Atnarko River Chinook Salmon Spawning Escapement Estimation for 2017

Final Report for Pacific Salmon Commission

Prepared by Kate McGivney and Bradley Koroluk

Fisheries and Oceans Canada
Stock Assessment, Pacific Region
North Coast Area
Bella Coola, BC
V0T 1C0

February 2018

Fisheries and Oceans | Pêches et Océans
Canada

Contents

ABSTRACT 4
1 INTRODUCTION 4
1.1 Background 4
1.2 The Atnarko River 4
1.3 Objectives 5
2 METHODS 5
2.1 In Field Methods 5
2.1.1 Marking 5
2.1.2 Broodstock collection 6
2.1.3 Dead-pitch and Sampling: 7
2.2 Analyses 7
2.2.1 Petersen Estimate 7
2.2.2 Bias Assessments 8
2.2.3 Maximum-likelihood model using Independent Encounter History data 8
2.2.4 Age Distribution 8
2.2.6 Hatchery Contribution 8
3 RESULTS 8
3.1 Petersen Estimate 9
3.1.1 Sexual Bias 9
3.1.2 Size Bias 9
3.1.3 Recovery Area Bias 9
3.1.4 Mark Application Bias 9
3.1.4 Temporal Bias 9
3.2 Maximum-likelihood model using Independent Encounter History data 10
3.5 Age Distribution 10
3.5 Hatchery Contribution 10
DISCUSSION 10
4.1 Evaluation of Results 10
4.2 Recommendations and Future Challenges 11
5. ACKNOWLEDGEMENTS 11
6. REFERENCES 12
FIGURES 13

Figure 1. Map of British Columbia showing location of the Atnarko River. 13
Figure 2. The Atnarko River drainage. 14
Figure 3. Atnarko River project sample area. 15
TABLES 15
Table 1. Petersen calculations for 2017 15
Table 2. Atnarko Chinook Mark Recapture Results 2001 to 2003, 2009 to 2017. 15
Table 3. Egg retention for Atnarko Chinook Mark Recapture 16
Table 4. Incidence of tag recoveries compared by week of tag application. 16
Table 5. Scale ages of Atnarko River Chinook salmon from 2017. 16
Table 6. CTW ages of Atnarko River Chinook salmon from 2017. 17
APENDICES 17
Appendix A. Bella Coola Watershed (Atnarko River) Chinook Escapement 1950 to 2017. 17
Appendix B. Time series of Atnarko River water level and discharge. Station 08FB006 [BC], for the period of August 1, 2017 to October 15, 2017. Source: https://wateroffice.ec.gc.ca 18
Appendix C. Tagging/Dead-pitch Data Form 18
Appendix D. Broodstock Form 19
Appendix E. Tagging Recapture Form 19
Appendix F. Yearly Program Changes from 2010 to 2017 20
Appendix G. Tagging effort by area, date and sex for the Atnarko River 2017 Chinook Escapement Estimate 21
Appendix H. Summary of broodstock effort for the Atnarko River Chinook in 2017. 21
Appendix I. Summary of dead-pitch effort for Atnarko River Chinook Escapement in 2017. 22
Appendix J. Summary of tag recoveries for Atnarko River Chinook in 2017 by area and sex. 23
Appendix K. Summary of sampling effort non-adipose fin clipped Atnarko River Chinook in 2017. 23
Appendix L. Summary of sampling effort adipose fin clipped Atnarko River Chinook in 2017 24

ABSTRACT

The Atnarko River Chinook salmon enumeration project works together with other programs, including the production of Chinook salmon fry with Coded Wire Tags and fisheries monitoring to improve knowledge of Central Coast Chinook salmon and further develop better planning and management of terminal and mixed-stock fisheries. The primary objective of the project was to determine an unbiased total spawning escapement estimate of Atnarko River Chinook salmon (*Onchorynchus tshawytscha*) for 2017 using the Petersen method within the data standard coefficient of variation (CV) of 15% or less. Chinook were tagged and dead-pitched on the Atnarko River between August 16th and October 12th. Several tests were performed to identify potential sources of bias in the data collected. The Petersen estimate was stratified by sex and found 5,079 females, 5,779 males, and 76 jacks for a total spawning escapement of 10,934 fish. The coefficient of variation was 6.6% for the entire population. Additionally, analyses using individual encounter history data following Velez-Espino *et al.* 2010 methods were performed. Age composition of the population was derived through sampling scales and CTWs during tagging and dead-pitch.

1 INTRODUCTION

1.1 Background

Atnarko River Chinook salmon were proposed and identified as an exploitation indicator stock in 2009 after the Pacific Salmon Commission identified that there was a gap in representation of Central Coast British Columbian (B.C.) Chinook salmon stocks. In response to recommendations, a mark-recapture program on Atnarko River Chinook salmon was initiated to improve escapement estimates. This program has run every year since 2009 (Table 2), and provides accurate estimates for the only Chinook salmon indicator stock on the mainland of B.C. between Kitsumkalum and Harrison River. This project works together with other programs, including the production of Chinook salmon fry with Coded Wire Tags (CTWs) released in the Atnarko River by Snootli Hatchery (under separate submission to the Northern Fund), and fisheries monitoring to improve knowledge of Central Coast Chinook salmon and further develop better planning and management of terminal and mixed-stock fisheries.

Atnarko Chinook Salmon are a summer run stock. These Chinook salmon predominantly exhibit an ocean-type life history, however, stream life history is also present in the stock. A majority of Chinook salmon that enter the Bella Coola River spawn in the Atnarko River. The Chinook salmon population is the largest contributor to the Bella Coola-Bentick Conservation Unit and constitutes the largest complex of Chinook salmon in Central B.C. Furthermore, the run is timed similarity to three (Chuckwalla River, Rivers Inlet, and Dean River) of the five Chinook Conservation Units identified for the Central Coast (Docee, Rivers Inlet, Wannock, Bella Coola-Bentick, and Dean River; Holtby and Ciruna; 2007). Atnarko River Chinook salmon have also shown tag recoveries in similar fisheries demonstrated through recovery of historical hatchery marked releases (e.g. the Chuckwalla River). In addition, exploitation rates may be well represented by the Atnarko River since both ocean and stream types life histories present.

1.2 The Atnarko River

The Atnarko River feeds the Bella Coola River and is situated in Statistical Area 8 on the Central coast of B.C. (Figure 1). The river is north of Cape Caution and resides within the Northern Fund region of the Pacific Salmon Treaty. The Atnarko River drains a 2,440 km^2 watershed and merges with the Talchako River approximately 45 km downstream from Knot Lake to form the Bella Coola River (Figure 2), With the exception of Charlotte Lake and the headwaters of the Hotnarko River, the Atnarko and its tributaries are situated within the boundaries of Tweedsmuir Provincial Park.

