Genetic Stock Identification of Canadian-Origin Yukon River Chinook and Fall Chum Salmon, 2017

Final Report

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Prepared for The Yukon River Panel

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Abstract

Genetic stock identification of Chinook salmon *Oncorhynchus tshawytscha,* and chum salmon *O. keta* migrating past the Eagle sonar site in Alaska near the international border was conducted in 2017. Single Nucleotide Polymorphism (SNP) variations were surveyed for 733 Chinook salmon and variations at 14 microsatellites were surveyed for 697 chum salmon. The samples were collected from test fisheries at the Eagle sonar site. The Chinook salmon data indicates that the major regional stock contributions to the run were: North Yukon Tributaries (4.9%), White River (2.9%), Stewart River (5.7%), Pelly River (13.8%), Mid-mainstem Tributaries (16.0%), Carmacks Area Tributaries (20.7%), Teslin River (30.9%), and Upper Yukon Tributaries (5.1%). Chum salmon from the Yukon River mainstem stocks were estimated to comprise 54.9% of the samples collected and the remaining 45.1% were White River chum salmon. The Teslin River and Yukon Early chum stocks were unrepresented with proportions below 1%. Stock identification via genetic analysis is an essential tool for regional abundance estimates and fisheries management when dealing with mixed-stock salmon runs.

Acknowledgments

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Introduction

Background

Chinook salmon (*Oncorhynchus tshawytscha)* and chum salmon (*O. keta)* are widely distributed throughout the Yukon River drainage, spawning in tributaries ranging from the headwaters (e.g. Teslin River drainage, Yukon Territory and British Columbia) 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 populations migrating in the mainstem Yukon River have been estimated through the analysis of variation in microsatellite loci since 2005 (Beacham et al. 2008). Microsatellite analysis was used to identify the stock composition of Chinook salmon sampled in DFO fish wheels between 2004 and 2008 and Chinook captured by the Eagle sonar project since 2008 (JTC, 2017). Microsatellites were also used to estimate the stock composition of chum salmon samples collected from DFO fish wheels between 2005 and 2008 and in test netting at the Eagle sonar site since 2009. In 2017 the analysis of Single Nucleotide Polymorphism (SNP) variations was used as an alternative to microsatellite analysis for Chinook salmon. The SNP method eases the data standardization between laboratories and produces fewer genotyping errors than microsatellites (Beacham et al. 2002) which results in more accurate data on stock composition and increased management efficiency.

Project overview

The intent of this project is to determine stock composition of Chinook and chum salmon runs entering Canada in 2017 through genetic analysis of tissue samples. In 2017 Chinook and chum salmon were live-captured in the test fishery associated with the sonar operations near Eagle, Alaska (Lozori and McDougall, 2017). Genetic stock identification was analyzed using variation of SNP locus for Chinook salmon and microsatellite variations for chum salmon.

Materials and Methods

Collection of DNA Samples

Tissue samples were collected from 803 adult Chinook and 808 chum salmon captured in the Eagle sonar test fishery between July 1, 2017 and September 30, 2017. Salmon were captured systematically in drift gill nets to reflect the age, sex and length composition of the Chinook salmon escapement to Canada (Lozori and McDougall, 2017). Test fishing was also used to identify the date at which chum salmon exceeded Chinook salmon returns.

All salmon caught during the operational period were sampled. Axillary appendages were taken from all Chinook salmon and placed in individual vials containing 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. Three bulk sample vials were collected over the course of the season. At the end of the season all samples were shipped to the ADF&G genetics lab in Anchorage where technicians catalogued the samples and prepared them for shipping.

Laboratory Analysis

DNA extraction and laboratory analysis was conducted at the Pacific Biological Station in Nanaimo (British-Columbia, Canada). Chinook sampling procedures followed those described in Beacham et al. (2017), and chum following the same procedures described in Beacham and Candy (2014). Further information on laboratory equipment and techniques is available at the Molecular Genetics Laboratory website at: http://www.pac.dfo-mpo.gc.ca/science/facilities-installations/pbs-sbp/mgl-lgm/proj/index-eng.html.

Variation of SNP locus was analysed from 733 Chinook salmon samples collected between July 1 and August 20, 2017. Originally 803 Chinook samples were submitted but 70 rendered no results (e.g. no amplification of the loci). Variation at 14 microsatellite loci was surveyed a subsample of 697 from a total of 808 chum salmon tissue samples collected between August 1 and September 30, 2017 in the Eagle sonar test fishery.

Baseline Populations

In 2017 several additions were made to the current Chinook salmon baseline. The Hoole River was included in the population baseline for the Pelly River aggregate group and the Hundred Mile River and the Wolf River were included in the population baseline for the Teslin River aggregate group (Table 1). The 2017 baseline survey consisted of SNPs analysis of Chinook salmon from eight stocks and 31 populations (Table 1) and microsatellite analysis of chum salmon from four stocks and nine populations within the Canadian portion of the drainage (Table 2). The populations investigated for the chum salmon baselines remained unchanged in 2017 from those described in the 2016 border GSI report (DFO, 2017 CRE-79-16).

Chinook Salmon

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

TABLE 1. Chinook baseline comprised of eight stocks and thirty-one populations used to estimate stock compositions of Chinook salmon collected from the test gillnetting program at the Mainstem Yukon River sonar project at Eagle Alaska, 2017.

