Genetic Stock Identification of Yukon River Chinook and Fall Chum Salmon using Microsatellites, 2016

Prepared for	The Yukon River Panel
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March 2017

Abstract

Stock identification of Chinook and chum salmon migrating past the Eagle, Alaska sonar site near the Yukon-Alaska border was conducted in 2016 through analysis of microsatellite variation. Variation at 15 microsatellites was surveyed for 728 Chinook salmon and variation at 14 microsatellites was surveyed for 736 chum salmon samples collected during test fishing at the sonar site. Chinook salmon samples collected at the Eagle sonar site indicated that the major regional stock contributions to the run were Upper Yukon tributaries (6.6%), Teslin River (35.0%), Carmacks area tributaries (16.4%), Mid-mainstem Yukon River tributaries (11.8%), Pelly River (15.3%), Stewart River (8.0%), North Yukon tributaries (4.2%) and White River (2.7%). Chum salmon from the Yukon River mainstem stocks were estimated to comprise 70.0% of the samples collected through the season at the Eagle sonar site, while an estimated 29.3% of the samples were White River chum salmon.

Acknowledgments

Genetic analysis was conducted by staff at the DFO Pacific Biological Station Molecular Genetics Laboratory. Financial support for the project was provided by the Yukon River Panel's Yukon River Restoration and Enhancement Fund as well as DFO.

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Introduction

Background

Chinook salmon (*O. tshawytscha*) and Chum salmon (*Oncorhynchus keta)* are widely distributed throughout the Yukon River drainage, spawning in tributaries ranging from the headwaters (e.g. Teslin River drainage) to near the river mouth (e.g. Andreafsky River, Alaska). Management for conservation of biodiversity within the drainage requires knowledge of genetic variation among populations, as well as population-specific information from fisheries. Effective management of fisheries in major drainages like the Yukon River requires information on the harvest and timing of specific populations to enable managers to adjust exploitation rates for conservation purposes and to understand how management measures affect specific stocks. It is important to accurately assess the status of these stocks so that management decisions can ensure that treaty obligations and conservation objectives are achieved. Run reconstructions are important for monitoring the achievement of treaty objectives, for developing pre-season forecasts, and for assessing the adequacy of current escapement targets. Assessment of individual stock status provides critical information for assessing the factors influencing stock productivity levels, which appear to have fluctuated widely in recent years. Genetic stock identification (GSI) is one tool that can be used to address these management objectives.

Stock identification of Chinook and chum salmon migrating in the mainstem Yukon River through analysis of variation in microsatellite loci has been used for population-specific estimates of stock composition since 2005 (Beacham et al. 2008). Microsatellite analysis has been used to identify the stock composition of Chinook salmon sampled in test netting associated with the Eagle sonar project since 2008, and was used to identify stock composition of Chinook salmon captured in DFO fishwheels between 2004 and 2008 (JTC, 2016). Microsatellites have also been used to estimate the stock composition of chum salmon samples collected in test netting at the Eagle sonar site since 2009, and of samples collected at DFO fishwheels between 2005 and 2008.

Project overview

The intent of this project was to determine stock compositions of Chinook and chum salmon runs entering Canada through genetic analysis of tissue samples from the Eagle sonar project test fishing operation. In 2016, the DFO Molecular Genetics Laboratory surveyed variation at microsatellite loci for 728 Chinook salmon and 736 chum salmon live-captured in the test fishery associated with the sonar operations near Eagle, Alaska. Microsatellite variation was used to estimate stock composition in the samples collected.

Materials and Methods

Collection of DNA Samples

Tissue samples were collected from adult Chinook and chum salmon captured in the test fishery associated with the Eagle sonar salmon enumeration project between July 2, 2016 and September 30,

2016. Salmon were captured in drift gill nets following a study design to reflect the age, sex and length composition of the Chinook salmon escapement to Canada, and to identify the date at which the portion of chum salmon exceeded the returns for Chinook salmon. Gill net mesh sizes utilised included 5.25", 6.5", 7.5" and 8.5" (Lozori & McDougall, 2015). All salmon caught during this period were sampled. Axillary appendages were taken from all Chinook salmon and placed in individual vials containing anhydrous ethanol; vials were labelled with a unique number recorded alongside the age, sex and length data from the corresponding sampled fish. Axillary appendages taken from chum salmon were placed in bulk sample vials rather than individual sample vials; three bulk sample vials were collected over the course of the season. Samples were shipped to the ADF&G genetics lab in Anchorage at the end of the season, where technicians catalogued the samples and prepared them for shipping.

Laboratory Analysis

DNA was extracted, samples were processed and laboratory analysis was conducted at the Pacific Biological Station in Nanaimo, BC, Canada following the same procedures used in analysis of the 2013 Eagle test fishery samples, and as described in the report to the Panel (Beacham &Candy, 2014). (Further information on laboratory equipment and techniques is available at the Molecular Genetics Laboratory website at: http://www.pac.dfompo.gc.ca/science/facilities-installations/pbs-sbp/mgl-lgm.) Variation of 15 microsatellite loci was analysed from 728 (from a total of 748) Chinook salmon samples collected between July 2 and September 16, 2016. Variation at 14 microsatellite loci was surveyed for 736 (from a total of 863) chum salmon tissue samples collected between August 5 and September 30, 2016 in the Eagle sonar test fishery.

Baseline Populations

The baseline survey consisted of microsatellite analysis of Chinook salmon from 27 locations within the Canadian portion of the drainage (Table 1) and microsatellite analysis of chum salmon from nine locations within the Canadian portion of the drainage (Table 2). All annual samples available for a specific sample location were combined to estimate population allele frequencies, as was recommended by Waples (1990). Calculations of stock proportion were completed for each sample period and for the season as a whole. Seasonal estimates of proportional contribution for each stock aggregate were not weighted by sonar passage period. Chum salmon baselines remained unchanged from those described in the 2015 border GSI Report. Two additions were made to the 2016 Chinook salmon baseline, the Hoole river was included in the population baseline for the Pelly River aggregate group and the Hundred Mile River was included in the population baseline for the Teslin River aggregate group.

Chinook salmon

Chinook salmon stock contribution estimates were based on 8 regional reporting groups (Table 1) and estimated by period and for the entire season (Figures 1; Appendix A1 and A2).

Table 1. Baseline comprised of 29 stocks used to estimate stock compositions of Chinook salmon collected from the test gillnetting program at the Mainstem Yukon River sonar project at Eagle Alaska, 2016.