The river can be divided into three segments with specific biotic and abiotic attributes specific to Chinook salmon. Atnarko Chinook salmon are primarily distributed between Hotnarko River and Janet Creek in the Upper Atnarko River, and from Alger Creek to the confluence of the Talchako River in the lower Atnarko River (Figure 2;Vélez-Espino et al; 2009). The Upper segment has many sections with deep and large holding areas that constitute high quality spawning areas. Overall, the spawning habitat is excellent in the Upper section with exception to the lower part where the river gradient decreases and water velocity slows. The Middle segment is characterized by sections with larger substrate, boulders, and increased gradient drops. The higher water velocity creates a lower quality spawning habitat. Chinook salmon holding capacity in this section is limited and spawning is spread-out. The Lower segment is characterized by braided sections and is predominantly high-quality Chinook spawning habitat in its middle and lower portions. The upper part of the Lower section does have some areas with large boulders and large substrate (due to increases in the river gradient), and thus limited areas to spawn. Most of the holding areas are small to moderately sized, with the exception of Alger's Pool (the largest holding area on the river). These holding areas have suitable spawning habitat located both above and below.

Atnarko Chinook salmon are easily captured and recovered as the system is not as susceptible to fall flooding as many other coastal Chinook systems (BCWCS 2007). The past years of experience working on the system and close proximity of qualified personnel also reduce the risk associated with conducting mark-recapture programs on remote systems. Given past mark-recapture and dead pitch programs conducted on the Atnarko River, a good understanding of effort requirements for sufficient tag application as well as carcass recovery exists.

1.3 Objectives

The primary objective of the 2017 Atnarko River Chinook Escapement Estimation Project was to determine an unbiased total spawning escapement estimate of Atnarko River Chinook salmon (*Onchorynchus tshawytscha*) for 2017 using the Petersen method within the data standard coefficient of variation (CV) of 15% or less. The project has continued to meet the data standard of CV of 15% or less every year since running (Table 2). Additional objectives include collecting data to develop and apply the best maximum likelihood model using Independent Encounter History (IEH) data to determine more accurate escapement estimates, estimate age structure of the population (within 5% of the true value), and estimate hatchery contribution to escapement (conducted by SEP separately). Goals are also set to continue to improve study methodology and project efficiency (Appendix F).

2 METHODS

2.1 In Field Methods

2.1.1 Marking

Chinook were tagged on the Atnarko River from August 16th 2017 to September 14th 2017. During this period, 1220 tags were applied and the tagging goal of 1,000 Chinook was achieved. Tagging continued exclusively until August 27th 2017. Between August 28th 2017 and September 14th 2017, both broodstock collection and tagging occurred. During both tagging and broodstock, fish were captured using eight inch Alaskan twist mono mesh nylon gill nets. These nets were 21 to 36 m long (depending on river morphology) and 20 meshes deep. Additionally, a seine net of 60 m length by 5 m depth was used in two Lower-river locations where river morphology allowed for seine netting.

A typical drift net set involved a diver/swimmer who pulled the gill net across the river by the cork line. A crew member held the opposite end of the cork line and walked downstream along the bank, pulling the net into the edge of the river at the end of the set. When the net got close to shore the rest of the crew immediately started to untangle Chinook and hold them in preparation for tagging. Distressed fish (bleeding gills, pinned gills etc.) were attended to first then any previously tagged fish were recorded as recaptured fish and released. Thirdly,

females were tagged and then remaining Chinook were tagged. Variations, such as boat to walking shore sets, two person walking sets and two swimmer sets, were used if more appropriate in the river conditions.

In order to tag a representative and unbiased portion of the Chinook spawning population throughout the spawning area, the Atnarko River is divided into three sections (Upper, Middle, and Lower) with each section further subdivided into two reaches (Upper: reach 1-2, Middle: reach 3-4, Lower: reach 5-6; Figure 3). Divisions are based on accessibility to the river, historical evidence of spawning similarity, and ability to drift each reach in a single day. Tagging occurred along all reaches concurrently by multiple crews. However, most fish are usually tagged in the Upper and Lower sections because of access and fish abundance (approximately 40% tagged in Upper reaches, 20% Middle reaches, and 40% in Lower reaches). Multiple tagging locations were chosen to improve marked fish mixing completely with the unmarked population.

Each Chinook was marked with an individually numbered metal #3 Kurl-Lock tag applied to the right operculum and a secondary mark consisting of a hole punched through the operculum. This allowed fish with missing Kurl-Lock tags to be included in escapement estimates. The number of punches a fish received was determined by which river section the fish was tagged in. Chinook tagged in the Upper section (reach 1-2) received one punch applied to the right side, those tagged in the Middle section (reach 3-4) received two punches applied to the left side and those tagged in the Lower section (reach 5-6) received one punch on the left side.

For every Chinook caught during tagging, crew initials, set number, date, reach, location, sex (male, female or jack), tag number, punch scheme, nose-fork length, and adipose fin presence was recorded on either a tagging sheet, or tagging recapture form (Appendices C and E). Scale samples were taken from 532 non-adipose fin clipped Chinook during tagging for ageing analysis and an additional scales samples were taken from 532 non-adipose fin clipped Chinook during dead-pitch. Five scales were taken from each fish that was sampled for scale ageing analysis and all scale samples were randomly taken to represent all stream reaches. All scale samples were shipped to the Fish Ageing Laboratory at the Pacific Biological Station immediately following the dead-pitch portion of the project. For the purposes of this report, only scale samples that produce both marine and freshwater ages following the Gilbert and Rich (1927) method were used in age analysis. Age composition of the population was determined by the proportion of each age class found in the scale samples. No scale or CTW sampling occurred for adipose-clipped fish during tagging.

The data collected for the Petersen estimate and the recapture data are used to derive an additional escapement estimate using the best maximum likelihood methods (Velez-Espino *et al.* 2010). This process provides an additional estimation process that takes place parallel to the Petersen estimation, using the latest analytical and computational developments.

2.1.2 Broodstock collection

Broodstock collection occurred between August 28th 2017 and September 20th 2017. Broodstock included both in-field gamete collection and transporting unripe Chinook to the hatchery for holding until there were ready to spawn. When tagging and broodstock occurred simultaneously, fish that were appropriate for broodstock were removed and those that were not suitable for broodstock were tagged and released.

During broodstock collection, all Chinook encounters and removals were recorded the model using recapture and broodstock data forms (Appendices D and E). A total of 960 Chinook salmon were removed from the Atnarko River for Broodstock. Of the 960 fish removed, 144 Chinook were tagged, thus leaving a total of 1,076 tagged Chinook (373 females, 685 males, and 18 jacks) in the population available for dead-pitch recovery. Tagged fish were removed when encountered to meet one of the assumptions of maximum likelihood models using the IEH data described in Velez-Espino *et al.* 2010. Samples were also taken during broodstock collection for DNA analysis, and Bacterial Kidney Disease screening. This data is maintained and reported by Snootli Hatchery.

During broodstock collection, a total of 124 adipose-clipped fish were sampled for scales and CTWs by removing the snout 1 cm past the eye. All snouts collected on the Atnarko River were sent to J.O. Thomas and Associates for dissection and CTW reading immediately after the dead-pitch portion of the project concluded. For age analysis, all CTW readings were compared to their respective scale ages to determine error in scale readings.

