-1983 was not consistent. Spawning stage was identified in three classes; before peak, during peak, and after peak.
- Between 1966-1983, dates when the surveys were conducted was inconsistent, ranging from 15-Aug to 8-Sep.
- The surveyors overall rating of the survey is inconsistent throughout the years 1966-1983.
- Unknown if the surveys were conducted over the same extent (although likely given short length of watercourse)
- Unable to find the data sources for 1984-1994.

H.6.2 Project Details - Tatchun G Surveys

Table H.11. Tatchun Surveys - Operational Timeline

Years	Component	Change/Event
1966 to 1996	All	Changes between survey methods (mostly foot, but 1 aerial and 1 boat), survey effort, surveyors.
1997 to 1998	All	Weir and foot surveys conducted
1999 to 2000	All	Only weir survey

Table H.12. Tatchun Surveys - Potential Data Issues

Years Affected	Potential Issue
1971	incomplete survey
1978	boat survey (different method from all other years)
1986	aerial survey (different method from all other years)
1991	missing data, unknown if survey was completed
1984 to 1994	unable to find source data

H.6.3 Project Summary - Big Salmon Sonar

Introduction

The Big Salmon sonar has been implemented annually since 2005 by consultants with R&E funding. The project estimates Chinook salmon passage using sonar. Age, sex and length (ASL) data are collected primarily through a carcass pitch upriver of the sonar, in spawning areas in the watershed's upper reaches.

The sonar is located at 61.878840, -134.889482, approximately 1.5 km upstream of the Big Salmon River's confluence with the Yukon river.

Methods

The primary objective for this project has been the enumeration of Chinook salmon escapement to the Big Salmon drainage. The approach to collect the data to produce daily and total Chinook passage estimates is based on one sonar unit on the left (south) bank, which ensonifies the width of the river, with two diversion weirs to ensure passage is confined to within the sonar beam. No chum are known to migrate into the Big Salmon, and freshwater species of comparable size and behaviour to Chinook are considered negligible. No expansion for missed passage at the beginning of the run typically occurs as the sonar usually captures the first or early fish. If the sonar is removed before the end of the run ((end sonar operation after three consecutive daily counts of less than 1% of the total run / day), daily passage is extrapolated past the operational period using polynomial or logarithmic equations based on the previous 6-16 days of counts depending on the year.

The carcass pitch takes place after the run. Carcass sampling occurs to the junction of Souch Creek and Big Salmon River. Age, sex and length is taken annually. Age, sex, and length is taken annually. In some years, additional sampling of genetics, female pre-spawn mortality and egg retention, and collection of eggs for thiamine analysis is completed, and locations of spawning concentrations are recorded

Discussion

Critical assumptions include:

- Co-migrating fish are not mis-identified as Chinook: resident fish could co-migrate. This is considered numerically inconsequential based on information from the area and gained over the course of the project:
  - there is an absence of significant non-chinook by-catches in the upper Yukon River First Nation or other fisheries (M.E.Jarvis, Aboriginal Fisheries Coordinator DFO Whitehorse, per. Comm.)
  - freshwater behavior observed is considered markedly different
  - Chum are thought to be absent in the system (and the timing/migration rate of the upper Yukon chum precludes their presence when the Chinook are migrating.)
  - The normal distribution, (few or no Chinook identified at the beginning of the project) of the run indicates that fish the could be mis-identified as Chinook.

- A trial test fishery caught only salmon in minimal numbers and it was concluded that the level of effort required relative to likelihood does not require a concurrent test fishery. See 2016 report for more detail and discussion.

- All migrating chinook passing the site are detected: Since the site has good, stable bottom profile and field of view and there is not a lot of evidence to suggest fish are passing undetected.
- Milling salmon not double-counted in total escapement; all targets considered downstream salmon were subtracted from the total, the site has strong laminar flow (not conducive to milling), and the sonar is located 1.5 km upriver from the confluence with the Yukon River.
- Counts from DIDSON LR and ARIS 1800 units are comparable across years

The Chinook salmon estimates, when compared to Carmack's area tributaries genetic estimate of the Eagle Test Fishing GSI tracks well in terms of relative stock proportions. Additionally, the relative stock proportions and Big Salmon run timing derived from the sonar operation also track well with 3 years of radio telemetry data. See the 2011 report for further details and discussion.

H.6.4 Project Details - Big Salmon Sonar

Table H.13. Big Salmon Sonar - Operational Timeline

Years	Component	Change/Event
2005	All	First year of operation, DIDSON-LR, ensonification confirmed with target testing at beginning of season. Traces identified as salmon based behaviour and size (0.55 m general threshold). Review of 20 randomly chosen files by second reviewer post season found 98% concordance in counts.
2006	Sonar	Downstream salmon subtracted from hourly counts beginning this year. After the sonar count was complete, annual upstream carcass pitch conducted. Review of 20 randomly chosen files by second reviewer post season found 99% concordance in counts.
2007	Sonar	Acquired heavier duty weir tripods. Target sized used to identify salmon decreased to 0.50 based on previous years ASL collection and observation of lengths interpreted to be freshwater fish based on behaviour.
2009	Sonar	Addition of 8 degree concentrator lenses to improve clarity at distance past 20m. More substantial weir tripods in place, resulting in narrower migration corridor in front of sonar, approximately 36 m.
2010	Sonar	Position of targets within 5 m sections of river from sonar recorded beginning this year for production of range frequency histograms.
2005-2012	Sonar	Passage during missing data gaps was interpolated based on the mean number of fish per hour recorded the previous 24 hours

Years	Component	Change/Event
2013	Sonar	From this year on, missing samples estimated by interpolation of the average file count over the 12 hours before and after the missing sample
2013	Sonar	Starting this year onwards 10% of sonar files were recounted each day to measure the precision of counts - repeatability between individuals described using APE as in Enzenhofer et al. 2010.
2014	Sonar	Since this year, sample variance estimator reported based on absolute difference between readers to quantify the person of counts and net variability between readers.
2014	Sonar	Three cross sectional profiles taken with a Biosonics DTX splitbeam echo-sounder confirms minimal change to the river profile since project inception.
2016	Test Fishery	Over one week (August 7-14) 46 complete drifts undertaken for a fishing effort of 173 minutes. The net was a 16.25 cm mesh gillnet, 30 m long by 2.0 m deep. See 2016 report for further details and discussion. Total catch was two female Chinook.
2016, 2017	Sonar	Deployment of ARIS (2016, 69 hours and 2017, 73 hours) to compare counts with DIDSON, and to obtain accurate measurements of fish over 50 cm from a subset of the files.
2018	Sonar	Change to ARIS 1800 for full season to capture higher resolution images and use of ARIS fish software for identification and enumeration of targets. Switch to use of coefficient of variation to quantify repeatability/precision of counts (Enzenhofer et al., 2010).

Table H.14. Big Salmon Sonar - Potential Data Issues

Years Affected	Potential Issue
2005-2006	The resolution of target images at ranges 25 - 40 m was described as poor and the relative size of the targets beyond this distance could only be determined qualitatively; however, the authors suggest Chinook salmon were readily distinguishable from resident fish species by the relative size of the image and difference in swimming behavior. In 2009 the addition of an 8° concentrator lens further improved visibility in the outer range.
2007	Sudden high water event collapsed north bank (river right) weir on August 8, reinstalled August 11 when water levels dropped sufficiently. Although lower passage was observed August 8, it was presumed to be from increased discharge, not missed fish.

Years Affected	Potential Issue
2008	High water affected 2008 operations. From July 13 - July 20, the sonar was in a protected eddy, then moved to the usual location July 21. Weir structures for fish deflection were not completed until August 9. The first salmon target was observed July 19. A comparison was made of the proportion of Chinook migrating in the 5 to 10 m range and the 40 to 45 m range both before and after the partial weirs was installed, and there was an increase of 21% in these areas. This expansion was applied to August 9, adding 102 salmon, an increase to the total count of 7.8%. This estimate is believed to be biased low due to missed fish, and comparison in order of magnitude to Eagle GSI proportions, its use is not recommended.

H.6.5 References

Tatchun Surveys

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Big Salmon Sonar

Mercer B. and J. Wilson, years 2006 - 2019. Chinook Salmon Sonar Enumeration on the Big Salmon River. CRE project 41-xx, Reports for the Yukon River Panel

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H.7 Yukon River Headwaters

Also referred to as the Upper Lakes or South Mainstem, this drainage contains many large lakes (many glacial fed) and is considered to be the headwaters of the Yukon River. Ta'an Kwachan Council, Kwanlin Dun First Nation, Champagne and Aishihik First Nations, Taku River Tlingit First Nation, and Carcross/Tagish First Nation have traditional territory within this drainage. The watershed begins south of Lake Laberge, a 50 km lake through which Chinook pass. The Takhini River is a large lake-headed system joining the Yukon River just north / downstream of Whitehorse. In Whitehorse, the Whitehorse Rapids hydroelectric facility and Fishway are another longstanding operation.

Chinook abundance in the Yukon River Headwaters is estimated annually at the fishway on the mainstem at Whitehorse, supplemented by assessment of the Takhini tributary with a sonar program and aerial surveys. The fishway and sonar program are described in this section. The aerial surveys are covered in Section I, which summarizes the Canadian aerial surveys.

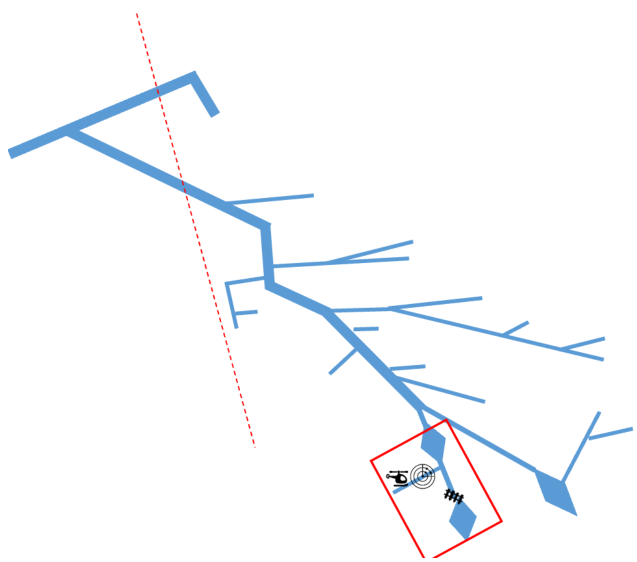

Figure H.4. Location of Yukon River Headwater Surveys

H.7.1 Project Summary - Whitehorse Fish Ladder

Introduction

The Whitehorse Rapids Fish ladder is a 366 metre long wooden fish ladder built to allow salmon migrating to spawn to pass above the Whitehorse Rapids Hydroelectric Facility. The fish ladder is located at 60.6965, -135.0407. Chinook migrating through the fish ladder have been enumerated annually since 1959.