Stock aggregate name	Populations in baseline
North Yukon Tributaries	Chandindu and Klondike rivers
White River	Tincup Creek, Nisling River
Stewart River	Mayo, McQuesten, and Stewart rivers
Pelly River	Little and Big Kalzas, Earn, Glenlyon, Ross, Hoole and Pelly rivers, Blind Creek
Mid-mainstem Tributaries	Mainstem Yukon and Nordenskiold rivers
Carmacks Area Tributaries	Little Salmon, Big Salmon, and North Big Salmon rivers, Tatchun Creek
Teslin River	Teslin Lake, Nisutlin, Morley, Jennings, Hundred Mile, Wolf and Teslin rivers
Upper Yukon Tributaries	Whitehorse Hatchery and Takhini River

Chum salmon

Chum salmon stock contribution estimates were based on four regional reporting groups (Table 2) and estimated by period and for the entire season (Figures 5; Appendix B1 and B2).

Table 2. Baseline comprised of 9 stocks used to estimate stock compositions of fall chum salmon collected from the test gillnetting program at the Mainstem Yukon River sonar project at Eagle Alaska, 2016.

Stock Aggregate Name	Population in Baseline
Yukon Early	Chandindu River
White River	Kluane River, Kluane Lake, Donjek River
Mainstem Yukon River	Mainstem Yukon River at Pelly River, Tatchun Creek, Big Creek, and Minto
Teslin River	Teslin River

Estimation of Stock Composition

Analysis of genetic samples was conducted using a Bayesian procedure (BAYES) as outlined by Pella and Masuda (2001), and as described in the 2014 report for the project (Beacham & Candy, 2014). Passage estimates (i.e., abundance) by stock aggregate for the 2015 Chinook and chum salmon migration bound for Canada were calculated using the stock aggregate proportions of genetic samples collected from the Eagle sonar test fishery samples and the Eagle sonar passage estimates. The Eagle sonar salmon passage estimate for each sampling period was multiplied by the stock proportion estimate of the samples analyzed from that period to estimate the salmon stock aggregate abundance for each sampling period, and for the season sampling period as a whole. The chum salmon run continued after the sonar enumeration project ended for the season on October 6. In order to account for chum passage after this date, an expansion formula was used to estimate chum salmon passage from October 7 to 18. Estimated chum salmon stock proportions derived from samples collected in the last sampling period (September 25 – 30) were expanded to the remainder of the run to calculate stock passage estimates for the period after genetic sampling had ceased (October 1 to October 18, 2017).

Results and Discussion

Chinook Salmon

Stock Proportions

The contributions of Chinook salmon stock aggregates to the total 2016 Eagle sonar test fishery samples were estimated by period and for the total season sample (Appendix A1, Figure 1). It was determined that Teslin River Chinook represented the greatest proportion of the run. The Chinook salmon stock composition of the total season sample was Upper Yukon Tributaries (6.6%), Teslin River (35.0%), Carmacks Area Tributaries (16.4%), Mid-mainstem Tributaries (11.8%), Pelly River (15.3%), Stewart River (8.0%), North Yukon Tributaries (4.2%) and White River (2.7%).

The Upper Yukon Tributaries and Mid-mainstem stock aggregate proportions were lowest (0.6% and 2.6% respectively) in the beginning of the run (July 2 – 13) and increased with successive sampling periods throughout the season (Figure 1). The Teslin River stock aggregate followed a general increasing trend peaking in the last sample period (July 27 – August 17). The Carmacks Area Tributaries population was fairly consistent throughout the run and declined towards the end of season. The Stewart River stock aggregate proportion peaked (19.0%) mid-way through the run (July 20 – 26). The Pelly River aggregate was highest (24.3%) during the first sampling period (July 2 – 13) and decreased as the run progressed. Both the North Yukon Tributaries and White River populations followed a general decreasing trend through the season, but showed a slight increase in the final sampling period (July 27 – August 17).

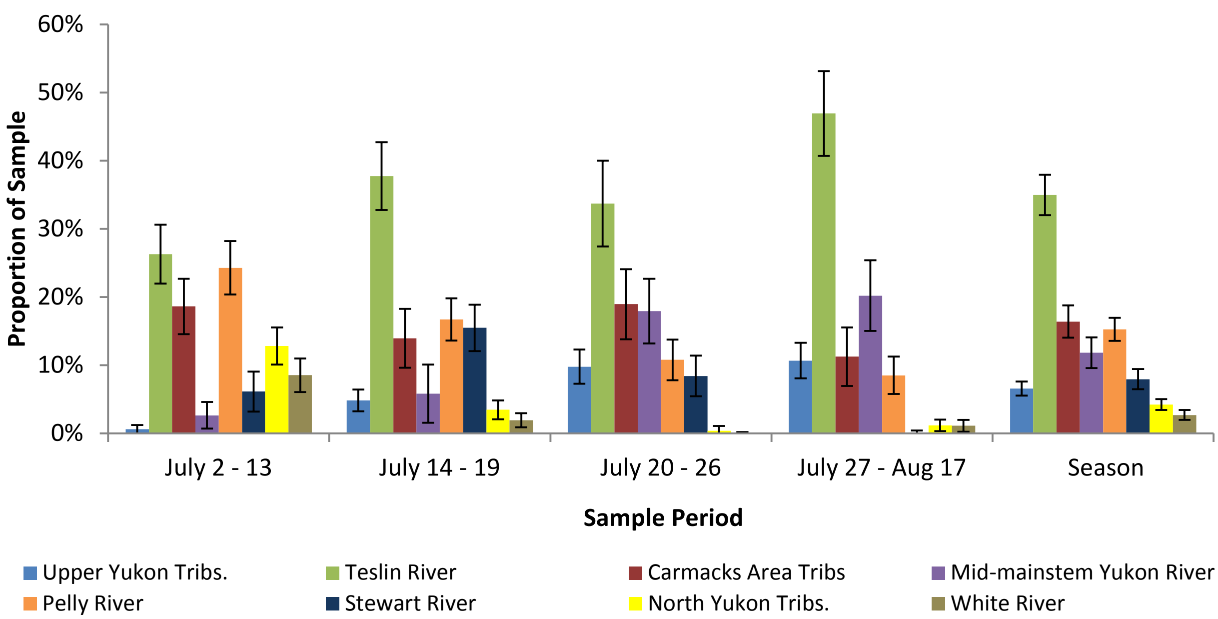

Figure 1. Estimated aggregate stock composition of Chinook genetic samples collected from the Eagle sonar site, 2016. Error bars indicate standard error for each stock aggregate.