2.1.3 Dead-pitch and Sampling:

Dead-pitch began on September 18th, 2017 and continued until October 12th, 2017, when new carcasses were becoming rare. Dead-pitch crews consisted of one swimmer/diver, one oarsman and two or more spotter/shore walkers. Divers were equipped with a gaff hook and shore crews were equipped with fish pews. Crews were switched between all reaches of the river to minimize any bias in looking at different locations where carcasses build up. As many carcasses as possible were recovered throughout all 6 river reaches as soon as they became available.

All carcasses recovered were checked for pre-spawn mortality/egg retention, sex, primary and secondary marks, and adipose clipped fins (indicating a fish of hatchery origin and probably a CWT). Additional data recorded for each carcass recovered included recorders initials, date, reach, location, sex, nose fork length, post orbital-hypural (POH) length, tag number, and opercular punch scheme if present. Once observed, carcasses were pitched high onto the banks so they would not be counted twice.

During dead-pitch, scale samples were collected randomly from 532 non-adipose clipped Chinook, as well as scale samples and snouts from 137 adipose fin clipped Chinook.

The POH and NF lengths taken from carcasses during dead-pitch were used to derive a linear equation to predict the POH length of fish encountered during tagging using the NF length that was recorded. This was done to reduce live fish handling time during tagging. All fish with measured or calculated Post-orbital hyperal (POH) lengths smaller than 460 mm were considered jacks.

2.2 Analyses

2.2.1 Petersen Estimate

The Chapman modification of the Petersen estimator (Ricker 1975) is used to estimate escapement on the Atnarko River.

$$P_{i,r} = \frac{(C_{i,r}+1)(M_{i,r}+1)}{(R_{i,r}+1)}$$

Where *P* is the population estimate, *C* is the total number of fish recovered, *M* is the total number of fish tagged (with all tagged broodstock removed), and *R* is the number of tagged fish recovered with primary or secondary marking. Population estimates are completed separately for each sex and summed together for an estimate of the total population to reduce bias. The number of marked fish used in the Petersen method was adjusted to account for the tagged fish removed during broodstock.
Estimates were stratified by sex.
This model makes the following assumptions which are addressed throughout the field procedures

- All fish have an equal probability of capture (application) and recapture (carcass recovery)
- Marked fish mix completely with unmarked fish between marking and recovery
- Marked and unmarked fish behave the same
- Marked fish suffer the same mortality rate as unmarked fish

- There is no immigration or emigration between marking and recovery (closed population)
- Fish do not lose their marks, all marks are recognizable and reported upon encounter

2.2.2 Bias Assessments

In order to identify potential sources of bias to the population estimation procedure, tests to assess whether samples met the assumption of equal probability of selection were performed. Sample groups of sex, time, and size were compared against the expectation that random samples of the same population would have the same characteristics; the characteristics of marked and unmarked components of the recovery samples were expected to be the same as were the recovered and non-recovered components of the application samples. Kolmogorov-Smirnov two sample t-tests (Sokal and Rohlf 1981) were used to compare length frequency distributions testing for size bias between tagging and recovery samples, recovered tags and unrecovered tags, and tagged and untagged recoveries in dead-pitch. Chi-square contingency tables (Zar 1985) were used to assess bias in sex, time and space in tagging and recovery sampling. Mark application bias was assessed by comparing egg retention rates between marked and unmarked females recovered during dead-pitch using a Chi-square contingency table (Zar 1985).

2.2.3 Maximum-likelihood model using Independent Encounter History data

All encounters for each fish were recorded and used in an analysis completed by Antonio Velez-Espino using methods from Velez-Espino *et al*. 2010. Encounters were broken into 13 time periods consisting of 3 or 4 days that similar events were occurring (e.g. tagging) for the analysis, and separate estimates were done for each sex. Collecting independent encounter history data requires more detailed record keeping in the field. These data allow for evaluation of the closed population assumption required by Petersen estimators, and analysis of migration phenology and stream residence times resulting in a robust and unbiased spawning escapement estimate (Velez Espino *et al.* 2009).

2.2.4 Age Distribution

An estimate of age composition will be made from the results of scale and CTW ageing analysis.

2.2.6 Hatchery Contribution

Atnarko River Chinook hatchery production has averaged around 2 million annually with 400,000 of released fry receive adipose fin clips and CTW inserts at the Snootli Hatchery. Release timings are structured to match the various life history strategies present and split between Upper and Lower Atnarko in an attempt to cover potential differences in outmigration timing between the areas. Further information on Hatchery production can be found through Snootli Hatchery.

Percent of Natural Incidence (PNI) will be calculated by SEP using estimates of the contribution of hatchery-reared Chinook. SEP uses proportion of CTWs from each brood year encountered during sampling and the percentage of juvenile fish having a CTW at their release to make these calculations. An estimate of hatchery contribution calculation will be included in this report.

3 RESULTS

Between August 16th, 2017 to September 14th, 2017, 43% (525/1220) Chinook were tagged in the Upper reaches, while 11% (131/1220) were tagged in the Middle, and 46% (564/1200) were tagged in the Lower reaches (Tagging summarized in Appendix G). A total of 2,166 carcasses were recovered consisting of 1099 female, 1052 male, and 15 jack carcasses. In the Lower reaches, 1,089 (50%) carcasses were recovered, while 428 (20%) were recovered from the Middle reaches, and 649 (30%) were recovered from the Upper reaches

(Dead-pitch summarized in Appendix I). Of the Chinook carcasses recovered, a total of 207 were tagged Chinook (80 female, 124 male, and 3 jack; tag recoveries summarized in Appendix J).

Overall, tag recovery rate was 19.2% (207 tagged fish recovered out of 1076 marked in the population after broodstock removal). Tag retention for Kurl-Lock tags was estimated to be 9.7% as 20 of 207 carcasses recovered had lost their Kurl-Lock tag but were all still identified as tagged by their punch scheme.

3.1 Petersen Estimate

The Petersen method estimates the Atnarko Chinook population to consists of 5,079 (95% CI: 4,091 – 6302) females, 5,779 (95% CI: 4,853 – 6,879) males, and 76 (95% CI: 31 – 152) jacks for a total spawning escapement of 10,934 fish (95% CI: 9,484 – 12,384; Table 1). The coefficient of variation was 10.6%, 8.4%, and 38.6% for females, males and jacks respectively, and 6.6% for the entire population.

3.1.1 Sexual Bias

The tagged and recovery samples showed differences in male: female ratios (x^2: $p<0.001$). Approximately double the males were tagged compared to females (1:0.55 male to female) while the sex ratio was approximately even in the recovery sample (0.96: 1 male to female). Removing broodstock fish did not change the sex ratio of fish in tagging and recovery samples (x^2: $p<0.001$).

The difference in tagging between females and males reflected in the probability of recovering marked fish. The proportion of marked recoveries was larger in males than females (males 13.3% and females 7.9%) and the probability of recovering a male marked fish during recovery was more likely than recovering a female marked fish (x^2: $p<0.001$). Sexual bias was not evident in recovery in the comparison of recovered to not recovered tags (x^2: $p>0.05$). To avoid influence by sexual bias, the male, female and jack components of the population were estimated separately.