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 River
Teslin River	Teslin Lake, Nisutlin, Morley, Jennings, Hundred Mile, McNeil River, Swift River, 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/stock aggregates (Table 2) and estimated by period and for the entire season (Figures 5; Appendix B1; B2).

TABLE 2. Chum baseline comprised of four stocks and nine populations 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, 2017.

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 River, Big Creek, and Minto
Teslin River	Teslin River

Estimation of Stock Composition

All annual samples available 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.

Statistical 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 and Candy, 2014). Passage estimates (i.e., abundance) by stock aggregate for the 2017 Chinook and chum salmon migration bound for Canada were calculated using the stock aggregate proportions and the Eagle sonar passage estimates. These estimates do not include the U.S. subsistence harvest between the sonar site and the border and therefore do not represent the border passages for Chinook or chum salmon. 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 salmon 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 20 to September 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).

Assumptions and Limitations

As with any sampling program, there are assumptions and limitations to the results of analysis which should be kept in mind when interpreting results. This project assumes that samples captured in the test fishery are representative of both the run as a whole, and when divided into time strata, are representative of those periods as well. As additional samples are collected the genetic baseline becomes more accurate and the certainty surrounding abundance estimates based on stock proportions increases. Confidence in a genetic assignment is also provided by the statistical analysis, providing a measure of certainty around point estimates.

Results and Discussion

Chinook Salmon

Stock Proportions 2017

The contributions of Chinook salmon stock aggregates to the total 2017 Eagle sonar test fishery samples were estimated by period and for the total season sample (Appendix A1; Figure 1). Teslin River Chinook salmon represented the greatest proportion of the run. The Chinook salmon stock composition of the total sampling season was North Yukon Tributaries (4.9%), White River (2.9%), Stewart River (5.7%), Pelly River (13.8%), Mid-mainstem Tributaries (16.0%), Carmacks Area Tributaries (20.7%), Teslin River (30.9%), and Upper Yukon Tributaries (5.1%).

During the first sampling period (July 1 to July 15, 2017) the Teslin River stock was the highest followed closely by the Carmacks Area Tributaries stock, with 24.9% and 21.1% respectively. During that same period the Upper Yukon Tributaries and the Mid-mainstem Tributaries stock aggregate proportions were the lowest (0% and 4.3% respectively); however, they increased with successive sampling periods over the season (Appendix 1; Figure 1). The Teslin River stock also increased in representation throughout the season, peaking at 36.6% in the last sampling period (July 28 to August 20, 2017). In the last sampling period the Mid-mainstem Tributaries stock was the second highest in proportion with 31.8% and the White River stock was the lowest at 0%. With the exception of the Upper Yukon Tributaries, Teslin River and Mid-mainstem Tributaries stocks all the other stock aggregates declined during the last sampling period. The Carmacks Area Tributaries and Stewart River stocks were fairly consistent throughout the run. The Stewart River stock showed a decline in proportion after the first sampling period and kept decreasing throughout the sampling periods. The Pelly River, the Carmacks Area Tributaries and the Teslin River stocks represented more than three-quarters of the run during the second sampling period.

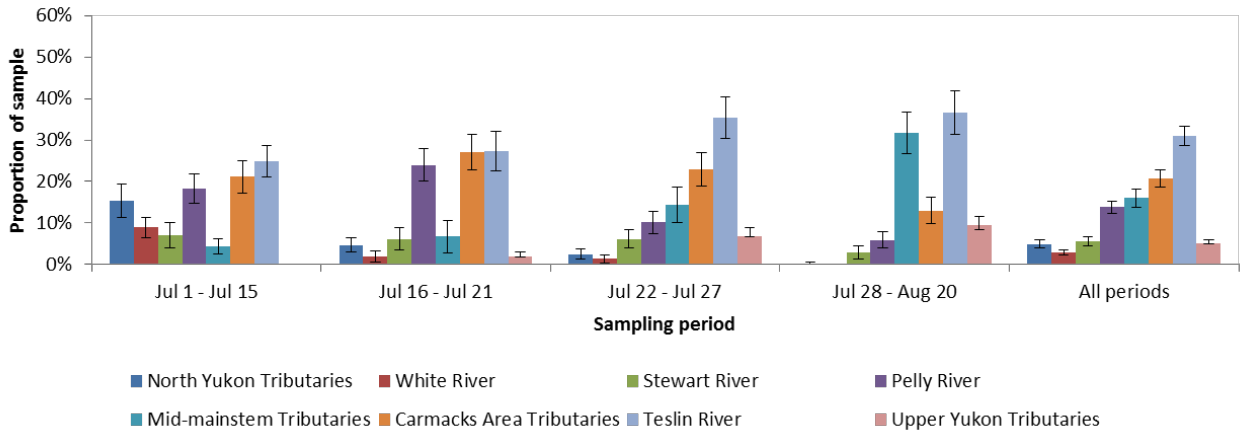

FIGURE 1. Estimated aggregate stock composition of Chinook salmon genetic samples collected from the Eagle sonar site, 2017. Error bars indicate standard error for each stock aggregate.