Methods

The fish ladder is of pool-and-weir design, 336 m long, located on the eastern (river right) side of the Whitehorse Rapids Hydroelectric Facility. The passage heads generally north briefly before turning south, ascending by a holding area and viewing window in the visitors center then travelling to Schwatka Lake (Ref - Yukon Energy Whitehorse Generating Facilities pamphlet). The ladder is typically opened to flow in late May, and closed in late September. The basic methods of the fish ladder related to enumeration have been consistent through time. A gate is closed when the fish ladder is not attended. Chinook are counted through the fish ladder when the gate is opened after a closure period, or when the gate is open and passage is being continually observed. Note that the gate was closed at night for 12 hours prior to 2021, and this could result in additional trips or exhaustion (i.e. fish that do not ascend).

Over time, a variety of activities related to the hydroelectric facility and the fish ladder have taken place. The most major consideration is the implementation of the hatchery program. Beginning in 1984 Chinook were removed for broodstock and beginning in 1988 hatchery origin adults began returning. Hatchery fry are released above the dam at spawning locations. The hatchery fry are essentially compensation for the fry mortalities through the turbines. Also the returning adults have hybridized with the wild stocks, which might make this assessment project less reliable for estimating the total Canadian run.

In addition to the passage counts, fish are visually assessed for sex, origin (either hatchery or wild stocks) and size category. Hatchery stocks are marked with an adipose fin clip for identification when returning as an adult, but there was at least 1 year where hatchery salmon were not adipose clipped due to the requirement to CWT any clipped Chinook. Length categories for mid-eye to fork of tail: Jack <500mm, Small 501-600, Medium 601-800 and Large >801mm. Any additional marks are noted, which depends on there being projects which tag fish operating in that year. Chinook removed for broodstock may also be sampled for age (scales), sex, and length. Coded Wire Tags (CWT) implanted in hatchery fish and indicated by the clipped adipose fin are also collected from broodstock removals and read to determine release location. At this level of use, this data is not reviewed.

Annual water temperatures in the ladder are collected through data loggers.

The focus of this data review is the enumeration of salmon which returned to the ladder. The data includes total annual counts of returns of hatchery and wild fish to the ladder; *Note: the data set is not escapement above the dam.*

Data Considerations

Fish ladder efficiency is affected by multiple factors in regards to attraction, entrance, and passage. Attraction has many interrelated factors which may play into how many fish ascend the ladder and are counted at the viewing chamber. Below the entrance to the Fishway is a back eddy caused by the spill way flows. Fish may spend a number of days facing downstream as the back eddy can have more flow than the flows exiting the Fishway. Relative flows in different areas are depending on water levels and power usage. Potential holding in this area may cause delayed migration or fish that might venture downstream to other alternative spawning areas. Another consideration is collective migration (Okasaki et al. 2020) where during years of lower overall returns, less fish may ascend (Twardek et al. 2021). Passage may also potentially be affected by gate closures, human cues from broodstock collection, and general energetics as part of overall considerations relevant to the use of fish ladder data for enumeration of returning adults when the fish ladder has multiple goals, objectives, and functions.

Separation into returns of hatchery vs. wild origin fish is dependent on visual identification of a missing adipose fin (clipped as a juvenile on hatchery raised fish before release). As the program developed, so did standards for external (adipose) and internal (CWT) tagging. In years where external tagging may have been decreased (ranges of clipped fish have historically been from 38-92% clipped (1984 to 1992), JTC 1993), the hatchery proportion of the return would likely be underestimated.

Ladder staff identification of sex, origin and size class have been assessed by hatchery staff as highly accurate. Visual examination of size is the most susceptible to variation of fish that are near the threshold between sizes. Data must be used in the correct application given its specific focus as a count of Chinook which have reached the counting chamber. The count is not a measure of escapement due to:

- Broodstock removals
- Mortalities in the ladder, although this is tracked and is currently less than 1% per year (and when appropriate are used for brood stock contributions). However, mortalities are only tracked above the counting chamber, this is not possible in the lower section of the ladder.
- Other lethal sampling in the ladder (see table) It is also not a count of fish which reach the ladder area when considering;
- Potential for fish to ascend the ladder multiple times (see table).
- Fish which do not completely ascend the ladder past the viewing chamber (there is spawning in suitable reaches below the dam).

Additionally, there is a small potential for uncounted fish to pass at the end of the run. After the last fish is considered recorded at the end of the run, gates are left closed for five days and checked at least four times a day from 9 am to 5 pm. An underwater video camera at the base of the fish ladder, active during the typical return timing also helps to ensure it is known if any Chinook are still remaining.

Uncertainty Evaluation

Visual fish counts by direct observation are generally assumed to be a complete census of the species passage and error is assumed to be negligible. Therefore, formal variance statistics have not been calculated.

H.7.2 Project Details - Whitehorse Fishway

Table H.15. Whitehorse Fishway - Operational Timeline

Years	Component	Change/Event
1956	Whitehorse Dam	Construction of Whitehorse Rapids Hydroelectric Facility begins.
1958	Whitehorse Dam	Hydroelectric Facility beings producing energy; two turbines.
1969	Whitehorse Dam	Third turbine added to Hydroelectric system.
1984	Hatchery Related	Whitehorse Hatchery begins operations. First year of removal for broodstock
1985	Whitehorse Dam	Fourth turbine added, known as the "fourth wheel", doubling the hydro capacity; between 90-277 cubic m per second pass through depending on electricity generation.
1985	Hatchery Related	Coded Wire Tagging of juveniles (1984 brood year) begins.
1988	Broodstock	Hatchery Origin Chinook begin to return. Mortality rates in the Fishway begin to be recorded.
1989 - 1994	Hatchery Related	Fry were held and fed in the fish ladder for 10 days, and then released in the ladder. This was intended to obtain information on differential mortality depending on release location relative to dam. These may have returned as adults which may have ascended the fish way multiple times in the following years.
1994 - 1998	Secondary marking	Secondary marking undertaken to note fish which ascended multiple times and avoid double counting, specifically males.
1991 - 1994	Adult Counts	No adjustments made to adipose clip tallies (JTC 1998).
1994 - 1998	Adult Counts	Adipose-clipped counts were expanded by the marked to not-marked release ratios using the age composition of adipose-clipped fish (sexes treated separately) - JTC 1998.
1995, 1996	Adult Sampling	Every 10th male and every 10th female Chinook with an adipose clip taken from the ladder for CWT sampling.
2000	Fishladder Construction	New baffle system installed in the upper (closest to Schwatka) section just below the exit to Schwatka Lake to better control the main attraction flow at the base of the Fishway. This occured after a number of years with high mortality in th upper ladder aera (JTC 2000). Removable stop blocks allow the inflow depth to adjust in relation to Schwatka lake water levels.
2000	Fishladder Construction	New baffle system installed in the upper (closest to Schwatka) section just below the exit to Schwatka Lake to better control the main attraction flow at the base of the Fishway.
2004	Fishladder General	Installation of underwater camera with live feed at base/entrance of ladder.

Years	Component	Change/Event
2010	Secondary marking	Subset of salmon given tag, none recovered below the dam or seen again in fish ladder.
2021	Adult Counts	Installation of video counting system to allow unimpeded salmon passage except for the occurrence of brood stock capture.

H.7.3 Project Summary - Takhini Sonar

Introduction

Fisheries and Oceans Canada (DFO) operated a sonar program on the Takhini River in 2017 and 2018, approximately 5 km upstream of the Takhini /Yukon River confluence (67 33'42.79, 139 53'6.58W).

The program collected sonar enumeration data, test fishing effort, and age, sex, length (ASL) data.

In 2018, an associated telemetry study was conducted: five male and three female Chinook captured during test netting were implanted with acoustic telemetry transmitters for a study on terminal spawning locations in the Yukon River Headwaters (Twardek & Lapointe 2019)

While this project only contributes 2 years of data to the run reconstruction analysis at this time, it is an on-going project, and is therefore included in this report.

Methods

The Takhini sonar program included:

- *Sonar enumeration data*: Collected using side view sonar.
- *Test fishing effort*: Fishing effort and catch data (catch per unit effort). Test fishing enables passage estimates to be apportioned between the target salmon species and resident freshwater species. Both set and drift gillnets were used in 2017; however drift netting resulted in no captures and was abandoned mid-season for a rotation of set gillnets. There was some inter-annual variation in the set gillnet, but the same mesh sizes and hang ratio were used in both years (Table H.16). Panel mesh sizes were 4.5", 5.25", 6", 7.5", and 8.5". Hang ratio was 3:1.
- *Test fishing ASL*: Age and sex data were collected from all salmon captured in the test fishery. The length of salmon and freshwater fish was also recorded.
- *Quality control*: recounts of 4 sonar files (per bank) randomly selected and recounted in season by technicians.
- *Target testing*: Visibility of an item dragging through the ensonified zone to confirm sonar aim and field of view.

The Takhini River sonar program was initiated to assess daily passage of Chinook salmon and meet the baseline objectives of a larger effort to assess the value of a Chinook salmon stock restoration plan for the Takhini River Watershed. During each season a deflection weir was constructed on left bank from vexar and t posts. Given the wedge-shaped bottom profile of the sonar site and steep right bank , a ~7m long floating boom weir (anchored with sandbags) was deployed on right bank to deflect fish from the shoreline.

Missing data gaps were estimated as the average passage during the period prior to and after the missing window for the length of the gap.

If sonar operations begin late or end early it is essential to estimate salmon passage outside the dates of operation. A quadratic equation is used to estimate daily passage (Crane and Dunbar 2011, Equation 1).

Discussion

Critical assumptions include:

- *Negligible mid-river salmon migration*: The 2017 a setup using two short range sonar was used to assess the Takhini River. The authors estimate that 78-90% of the river was ensonified and assumed that passage through the of the river center was negligible. Salmon were bank orientated and the majority (77% and 95%) of fish targets migrated on river left within 25m of the transducer in 2017 and 2018 (respectively).
- *Freshwater fish have a negligible effect on passage estimates*: It is assumed that salmon can be discerned from freshwater fishes based on size and behavior using sonar imaging. Additionally by subtracting downstream swimming fish, it is assumed any freshwater fishes accidentally counted as salmon will be removed when they return downstream. A number of large lake trout and pike were captured in the test fishery. As a result in both 2017 and 2018 count data was apportioned for weekly non-salmon captures to make estimation conservative.
- *Adequate bottom profile*: Bottom cover consists of fine sediment and gravel with low stability that could be seen drifting downstream; however bottom profile view was consistent. There were some deficiencies in the RB bottom profile in 2017 and target detection may have been as low as 60% (DFO 2018 target testing).