Passage Estimates

The Eagle sonar Chinook salmon passage estimate for each sampling period was multiplied by the genetic stock proportion estimates to provide an estimate of stock aggregate abundance for each sample period, and for the season as a whole (Appendix A3; Figure 2 and Figure 3). A total of 72,329 Chinook salmon were estimated to have passed by the Eagle sonar over the course of the 2016 Chinook salmon run (July 2 – August 18, 2016). Based on genetic stock proportions, seasonal estimates for passage at the sonar site for each aggregate group were 4,768 for Upper Yukon tributaries, 25,300 for Teslin River, 11,867 for Carmacks area tributaries, 8,565 for Mid-mainstem Yukon River tributaries, 11,045 for Pelly River, 5,762 for Stewart River, 3,069 for North Yukon tributaries and 1,953 for White River.

Stock proportion estimates for individual stocks comprising the aggregate groups (Appendix A2) are associates with higher levels of uncertainty, and were not used for passage estimation.

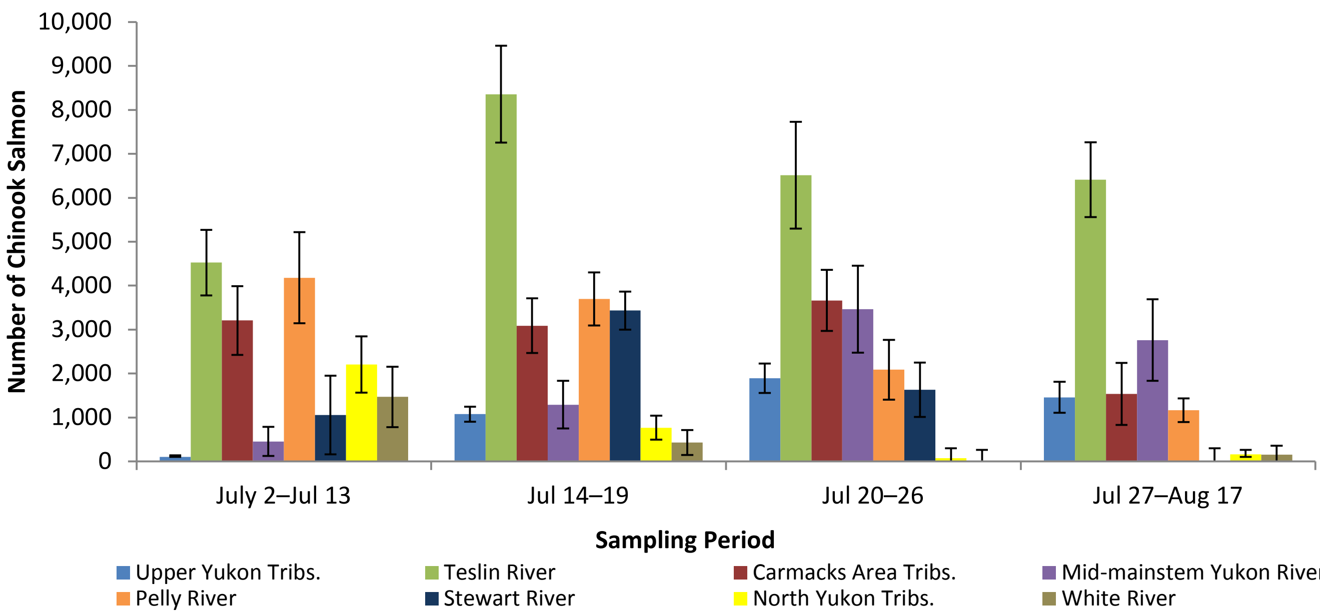

Figure 2. Estimated aggregate stock abundance of Chinook salmon migrating past the Eagle sonar site between July 2 and August 17, 2016. Error bars indicate standard error of the genetic estimate.

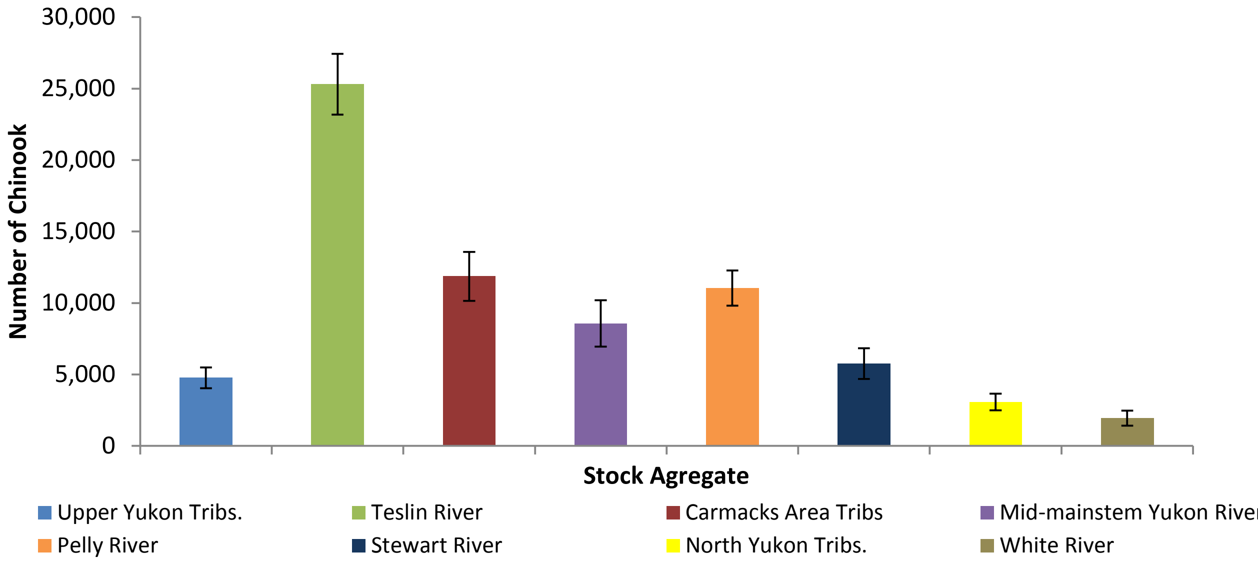

Figure 3. Estimated season abundance totals for Chinook salmon stock aggregates migrating past the Eagle sonar site between July 2 and August 17, 2016. Error bars indicate standard error of the genetic estimate.

Multi-Year Comparison of Chinook Salmon Stock Proportions

Appendix A4 contains the annual proportional contributions for each stock aggregate over the past twelve years (2005 to 2016). From 2005 to 2008 genetic samples were collected using fish wheels at Bio Island. Since 2008, genetic samples have been collected from gill net test fisheries in conjunction with the Mainstem Yukon River sonar project located near Eagle, Alaska. The estimated stock compositions for Chinook salmon sampled from the Eagle sonar test fishery are presented in Figure 4. With the exception of White River, estimated stock percentages from 2016 Chinook salmon samples are within ranges previously observed from 2008 to 2015. The 2016 White River stock aggregate was the lowest proportional contribution observed since 2008. The 2016 Mid-mainstem Yukon River, Pelly River, and White River stock proportion estimates fell below the 2008 – 2015 average. Upper Yukon Tributaries, Teslin River, Carmacks Area Tributaries, Pelly and Stewart River stock aggregate proportions were above the 2008 – 2015 average. The estimated proportion of Teslin River Chinook salmon migrating past the Eagle sonar station in 2016 was the second highest observed since 2008.