Passage Estimates 2017

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; Figure 3). A total of 73,313 Chinook salmon were estimated to have passed by the Eagle sonar over the course of the 2017 Chinook salmon run (July 1 to August 20, 2017). This estimate does not include the U.S. subsistence harvest between the sonar site and the border and therefore does not represent the border passages for Chinook salmon. Based on genetic stock proportions, seasonal estimates for Chinook salmon passage at the sonar site for each stock aggregate group were: 3,592 for the North Yukon Tributaries, 2,126 for the White River, 4,179 for the Stewart River, 10,117 for the Pelly River, 11,730 for the Mid-mainstem Tributaries, 15,176 for the Carmacks Area Tributaries, 22,654 for the Teslin River and 3,739 for the Upper Yukon Tributaries. The total Chinook return estimated for 2017 is slightly higher than in 2016 (72,329) (DFO, 2017 CRE-79-16). Stock proportion estimates for individual stocks comprising the aggregate groups (Appendix A2) are associated with higher levels of uncertainty, and were not used for passage estimation.

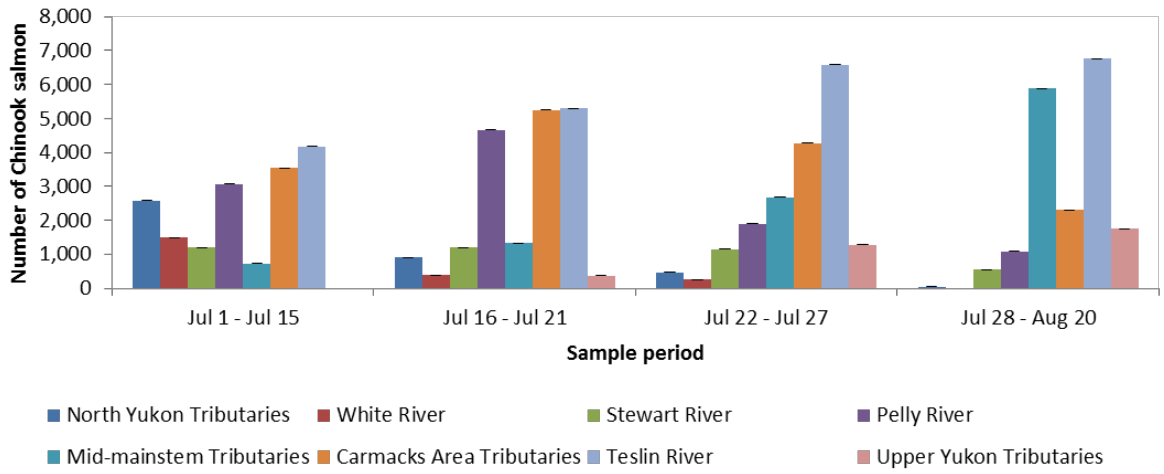

FIGURE 2. Estimated aggregate stock abundance of Chinook salmon migrating past the Eagle sonar site between July 1 and August 20, 2017 (four sampling periods). Error bars indicate standard error of the genetic estimate.

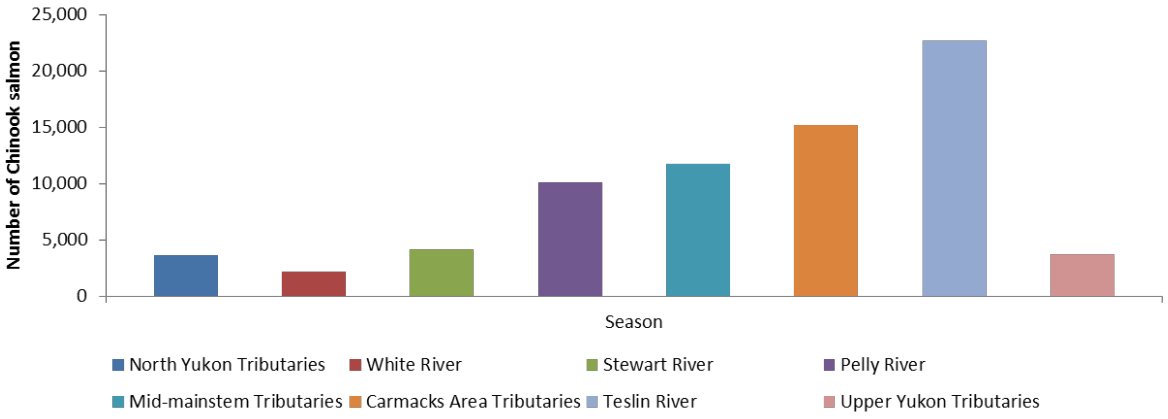

FIGURE 3. Estimated season abundance totals for Chinook salmon stock aggregates migrating past the Eagle sonar site between July 1 and August 20, 2017.

Multi-Year Comparison of Chinook Salmon Stock Proportions

Appendix A4 contains the seasonal 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 from 2008 to 2017 are presented in Figure 4. When comparing the 2017 season with the 2008 to 2016 average in the Appendix 4 it shows that: the Pelly River and Upper Yukon Tributaries are similar to the average; the Carmacks Area Tributaries and Teslin River show an increase; and the North Yukon Tributaries, White River, Stewart River and Mid-mainstem Tributaries have all declined.