Uncertainty in the estimates was calculated as:

- *Error*: Repeatability of a count for the same sonar file between different individuals (known as average percent error (APE) (Chilton and Beamish, 1982).
- *Variance*: A variance estimator based on the squared differences of successive observations was used (Wolter 1985). The exact equation varied slightly between the two years due to the presence of inshore/offshore stratum in 2018 (see DFO 2018 and 2019).
- *Confidence Intervals*: 95% confidence intervals are calculated by multiplying the square root of the variance for each stratum (s) plus the APE for stratum (s) by 1.96 (Cronkite et. al. 2006, Equation 4).

H.7.4 Project Details - Takhini Sonar

Table H.16. Takhini Sonar - Operational Timeline

Years	Component	Change/Event
2017	Sonar	ARIS 1800 (x2). Two short-range sonars (ARIS 1800) were installed upstream of the deflection weirs in 2017, each ensonifying an Inshore range (at 30 minute intervals).
2018	Sonar	ARIS 1200. A s ingle long-range on LB (ARIS 1200) was used to assess the entire river . The ensonified range was divided into an Inshore and Offshore strata, each recorded for only 30 minutes of the hour. Counts were tallied using Echotastic software.
2017	Range	Inshore (2 to 35-40m) and Inshore (0 to 29m)
2018	Range	Offshore (29 to 55-60m)
2017	Set Net	Depth: 6' or 10';Length: 50' or 100'; Same mesh sizes and hang ratio in both years.
2018	Set Net	Depth: 8', 10', or 15'; Length: 50'; Same mesh sizes and hang ratio in both years.

Table H.17. Takhini Sonar - Potential Data Issues

Years Affected	Potential Issue
2017	Two short range sonars were deployed. Due to the steep bank profile it was difficult to achieve an adequate view of the bottom profile on RB.
2017	The sonar began operating two days after peak passage at the Whitehorse Rapids Fishway (located about 20km upstream of the Takhini-Yukon River confluence). A large portion of the run was therefore estimated in a pre-season expansion (29.6%). The expansion start date applied was the date of first passage through the Fishway.
2017	The RB sonar was aimed downstream towards the weir at an exaggerated 450 angle from shore. As a result the effective range ensonified from shore was reduced to approximately 18m. The setup and exaggerated angle made it difficult to discern upstream targets and target detection rate may have been low (DFO 2018).
2018	Switched to a single long-range ARIS (1200) sonar. This sonar was deployed on LB to assess the entire width of the river in two scan ranges (alternating between an inshore and offshore ranges)
2017 and 2018	The size threshold used to discriminate salmon from freshwater fish was 500mm in 2018, and 600mm in 2017. However weekly species apportionment (reducing estimates based on large freshwater captures) was applied in both years using the respective thresholds

H.7.5 References

Whitehorse Fishladder

An overview of the fish ladder is available online at https://yukonenergy.ca/media/site_documents/491_fish_ladder_eng.pdf.

An overview of the Hydroelectric facility is available online at https://yukonenergy.ca/media/site_documents/brochure_Whse_facilities_eng_new_logo2018.pdf

Annual fish ladder reports are published on the Yukon River Panel website (e.g. https://www.yukonriverpanel.com/download/168/stewardship/2319/cre-64-18-fishladder-year-end-report-2018.pdf).

Estimates are also included in the annual reports of the Yukon River Joint Technical Committee.

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Per.Com Lawrence Vano - Operation Manager of the Whitehorse Rapids Fish Hatchery

Per Com Warren Kapaniuk – Assistant Operation Manager of the Whitehorse Rapids Fish Hatchery

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Cronkite, G.M.W., Enzenhofer, H.J., Ridley, T., Holmes, J., Lilja, J., and K. Benner. 2006. Use if high-frequency imaging sonar to estimate adult sockeye salmon escapement in the Horsefly River, British Columbia. Can. Tech. Rep. Fish. Aqua. Sci. 2647: vi + 47p.

Twardek, W.M., Lapointe, N.W.R. 2019. Assessing the fate of returning upper Yukon River Chinook salmon. CRE-489-18. Prepared for the Yukon River Panel

H.8 Teslin Headwaters

The Teslin drainage is a large drainage with a significant contribution of Chinook salmon to the Canadian mainstem escapement. The Teslin drainage is included in much of Teslin Tlingit Council's traditional territory, as well as Kaska Dene, Ta'an Kwachan Council, Kwanlin Dun First Nation, Carcross/Tagish First Nation, Taku River Tlingit First Nation, Tahltan First Nation, and Little Salmon Carmacks. The Teslin River drains Teslin Lake, and a previously operated sonar on the mainstem before the lake enumerated the majority of the run into upstream habitat. The Nisutlin River is an important input into Teslin Lake, and aerial surveys have been undertaken on the Nisutlin mainstem as well as one of its tributaries (Wolf River).

The sonar program is described in this section. The aerial surveys are covered in Section I, which summarizes the Canadian aerial surveys.

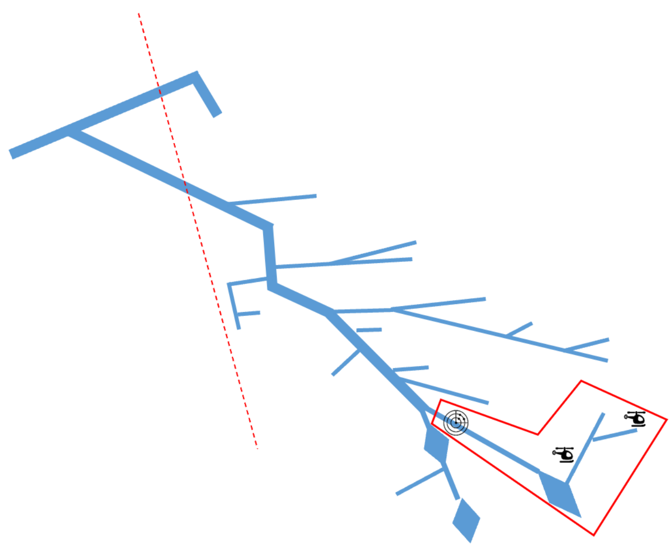

Figure H.5. Location of Upper Yukon Surveys

H.8.1 Project Summary - Teslin Sonar

Introduction

The Teslin River sonar operated from 2011 to 2015, run by a consultant with R&E funding. The project estimated passage with sonar. Telemetry work, GSI, and sonar data have indicated the Teslin drainage is usually the largest single tributary to Canadian mainstem Chinook production. Age, sex and length (ASL) of Chinook was collected from carcasses, and daily air and water temperatures, and water levels were collected during project operation. The sonar was located on the Teslin River, approximately 12 km upstream of the Teslin /Yukon River confluence (also known as Hootalinqua), with the camp location at 61.4908, -134.7571.

Methods

The objectives of this project were:

1. Enumerate the Teslin River Chinook salmon escapement using sonar and obtain information on run timing and diel migration patterns.
2. To conduct a carcass pitch/spawning ground sampling on the mainstem Teslin River after sonar operations, to obtain age-sex-length (ASL) data and when possible document egg retention in female spawners and the principal recovery locations of spawned out fish.

Fixed location side-view sonar units (DIDSON and/or ARIS) were installed on opposing shores upstream of short diversion fences to assess Chinook upstream migration, following annual cross section river profiles. Sonars covered from 40 to 50 m from each bank, and recorded the entire distance continuously. These ranges covered the width of the river, expect in cases of high water where up to 10 m in the center of the river might be unensonified. Units were operated continually, and data stored in 20 minutes files. In case of downtime, potentially missed fish were added to the counts by various methods of extrapolation and interpolation. Target size (over 50cm) and behavior were used to identify salmon. The position of fish within the cross section of the river recorded at 5m intervals to track spatial behavior. Precision (repeatability) of counts was undertaken by reviewing a subset of files by a different individual, and this was quantified with average percent error (APE, Enzenhofer et al. 2010) from an aggregate of daily counts with files over five fish, so that small discrepancies did not affect the magnitude of error. Sample variance of the absolute difference between two counters was also used to illustrate precision and net variability. At the end of the season, expansion was undertaken if deemed applicable based on the final day's sonar count. Since both sonar units run continuously over the entire range, there is no variance from expanding subsets of data, and estimates are considered to accurately reflect actual passage.

Discussion

Critical assumptions related to this project are similar to other sonar projects, but a few considerations warrant specific discussion here:

- *Date range over which sonar is operational captures the entire Chinook run*: Low values of Chinook at the beginning of the project and end of the project, with only one extrapolation at the end of the run suggest this assumption is either met or accounted for.
- *Negligible mid-river salmon migration*: Assumes migration through the middle of the river was negligible, with sonar coverage gap in the middle of the river being up to 10m wide (dependent on water level). The authors noted that Chinook were bank-orientated with migration heavily skewed towards the right (north) bank.
- *Freshwater fish or other salmon species have a negligible effect on passage estimates*: The author cites blind trials on the Klondike River that suggest trained observers can correctly identify Chinook (Mercer 2010). They also indicate that the Chinook run likely complete before arrival of chum based on migration rates and passage timing at the Eagle Sonar (Mercer 2014 – 2013 Teslin Sonar Report). No test fishing was performed as part of this project.
- Counts from DIDSON and ARIS 1800 units are comparable across years

Uncertainty Evaluation

No formal estimates of uncertainty.