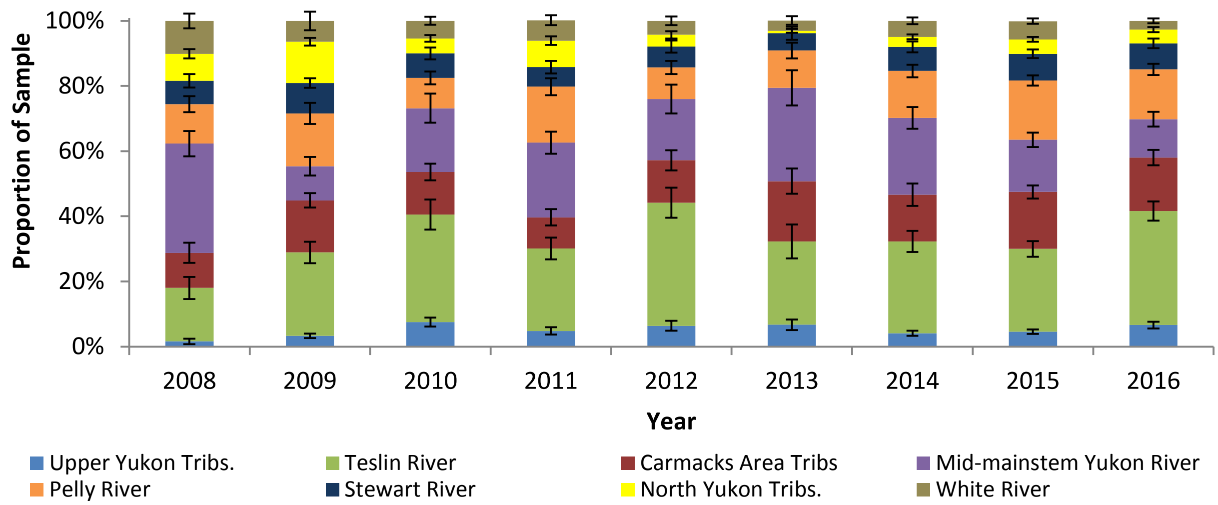

Figure 4. Estimated aggregate stock composition from Chinook genetic samples collected during test netting at Eagle, Alaska 2008–2016. Error bars indicate standard error for each stock aggregate.

Chum Salmon

Stock Proportions

In the 2016 season, chum salmon spawning populations from the Mainstem Yukon River aggregate, represented by Pelly, Tatchun, Big Creek, and Minto populations, accounted for 70.0% of the samples collected from the Eagle sonar test fishery. The White River drainage, represented by Kluane River, Kluane Lake, and Donjek River chum salmon populations was estimated to comprise 29.3% of the samples (Appendix B1; Figure 5). The Mainstem Yukon River population formed the majority of samples collected for all sampling periods. The White River proportion was highest (46.1%) in the beginning of the run (August 18 – September 3) and declined as the run progressed. The proportion of main stem spawning Yukon River populations was lowest (53.5 %) in the beginning of the run (August 18 – September 3) and highest (83.9 %) in the final sampling period (September 25 – 30). Less than 1% of the return was estimated to originate from the remaining two reporting groups: the Teslin River and the Yukon Early group. Yukon Early chum salmon (Chandindu River) were estimated to form a negligible proportion (0% to 0.2%) of the sample throughout the run and formed an estimated 0% of the pooled season samples. Teslin River chum salmon were estimated to form a very small proportion (0.2% to 1.3%) of each sample group, and 0.6% of the pooled season samples (Appendix B1; Figure 5).

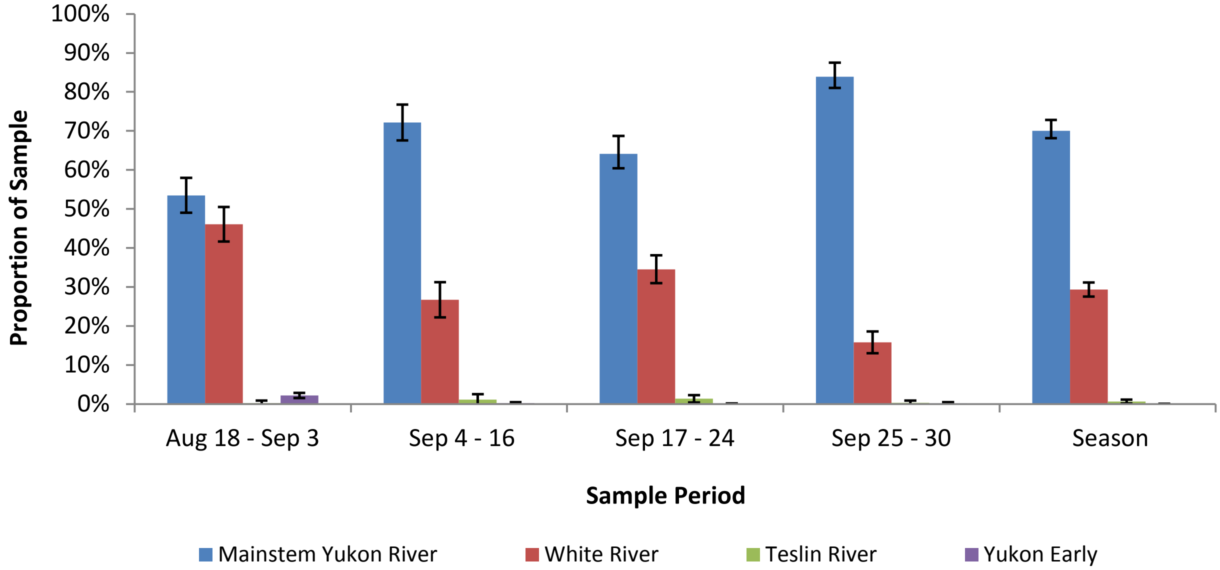

Figure 5. Estimated aggregate stock composition of chum genetic samples collected from the Eagle sonar site, 2016. Error bars indicate standard error for each stock aggregate.