3.1.2 Size Bias

The mean POH of female Chinook salmon sampled was 716.2 mm and 625.0 for males. Standard deviation was 45.9mm and 84.6mm respectively. Size bias was not detected in either male or female Chinook salmon when comparing POH length frequencies between samples (KS two sample t-test: $p>0.05$), within recoveries (KS two sample t-test: $p>0.05$), and within tagging (KS two sample t-test: $p>0.05$).

3.1.3 Recovery Area Bias

Mark recovery was independent of area for both sexes (x^2: $p>0.05$).

3.1.4 Mark Application Bias

From the 1099 females sampled during dead-pitch for egg retention 71 tagged females showed less than 50% egg retention while 9 showed 50% or more egg retention. There were 1019 untagged female Chinook with 947 females showing less than 50% egg retention and 72 showing more than 50% egg retention (Table 3). A chi-squared test indicated that pre-spawn mortality was independent of tag status (x^2: $p>0.05$).

3.1.4 Temporal Bias

Tag recovery status was compared by week of tag application and by week of dead-pitch to assess if there was a temporal bias within males and females. Tag recovery was shown to be independent of week of tag application for both sexes (x^2: $p>0.05$). However, bias was present in time of recovery as both male and females showed more tags recovered during September 21 to September 28th while most carcasses without tags were recovered during September 26 to 28th (female x^2: $p<0.005$; male x^2: $p<0.05$; Table 4).

3.2 Maximum-likelihood model using Independent Encounter History data

The best maximum likelihood model estimated Atnarko River Chinook escapement to be 4,933 (95% CI: 4343 to 5605) females, 5,375 (95% CI: 4733 – 4733) males, and 87 (95% CI: 66 to 114) jacks for a total spawning escapement of 10,395 (95% CI 9142 – 11, 823) Chinook. The coefficient of variation was 6.5%, 6.5%, and 14.2% for females, males and jacks respectively, and 4.6% for the entire population.

3.5 Age Distribution

In total, scale samples were collected from 1325 (665 female, 643 male, and 17 jack) Chinook. Of all scale samples collected, 977 samples were read successfully (774 non-adipose clipped fish and 203 adipose clipped fish). Out of the 977 successfully aged fish from scales, 0.8% were age-2, 17.8% were age-3, 40.2% were age-4, 39.9% were age-5, and 1.2% were age-6 (Table 5). The analysis of freshwater versus marine annulus indicated that 92.9% of the sample corresponded to ocean-type fish while 7.1% corresponded to stream-type fish. At the age-specific level 100% of the age-2 fish, 98.9% of the age-3 fish, 98.3% of the age-4 fish, 85.4% of the age-5 fish and 66.7% of the age-6 fish exhibited ocean-type life history.

Of the 360 CTW heads submitted from adipose fin clipped fish, 331 were successfully read. Analysis of age structure using CTW readings indicated that 0% of the sample corresponded to age-2 fish, 20.2% corresponded to age-3 fish, 32.0% corresponded to age-4 fish, 46.2% corresponded to age-5 fish and 1.5% to age-6 fish (Table 6). Analysis of freshwater versus marine annulus indicated that 98.8% of the sample corresponded to ocean-type fish while 1.2% corresponded to stream-type fish. At the age specific level 100% of age-3, age-4 fish, and age-5 fish, and 20% of age-6 fish exhibited ocean-type life history.

3.5 Hatchery Contribution

Hatchery contribution was estimated to be approximately 52% of the Atnarko River Chinook escapement using CTW results. The exact contribution is not available at this time from SEP biologists, but will be available later in 2018.

4 DISCUSSION

4.1 Evaluation of Results

The primary objective of this study was to collect data to provide an estimate of the 2017 Atnarko River Chinook spawning escapement using modified Petersen Mark Recapture techniques with a CV of 15% or less. This primary objective was achieved and estimated the population to be 10,934 (95% CI: 9409 to 12307) with a CV of 6.6% (Table 2). The Petersen method estimated the population to be made up of 46.5% females, 52.9% males, and 0.7% jacks. The additional objectives of collecting age samples, estimating hatchery contribution, and obtaining more information from the population using IEH data was also achieved.

Several sources of error have been addressed over the past eight seasons, through operational revisions and continual refinements issues, such as high tag loss rate (2009), lack of upper river access (2010-2012) and inconsistent recording of broodstock, recaptures and losses-on-capture have been eliminated to the greatest

extent possible. Additional refinements such as those applied in 2016 and 2017 provide better results in both the Petersen estimates and the application of Maximum-likelihood models (Appendix F).

4.2 Recommendations and Future Challenges

In-season and post-season evaluations are conducted in an effort to continuously improve the quality and effectiveness of this program. All aspects of the project are constantly reviewed; standard operating practices, methodology, results and data analysis. In 2017, recommendations for improvement from 2016 were successfully implemented. These included using Floy 'spaghetti' tags on broodstock held at Snootli Hatchery, and revisiting and updating Program Safety Plans and First Aid equipment. In addition, a barcode scanner was used to inventory fish heads for CTW shipment. No recommendations were made for 2018.

5 ACKNOWLEDGEMENTS

Thank you to Pacific Salmon Commission for financial support, BC Parks and local property owners for access to the Atnarko River. Central Coast Stock Assessment would also like to thank A. Krimmer, DFO stock assessment staff field staff, J. Willis, H. Hammer, and the field crews of the Snootli Hatchery for their continued co-operation and hard work to make this project successful. Thanks are also due to the continued support and work put in by C. Masson, I. Winther, and A. Velez-Espino.

6 REFERENCES

BCWCS. 2007. *Bella Coola watershed –based Fish Sustainability Plan Stage II. Bella Coola Watershed Conservation Society.* Prepared for Communities of Bella Coola Valley and Fisheries and Oceans Canada. January 2007. 112 p.

DFO. 2005. *Canada's Policy for Conservation of Wild Pacific Salmon.* Fisheries and Oceans Canada, Vancouver, BC. 50 p.

Gilbert, C. H., and Rich, W.H. 1927. Investigations concerning the red salmon runs to the Karluk River, Alaska. Bull. U.S. Bus. Fish. 43(2): 1-69 (Doc. No 991).

Holtby, L.B., and Ciruna, A. 2007. *Conservation Units for Pacific salmon under the Wild Salmon Policy. Canadian Science Advisory Secretariat, Research Document 2007/070.* Fisheries and Oceans Canada, Vancouver, BC.

Mullins, J. 2012. *Bella Coola/Atnarko Chinook Examination of a Central Coast Chinook Stock; 2012 Update*. Prepared for DFO Stock Assessment Program, Bella Coola. Unpublished. 21 p.

Sokal, R.R., and Rohlf, F.J. 1981. Biometry, the principles and practices of statistics in biological research. Second Edition. W. H. Freeman and Company. San Francisco, CA. 859 p.