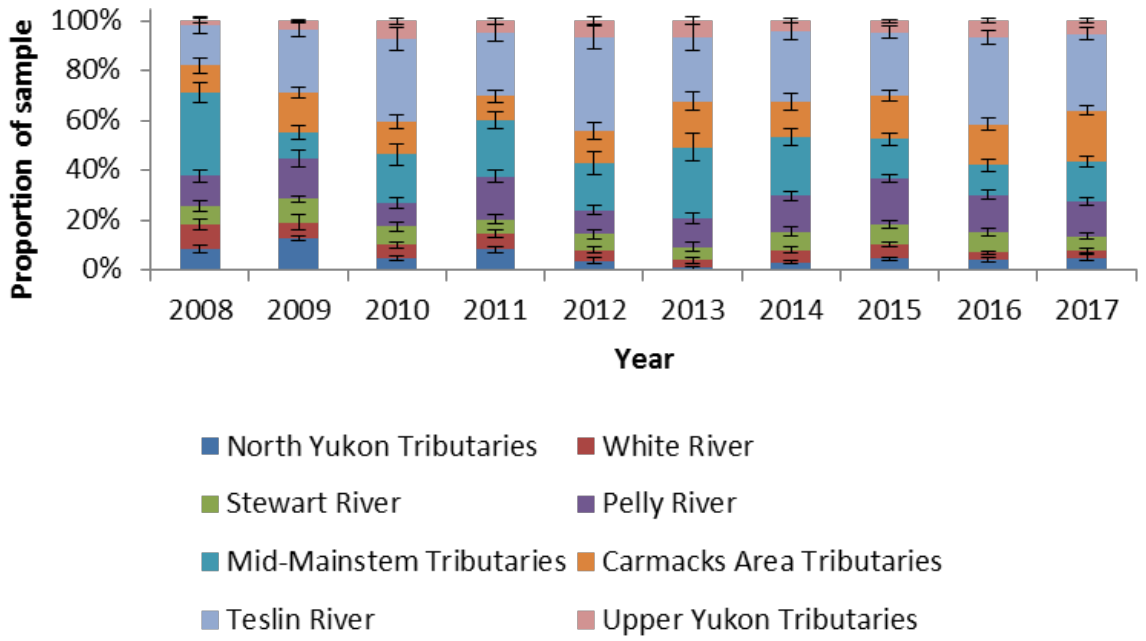

FIGURE 4. Estimated aggregate stock composition from Chinook salmon genetic samples collected during test netting at Eagle, Alaska 2008–2017. Error bars indicate standard error for each stock aggregate.

Chum Salmon

Stock Proportions 2017

In the 2017 season, chum salmon spawning populations from the Mainstem Yukon River aggregate, represented by Pelly, Tatchun, Big Creek, and Minto populations, accounted for 54.9% 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 45.1% of the samples (Appendix B1; Figure 5). For more than three quarters (82%) of the sampling season (first and second sampling periods) the proportions of the White River stock was above the Mainstem Yukon River stock. During the third sampling period the proportion of the Mainstem Yukon River stock was nearly double the White River stock proportion (Appendix B1; Appendix B2; Figure 5). The Mainstem Yukon River stock was in highest proportion (67.4%) during the third sampling period (September 20 to September 30, 2017) and the White River stock (56.3%) during the second sampling period (September 9 to September 19, 2017). The Teslin River and Yukon Early stock are less than 1% of the sample proportions during all the sampling periods (Appendix B1; Figure 5). The 2017 stock proportions are very similar to the average of 2009 to 2016 for their respective stocks (Appendix B4).

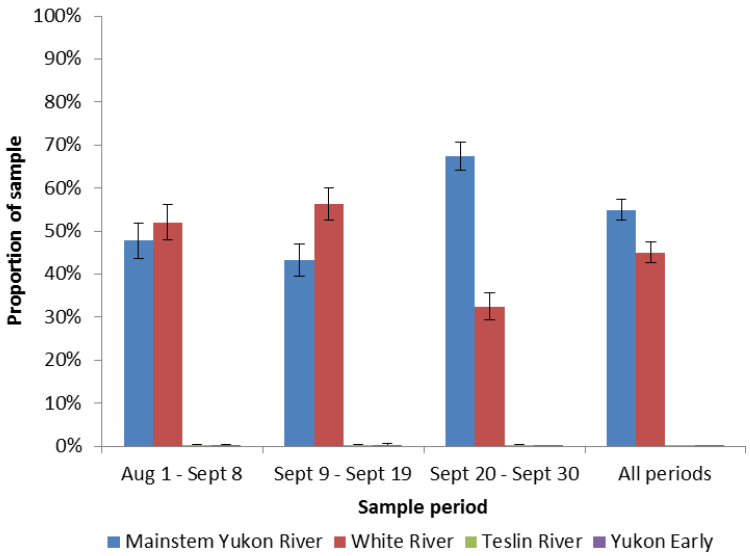

FIGURE 5. Estimated aggregate stock composition of chum salmon genetic samples collected from the Eagle sonar site, 2017. Error bars indicate standard error for each stock aggregate.

Passage Estimates 2017

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; Figure 7). A total of 377,782 (expanded numbers) chum salmon were estimated to have passed by the Eagle sonar over the course of the 2017 genetics sampling period (August 1 to September 30, 2017). A total run passage of 419,099 (expanded numbers) chum salmon was estimated to have migrated past the eagle sonar station from August 21 to October 18, 2017. These estimates do not include the U.S. subsistence harvest between the sonar site and the border and therefore do not represent the border passages for chum salmon. This estimate for total run passage includes 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 applied to the total estimated sonar passage, between August 21 and October 18, the estimate for passage at the sonar site for the Mainstem Yukon River was 230,081 chum salmon, while the estimate for the White River stock aggregate was 188,812. A passage estimate of 106 and 100 chum salmon were assigned for the Teslin River and the Yukon Early stock aggregates.