Passage Estimates

The Eagle sonar chum salmon passage estimate for each sampling period was multiplied by the genetic stock proportion estimates to provide an estimate of stock aggregate abundance for each sample period, and for the season as a whole (Appendix B3; Figure 6 and Figure 7). A total of 111,717 chum salmon were estimated to have passed by the Eagle sonar over the course of the 2016 genetics sampling period (August 18 – September 30, 2016). A total run passage of 161,027 chum salmon was estimated to have migrated past the eagle sonar station from August 18 to October 18. This estimate for total run passage includes 49,310 chum salmon that were estimated to pass by the sonar site after the test fishery and all genetic sampling had ceased for the season. Based on genetic stock proportions, the estimate for passage at the sonar site for the Mainstem Yukon River was 112,754 chum salmon for this period, while the estimate for the White River stock aggregate was 47,238. A passage estimate of 1,029 chum salmon was assigned for the Teslin River stock aggregate. The passage for Yukon Early stocks was negligible and an estimate of 0 was within the standard error range for this stock aggregate.

A large proportion of the 2016 run went un-sampled, with an estimated 30% of the run passing the sonar site after the last genetic sampling period. Genetic sampling ceased on September 30 and abundance estimates for the October 1 to October 18 period were derived from genetic samples collected from September 25 to 30. As a result there is greater uncertainty associated with stock abundance estimates for the month of October, due to the absence of stock proportion data for this period. GSI analysis of Eagle samples in recent years (R&E projects CRE-79-13, CRE-79-14, CRE-79-15) has indicated that the Mainstem Yukon River chum salmon component increases in the latter part of the run, while the White River proportion declines. This pattern was also observed in 2016 (Figure 5), which was determined to be a late run year with over 30% of the run passing the sonar site after the last genetic sampling period. For this reason it is suspected that the 2016 GSI estimates may underestimate the abundance of the mainstem stock group and overestimate the abundance of the White River stock group migrating past the Eagle sonar site during the last sampling period (September 25 to October 18) and the season as a whole (August 18 and October 18).

Stock proportion estimates for the individual stocks comprising the aggregate groups (Appendix A2) are associated with high levels of uncertainty, and were not used for passage estimation.

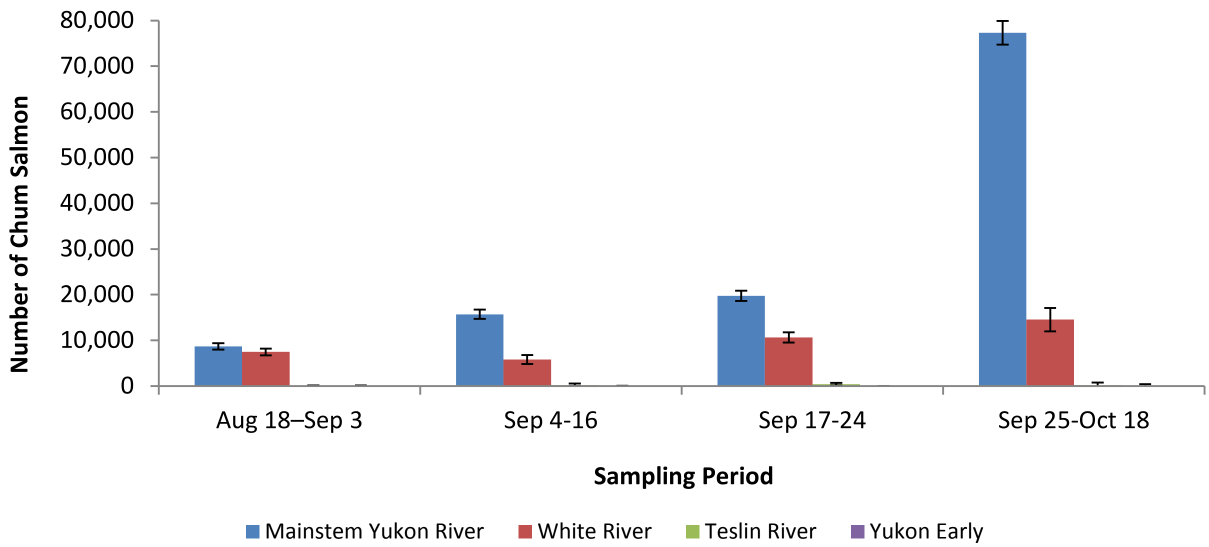

Figure 6. Estimated aggregate stock abundance of chum salmon migrating past the Eagle sonar site between August 18 and October 18th, 2016. Error bars indicate standard error of the genetic estimate. Stock proportions derived from samples collected in the last sampling period (September 25 – September 30) were expanded to the remainder of the run to calculate passage abundance to October 18, 2016.

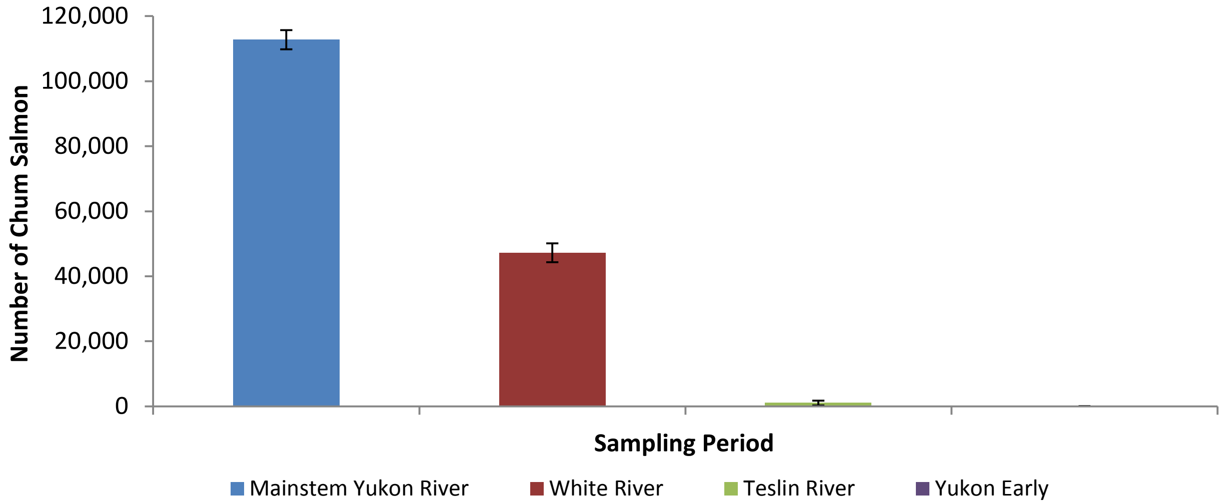

Figure 7. Estimated season abundance totals for chum salmon migrating past the Eagle sonar site between August 18 and October 18, 2016. Error bars indicate standard error of the genetic estimate. Stock proportions collected during the last sampling period (September 25 – 30) were expanded to the remainder of the run to calculate passage abundance estimates to October 18, 2016.