Sturhahn, J.C. 2009. *Atnarko River Chinook Escapement Estimation Project-Central B.C.* Proposal prepared for Pacific Salmon Commission Chinook Salmon Sentinel Stocks Program. Unpublished. 14 p.

Vélez-Espino, L.A., Willis, J., Parken, C.K., and Brown, G. 2011. *Cohort analyses and new developments for coded wire tag data of Atnarko River Chinook salmon.* Can. Manuscr. Rep. Fish. Aquat. Sci. 2958: xiii + 68 p.

Vélez-Espino, L.A., Winther, I., Koroluk, B., and Mullins, G. 2014. *Time series calibration (1990-2013) and escapement goal for Atnarko River Chinook salmon.* Can. Tech. Rep. Fish. Aquat. Sci. 3058: vii + 90p.

Vélez-Espino, L.A., Mullins, G., Willis, J., Krimmer, A., and Levesque, W. 2010. *Mark-recapture experiment for the 2009 Chinook salmon spawning escapement in the Atnarko River*. Can. Manuscr. Rep. Fish. Aquat. Sci. 2930: xii + 51 p.

Winther, I., Krimmer, A. 2015. *Operational Guide – Atnarko Chinook Mark Recapture Project. Prepared for DFO Stock Assessment Bella Coola. Unpublished. 9 p.*

Zar, J.H. 1984. Biostatistical Analysis. Second edition. Prentice Hall, Inc. Englewood Cliffs N.J. 718 p.

FIGURES

Figure 1. Map of British Columbia showing location of the Atnarko River.

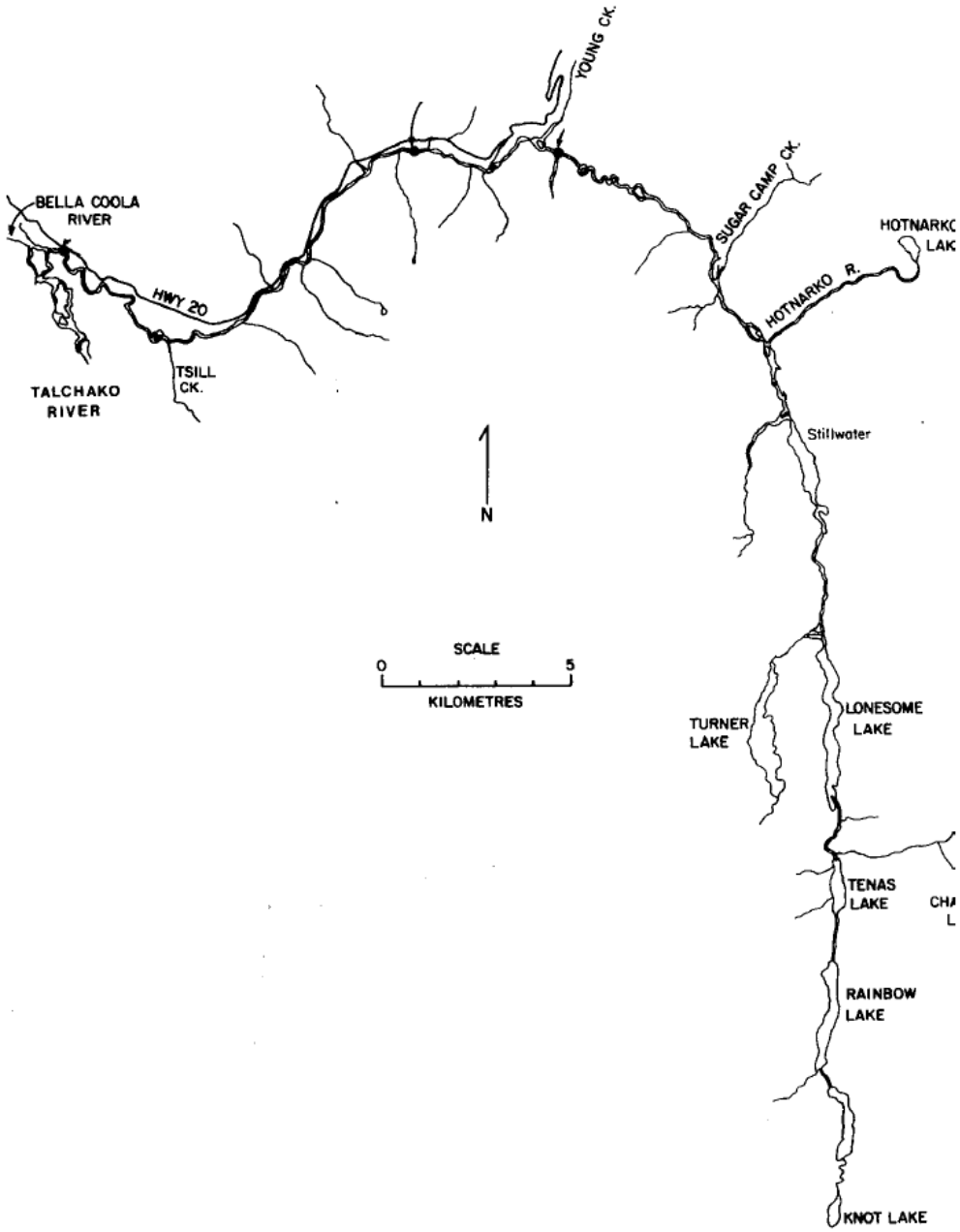


Figure 2. The Atnarko River drainage.

Figure 3. Atnarko River project sample area.

TABLES

Table 1. Petersen calculations for 2017

	Marked	Recovered	Carcasses	Modified Peterson	95% lower	95% upper	CV (%)	Variance	SD
Females	373	80	1099	5079	4091	6303	10.6	291424.6	539.8
Males	685	124	1052	5779	4853	6879	8.4	233579.1	483.3
Jacks	18	3	15	76	31	152	38.7	866.4	29.4
F+M+J	**1076**	**207**	**2166**	**10934**	**9484**	**12384**	**6.6**	**525870.1**	**725.2**

Table 2. Atnarko Chinook Mark Recapture Results 2001 to 2003, 2009 to 2017.

Year	Total Peterson Estimate	95% lower limit	95% upper limit	CV
2001	20,769	17,400	25,125	5.6%
2002	16,352	11,212	25,168	11.7%
2003	13,433	10,142	18,625	8.5%
2009	10,0761	8,745	12,775	5.7 %
2010	11,037	7,610	16,045	12.2 %
2011	9,105	6,297	13,137	14 %
2012	10,389	7,912	12,866	11.9 %
2013	28,010	23,738	32,283	7.6%
2014	25,968	21,206	30,729	9.2%
2015	57,778	50,087	65,469	6.7%
2016	21,971	18,778	25,197	7.3%
2017	10,934	9,484	12,384	6.6%

Table 3. Egg retention for Atnarko Chinook Mark Recapture

Percentage of egg retention (%)	Count of untagged females	Count of tagged females
0	941	70
20 to 40	6	1
50	8	0
60	3	0
70	1	0
80	6	0
95	1	0
100	54	9
Total	1019	80

Table 4. Incidence of tag recoveries compared by week of tag application.