H.8.2 Project Details - Teslin Sonar

Table H.18. Teslin Sonar - Operational Timeline

Years	Component	Change/Event
2011	All	Feasibility year. Suitable sonar site was located and operated for 12 days with DIDSON sonars and no deflection fences. Carcass pitch was completed.
2012-2013	Sonar Units	An ARIS sonar unit was deployed from the north bank of the river and a DIDSON sonar was deployed on the left (south) bank.
2012	Fish deflection	Fish deflection on both banks fences were constructed from floating boom logs, which suspended wire fencing weighed down by rocks (boom weir). May not have been completely impervious to fish (page 14, 2015 report)
2012	Missing Files	During any downtimes, potentially missed fish were added to the counts by extrapolation based on the mean number of fish per hour recorded the previous 24 hours.
2013-2015	Recounts	8-10% of the sonar files were recounted each day to measure the precision of counts, using methods described above.
2013-2014	Fish deflection	North (RIGHT??) bank weir was constructed from metal tripods, wooden stringers, and conduit. South bank remained a boom weir.
2014-2015	Sonar Units	Two ARIS 1800 units used, one on each bank.
2015	Fish deflection	Fence panels used in conjunction with boom weir on south bank (river left) - lower water levels than previous years made placement and maintenance easier.
2013-2015	Missing Files	Missing counts calculated based on the mean number of fish per hour counted 12 hours before and after the outage. When complete files were missed the Chinook passage was estimated by interpolation of the average file count over the 12 hour period before and after the missing sample event.
2015	End of season extrapolation	First year where last day of counts over 15 salmon (n = 33). Last five days of sonar counts used to calculate a logarithmic regression formula for the end of season expansion, adding 60 fish to the final count over five days.

Table H.19. Teslin Sonar - Potential Data Issues

Years Affected	Potential Issue
2012	The DIDSON was removed on August 19 (no fish counted on the left/south bank) and the ARIS September 4. No targets were counted on the left/south bank. Following years of sonar indicated that fish passage would be expected on this bank. With a combination of high water flows affecting fish distribution and the likelihood that in 2012 the boom weir on the south bank may not have been completely impervious to fish (page 14, 2015 report) the total count for this year is likely unreliable, and should at the very least be considered a definite underestimate.

H.8.3 References

Project Reports

Mercer, B. 2012. 2011 Teslin River DIDSON Sonar Feasibility Study CRE-01N-11. Prepared for the Yukon River Panel

Mercer, B. 2013. 2012 Teslin River Chinook Sonar Project CRE-01N-12. Prepared for the Yukon River Panel

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Additional Sources

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H.9 Porcupine

The Porcupine River is the most northerly river in the Yukon drainage, mostly above the Arctic Circle. It is separate from the rest of the Canadian mainstem in that it joins the mainstem Yukon River in Alaska (it has its own border crossing). Although other smaller tributaries also cross the border and join the Yukon River in Alaska, the Porcupine is by far the largest. The Porcupine drainage is almost entirely contained within the traditional territory of Vuntut Gwitchin First Nation. Given the size of the mainstem Porcupine, options for sonar assessment have only become available relatively recently, and a sonar operated near the community of Old Crow currently assesses the Chinook run.

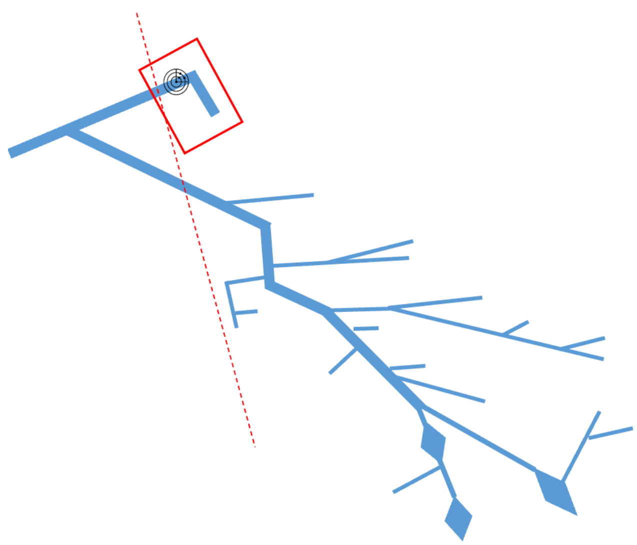

Figure H.6. Location of Porcupine Sonar

H.9.1 Project Summary - Porcupine Sonar

Introduction

The Porcupine River sonar program is a joint effort between the Vuntut Gwitchin First Nation (VGFN) and the Department of Fisheries and Oceans. The sonar began operation as a fall chum project in 2011, after previous years preliminary work. The first few years of operation (2011-2013) were fall chum enumeration, between VGFN and a consultant. In 2014, the sonar began earlier in the summer to also enumerate Chinook salmon, with DFO becoming involved with the chum enumeration. In 2017 the sonar transitioned to full season operation by VGG and DFO. In 2018, DFO funding was committed to the sonar project, replacing the previous support from the Yukon River Panel's Restoration and Enhancement fund.

The project estimates salmon passage by species based on sonar. Age-Sex-Length (ASL) data are also collected from fish sampled in a test fishery using set and drift gillnets. Additional information collected in various years is detailed further below.

The project is located on the Porcupine River, approximately two kilometers downstream of the community of Old Crow. Camp is located on the river right, at 67.5643, -139.8847 in close proximity to left bank (LB, south) and right bank (RB, north) sonars.

Methods

The main approach to establishing the collection of daily salmon counts is the operation of two sonars, one on each bank of the river. The sonar units alternate an "inshore" and "offshore" setting, with the distances of each being refined over the project's initial years (details in Table H.20), ty[ically] operating at 0-20 m range inshore, and 20-40 m range offshore. Each range records for 30 min, and then switches. Counts from each range are doubled to produce a total hourly count for each bank, continuously for 24 hours/day.

A test fishery is undertaken with the objectives of the collection of ASL samples from migrating salmon, fork lengths of freshwater fish, and generally informing the crossover to chum salmon. The test fishery is set gillnet focused during the Chinook run, with drift gillnets also being used during the crossover period. Specific details of the test fishery have varied over the project's development, additional details can be found in Table H.20 and annual project reports.

Discussion

The same basic critical assumptions are used at all the acoustic sites in the Yukon River drainage, i.e. Eagle Sonar, Teslin Sonar, etc and are generally accepted as valid. These include;

- *Negligible mid-river salmon migration*: The wetted width of the Porcupine River is approximately 210m (varies with specific location and water level). Long range ARIS sonar imaging can ensonify a maximum of 80m past each bank, and even with deflection weirs that may be up to 20 m long, this still leaves the middle portion of the river unassessed. Low capture success during mid river drift test fishing and strong evidence of bank orientation (Chinook seem to have some preference for right bank while chum have a strong preference for left bank, though water conditions can influence trends) suggest the number of salmon migrating through the center of the river is limited. The low occurrence of offshore salmon targets over early years was used to justify shortening the ensonified range of each bank from 80m to 40m over time (see Table 1). In general since 2014, over three-quarters of sonar marks are within 20 meters of each banks sonar transducers.
- *Freshwater fish have a negligible effect on passage estimates*: It is assumed that salmon can be discerned from freshwater fish based on size and behavior using sonar imaging. Additionally by subtracting downstream swimming fish, it is assumed that some freshwater fish will be removed from the counts through this method as they may be just as likely to be headed upstream as downstream.
- *Crossover Timing*: Assumptions on the date and shape of transition from Chinook to fall chum migration is made annually. Due to low capture success, during the crossover period sonar counts are not specifically apportioned between Chinook and chum based on the test fishery. No standardized protocol is yet in place to determine how this crossover date is determined, Table 1 details different methods between years. Generally, passage at this time is low, so the effect may be negligible. Work is ongoing on equalization of metrics for crossover, including sonar target size. An important consideration with changing

environmental conditions and adaptive migration strategies is the possibility Chinook salmon may be extending their migration timing later – local reports of Chinook catches later than traditionally known, and a test fishery catch of a Chinook in early September (2018) enforce that this is important to consider going forwards.

- *Adequate bottom profile*: Water level on the Porcupine River can fluctuate rapidly and frequently, and sonars are repositioned and aimed multiples times a week. Small trenches (areas with no bottom profile spanning ~1-2m) can increase in size and severity as water level changes. Technical staff is responsible for maintaining adequate bottom profile view, and using judgement on whether files can be counted when profile is marginal. This is confirmed post season. Target testing (physically dragging an object on the bottom in front of the sonar to confirm field of view) is one way to do this when "trenches" could imply a lack of beam pattern coverage. While it is performed monthly or when bottom profile is questionable; there is no current standard for interpreting or reporting target testing data. It's utility is also limited by the physical difficulty of deploying the target in the desired location and depth, and the possibility of missing viewing the target on the sonar in real time, and appearance of an artificial target vs. a salmon.
- *Local Harvest*: This project enables the Vuntut Gwitchin Government to improve in-season management capacity in Old Crow by providing daily run updates. VGFN subsistence harvest happens both above and below the sonar. In some instances harvest upstream of the sonar was known or assumed, and subtracted from the sonar estimate to produce an escapement estimate.

Uncertainty Evaluation

- *Error*: The repeatability of a count for the same sonar file between different individuals. While APE measures error between technicians, errors have higher leverage when counts are low, making it difficult to make comparisons across years and species (Holmes et al. 2006).
- *Variance*: variance estimator based on the squared differences of successive observations is used (McDougall and Lozori 2018). Variance is not calculated for a sample period without an associated recorded time (eg. sonar was not operational) was not incorporated into the variance calculation. Total variance for each of inshore and offshore (stratum) is the sum of the daily variance (Table 2).
- *Confidence Intervals*: 95% confidence intervals are calculated by multiplying the square root of the variance for each stratum (s) plus the APE for stratum (s) by 1.96 (Cronkite et. al. 2006, Equation 4). This number is then added to and subtracted from the total passage estimate

H.9.2 Project Details - Porcupine Sonar

Table H.20. Porcupine Sonar - Operational Timeline

Years	Component	Change/Event
2009	All	Site search
2010	All	Pilot program / feasibility test.
2011-2013	All	Fall chum sonar program operated by VGG and a consultant. Sonar was transitioned from split-beam (EK60) systems to ARIS 1200 in 2013 (all split beam from 2009-2012).
2014	All	Season extended to include Chinook run, project undertaken by VGG and a consultant. VGG and DFO undertake the fall chum sonar.
2014	Sonar	Both bank sonar ARIS 1200 (long range) units. Operated at full range (80 m), continuously recording, files saved in one hour segments.
2014	Test Fishery	Drift fishery using 5, 5.25, 6.5, and 7.5 nets, each 100 feet long and a depth of 29 meshes. All hung at 2:1 ratio. Nets were all intended to be 12 feet / 3.65 m deep, so the 6.5 and 7.5 mesh nets were deeper than was practical for drifting, and the 5.25 was used 60% of the time. Roughly 48 drift netting hours captured one Chinook salmon and no other species.
2014	Crossover	The Chinook program (VGG and consultant) estimated a decrease in Chinook passage after the last day of sonar counts based on the average decrease from the last week of counts applied to the last day of counts. The same was calculated for the chum program which started after a two day gap in operations, subtracting the early estimated chum counts from the Chinook sonar counts. The chum program estimated different dates for a cross over period and determined a hard date on which all estimates were called fall chum. These methods produced final totals within a range of 259 fish.
2014-2017	Sonar	Management of missing data; short windows of missing passage. Interpreted manually as the average passage during the equivalent time on either side of the gap, or estimated from the daily average passage. Management of missing data; long windows of missing passage. Generally manually estimated from linear relationship between banks when one sonar remained operational. See annual reports for specific yearly methods of estimating counts during downtime.
2015	Test Fishery	The primary method of captured changed to a set net test fishery for Chinook, due to level of effort required drifting compared to passage numbers. Set nets were 6.75 and 7.5 inch mesh.. Over approximately 225 set net hours, 25 Chinook, one fall chum, two broad whitefish and one burbot were captured. Drift netting was also undertaken July 22 - August 1 with the intent of capturing the early fall chum. Mesh sizes were 5.75, 6, 6.75 and 7.5 inch mesh. Nearly 8 hours of drift netting effort captured one fall chum and no other species. All nets dimensions 100 ft long, mesh depths equivalent to 10-12 feet and hang ratio of 3:1.