Multi-Year Comparison of Chum Salmon Stock Proportions

Appendix B4 contains the annual proportional contributions for each stock aggregate over the previous eleven years (2005 to 2016). From 2005 to 2008 genetic samples were collected using the Bio Island fish wheels. Since 2009 all genetic samples have been collected from chum captured during the Eagle sonar test fishery. The 2016 Mainstem Yukon River chum stock aggregate proportion for Eagle sonar passage was the highest estimated since the first year genetic sampling took place in 2005 (Appendix A4). The stock aggregate proportion for White River and Yukon Early chum was the lowest estimated for the same period (Appendix B4). The 2016 percent composition of the mainstem stock group as well as the Teslin River stock group was above the 2009-2015 average (Figure 8). Conversely, the percent composition of the White River and Yukon Early stock groups for 2016 fell below average for the same time period. Stock compositions for White River and Teslin River stock groups were within previously observed ranges (Appendix B4). The percent composition of Yukon Early stock grouping was the lowest on record. However, the Teslin River and Yukon Early groups comprise very small proportions of the total Eagle sonar chum salmon passage and of the genetic sample; thus, there is greater uncertainty associated with these estimates. GSI analysis of chum salmon samples collected at the Eagle sonar site suggests that the Mainstem Yukon River chum salmon component increases in the latter part of the run, while the White River proportion declines. For this reason it is suspected that GSI estimates may underestimate the proportion of the mainstem stock group and overestimate the proportion of the White River stock group in late run years. Over 30% of the run passed the sonar site after genetic sampling had ceased for the season in 2016 and as a result there is reduced confidence in estimates of stock composition expanded to the entire run.

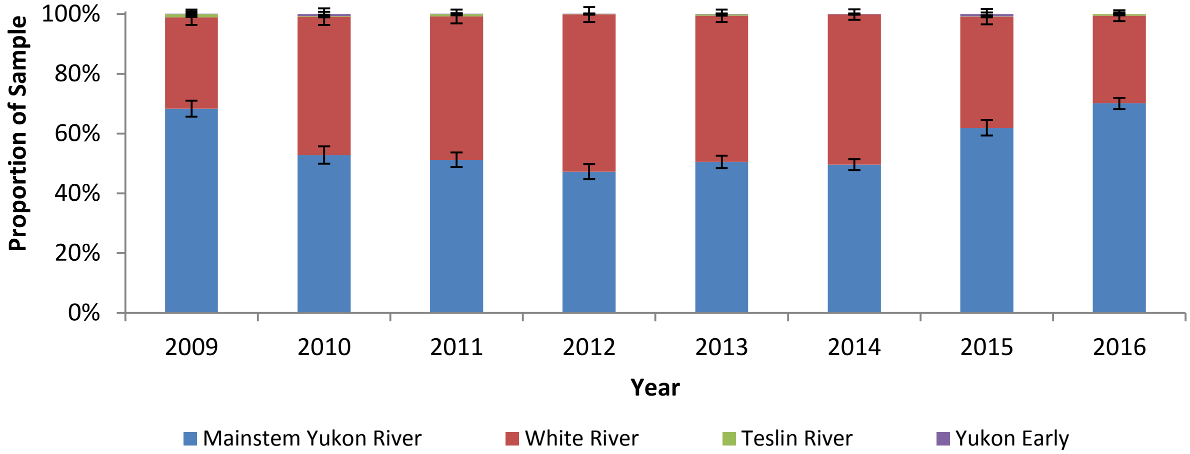

Figure 8. Estimated aggregate stock composition from chum genetic samples collected in test netting at Eagle, Alaska 2009–2016. Error bars indicate standard error for each stock aggregate.

Conclusion

Stock identification of Chinook and chum salmon migrating past the Eagle sonar site near the Yukon-Alaska border continues to provide important information for managing and understanding Yukon River salmon stocks. Every year, with additional samples, the genetic baseline becomes more accurate and the certainty surrounding abundance estimates based on stock proportions increases. Results in 2016 will continue to build understanding of when different stocks migrate and how their proportions change over time. In combination with increased resolution of the genetic baseline for Canadian Yukon River stocks, analysis of long term trends and an increase in information available for management will continue to improve the understanding of this joint resource.

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Appendices

Appendix A: Chinook Salmon Genetic Stock Estimates

Appendix A1: Canadian-origin Chinook Salmon Aggregate Stocks (Regional) Proportion Estimates in 2016.

Samples Analysed Sample Period	*n*=165 Jul 2 – Jul 13		*n*=223 Jul 14 – Jul 19		*n*=164 Jul 20 – Jul 26		*n*=176 Jul 27 – Aug 17		*n*=728 Season	
Region	Estimate	SD	Estimate	SD	Estimate	SD	Estimate	SD	Estimate	SD
Upper Yukon Trbs.	0.6	(0.6)	4.9	(1.6)	9.8	(2.5)	10.7	(2.6)	6.6	(1.0)
Teslin River	26.3	(4.3)	37.8	(5.0)	33.7	(6.3)	46.9	(6.2)	35.0	(2.9)
Carmacks Area Tribs.	18.6	(4.1)	13.9	(4.3)	19.0	(5.1)	11.3	(4.3)	16.4	(2.4)
Mid-mainstem	2.6	(2.0)	5.8	(4.3)	17.9	(4.7)	20.2	(5.2)	11.8	(2.2)
Pelly River	24.3	(3.9)	16.7	(3.1)	10.8	(3.0)	8.5	(2.7)	15.3	(1.7)
Stewart River	6.1	(2.9)	15.5	(3.4)	8.4	(3.0)	0.1	(0.4)	8.0	(1.5)
North Yukon Tributaries	12.8	(2.7)	3.5	(1.4)	0.4	(0.7)	1.2	(0.9)	4.2	(0.8)
White River	8.5	(2.5)	1.9	(1.0)	0.0	(0.2)	1.1	(0.9)	2.7	(0.7)

Note: The mainstem Yukon River sonar operated near Eagle switched from enumerating Chinook to fall chum salmon on August 18, 2016.

Appendix A2: Canadian-origin Chinook Salmon Stock Proportion Estimates in 2016.