Week	Males recovered	Males not recovered	Females recovered	Females not recovered
Sept 18, 19, 20	6	34	12	48
Sept 21, 22, 25	45	242	33	309
Sept 26, 27, 28	48	353	24	380
Sept 29, Oct 2, 3	22	214	6	211
Oct 4, 5, 6, 11	1	80	3	62
Total	**122**	**923**	**78**	**1010**

Table 5. Scale ages of Atnarko River Chinook salmon from 2017.

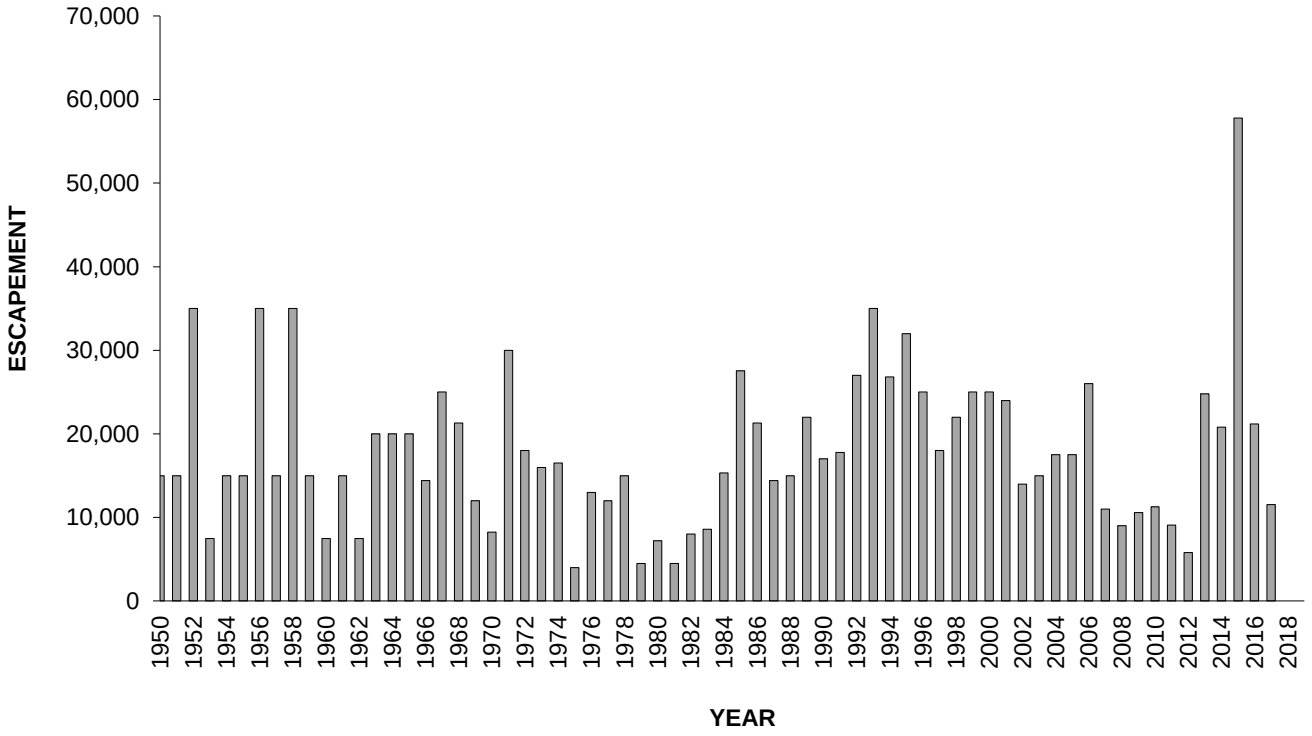
Age	Count	%
2.1	8	0.82
3.1	172	17.60
3.2	2	0.20
4.1	387	39.61
4.2	6	0.61
5.1	333	34.08
5.2	57	5.83
6.1	8	0.82
6.2	4	0.41
Total	977	100

Table 6. CTW ages of Atnarko River Chinook salmon from 2017.

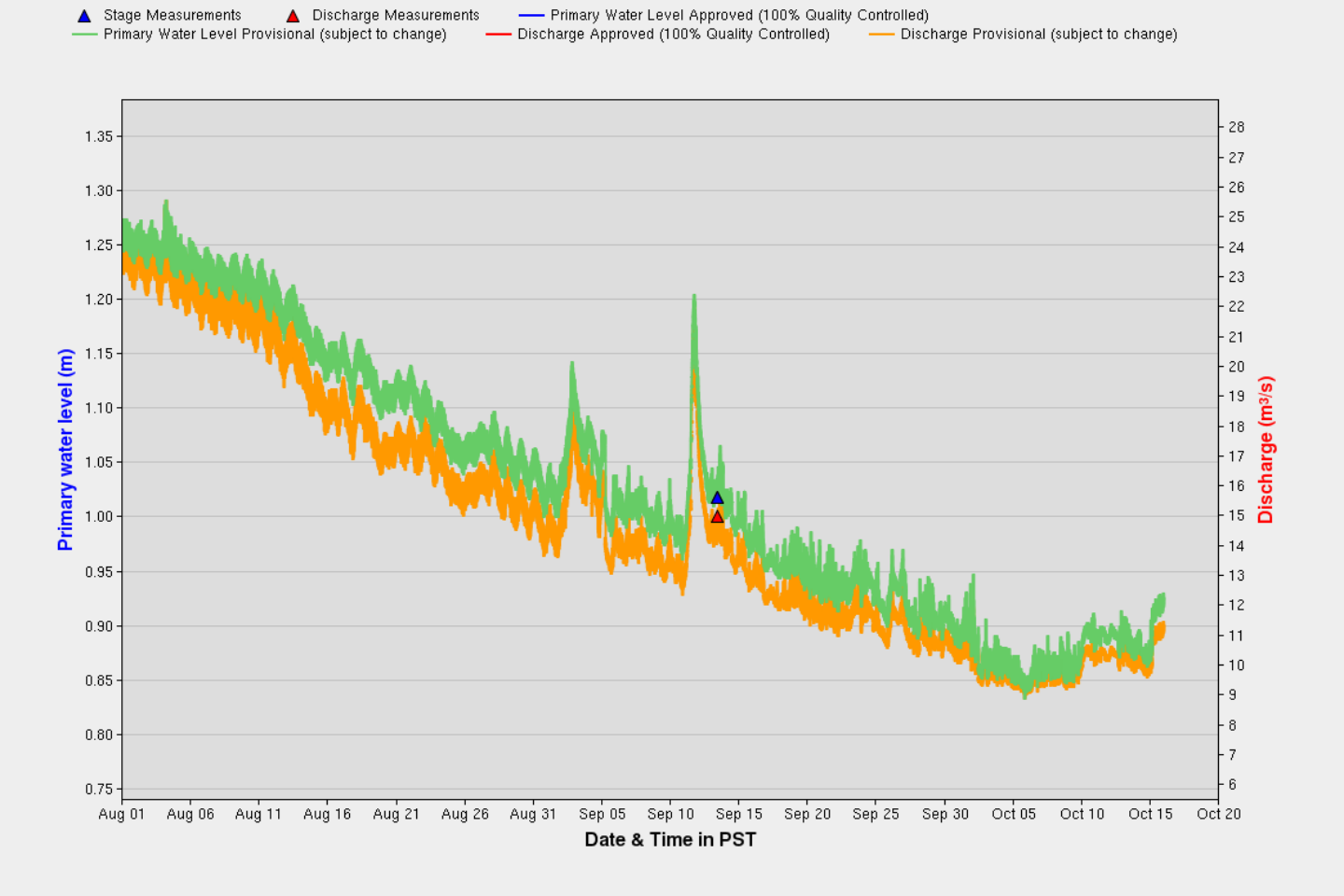
Age	Count	%
2.1	0	0.00
3.1	67	20.24
3.2	0	0.00
4.1	106	32.02
4.2	0	0.00
5.1	153	46.22
5.2	0	0.00
6.1	1	0.30
6.2	4	1.21
Total	331	100