Years	Component	Change/Event
2016	Sonar	In season daily recounts of four randomly selected files per bank for QA/QC, by a second reviewer who did not count the original file. Qualitative review of 12 hours of data per week also done by DFO in season. Prior to this, quality control checks done by biologists post season.
2016	Sonar	Sonar units set to alternate every half hour between a 0-25 m high frequency viewing window (inshore) and 25-50 m low frequency viewing window (offshore). Reduction in range based on previous years evidence of bank orientation. Hourly counts created by doubling the inshore and offshore counts for each bank.
2016	Test Fishery	Set net test fishery for Chinook mesh sizes was undertaken rotating nets of 5.25, 6.75, 7.5 and 8.5 inch mesh sizes. Nearly 130 hours of set net effort captured 74 Chinook, one burbot, two lake whitefish, and no fall chum. Drift netting was conducted towards the end of the Chinook tun, to target early chum salmon primarily using a 5.25 inch net (3 drifts with a 6.75" net) and undertook onshore drifts only. Nearly 4 hours of drift netting effort captured three fall chum and one inconnu. All nets dimensions 100 ft long, mesh depths equivalent to 10-12 feet and hang ratio of 3:1.
2016	ASL	Started collecting ASL (salmon) and length (freshwater fish) from community harvest on a voluntary basis, to supplement test fishery data opportunistically.
2016	Crossover	A high water event necessitated removing the sonar units from the river from August 12 - August 21/22. August 12 was also the last Chinook capture and the first chum capture in the test fishery, and a post season estimate from August 12 was calculated with a second order polynomial equation. The same was done for the start of the fall chum run which resulted in the subtraction of an estimated three fall chum from the Chinook count.
2017	All	Chinook and fall chum programs combined and run by DFO and VGG.
2017	Sonar	Sonar units set to alternate every half hour between a 0-20 m high frequency viewing window (inshore) and 20-40 m low frequency viewing window (offshore). Reduction in range based on previous years evidence of bank orientation. Hourly counts created by doubling the inshore and offshore counts for each bank.
2017	Test Fishery	Set net test fishery for Chinook mesh sizes 4.5, 5.25, 6.75, 7.5, and 8.5 (addition of 4.5 mesh size to previous years). Set nets were rotated through these sizes as well as within 10 and 15 foot hanging depths. Set nets were 50 feet long and hunt at a 3:1 ratio. Set netting effort of 173 hours captured eight Chinook, two fall chum, two broad whitefish, and one sucker. Drift net rotation composed of 5.25 and 78.5 inch mesh, hang depth of 6 and 8 feet, and lengths of 100 feet, with hang ratio of 3:1. Drift netting did not take place during the Chinook operational period, however no Chinook were caught in the chum operational drift netting effort of 20 hours.

Years	Component	Change/Event
2017	Crossover	Based on the first chum capture in the test fishery August 4, sonar counts were presumed to be chum starting August 5. A second order polynomial was used to estimate Chinook passage from August 5 - 10. Post season Chinook and pre-season chum expansions counts for individual days were not subtracted from actual sonar counts, but used as an estimate of additional passage.
2017	Sonar	Beginning in 2017, additional statistics around the sonar count have been calculated; Average Percent Error (repeatability of a count between individuals) using the APE equation from Chilton and Beamish 1982. Variance calculated using method from McDougall and Lozori 2018. Confidence intervals calculated based on APE and variance (Cronkite et al. 2006).
2018	Sonar	Started collecting ASL (salmon) and length (freshwater fish) from community harvest on a voluntary basis, to supplement test fishery data opportunistically.
2018	Crossover	Due to a high water event, LB sonar was not operational from Aug 16 to Sept 6 and RB sonar was not operational Aug 16 to Aug 27. To estimate Chinook passage a linear equation based on the previous five days of sonar counts was used to select August 18 as the last date of Chinook passage, and a quadratic equation (Crane and Dunbar 2011, Equation 1) was used to create an end of season expansion (adding 33 Chinook).
2019	Sonar	Introduction of R program to collect and manage enumeration data, automating the collection, entry, and estimation of hourly passage. Missing data estimated using structural models and Kalman smoothing (Milligan et al. 2020).
2019	Sonar	Estimates of total length from sonar targets (fish) measured using Echotastic Software for a subset of fish.
2019	Crossover	The crossover date was determined as the midpoint between the last in season Chinook test fishery catch and the first chum catch. This was supported by sonar target length measurements, and bank choice (left bank dominant). No overlap was calculated (hard transition).

Table H.21. Porcupine Sonar - Potential Data Issues

Years Affected	Potential Issue
2014	Large inseason data gap: No data was collected on RB from July 4 to July 13 due to a command module error. Post season, a linear relationship developed from cumulative right bank counts was used to estimate missed passage during this time (more details in final report). Using a linear relationship meant the number of fish estimate per day was consistent, and did not increase with time. As further years of Porcupine sonar counts have shown, the Porcupine cumulative run does not always follow a sigmoid shaped curve, as projects with more strongly unimodal (daily count) passage. Additionally, the missing time period being at the beginning of the run when passage would be lower, suggest that a linear estimate is a conservative measure that is sufficient for estimating a small amount of missed passage.
2015	Crossover date: As well as different methods used to select crossover date between years, in 2015 the reported values for Chinook and fall chum during the crossover period are different. From Aug 5 to Aug 17 EDI reported 235 Chinook (EDI 2016, Table 9) and DFO 377 (MacDonald et al. 2016b, Table 1).
2016	Large inseason data gap: No data was collected on left bank from the evening of July 8 to mid-day July 12 due to a command module fault. After this point, the command module was alternated between banks, switched around 12 pm each day. For the almost four days of no left bank counts, missing data was estimated from average of counts before and after the gap for a daily passage rate. From July 12 – July 17 when the command module was switched between banks so only single day gaps existed, linear interpolation of the missing day was completed using the day before and day after counts (Ben Snow, 2020, personal communication).
2017	Environmental conditions for the Chinook run in 2017 were abnormal. Although sonar operations went well, severe low water levels and high water temperatures likely contributed to low observed passage, including potential for pre-spawn mortality and thermal barriers to migration. It is possible Chinook salmon migrated outside of the sonar range, however this occurring in substantial numbers seems unlikely given bank orientation and netting catches. It is also possible delayed migration occurred and more Chinook salmon passed than the end of season expansion estimates, however test fishery catches did not reflect this.

H.9.3 References

Summary Reports

DFO. 2020. Enumeration of Porcupine River Chinook and chum Salmon Passage at Old Crow-2019. Internal Report

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DFO. 2018. Assessing passage of Porcupine Rive Chinook and chum salmon at Old Crow using sonar-2017. CRE-09-17. Prepared for the Yukon River Panel

EDI. 2017. 2016 Porcupine River Chinook Sonar Program. CRE-09-16. Prepared for the Yukon River Panel.

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APPENDIX I Canadian Aerial Surveys

I.1 Overview

Aerial surveys of Canadian Yukon tributaries have been used for visual counts since the 1960s. Surveys were mostly implemented by the Department of Fisheries and Oceans (DFO).

Canadian aerial survey records include:

- Visual counts
- Survey method
- Date
- Quality rating
- Observer comments

Aerial surveys have been implemented in the following tributaries:

- White watershed: Tincup River
- Pelly watershed: Ross River
- Carmacks Area Tributaries: Big Salmon River, Little Salmon River
- Stewart watershed: McQuesten River (reviewed and not included)
- Upper Yukon River - Southern Lakes: Takhini River
- Teslin headwaters: Nisutlin River, Wolf River

I.2 Methods

Aerial survey techniques are used to index Chinook salmon escapement throughout multiple spawning tributaries. Surveys counts are typically conducted once a year intended to correspond with the presumed peak spawning activity. Peak counts are treated as indices of relative abundance. Resulting indices can be used for monitoring abundance trends over years, informing estimation and proportions of spawning escapement, and providing information on spawner distribution at a variety of scales.

To the extent practical, survey methods are standardized to improve accuracy and comparability of the one-time peak index counts. Surveys are typically conducted using helicopters, preferably with a bubble window for the counter(s). Surveys are flown during date ranges suspected to correspond with peak spawning activity, informed by historical survey timing and available current-year information including local knowledge. Effort is made to conduct surveys on days when weather conditions are adequate to observe fish and facilitate safe aircraft operations. Standardized survey areas have been established for all index areas listed above as part of DFO's standard counts, with the exception of the Takhini River which is not a typical DFO index area but has had a relatively substantial amount of aerial & boat surveys done due in part to its proximity to Whitehorse.

Available data were summarized in several ways. Counts were the sum of live Chinook salmon and carcasses, for each year in which a survey was conducted. In a few instances, surveys may have been conducted by other methods (example: foot, boat/float) and this is indicated in this document and a data column. Total annual count was provided, by index area of the tributary, for each year in which a survey was conducted. The total count was presented regardless of survey rating; however, only surveys with an appropriate rating should be used. Survey ratings from DFO standards constitute excellent, good, fair and poor. Poor surveys should not be used as the rating can indicate incomplete and/or poor survey conditions resulting in minimal or inaccurate counts.
If more than one survey was flown in a specific year, the count from the survey with the most favorable rating (i.e., "poor" versus "fair/good") was presented.