Samples Analysed Sample Period	*n*=165 Jul 2 – Jul 13		*n*=223 Jul 14 – Jul 19		*n*=164 Jul 20 – Jul 26		*n*=176 Jul 27 – Aug 17		*n*=728 Season	
Region	Estimate	SD	Estimate	SD	Estimate	SD	Estimate	SD	Estimate	SD
Takhini	0.0	(0.1)	1.3	(0.9)	4.3	(1.8)	7.6	(2.2)	3.3	(0.8)
Whitehorse	0.6	(0.6)	3.6	(1.3)	5.5	(1.9)	3.1	(1.5)	3.3	(0.7)
Wolf_R	0.3	(1.1)	3.4	(2.7)	0.6	(1.4)	0.6	(1.3)	1.4	(1.3)
100_Mile_R	0.3	(0.8)	0.1	(0.3)	0.0	(0.2)	0.0	(0.2)	0.0	(0.1)
Morley	5.3	(3.1)	1.7	(2.4)	0.2	(1.0)	0.0	(0.2)	1.3	(1.5)
Nisutlin	6.4	(3.4)	2.5	(2.7)	4.4	(2.5)	0.1	(0.5)	3.6	(1.3)
Teslin	1.8	(2.5)	15.2	(4.3)	19.6	(6.0)	42.8	(6.3)	18.7	(2.9)
Teslin_Lake	12.2	(4.3)	14.9	(3.7)	8.8	(3.1)	3.3	(1.8)	9.9	(1.9)
Big_Salmon	16.1	(4.1)	0.5	(1.5)	0.9	(2.1)	6.1	(4.0)	6.8	(1.8)
L_Salmon	1.6	(3.0)	8.5	(4.0)	15.1	(4.8)	2.0	(3.2)	6.9	(2.4)
N_Big_Salmon	0.4	(1.1)	4.1	(1.9)	0.0	(0.4)	0.4	(1.1)	0.2	(0.5)
Tatchun	0.5	(1.1)	0.9	(1.6)	3.0	(2.1)	2.7	(2.6)	2.6	(1.0)
Nordenskiold	2.0	(1.3)	1.0	(0.9)	0.3	(0.7)	0.0	(0.1)	0.8	(0.5)
Yukon_main	0.7	(1.4)	4.9	(4.2)	17.6	(4.7)	20.2	(5.2)	11.0	(2.2)
Blind_Cr	4.2	(2.1)	3.4	(1.7)	0.5	(1.0)	0.0	(0.2)	2.4	(0.8)
Earn	0.4	(1.0)	0.2	(0.7)	0.2	(0.6)	0.1	(0.6)	0.4	(0.6)
Glenlyon	0.0	(0.2)	0.8	(1.1)	2.2	(1.7)	0.1	(0.5)	1.0	(0.6)
Hoole	0.1	(0.6)	3.8	(1.8)	0.0	(0.2)	0.1	(0.4)	0.9	(0.9)
Kalzas	1.2	(1.1)	0.0	(0.1)	0.5	(0.9)	0.4	(0.9)	0.3	(0.4)
L_andB_Kalzas	0.1	(0.5)	4.4	(1.7)	0.4	(0.6)	0.2	(0.6)	1.5	(0.7)
Pelly	17.8	(3.9)	0.3	(1.1)	6.9	(2.9)	7.4	(2.7)	7.9	(1.7)
Ross_YT	0.5	(1.0)	3.8	(2.2)	0.1	(0.4)	0.2	(0.7)	0.9	(0.9)
Mayo	0.2	(0.7)	3.1	(2.4)	0.3	(0.9)	0.0	(0.2)	1.2	(0.9)
McQuesten	1.4	(1.9)	1.9	(1.3)	1.2	(1.1)	0.0	(0.2)	1.3	(0.6)
Stewart	4.5	(2.9)	10.5	(3.3)	7.0	(2.9)	0.0	(0.3)	5.5	(1.4)
Chandindu	9.0	(5.4)	2.0	(1.8)	0.2	(0.5)	1.1	(0.9)	3.7	(1.1)
Klondike	3.8	(5.5)	1.5	(1.8)	0.2	(0.6)	0.1	(0.5)	0.5	(0.9)
Kluane	0.0	(0.1)	1.0	(0.7)	0.0	(0.1)	1.1	(0.9)	0.6	(0.3)
Nisling	8.5	(2.5)	0.9	(0.7)	0.0	(0.1)	0.0	(0.2)	2.1	(0.7)

Appendix A3: Estimated abundance of Canadian-origin Chinook salmon migrating past the mainstem Yukon River sonar operated near Eagle in 2016.

Period	Jul 2–Jul 13	Jul 14–19	Jul 20–26	Jul 27–Aug 17	Season estimate
Sample Size	*n*=165	*n*=223	*n*=164	*n*=176	*n*=728
Stock aggregate	Estimate	Estimate	Estimate	Estimate	Estimate
Upper Yukon Tribs.	106	1,074	1,892	1,458	4,768
Teslin River	4,525	8,358	6,515	6,409	25,300
Carmacks Area Tribs.	3,206	3,088	3,664	1,537	11,867
Mid-Mainstem	455	1,291	3,467	2,761	8,565
Pelly River	4,181	3,700	2,086	1,165	11,045
Stewart River	1,057	3,432	1,629	9	5,762
North Yukon Tribs.	2,207	767	73	163	3,069
White River	1,470	429	1	153	1,953
Totals	17,207	22,139	19,327	13,655	72,329

Note: The mainstem Yukon River sonar operated near Eagle switched from enumerating Chinook to fall chum salmon on August 18, 2016. Seven chinook tissue samples were collected after August 17, 2016.

Appendix A4: Stock percentage estimates of Canadian-origin Chinook border passage in the Yukon River, 2005–2016, Unweighted by sonar passage periods.

	Region							
Year	Upper Yukon Tributaries	Teslin River	Carmacks Tributaries	Mid-Mainstem	Pelly River	Stewart River	North Yukon Tributaries	White River
2005 [a, b]	5.6%	19.2%	24.6%	11.1%	17.5%	9.1%	12.5%	0.5%
2006 [a, b]	6.1%	13.0%	33.0%	10.2%	12.4%	13.4%	10.3%	1.7%
2007 [a, c]	2.4%	19.0%	21.7%	9.2%	20.9%	14.2%	11.5%	1.1%
2008 [a, d]	0.0%	14.7%	20.4%	11.6%	23.9%	13.1%	14.6%	1.7%
2008 [c, d]	1.6%	16.4%	10.8%	33.5%	12.1%	7.2%	8.3%	10.1%
2009 [c, d]	3.3%	25.6%	16.0%	10.5%	16.2%	9.3%	12.7%	6.4%
2010 [c, d]	7.5%	33.0%	13.1%	19.6%	9.3%	7.5%	4.6%	5.4%
2011[c, d]	4.8%	25.3%	9.6%	22.9%	17.2%	6.0%	8.1%	6.3%
2012 [c, b]	6.4%	37.8%	13.0%	18.8%	9.7%	6.4%	3.6%	4.3%
2013 [c, b]	6.7%	25.6%	18.5%	28.6%	11.5%	5.3%	0.7%	3.2%
2014 [c, d]	4.1%	28.2%	14.3%	23.6%	14.4%	7.4%	3.1%	4.9%
2015 [c,e]	4.6%	25.4%	17.5%	16.0%	18.2%	8.2%	4.4%	5.6%
2016 [c,e]	6.6%	35.0%	16.4%	11.8%	15.3%	8.0%	4.2%	2.7%
Average (2008–2015)[c]	4.9%	27.2%	14.1%	21.7%	13.6%	7.2%	5.7%	5.8%
Minimum (2008–2015)[c]	1.6%	16.4%	9.6%	10.5%	9.3%	5.3%	0.7%	3.2%
Maximum (2008–2015)[c]	7.5%	37.8%	18.5%	33.5%	18.2%	9.3%	12.7%	10.1%