41,317 chum salmon (10% of the run) were estimated to have passed the sonar site after the last genetic sampling period. Genetic sampling ceased on September 30 and stock abundance estimates for the October 1 to October 18 were derived from genetic samples collected from September 20 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. In 2017, from October 6 to October 18, an estimated 3% (11,933) of the run went past the sonar location after the end of the enumeration period.

In 2016 an estimated 30% of the run passed the sonar site after test fisheries ended and 10% passed the sonar site after sonar operations ceased. GSI analysis of Eagle samples in recent years (DFO, 2015 CRE-79-14; DFO, 2017 CRE-79-16) has indicated that the proportional contribution of the Mainstem Yukon River chum stock component increases in the latter part of the run, while the White River stock proportion declines. This pattern was also observed in 2017 (Figure 5). As a result it is suspected that current GSI estimates may underestimate the abundance of the Mainstem Yukon River stock and overestimate the abundance of the White River stock migrating pass the Eagle sonar site during the last sampling period (September 20 to October 18) which can potentially underestimate the proportion of the Mainstem stock across the entire season.

Stock proportion estimates for the individual stocks comprising the aggregate groups (Appendix B2) are associated with high levels of uncertainty, and were not used for passage estimation.

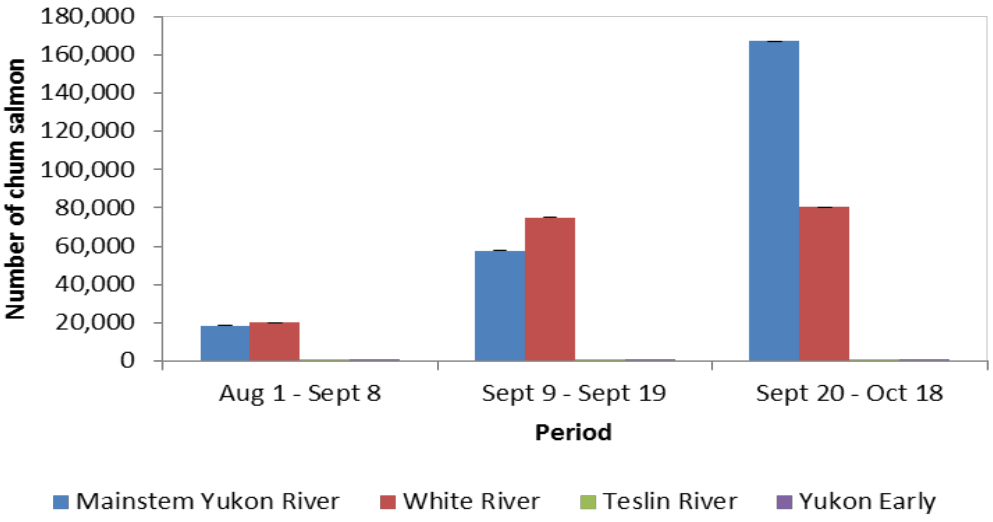

FIGURE 6. Estimated aggregate stock abundance of chum salmon migrating past the Eagle sonar site between August 1 and October 18, 2017. Error bars indicate standard error of the genetic estimate. Stock proportions derived from samples collected in the last sampling period (September 20 to September 30, 2017) were expanded to the remainder of the run to calculate passage abundance to October 18, 2017.

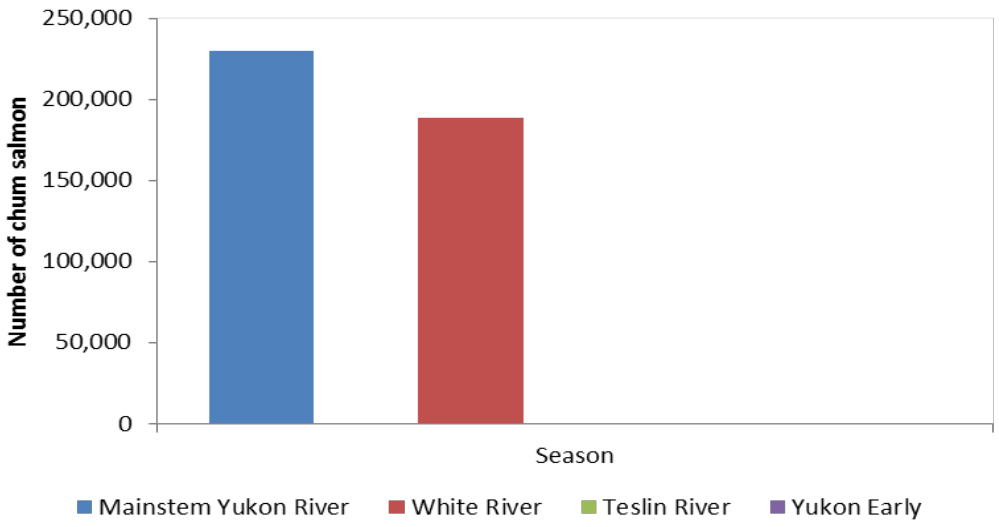

FIGURE 7. Estimated stock abundance totals for chum salmon migrating past the Eagle sonar site between August 1 and October 18, 2017. Error bars indicate standard error of the genetic estimate. Stock abundances were estimated using the "sampling season" proportion estimates (Appendix B2). Expansions were used to estimate the remainder of the run from October 6 to October 18, 2017.