If more than one person was counting, counts were averaged as long as each counters totals were within 10% of each other. If conditions (for instance, seat with reduced view) or experience were considered to be the cause of a greater than 10% difference, the higher count would be used.

I.3 Discussion

Critical assumptions include:

- Counts observed from all models of fixed-wing and helicopter were assumed to be comparable.
- Survey pilots were appropriately skilled to maneuver the aircraft along all portions of assigned survey reaches in a manner suitable for observing fish.
- Survey observers accurately identified and reported all Chinook salmon and carcasses that were observed in each survey reach.
- Timing of surveys correspond to peak-spawning activity.
- Survey rating was an adequate representation of the reliability of the index count.
- Single (or multiple) aerial surveys do not count the entire escapement within an aerial index area as runs are usually protracted with the early spawning fish disappearing before the late ones arrive. Weather and water conditions, the density of spawning fish, as well as observer experience and bias also affect survey accuracy. Index surveys are rated according to survey conditions

Uncertainty in aerial estimates has been evaluated as follows:

- No formal evaluation of survey accuracy is undertaken.
- Peak counts are an underestimate of the true inriver abundance at the time of survey. In addition, aerial counts may demonstrate a wide range in the proportion of fish enumerated from year to year in each river.
- Variability in accuracy is dependent upon several factors. Weather (e.g., wind, cloud cover), water conditions (e.g., turbidity, surface turbulence), river morphology (e.g., depth, sinuosity), substrate color, and bank vegetation can contribute substantially to an observers ability to see fish in the survey area. Timing of surveys with respect to peak spawning is a very important factor, with both early and late-timed surveys resulting in reduced counts relative to the peak. The type of aircraft, survey altitude, experience of both pilot and observer also contribute substantially to the accuracy of the counts. Each of these factors is carefully considered and a subjective survey rating of "poor," "fair," or "good" is assigned by the observer.

I.4 Project Details - General

- Historically, survey methods have included a range of helicopter models, and occasionally fixed wing aircraft. Boat and foot surveys have also been conducted in some locations as noted.
- Survey counts were obtained from the Joint Technical Committee's report, where they were last published in Appendix B12 in the 2012-2013 report. This compilation also includes a condensation of the four rating categories to categories of fair/good or poor to match ADF&G standards.
- Where available, these numbers were confirmed with reference back to the original survey document in DFO files, typically a standardized form (known as a Stream Inspection Log/Aerial Stream Inspection Worksheet) or a narrative "Note to File" including data.
- In cases where survey counts are contained as part of published reports beyond the JTC, such as Restoration and Enhancement Fund reports to the Yukon River Panel, or as part of environmental assessments these specific reports are referenced.
- The ADF&G database was also referenced for any additional data or obvious discrepancies, subject to the considerations discussed in the "Lower Yukon Air Surveys" Section.
- For a period of time in the 1980s both DFO and ADF&G flew surveys of some of the same index areas typically in the same time frame. In these cases, the higher count was used.

I.4.1 Project Details - Carmacks Area Tributaries (draining directly into Yukon River)

Big Salmon River

Draining nearly 7,000 square km (Braberts et al. 2000), the Big Salmon River is a direct tributary to the Yukon River. The aerial survey is typically flown in two sections: from Souch Creek to

Moose Creek, and then section two from Moose Creek to Big Salmon Lake. Spawners are throughout the survey area, with a significant amount of spawners usually located at the outflow of Big Salmon Lake.

Little Salmon River

The Little Salmon River is a direct tributary to the Yukon River. The aerial survey standardized reach is from the confluence with the Yukon River to the outlet of Little Salmon Lake. This is a distance of around 70 km. While some spawners are known to travel to streams flowing into Little Salmon lake, the majority of spawning in this system likely occurs in the survey reach (Walker et al 1974).

I.4.2 Project Details - Stewart River Drainage

Although the Stewart River is a significant contributor to the watershed, and supports a significant portion of the Canadian chinook run (average 7% - Appendix B18 JTC Report 2017-18) there have been no fixed aerial survey estimates in this drainage. There is one major spawning area (the mainstem McQuesten) as defined by Brown et al (2017), based on radio telemetry data (Eiler et al. (2014)) and thirteen minor areas. Review of the studies done in this areas also suggested the McQuesten River had the best potential for an aerial time series. However preliminary review of the data suggests that timing of surveys, areas surveyed are not consistent enough. Additionally, these lead to counts varying too much to be representative of magnitude between years.

The McQuesten River joins the Stewart River over 150 river km upstream of the Stewart's confluence with the Yukon River. Variations in survey implementation make it challenging to compare estimates from different years directly. The most commonly flown reach is the mainstem from the Stewart River to the split into the North and South McQuesten (or some subsection thereof). There are about 10 years of surveys in the early 1980s to late 1990s plus a few more in the 2000s. Survey dates occur through August and peak spawning generally considered to occur in the first week of August. Counts range from 32-833. While it may be possible to extract a time series, the wide variety of survey success (based on water levels, visibility, timing) and the location information available to define a consistent survey reach, it was considered a low priority in terms of the basin-wide run reconstruction

I.4.3 Project Details - Pelly Watershed

Ross River (drainage area over 7,000 square km – Brabets et al. 2000) is a tributary to the Pelly River (total drainage area over 18,000 square km – Brabets et al. 2000) , which joins the Yukon River. The standardized aerial survey reach of Ross River is from Big Timber Creek to Lewis Lake.

After an extensive burn along the area of the Ross River aerial survey in 1994 (JTC 1997) surveys were impeded by turbid conditions for the next two years, since which minimal surveys have taken place likely due to a combination of conditions and funding availability.

I.4.4 Project Details - Teslin Watershed

Th Teslin is one of the Yukon River's largest sub drainages (over 30,000 square km, Brabets et al. 2000).

Wolf River

Is a remote watercourse, draining from Wolf Lake to the Nisutlin River, which feeds into Teslin Lake, then draining to the Yukon River via the Teslin River. The standardized aerial survey index area consists of two segments; from the Wolf Lake outlet to the Wolf River's confluence with the Red River, then continuing down the Wolf River until the entrance of Fish Creek (also referred to as Fish Lake outlet).

Nisutlin River

Entering Teslin Lake, the Nisutlin River is a long / large river. The standard index area is from Sidney Creek to Hundred Mile Creek (the locations where both enter the Nisutlin). The Nisutlin River is somewhat wider than other index river sections and consequently countability can be lower (JTC 1998). This survey area is upstream of where the Wolf River enters the Nisutlin (fish are not double counted).

I.4.5 Project Details - White River Watershed

White River is unique in the amount of glacial meltwater contribution, with the White mainstem being a significant source of sediment input into the Yukon River. The White River system is also well known as spawning habitat for fall chum salmon, however Chinook salmon are present in smaller numbers.

The White River drainage is over 50,000 square km (Nowosad et al. 2016).

Tincup Creek

Tincup Creek flows from Tincup Lake (lake-headed system, not glacial like the larger tributaries to the south and west) into the Kluane River, shortly after which the Kluane River flows into the Donjek River which flows into the White River and then into the Yukon River. The index area of Tincup Creek covers the entire reach, from the Kluane River confluence to Tincup Lake. The importance of this area is evident in the Southern Tutchone name - Gyú Chù referring to king salmon from Donjek River https://yukonplacenames.ca/dakeyi/maps/map10/tincup-lake/

I.4.6 Project Details - Upper Yukon River / Southern Lakes

Takhini River

Although not part of DFO's standard index areas, the Takhini River has been surveyed during Chinook spawning by aerial and float methods sporadically over several decades due to its proximity to Whitehorse, its accessibility (a road runs between the headwaters and the confluence with the Yukon River) and various environmental assessments over time, and collection of broodstock. The main challenge with these surveys has been varying methods and varying end points (the outlet of Kusawa Lake is the common starting point, with spawning dunes and no known movement of spawners into/through the lake).

Spawning occurs from the Kusawa Lake outlet down the Takhini mainstem, with visibility being progressively worse further downstream due to silt contributions. Typically the majority of spawning is observed between the Mendenhall River and the outlet of Kusawa Lake ,though the water clarity generally decrease noticeably after the Mendenhall River (Fernet 1982, DFO, 2018).

I.4.7 Project Details - Potential Data Issues

Table I.1. Canadian Aerial Surveys - Potential Data Issues

Project	Years Affected	Potential Issue
Big Salmon	1968	Survey count from North Big Salmon River to Big Salmon lake (Walker et al. 1974) - much longer than the standard index survey area. (also this count should be 827 – transcription error. Have addressed in data).
Big Salmon	1970	Survey count from South Big Salmon River to Big Salmon lake (Walker et al. 1974) - much longer than the standard index survey area.
Big Salmon	1971	Survey extent described as mainstem (Walker et al. 1974), insufficient description to confirm compatibility with standard index survey area.
Big Salmon	1968, 1969, 1973 to 1977	Incomplete or poor survey conditions resulted in minimal or inaccurate counts.
Little Salmon	1968, 1973, 1979, 1980, 1983, 1986, 2010 and 2011	Incomplete and/or poor survey conditions resulting in minimal or inaccurate counts
Ross River	1968, 1983 to 1990, 1995, 1996	viewing conditions poor and/or not a comparable survey extent.
Wolf River	1970, 1975, 1979	Incomplete or poor survey conditions resulted in minimal or inaccurate counts.
Wolf River	All	Depending on existing databases, counts are not consistently applied between sections (Wolf Lake to Red River, or Wolf Lake to Fish Creek). Some years remain unclear as to which index section(s) the count is from.
Wolf River	1970, 1975, 1979.	Incomplete or poor survey conditions resulted in minimal or inaccurate counts:
Nisutlin River	1968, 1673, 1974, 1986	Incomplete or poor survey conditions resulted in minimal or inaccurate counts:
Tincup	1994	Incomplete or poor survey conditions resulted in minimal or inaccurate counts:
Tincup	2000, 2001	Foot surveys were untaken as part of CRE-33-00 and CRE-33-01 “Inventory of Chinook Habitat in the Tincup Creek Drainage”. Although the area and the timing was comparable to aerial surveys, visibility is likely not sufficiently similar and including these counts is not recommended).