[a] Samples from BioIsland site collected from fish wheels.
[b] Samples were run against the current year's baseline.
[c] Samples from the mainstem Yukon River sonar operated near Eagle collected from the drift gillnet test fishery and may not be comparable to those collected at the fish wheels because of the proportion of Chinook salmon migrating offshore. Average, minimum and maximum are calculated using Eagle sonar samples only.
[d] Samples were run against the 2011 baseline.
[e] Samples were run against the 2015 baseline.

Appendix B: Chum Salmon Genetic Stock Estimates

Appendix B1: Canadian-origin Chum Salmon Aggregate Stocks (Regional) Proportion Estimates in 2016.

Samples Analysed Sample Period	152 Aug 18 – Sep 3		137 Sep 4 – Sep 16		225 Sep 17 – Sep 24		222 Sep 25 – Sep 30		736 Season	
Region	Estimate	SD	Estimate	SD	Estimate	SD	Estimate	SD	Estimate	SD
Mainstem	53.5	(4.5)	72.2	(4.6)	64.1	(3.7)	83.9	(2.8)	70.0	(1.9)
White	46.1	(4.4)	26.7	(4.5)	34.5	(3.6)	15.8	(2.8)	29.3	(1.8)
Teslin	0.2	(0.6)	1.1	(1.4)	1.3	(0.9)	0.3	(0.6)	0.6	(0.5)
Yukon Early	0.2	(0.7)	0.0	(0.3)	0.0	(0.1)	0.1	(0.3)	0.0	(0.1)

Appendix B2: Canadian-origin Chum Salmon Stock Proportion Estimates in 2016.

Samples Analysed Sample Period	152 Aug 18-Sep 3		137 Sep 4–16		225 Sep 17-24		222 Sep 25-30		736 Season	
Region	Estimate	SD	Estimate	SD	Estimate	SD	Estimate	SD	Estimate	SD
Big_Cr	50.1	(4.9)	8.2	(7.0)	63.7	(3.7)	41.7	(36.9)	54.4	(29.0)
Minto	1.6	(1.8)	1.2	(2.0)	0.1	(0.3)	0.1	(0.5)	7.8	(21.9)
Pelly	0.8	(1.9)	62.6	(7.9)	0.3	(0.7)	41.9	(37.2)	7.8	(22.0)
Tatchun	1.0	(1.6)	0.1	(0.6)	0.0	(0.2)	0.1	(0.5)	0.0	(0.1)
Donjek	46.0	(4.4)	14.2	(13.0)	23.5	(16.8)	14.2	(5.6)	22.8	(12.3)
Kluane	0.0	(0.3)	0.2	(0.6)	0.0	(0.2)	0.0	(0.2)	0.0	(0.1)
Kluane_Lake	0.0	(0.3)	12.3	(13.9)	11.0	(15.6)	1.6	(4.6)	6.5	(12.2)
Teslin	0.2	(0.6)	1.1	(1.4)	1.3	(0.9)	0.3	(0.6)	0.6	(0.5)
Chandindu	0.2	(0.7)	0.0	(0.3)	0.0	(0.1)	0.1	(0.3)	0.0	(0.1)

Appendix B3: Estimated border passage of Canadian-origin fall chum salmon migrating past the mainstem Yukon River sonar operated near Eagle in 2016.

Period Sample Size	Aug 18–Sep 3 *n*=152	Sep 4-16 *n*=137	Sep 17-24 *n*=225	Sep 25-Oct 18 *n*=222	Total Season *n*=736
Region	Estimate	Estimate	Estimate	Estimate	Estimate
Mainstem	8,684	15,727	19,764	77,303	112,754
White	7,478	5,818	10,645	14,553	47,238
Teslin	36	244	413	236	1,029
Yukon Early	36	4	1	88	6
Totals	16,234	21,793	30,823	92,180	161,027

Note: The mainstem Yukon River sonar enumerated chum salmon from August 18 to October 6, 2016. An expansion formula was used to estimate passage October 7 to 18 and is included in these estimates. Chum genetic samples were collected between August 5 and September 30, 2016. Stock proportions in the last sample were applied to estimate composition of the last period which includes expansion to October 18.

Appendix B4: Stock percentage estimates of Canadian-origin fall chum salmon border passage in the Yukon River, 2005–2016, Unweighted by sonar passage periods.

	Region			
Year	Mainstem	White	Teslin	Yukon Early
2005 [a]	67.7%	29.8%	0.4%	2.1%
2006 [a]	41.0%	54.9%	3.1%	1.0%
2007 [a]	46.9%	52.1%	0.5%	0.5%
2008 [a]	48.0%	49.9%	2.1%	0.1%
2009 [b]	68.3%	30.6%	1.0%	0.1%
2010 [b]	52.8%	46.3%	0.2%	0.7%
2011 [b]	51.2%	48.0%	0.7%	0.1%
2012 [b]	47.3%	52.6%	0.1%	0.1%
2013 [b]	50.5%	48.9%	0.4%	0.2%
2014 [b]	49.5%	50.1%	0.0%	0.2%
2015 [b]	61.9%	37.2%	0.1%	0.8%
2016 [b]	70.0%	29.3%	0.6%	0.0%
Average (2009–2015)	54.5%	44.8%	0.4%	0.3%
Minimum (2009–2015)	47.3%	30.6%	0.0%	0.1%
Maximum (2009–2015)	68.3%	52.6%	1.0%	0.8%

Note: Samples were run against the current year's baseline (ex. 2005 samples were run against the 2005 baseline).
[a] Samples from BioIsland site collected from fish wheels.
[b] Samples from the mainstem Yukon River sonar operated near Eagle collected from the drift test fishery.