Multi-Year Comparison of Chum Salmon Stock Proportions

Appendix B4 contains the annual proportional contributions for each stock aggregate over the previous 12 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 during the Eagle sonar test fishery. The 2017 Mainstem Yukon River chum salmon stock aggregate proportion for Eagle sonar passage was just under the proportion average of 2009 to 2016 (Appendix B4). The stock aggregate proportion for White River was above the average for the same period and conversely, the percent composition of the Mainstem Yukon River, the Teslin River and Yukon Early stocks for 2017 fell below the average for the same time period (Appendix B4). The Yukon Early chum salmon stock was the lowest estimated proportion and is below the average for 2009 to 2016 (Appendix B4). All stock compositions were within their previously observed ranges of maximum and minimum between 2009 and 2016 (Appendix B4). 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.

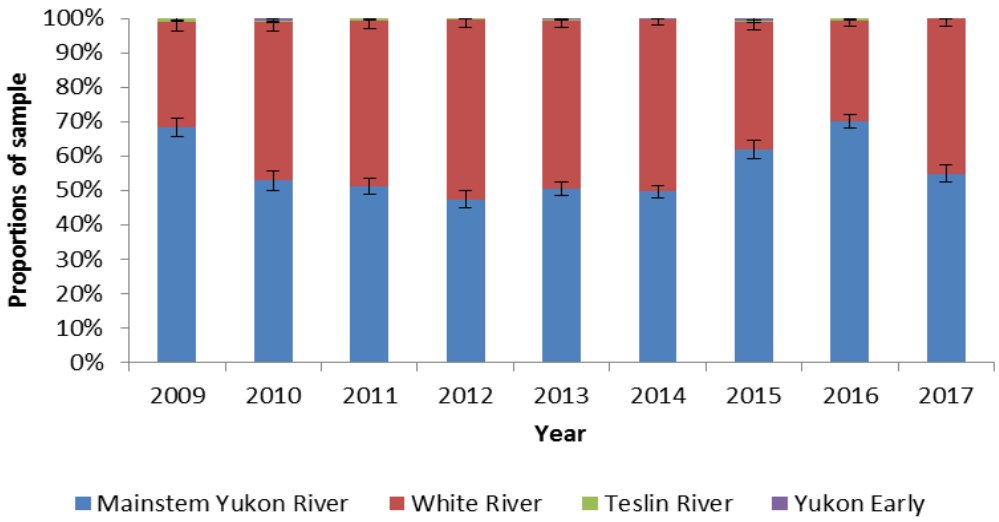

FIGURE 8. Estimated aggregate stock composition from chum salmon genetic samples collected in test netting at Eagle, Alaska 2009–2017. Error bars indicate standard error for each stock aggregate.

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. Results in 2017 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 2017.

n sample analyzed	*161*		*161*		*183*		*228*		*733*	
Period	*Jul 1 - Jul 15*		*Jul 16 - Jul 21*		*Jul 22 - Jul 27*		*Jul 28 - Aug 20*		*Jul 1 - Aug 20*	
Stock	Estimate %	SD	Estimate %	SD	Estimate %	SD	Estimate %	SD	Estimate %	SD
North Yukon Tributaries	15.4	4.0	4.7	1.7	2.5	1.2	0.2	0.5	4.9	1.0
White River	8.9	2.5	2.0	1.3	1.4	1.0	0.0	0.1	2.9	0.7
Stewart River	7.1	3.1	6.2	2.7	6.2	2.3	3.0	1.6	5.7	1.1
Pelly River	18.3	3.6	24.0	4.0	10.2	2.7	5.9	2.0	13.8	1.5
Mid-mainstem Tributaries	4.3	1.8	6.8	3.9	14.4	4.3	31.8	5.0	16.0	2.2
Carmacks Area Tributaries	21.1	3.8	27.0	4.3	23.0	4.0	13.0	3.2	20.7	2.0
Teslin River	24.9	3.7	27.3	4.8	35.4	5.1	36.6	5.2	30.9	2.3
Upper Yukon Tributaries	0.0	0.2	1.9	1.1	6.9	1.9	9.5	2.0	5.1	0.8

Note: The mainstem Yukon River sonar operated near Eagle switched from enumerating Chinook to fall chum salmon on August 21, 2017.

Appendix A2: Canadian-origin Chinook Salmon Populations Proportion Estimates in 2017.