APENDICES

Appendix A. Bella Coola Watershed (Atnarko River) Chinook Escapement 1950 to 2017.



Appendix B. Time series of Atnarko River water level and discharge. Station 08FB006 [BC], for the period of August 1, 2017 to October 15, 2017. Source: **https://wateroffice.ec.gc.ca**



Appendix C. Tagging/Dead-pitch Data Form

Atnarko Chinook Tagging or Deadpitch/BS Samplers Initials:

Net / Set	Date	Reach (1-6)	Location	Sex (M/F/J)	Tag #	Punch (1R/2L/1L)	AD Clip (Y/N)	Scale book	Scale #	NF-Length (cm)	POH (cm)	Egg-Ret. (%)	E -label	DP or BS*	Comments

*Record as DP or BS if fish is AD clip (E-label applied)

Rev July 2016

Appendix D. Broodstock Form

Atnarko Chinook Brood Stock

Initials	Date	Reach	Location	Net (S/G)	Released/ Recaptured			Back to Hatchery			Kelts			Spawned			Total Spawned		
					F	M	J	F	M	J	F	M	J	F	M	J	F	M	J

Appendix E. Tagging Recapture Form

Atnarko Chinook Recapture*

Initials	Date	Reach (1-6)	Set #	Location	Sex (M/F/J)	Tag #	Punch (1R/2L/1L)	AD Clip (Y/N)	Released/ BTH	Comments

* These fish are all released alive

Rev July 2016

Appendix F. Yearly Program Changes from 2010 to 2017

2010

- The field season ended unusually early on Sept 25 2010 because of record high water levels.

2011

- On Sept 23, 2011 there was another unseasonably high water event that limited the ability to perform an effective thorough dead-pitch for the remainder of the season.
- The Upper two river reaches (along the Tote Road) were only assessable via ATV because of road damage that occurred in the 2010 flood.

2012

- During broodstock collection a tagged fish will not be treated any differently than non-tagged fish. In past years, tagged fish were released and not spawned out.
- Biological sampling will occur on live Chinook as they are being tagged. In past years, biological sampling was only performed on dead Chinook.
- The Upper two river reaches (along the Tote Road) were only accessible via ATV because of road damage that occurred in the 2010 flood. Repairs to the road and bridges are expected to be completed by the end of 2012.

2013

- Repairs to the Tote Road and bridges have restored vehicle access to the Upper two reaches.

2014

- Jacks were defined as >46cm POH (>58 NF) in 2014; whereas in previous years a Jack had a POH ≥58cm.
- CWT heads were frozen individually and then bagged according to river reach and date to assist with inventory at the end of the season.

2015

- The recapture form was updated to include set#, AD clip, and Released/BTH. The recap form should represent one day only, even if the sheet is not full.
- Tags recovered in dead-pitch were collected and stored in separate bags categorized by date and river reach to assist in tag inventory at the end of the season.
- Fish that were brought back to the hatchery were marked with a unique Kurlock tag (a different number series than that for the mark and recapture program). This allowed the fish to be tracked until the day they were spawned.

2016

- For efficiency, the recapture form was printed onto forms, instead of being hand written or photocopied as in past years.
- Fish that were brought back to the hatchery were marked with a unique T-bar anchor tags instead of Kurlock tags. In past years, there has been a high proportion of tags that fall out in the ponds and a high occurrence of rot on the gill plate around the tag. The T-bar tags helped reduce these issues.
- Effort factor was determined for ‘Dead-pitch’ based on person days and will be recorded in following years.

2017

- A barcode scanner was used to inventory our fish heads which was very efficient and effective. There was more overlap between tagging brood stock and dead pitch because of a smaller total escapement.

Appendix G. Tagging effort by area, date and sex for the Atnarko River 2017 Chinook Escapement Estimate

Date	Lower Reach				Middle Reach			Upper Reach				Total
	Female	*Jack*	*Male*	*Total*	*Female*	*Male*	*Total*	*Female*	*Jack*	*Male*	*Total*	
16/08/2017	46	3	55	104								104
17/08/2017								17		5	22	22
18/08/2017	14		21	35								35
21/08/2017								36	6	62	104	104
22/08/2017								16		13	29	29
23/08/2017					18	20	38	22		25	47	85
24/08/2017					16	18	34	14		19	33	67
25/08/2017	31	2	37	70				16	1	20	37	107
28/08/2017		1	79	80								80
29/08/2017	11		23	34	5	21	26					60
30/08/2017					1	15	16	9		20	29	45
31/08/2017	40	2	47	89						15	15	104
01/09/2017									1	40	41	41
05/09/2017	29	1	34	64				7		18	25	89
06/09/2017			34	34								34
07/09/2017								1		38	39	39
08/09/2017								1		10	11	11
09/09/2017										14	14	14
11/09/2017	18		20	38						10	10	48
12/09/2017	19	1		20				18		15	33	53
13/09/2017					10	7	17	12		16	28	45
14/09/2017										11	11	11
Total	208	10	350	568	50	81	131	169	8	351	528	**1227**

Appendix H. Summary of broodstock effort for the Atnarko River Chinook in 2017.

Date	Lower Reach				Middle Reach			Upper Reach				Total
	Female	*Jack*	*Male*	*Total*	*Female*	*Male*	*Total*	*Female*	*Jack*	*Male*	*Total*	
28/08/2017	51		2	53								53
29/08/2017	3			3	8		8					11
30/08/2017					9	1	10	12		1	13	23
31/08/2017	5			5				14			14	19
01/09/2017								29		5	34	34
05/09/2017	21			21				19			19	40
06/09/2017	48		19	67								67
07/09/2017								39		6	45	45
08/09/2017								14		11	25	25
09/09/2017								12			12	12

11/09/2017	5		2	7				6		3	9	16
12/09/2017	9	2	40	51				2		21	23	74
13/09/2017	9		8	17				5		5	10	27
14/09/2017	9		12	21				17		3	20	41
15/09/2017	22	1	50	73				20		45	65	138
16/09/2017	25		26	51				17	1	41	59	110
18/09/2017	29		62	91				14		47	61	152
19/09/2017	21		20	41				14		15	29	70
20/09/2017								12		23	35	35
Total	257	3	247	501	17	1	18	246	1	226	437	**992**

Appendix I. Summary of dead-pitch effort for Atnarko River Chinook Escapement in 2017.