Project	Years Affected	Potential Issue
Takhini River	All	Included years were selected from the complete record available in Appendix I (DFO, 2018) to exclude any years where only a range was presented as opposed to a count. Otherwise qualifications for method, survey reach, timing, and rating are included here.
Takhini River	1958 to 1960, 1972, 1974-1977, 1979, 1984 and 1985	method unknown (do not recommend use)
Takhini River	2003, 2005, 2008, 2009	boat survey and not covering full extent (do not recommend use)
Takhini River	1982 and 1983	foot survey, not comparable, do not recommend use.
Takhini River	1989	poor viewing conditions, do not use
	1963	fixed wing but survey area shorter than main extent, do not recommend use
	1966	fixed wing but lack of detail on extent or timing, do not recommend use
	1978	poor survey conditions, do not use.

I.5 References

Data Sources

- Published JTC reports (aerial survey data published annual until the JTC 2012-13 report was the last year.
- Comparison with Survey data were retrieved from the ADF&G AYK Database Management System.
- Results cross referenced with original field data whenever available.
- Other resources included R&E Fund Reports, and environmental assessments.

Other References

Brabets, Timothy P., Bronwen Wang, and Robert H. Meade. "Environmental and hydrologic overview of the Yukon River Basin, Alaska and Canada." Water-Resources Investigations Report 99 (2000): 4204.

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APPENDIX J Data Extract from OceanAK Database

J.1 Overview

A full data extract of all Yukon River Chinook survey records from Alaska's OceanAK database was compiled in June 2021, summarizing the range of years covered, the number of years with estimates, and the range of observed Chinook counts.

The full suite of projects covered 132 systems, of which 36 systems had a maximum Chinook count of at least 100 Chinook (Section J.2).

The raw data dump includes 232 projects, of which 70 projects had a maximum Chinook count of at least 100 Chinook and 72 projects had a maximum Chinook count of 0 Chinook (Section J.3).

All systems listed in Section J.2 are either covered in this report (Table 6) or excluded with a rationale (Table 8).

J.2 Summary

Table J.1. *US systems with Chinook survey records (Largest Count at least 200 Chinook). System* is based on an automated extract of the first 2 words in the project label. *NumProj* is the number of individual projects imn the database for that system. *FirstYear* and *LastYear* are the range of years year with survey records for that system, and *MaxCount* is the largest observed count of Chinook salmon

System	NumProj	FirstYear	LastYear	MaxCount
Pilot Station	1	1986	2021	318,088
Eagle Escapement	1	2005	2021	84,015
Salcha River	7	1954	2021	18,404
Tanana River	4	1962	2014	15,502
Chena River	6	1954	2021	13,390
Andreafsky River	9	1954	2021	8,620
Nulato River	5	1958	2020	4,766
Goodpaster River	6	1954	2020	4,107
Gisasa River	3	1960	2020	4,023
Anvik River	7	1957	2020	3,979
Rapids Test	1	2000	2014	3,423
Lower Yukon	1	1980	2020	2,998
Chatanika River	5	1960	2013	2,448
Henshaw Creek	3	1969	2021	2,391
Tozitna River	2	1985	2012	1,880
South Fork	1	1996	1999	1,580
Chuilnak River	2	1957	2020	915
Rodo River	1	1959	2015	819
Bonasila River	2	1957	2019	800
Koyukuk River	7	1960	2015	747
Seventeenmile Slough	2	1974	2014	644
Barton Creek	1	1983	2008	561
Jim River	5	1969	2015	432
Atchuelinguk (Chulinak)	1	2012	2018	423
Bearpaw River	2	1973	2014	390
Beaver Creek	4	1985	2013	315
Kaltag River	3	1958	2015	241
Alatna River	1	1960	2015	230
Glacier Creek	2	2001	2014	223

J.3 Full Extract

Table J.2. *US projects with Chinook survey records*. Projects are listed in alphabetical order. *FirstYear* and *LastYear* are the range of years year with survey records for that project. *NumYr* is the number of years with estimates. *MinCount* and *MaxCount* are the observed range of Chinook salmon counts.

Project	FirstYear	LastYear	NumYears	MinCount	MaxCount
Alatna River (Aerial Survey)	1960	2015	10	0	230
Andreafsky River (East Fork) (Aerial Survey)	2001	2020	16	84	2,879
Andreafsky River (East Fork) (undefined)	2000	2000	1	1,018	1,018
Andreafsky River (East Fork) (Weir)	1994	2021	28	1,148	8,045
Andreafsky River (East Fork) (Tower)	1986	1988	3	1,341	2,011
Andreafsky River (Aerial Survey)	1954	2020	61	150	8,620
Andreafsky River (Sonar)	1981	1981	1	5,343	5,343
Andreafsky River (undefined)	2000	2000	1	427	427
Andreafsky River (Boat)	1956	1982	2	109	198
Andreafsky River (Foot)	1968	1968	1	0	0
Anvik River (Aerial Survey)	1958	2020	55	25	3,979
Anvik River (undefined)	2000	2000	1	1,394	1,394
Anvik River (Tower)	1972	1979	8	471	1,261
Anvik River (Boat)	1971	1979	6	0	245
Anvik River (Foot)	1957	1968	2	0	0
Anvik River (Sonar)	1979	1980	2	0	0
Anvik River (Tower)	1972	1976	5	472	1,104
Archuelinguk River (Clearwater Creek) near Mountain Village (Aerial Survey)	1958	2011	11	0	87
Archuelinguk River (Clearwater Creek) near Mountain Village (Unknown)	1960	1960	1	10	10
Archuelinguk River (Clearwater Creek) near Mountain Village (Foot)	1956	1956	1	9	9
Archuelinguk River (Clearwater Creek) near Mountain Village (Boat)	1977	1977	1	7	7
Atchuelinguk (Chulinak) (Aerial Survey)	2012	2018	3	23	423
Baker Creek (Foot)	1974	1974	1	0	0
Banner Creek (Foot)	1975	1975	1	0	0
Barton Creek (Aerial Survey)	1983	2008	11	0	561
Batza Creek (Aerial Survey)	1975	1975	1	0	0
Bear Creek (Tributary Salchaket Slough) (Aerial Survey)	1986	2006	3	0	6

Project	FirstYear	LastYear	NumYears	MinCount	MaxCount
Bear Creek (Y4 Below Bullfrog Island) (Aerial Survey)	1960	2012	4	0	8
Bearpaw River (Aerial Survey)	1973	2014	19	0	390
Bearpaw River (Foot)	1982	1982	1	3	3
Beaver Creek (Downstream Beaver Village) (Boat)	1987	1994	5	1	302
Beaver Creek (Downstream Beaver Village) (Aerial Survey)	1985	2012	3	3	31
Beaver Creek (Downstream Beaver Village) (Weir)	1996	2000	4	114	315
Beaver Creek (Tributary Anvik River) (Aerial Survey)	1985	2013	4	29	81
Benchmark No 735 Slough (Aerial Survey)	1972	1980	8	0	0
Benchmark No 735 Slough (Foot)	1980	1980	1	0	0
Big Salt River (Aerial Survey)	1974	2001	2	0	3
Billy Creek Slough (Aerial Survey)	1980	1980	1	0	0
Birch Creek (Downstream Fort Yukon) (Foot)	1971	1971	1	4	4
Birch Creek (Tributary Kantishna River) (Aerial Survey)	1974	1974	1	0	0
Black River (Aerial Survey)	1975	1985	2	0	0
Black Sand Creek (Aerial Survey)	2012	2012	1	0	0
Blackburn Creek (Foot)	1992	1994	3	0	2
Blackburn Creek (Aerial Survey)	1976	2012	2	0	0
Blue Creek (Aerial Survey)	1974	1976	2	0	0
Bluff Cabin Slough (Aerial Survey)	1972	1980	9	0	0
Bluff Cabin Slough (Foot)	1978	1978	1	0	0
Bluff Cabin Slough (Literature review)	1975	1975	1	0	0
Bonasila River (Aerial Survey)	1959	2019	10	0	800
Bonasila River (Foot)	1957	1957	1	1	1
California Creek (Aerial Survey)	2011	2012	2	1	20
Canyon Creek (Aerial Survey)	1985	1985	1	8	8
Caribou Creek (Tributary Hogatza River) (Aerial Survey)	1997	2020	4	0	8
Central Creek (Aerial Survey)	2001	2004	4	0	8
Chandalar River (Aerial Survey)	1974	1988	8	0	62
Charley River (Aerial Survey)	1974	2002	5	0	92
Charley River (Boat)	1987	1987	1	1	1
Chatanika River (Aerial Survey)	1974	2013	24	14	499

Project	FirstYear	LastYear	NumYears	MinCount	MaxCount
Chatanika River (Boat)	1972	1996	7	8	444
Chatanika River (Unknown)	1960	1962	2	0	4
Chatanika River (Weir)	1968	1968	1	2	2
Chatanika River (Tower)	1998	2005	8	311	2,448
Chena River (Aerial Survey)	1954	2014	44	0	3,575
Chena River (Boat)	1962	2013	7	61	959
Chena River (Foot)	1970	1994	4	0	17
Chena River (Tower)	1993	2021	28	3	13,390
Chena River (Sonar)	2015	2018	2	2,232	4,889
Chena River (undefined)	2018	2018	1	327	327
Chisana River (Aerial Survey)	1975	1977	2	0	0
Christian River (Aerial Survey)	1985	1985	1	1	1
Chuilnak River (Atchuelinguk) (Aerial Survey)	1966	2020	13	76	915
Chuilnak River (Atchuelinguk) (Foot)	1957	1957	1	1	1
Clear Creek (Tributary Hogatza River) (Koyukuk Drainage) (Weir)	2005	2005	1	9	9
Clear Creek (Tributary Hogatza River) (Koyukuk Drainage) (Aerial Survey)	2015	2018	2	0	1
Clear Creek (Tributary Julius Creek) (Nenana Drainage) (Aerial Survey)	2000	2014	7	0	135
Clear Creek (Tributary Kantishna River) (Aerial Survey)	1983	1991	6	11	75
Clear Creek (Tributary Tanana River) (Aerial Survey)	2006	2006	1	0	0
Clearwater Lake & Outlet (Aerial Survey)	1962	1980	6	0	0
Clearwater Lake & Outlet (Boat)	1975	1980	5	0	0
Clearwater Lake & Outlet (Unknown)	1972	1973	2	0	0
Clearwater Lake Outlet Slough (Aerial Survey)	1972	1980	4	0	0
Coleen River (Aerial Survey)	1985	1985	1	10	10
Dakli River (Aerial Survey)	1975	2020	18	0	36
Delta Clearwater River (Aerial Survey)	1962	1980	9	0	0
Delta Clearwater River (Boat)	1972	1995	7	0	0
Delta Clearwater River (Unknown)	1973	1973	1	0	0
Delta River Foot and (Aerial Survey)	1962	1980	10	0	0
Delta River Foot and (Foot)	1970	1978	3	0	0
Dishna River (Aerial Survey)	1974	1975	2	1	7