	n sample analyzed	*161*		*161*		*183*		*228*		*733*	
	Period	*Jul 1 - Jul 15*		*Jul 16 - Jul 21*		*Jul 22 - Jul 27*		*Jul 28 - Aug 20*		*Jul 1 - Aug 20*	
Stock	**Population**	Estimate %	SD	Estimate %	SD	Estimate %	SD	Estimate %	SD	Estimate %	SD
North Yukon Tributaries	Chandindu River	11.9	3.7	0.1	0.5	0.0	0.2	0.0	0.2	2.3	0.9
	Klondike River	3.5	1.8	4.6	1.7	2.4	1.2	0.1	0.4	2.6	0.6
White River	Nisling River	8.7	2.5	0.7	0.9	0.8	0.9	0.0	0.1	2.3	0.6
	Tincup Creek	0.2	0.5	1.3	0.9	0.6	0.6	0.0	0.1	0.6	0.3
Stewart River	Mayo River	0.0	0.2	5.5	2.3	1.9	1.7	0.0	0.2	0.8	0.6
	McQuesten River	3.1	2.2	0.1	0.3	0.0	0.2	1.9	1.2	1.4	0.6
	Stewart River	4.0	2.6	0.6	1.8	4.3	2.2	1.1	1.4	3.4	1.0
Pelly River	Blind Creek	4.1	2.3	0.1	0.6	0.3	0.8	0.1	0.3	1.3	0.7
	Earn River	0.3	0.9	0.0	0.2	0.1	0.4	0.2	0.5	0.1	0.2
	Glenlyon River	0.1	0.4	0.1	0.5	0.1	0.4	0.0	0.1	0.0	0.1
	Hoole River	8.3	2.9	12.0	3.0	2.8	1.8	1.1	1.0	5.3	1.1
	Little Kalzas River	1.2	1.1	2.7	1.4	3.3	1.4	1.5	0.9	1.8	0.6
	Pelly River	0.1	0.5	6.4	2.6	3.6	1.8	2.7	1.4	3.1	0.8
	Ross River	4.3	1.8	2.7	2.0	0.1	0.4	0.3	0.7	2.2	0.7
Mid-mainstem Tributaries	Nordenskiod River	3.8	1.5	1.9	1.1	0.0	0.2	0.0	0.1	1.4	0.5
	Yukon River Mainstem	0.4	0.9	4.9	3.8	14.4	4.3	31.8	5.0	14.5	2.1
Carmacks Area Tributaries	Big Salmon River	12.9	3.4	7.9	3.7	11.3	3.3	0.9	1.5	8.5	1.5
	Little Salmon River	8.2	3.1	19.1	4.6	11.7	3.9	11.6	3.2	12.2	2.0
	Tatchun River	0.0	0.1	0.0	0.1	0.0	0.2	0.5	1.1	0.0	0.2
Teslin River	Hundred Mile Creek	0.0	0.2	0.4	0.9	0.1	0.2	0.0	0.2	0.0	0.1
	McNeil River	0.0	0.2	0.0	0.2	0.0	0.1	0.0	0.2	0.0	0.1
	Morley River	12.7	3.8	4.9	2.2	5.0	2.0	0.1	0.4	5.1	1.1
	Nisutlin River	4.9	2.8	9.6	3.4	4.8	2.1	0.1	0.2	4.4	1.1
	Swift River	0.0	0.3	0.0	0.1	0.0	0.2	0.0	0.1	0.0	0.1
	Teslin River	0.3	0.8	10.5	4.0	25.5	4.9	36.3	5.1	18.9	2.1
	Wolf River	7.0	2.7	1.9	2.5	0.0	0.2	0.0	0.1	2.5	0.8
Upper Yukon Tributaries	Takhini River	0.0	0.1	1.3	0.9	2.3	1.1	3.7	1.3	2.0	0.6
	Whitehorse Hatchery	0.0	0.1	0.6	0.6	4.6	1.6	5.8	1.6	3.0	0.7

Appendix A3: Estimated abundance of Canadian-origin Chinook salmon migrating past the mainstem Yukon River sonar operated near Eagle in 2017.

n sample analyzed	*161*	*161*	*183*	*228*	*733*
Period	*Jul 1 - Jul 15*	*Jul 16 - Jul 21*	*Jul 22 - Jul 27*	*Jul 28 - Aug 20*	*Jul 1 - Aug 20*
Stock	Estimate	Estimate	Estimate	Estimate	Estimate
North Yukon Tributaries	2,586	913	465	37	3,592
White River	1,494	389	261	0	2,126
Stewart River	1,192	1,204	1,154	555	4,179
Pelly River	3,072	4,662	1,898	1,091	10,117
Mid-mainstem Tributaries	722	1,321	2,680	5,880	11,730
Carmacks Area Tributaries	3,542	5,245	4,280	2,422	15,176
Teslin River	4,180	5,303	6,587	6,768	22,654
Upper Yukon Tributaries	0	369	1,284	1,757	3,739
Total	**16,789**	**19,406**	**18,608**	**18,509**	**73,313**

Note: The mainstem Yukon River sonar operated near Eagle switched from enumerating Chinook to fall chum salmon on August 21, 2017.

Appendix A4: Stock percentage estimates of Canadian-origin Chinook salmon border passage in the Yukon River, 2005–2017, Unweighted by sonar passage periods.

Year	Region							
	North Yukon Tributaries	White River	Stewart River	Pelly River	Mid-Mainstem Tributaries	Carmacks Area Tributaries	Teslin River	Upper Yukon Tributaries
2005 [a, b]	12.5%	0.5%	9.1%	17.5%	11.1%	24.6%	19.2%	5.6%
2006 [a, b]	10.3%	1.7%	13.4%	12.4%	10.2%	33.0%	13.0%	6.1%
2007 [a, c]	11.5%	1.1%	14.2%	20.9%	9.2%	21.7%	19.0%	2.4%
2008 [a, d]	14.6%	1.7%	13.1%	23.9%	11.6%	20.4%	14.7%	0.0%
2008 [c, d]	8.3%	10.1%	7.2%	12.1%	33.5%	10.8%	16.4%	1.6%
2009 [c, d]	12.7%	6.4%	9.3%	16.2%	10.5%	16.0%	25.6%	3.3%
2010 [c, d]	4.6%	5.4%	7.5%	9.3%	19.6%	13.1%	33.0%	7.5%
2011 [c, d]	8.1%	6.3%	6.0%	17.2%	22.9%	9.6%	25.3%	4.8%
2012 [c, b]	3.6%	4.3%	6.4%	9.7%	18.8%	13.0%	37.8%	6.4%
2013 [c, b]	0.7%	3.2%	5.3%	11.5%	28.6%	18.5%	25.6%	6.7%
2014 [c, d]	3.1%	4.9%	7.4%	14.4%	23.6%	14.3%	28.2%	4.1%
2015 [c,e]	4.4%	5.6%	8.2%	18.2%	16.0%	17.5%	25.4%	4.6%
2016 [c,e]	4.2%	2.7%	8.0%	15.3%	11.8%	16.4%	35.0%	6.6%
2017	4.9%	2.9%	5.7%	13.8%	16.0%	20.7%	30.9%	5.1%
Average (2008–2016)[c]	5.5%	5.4%	7.3%	13.8%	20.6%	14.4%	28.0%	5.1%
Minimum (2008–2016)[c]	0.7%	2.7%	5.3%	9.3%	10.5%	9.6%	16.4%	1.6%
Maximum (2008–2016)[c]	12.7%	10.1%	9.3%	18.2%	33.5%	18.5%	37.8%	7.5%