Date	**Lower Reach**				**Middle Reach**				**Upper Reach**				**Total**
	Female	*Jack*	*Male*	*Total*	*Female*	*Jack*	*Male*	*Total*	*Female*	*Jack*	*Male*	*Total*	
18/08/2017	1			1									1
21/08/2017											2	2	2
25/08/2017	1			1									1
29/08/2017	1			1									1
05/09/2017	1			1									1
06/09/2017	1			1									1
12/09/2017			1	1							1	1	2
13/09/2017	1		1	2					1			1	3
16/09/2017	2		2	4					2			2	6
18/09/2017	18		15	33							1	1	34
19/09/2017					6		5	11	9		1	10	21
20/09/2017					10		10	20	17		8	25	45
21/09/2017	54		44	98					37	1	14	52	150
22/09/2017	36	1	20	57	8		7	15	11		17	28	100
25/09/2017	79		80	159	51	1	58	110	66		47	113	382
26/09/2017	105		94	199					39	2	50	91	290
27/09/2017	45	1	61	107	36	2	31	69	55	1	34	90	266
28/09/2017	63		43	106	44	1	58	103	17		30	47	256
29/09/2017	55		78	133	17	1	14	32	65	3	57	125	290
02/10/2017	27		20	47					10		13	23	70
03/10/2017	43	1	54	98									98
04/10/2017					25		23	48	9		14	23	71
05/10/2017	4		14	18	12		8	20	5		2	7	45
06/10/2017	7		15	22									22
11/10/2017									3		5	8	8
Total	544	3	542	1089	209	5	214	428	346	7	296	649	**2166**

Appendix J. Summary of tag recoveries for Atnarko River Chinook in 2017 by area and sex.

Date	Lower Reach				Middle Reach			Upper Reach				Total
	Female	*Jack*	*Male*	*Total*	*Female*	*Male*	*Total*	*Female*	*Jack*	*Male*	*Total*	
18/08/2017												
21/08/2017												
25/08/2017												
29/08/2017												
05/09/2017												
06/09/2017	1			1								1
12/09/2017			1	1						1	1	2
13/09/2017												
16/09/2017	1			1								1
18/09/2017	6		2	8						1	1	9
19/09/2017						1	1	2			2	3
20/09/2017					1	1	2	3		1	4	6
21/09/2017	5		7	12				5	1	3	9	21
22/09/2017	3		2	5		1	1	3		4	7	13
25/09/2017	10		10	20	2	10	12	5		8	13	45
26/09/2017	6		10	16				2		11	13	29
27/09/2017	2	1	9	12	2	4	6	5	1	4	10	28
28/09/2017	4		5	9	2	3	5	1		2	3	17
29/09/2017			6	6	1	1	2	3		9	12	20
02/10/2017	2			2								2
03/10/2017			6	6								6
04/10/2017								2			2	2
05/10/2017			1	1	1		1					2
06/10/2017												
11/10/2017												
Total	40	1	59	100	9	21	30	31	2	44	77	**207**

Appendix K. Summary of sampling effort non-adipose fin clipped Atnarko River Chinook in 2017.
Total number of fish sampled by date, sex, and reach.

Date	Lower Reach				Middle Reach				Upper Reach				Total
	Female	*Jack*	*Male*	*Total*	*Female*	*Jack*	*Male*	*Total*	*Female*	*Jack*	*Male*	*Total*	
16/08/2017	39	3	45	87									87
17/08/2017									13		5	18	18
18/08/2017	12		17	29									29
21/08/2017									31	6	53	90	90
22/08/2017									14		11	25	25
23/08/2017					17		18	35	16		16	32	67
24/08/2017					15		17	32	12		16	28	60

25/08/2017	27	2	32	61					13	1	19	33	94
28/08/2017		1	51	52									52
29/08/2017													
30/08/2017													
31/08/2017													
01/09/2017													
05/09/2017													
06/09/2017													
07/09/2017													
08/09/2017													
09/09/2017													
11/09/2017													
12/09/2017													
13/09/2017													
14/09/2017													
16/09/2017													
18/09/2017	11		9	20									20
19/09/2017					6		3	9					9
20/09/2017					7		9	16	10		6	16	32
21/09/2017	19		9	28					19		7	26	54
22/09/2017	21	1	8	30	8		4	12	7		12	19	61
25/09/2017	19		13	32	11		22	33	16		13	29	94
26/09/2017	56		35	91					25	1	22	48	139
27/09/2017	21		22	43	24	2	16	42	22		16	38	123
28/09/2017													
29/09/2017													
02/10/2017													
03/10/2017													
04/10/2017													
05/10/2017													
06/10/2017													
11/10/2017													
Total	225	7	241	473	88	2	89	179	198	8	196	402	**1054**

Appendix L. Summary of sampling effort adipose fin clipped Atnarko River Chinook in 2017.
Total number of fish sampled by date, sex, and reach.

Date	**Lower Reach**			**Middle Reach**			**Upper Reach**				**Total**
	Female	*Male*	*Total*	*Female*	*Male*	*Total*	*Female*	*Jack*	*Male*	*Total*	
16/08/2017											
17/08/2017											
18/08/2017											
21/08/2017									1	1	1

22/08/2017											
23/08/2017											
24/08/2017											
25/08/2017											
28/08/2017	6		6								6
29/08/2017				2		2					2
30/08/2017				2		2	1			1	3
31/08/2017							1			1	1
01/09/2017							5		1	6	6
05/09/2017	4		4				3			3	7
06/09/2017	6	6	12								12
07/09/2017							5		1	6	6
08/09/2017							2		2	4	4
09/09/2017							2			2	2
11/09/2017							1		1	2	2
12/09/2017	1	5	6						3	3	9
13/09/2017											
14/09/2017	1	2	3				5		1	6	9
15/09/2017	5	7	12				1		5	6	18
16/09/2017		6	6				5		1	6	12
18/09/2017	8	4	12						4	4	16
19/09/2017	5	3	8		1	1	4		3	7	16
20/09/2017				2		2	6		3	9	11
21/09/2017	10	7	17				6		2	8	25
22/09/2017	1	1	2		1	1	2		3	5	8
25/09/2017	7	8	15	10	8	18	10		6	16	49
26/09/2017	10	7	17				5		5	10	27
27/09/2017	3	5	8	4	4	8	8		5	13	29
28/09/2017	4	8	12	3	4	7	1		4	5	24
29/09/2017	5	12	17	2	1	3	10	1	7	18	38
02/10/2017	2	1	3				1			1	4
03/10/2017	1	5	6								6
04/10/2017				1	2	3	1		1	2	5
06/10/2017	1	1	2								2
Total	80	88	168	26	21	47	85	1	59	145	**360**