Project	FirstYear	LastYear	NumYears	MinCount	MaxCount
Dulbi River (Aerial Survey)	2011	2019	2	0	0
Eagle (Sonar, Yukon/Canadian Border Passage) (Sonar)	2005	2021	17	30,725	84,015
Engineer Creek (Foot)	1957	1957	1	0	0
Fish Creek (Koyukuk) (Aerial Survey)	1975	1985	3	0	6
Five Mile Clwtr River (Aerial Survey)	1974	1976	3	0	0
Geiger Creek (Aerial Survey)	2000	2000	1	0	0
Gisasa River (Aerial Survey)	1960	2020	37	45	2,775
Gisasa River (Boat)	1982	1987	2	189	193
Gisasa River (Weir)	1994	2020	27	1,083	4,023
Glacier Creek (Kantishna) (Aerial Survey)	2006	2006	1	82	82
Glacier Creek (Nenana) (Aerial Survey)	2001	2014	4	0	223
Goodpaster River (South fork) (Aerial Survey)	2002	2004	2	3	51
Goodpaster River (South fork) (Unknown)	2001	2001	1	27	27
Goodpaster River (Aerial Survey)	1954	2007	30	14	3,004
Goodpaster River (Personal interview)	1972	1972	1	8	8
Goodpaster River (Weir)	2004	2020	16	540	4,107
Goodpaster River (Tower)	2012	2012	1	778	778
Grayling Creek (Aerial Survey)	1976	2012	2	0	0
Hammond River (Personal interview)	1983	1983	1	48	48
Hammond River (Aerial Survey)	1997	1997	1	8	8
Henshaw Creek (Aerial Survey)	1969	2020	24	6	620
Henshaw Creek (Weir)	2000	2021	21	0	2,391
Henshaw Creek (Tower)	1999	1999	1	4	4
Hodzana River (Aerial Survey)	2011	2011	1	98	98
Hogatza River (Aerial Survey)	1960	2011	12	0	1
Hogatza River (Foot)	1993	1993	1	0	0
Honhosa River (Aerial Survey)	2011	2011	1	0	0
Hult Creek (Aerial Survey)	1994	1994	1	8	8
Huslia River (Aerial Survey)	2009	2020	6	0	0
Iditarod River (Aerial Survey)	1992	1992	1	0	0
Illinois Creek (Aerial Survey)	1960	1960	1	2	2
Indian River (Aerial Survey)	1960	2018	9	0	93
Innoko River (Boat)	1981	1981	1	1	1
Jim River (Aerial Survey)	1969	2015	33	1	432

Project	FirstYear	LastYear	NumYears	MinCount	MaxCount
Jim River (Unknown)	2000	2000	1	79	79
Jim River (Literature review)	1980	1980	1	57	57
Jim River (Foot)	1983	1983	1	8	8
Jim River (Boat)	1987	1987	1	5	5
John River (Aerial Survey)	1992	1992	1	6	6
Julius Creek (Aerial Survey)	1972	2013	10	0	130
Julius Creek (Boat)	1978	1980	2	56	58
Julius Creek (Foot)	1977	1986	2	0	26
June Creek (Aerial Survey)	2000	2000	1	0	0
Kako Creek (Foot)	1957	1957	1	0	0
Kala Creek (Aerial Survey)	1960	1977	2	1	7
Kaltag River (Aerial Survey)	1958	2015	9	0	31
Kaltag River (Foot)	2010	2010	1	0	0
Kaltag River (Tower)	1994	2005	11	20	241
Kandik River (Aerial Survey)	1985	2001	3	0	13
Kanuti River (Aerial Survey)	1969	1969	1	0	0
Kateel River (Aerial Survey)	1960	2019	14	0	185
Klikhtentotzna (Aerial Survey)	2011	2011	1	0	0
Kokrines Str (Foot)	1958	1958	1	0	0
Koyukuk River (Middle Fork) (Aerial Survey)	1971	2015	7	11	168
Koyukuk River (North Fork) (Aerial Survey)	1971	2015	5	1	38
Koyukuk River (South Fork) (Aerial Survey)	1960	2015	33	1	747
Koyukuk River (South Fork) (Unknown)	2000	2000	1	74	74
Koyukuk River (South Fork) (Boat)	1989	1989	1	54	54
Koyukuk River (South Fork) (Literature review)	1980	1980	1	22	22
Koyukuk River (Aerial Survey)	1960	1969	2	10	12
Lignite Spring (Foot)	1978	1978	1	0	0
Little Indian River (Aerial Survey)	2011	2011	1	0	0
Little Salcha River (Weir)	1953	1953	1	0	0
Lockwood Creek (Foot)	1957	1957	1	0	0
Lost Slough (Aerial Survey)	1973	1991	9	0	1
Lower Yukon (Test Fish)	1980	2020	41	371	2,998
McDonald Creek (Anvik) (Tower)	2004	2004	1	5	5
McDonald Creek (Tanana R) (Aerial Survey)	1996	2006	5	0	65
McKinley River (Aerial Survey)	1974	1974	1	0	0

Project	FirstYear	LastYear	NumYears	MinCount	MaxCount
McManus Creek (Aerial Survey)	2003	2003	1	0	0
Melozi Hot Springs Creek (Aerial Survey)	1994	2012	7	0	43
Melozitna River (Aerial Survey)	1960	2011	15	4	136
Melozitna River (Unknown)	1979	1979	1	9	9
Minook Creek (Foot)	1958	1958	1	0	0
Moose Creek (Kantishna) (Aerial Survey)	2002	2005	2	19	41
Morelock Creek (Aerial Survey)	1978	1978	1	0	0
Nageethluk River (Aerial Survey)	1985	1985	1	56	56
Nation River (Aerial Survey)	1985	2001	3	0	27
Nenana River (Aerial Survey)	1974	2013	2	0	18
Ninemile River (Aerial Survey)	2012	2012	1	106	106
Nowitna River (Boat)	1987	1987	1	1	1
Nulato River (South Fork) (Aerial Survey)	1998	2020	11	167	897
Nulato River (Aerial Survey)	1958	2020	40	0	3,025
Nulato River (Boat)	1987	1987	1	165	165
Nulato River (Tower)	1994	2002	8	756	4,766
Nulato River (Weir)	2003	2003	1	1,716	1,716
Onemile Slough (Aerial Survey)	1973	1980	8	0	0
Onemile Slough (Unknown)	1973	1973	1	0	0
Otter Creek (Aerial Survey)	1985	2013	5	17	118
Panguingue Creek (Foot)	1978	1978	1	0	0
Piledriver Slough (Aerial Survey)	1977	1977	1	2	2
Pilot Station (Sonar)	1986	2021	34	3,559	318,088
Pitka River (Aerial Survey)	2011	2011	1	0	0
Pocahontas Creek (Aerial Survey)	1993	1993	1	0	0
Rapids (Test Fish)	2000	2014	15	435	3,423
Richardson Clearwater River (Aerial Survey)	1962	1980	9	0	0
Richardson Clearwater River (Unknown)	1973	1973	1	0	0
Rodo River (Aerial Survey)	1959	2015	20	0	819
Salcha River (Aerial Survey)	1954	2015	51	0	11,379
Salcha River (Boat)	1968	1987	3	30	574
Salcha River (Foot)	1977	1994	4	0	47
Salcha River (Literature review)	1975	1975	1	0	0
Salcha River (Tower)	1993	2021	28	1,534	18,404
Salcha River (Sonar)	2018	2018	1	1,605	1,605

Project	FirstYear	LastYear	NumYears	MinCount	MaxCount
Salcha River (undefined)	2018	2018	1	321	321
Salchaket Slough (Aerial Survey)	1997	1997	1	71	71
Salmon Fork (Aerial Survey)	1974	2008	7	0	2
Salmon Trout River (Aerial Survey)	1974	1976	3	0	0
Seventeenmile Slough (Aerial Survey)	1974	2014	26	0	644
Seventeenmile Slough (Boat)	1977	1986	2	2	306
Seventymile River (Aerial Survey)	1997	1997	1	7	7
Sheenjek River (Aerial Survey)	1973	1985	9	0	45
Sheenjek River (Boat)	1973	1973	1	0	0
Simon Creek (Aerial Survey)	1978	1978	1	0	0
Slate Creek (Koyukuk) (Foot)	1974	1974	1	13	13
Slate Creek (Koyukuk) (Personal interview)	1982	1982	1	6	6
South Bank Tanana River (Aerial Survey)	1972	1980	8	0	0
South Bank Tanana River (Foot)	1970	1978	3	0	0
South Fork Koyukuk River (Weir)	1996	1999	3	30	1,580
Spruce Creek (Foot)	1957	1957	1	10	10
Squaw Creek (Aerial Survey)	1974	1974	1	0	0
Stink Creek (Aerial Survey)	1976	2012	2	0	8
Stuyahok River (Aerial Survey)	2003	2012	2	10	20
Sushana River (Aerial Survey)	2000	2000	1	0	0
Swift River (Anvik River) (Aerial Survey)	2003	2013	4	3	18
Tanana River (Aerial Survey)	1962	1976	5	0	0
Tanana River (Population estimate)	1979	1980	2	0	0
Tanana River (Sonar)	2013	2014	2	2,337	15,502
Tanana River (Test Fish)	1990	2013	5	37	37
Tatonduk River (Aerial Survey)	1997	1997	1	1	1
Teklanika River (Aerial Survey)	1997	1997	1	198	198
Teklanika River Springs (Aerial Survey)	2000	2000	1	0	0
Thompson Creek (Aerial Survey)	2012	2012	1	0	0
Tozitna River (Aerial Survey)	1985	2012	18	0	1,013
Tozitna River (Weir)	2004	2009	6	494	1,880
Unnamed Creek -4021 (Aerial Survey)	2014	2014	1	4	4
Unnamed Creek -4137 (Aerial Survey)	2006	2006	1	16	16
Unnamed Creek -4141 (Aerial Survey)	2006	2006	1	11	11
Wheeler Creek (Aerial Survey)	1995	1995	1	3	3

Project	FirstYear	LastYear	NumYears	MinCount	MaxCount
Willow Creek (Aerial Survey)	2006	2006	1	0	0
Wood Creek (Aerial Survey)	2013	2013	1	0	0
Yellow River (Aerial Survey)	1985	1985	1	4	4
Yuki River (Aerial Survey)	2011	2012	2	0	21