[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 2017.

n sample analyzed	*171*		*258*		*268*		*697*	
Period	*Aug 1 - Sept 8*		*Sept 9 - Sept 19*		*Sept 20 - Sept 30*		*Aug 1 - Sept 30*	
Stock	Estimate %	SD	Estimate %	SD	Estimate %	SD	Estimate %	SD
Mainstem Yukon River	47.8	(4.1)	43.3	(3.7)	67.4	(3.2)	54.9	(2.4)
White River	52.0	(4.1)	56.3	(3.7)	32.5	(3.2)	45.1	(2.4)
Teslin River	0.1	(0.3)	0.2	(0.4)	0.1	(0.3)	0.0	(0.1)
Yukon Early	0.1	(0.4)	0.2	(0.4)	0.0	(0.1)	0.0	(0.1)

Appendix B2: Canadian-origin chum salmon Stock Proportion Estimates in 2017.

n sample analyzed		*171*		*258*		*268*		*697*	
Period		*Aug 1 - Sept 8*		*Sept 9 - Sept 19*		*Sept 20 - Sept 30*		*Aug 1 - Sept 30*	
Stock	**Population**	Estimate %	SD	Estimate %	SD	Estimate %	SD	Estimate %	SD
Mainstem Yukon River	Big Creek	47.3	(4.2)	38.4	(13.8)	58.7	(20.3)	48.8	(17.2)
	Minto	0.1	(0.4)	0.1	(0.4)	1.5	(1.3)	0.0	(0.1)
	Pelly	0.2	(0.6)	4.8	(13.4)	7.1	(20.0)	6.1	(17.1)
	Tatchun	0.3	(0.8)	0.1	(0.3)	0.0	(0.3)	0.0	(0.1)
White River	Donjek	23.3	(25.9)	44.2	(23.7)	28.4	(10.5)	35.4	(18.9)
	Kluane	0.1	(0.4)	5.7	(16.1)	0.3	(0.6)	4.6	(13.0)
	Kluane Lake	28.7	(25.6)	6.4	(18.0)	3.8	(10.6)	5.1	(14.3)
Teslin	Teslin	0.1	(0.3)	0.2	(0.4)	0.1	(0.3)	0.0	(0.1)
Yukon Early	Chandindu	0.1	(0.4)	0.2	(0.4)	0.0	(0.1)	0.0	(0.1)

Appendix B3: Estimated abundance of Canadian-origin fall chum salmon migrating past the mainstem Yukon River sonar operated near Eagle in 2017.

n sample analyzed	*171*	*258*	*268*	*697*
Period	*Aug 1 - Sept 8*	*Sept 9 - Sept 19*	*Sept 20 - Oct 18*	*Aug 1 - Oct 18*
Stock	Estimate	Estimate	Estimate	Estimate
Mainstem Yukon River	18,348	57,708	166,929	230,081
White River	19,960	74,918	80,493	188,812
Teslin River	22	240	181	106
Yukon Early	33	256	11	100
Total	38,363	133,121	247,615	419,099

Note: The mainstem Yukon River sonar enumerated chum salmon from August 21 to October 6, 2016. An expansion formula was used to estimate passage October 7 to 18 and is included in these estimates. Chum salmon genetic samples were collected between August 1 and September 30, 2017. 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, 2005–2017, Unweighted by sonar passage periods.

Year	Region			
	Mainstem Yukon River	White River	Teslin River	Yukon Early
2005 [a]	67.70%	29.80%	0.40%	2.10%
2006 [a]	41.00%	54.90%	3.10%	1.00%
2007 [a]	46.90%	52.10%	0.50%	0.50%
2008 [a]	48.00%	49.90%	2.10%	0.10%
2009 [b]	68.30%	30.60%	1.00%	0.10%
2010 [b]	52.80%	46.30%	0.20%	0.70%
2011 [b]	51.20%	48.00%	0.70%	0.10%
2012 [b]	47.30%	52.60%	0.10%	0.10%
2013 [b]	50.50%	48.90%	0.40%	0.20%
2014 [b]	49.50%	50.10%	0.00%	0.20%
2015 [b]	61.90%	37.20%	0.10%	0.80%
2016 [b]	70.00%	29.30%	0.60%	0.00%
2017 [b]	54.90%	45.05%	0.03%	0.02%
Average (2009–2016)	56.44%	42.88%	0.39%	0.28%
Minimum (2009–2016)	47.30%	29.30%	0.00%	0.00%
Maximum (2009–2016)	70.00%	52.60%	1.00%	0.80%

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.