Mark-Recapture Experiment for the 2016 Chinook Salmon Spawning Escapement in the Atnarko River; Final Report for Pacific Salmon Commission (NF-2016-I-30)

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ABSTRACT

An estimation of the spawning population of Atnarko River Chinook (*Oncorhynchus tshawytscha*) using a mark-recapture study was conducted by Fisheries and Oceans Canada between August 19, 2016 and October 6, 2015.

There were 1,318 chinook salmon captured and tagged throughout the study area between August 19, 2016 and September 9, 2016. A total of 96 of the 1,318 tagged chinook were removed for brood stock purposes leaving 1,222 viable tagged chinook. A total of 178 tags were recovered from 3,403 carcasses, using a modified Petersen estimate model (M = 1,222, C =3,403, R = 178) the total number of chinook returning to the spawning grounds was estimated to be 21,971.

Spawning escapements of 9,414 (95% CI: 7,716 – 11,481; CV=9.9%) females, 12,288 (95% CI: 9,936 – 15,189; CV=10.5%) males and 270 (95% CI: 55– 281; CV=68.3%) jacks were estimated with the Petersen model for a total spawning escapement of 21,971 fish (95% CI: 18,765 – 25,178; CV = 7.3%). According to the Petersen estimate, 42.9% of the spawning escapement consisted of females, 55.9% males and 1.2% jacks.

Additional population estimation using the Independent Encounter History (IEH) model produced a spawning escapement of 11,998 (95% CI: 10,672 – 13,553; CV=6.1%) females, 12,236 (95% CI: 10,491 – 14,364; CV=8.0%) males, and 400 (95% CI: 237 – 698; CV=28.4%) jacks for a total spawning escapement of 24,634 fish (95% CI: 21,400 – 28,615; CV = 4.7.0%). According to the IEH estimate, 48.7% of the spawning escapement consisted of females, 49.7% males and 1.6% jacks.

1. INTRODUCTION

1.1 **The Atnarko River**

In 2009 the Atnarko River chinook stock was proposed as an exploitation rate indicator and was funded under Coded Wire Tag (CWT) Improvement program. The purpose was a mark-recapture program to be conducted over a five-year period in order to improve escapement estimates for early summer chinook.

The Atnarko Mark Recapture program has run annually since 2009 and has met the data standard of a coefficient of variation (CV) of 15% or less every year (see Table 9) and the continued mark-recapture estimates on the Atnarko River for 2016 have built upon that information previously collected.

This program is also part of a comprehensive group of programs on Atnarko River chinook salmon that includes terminal fishery monitoring, and the production of chinook fry and CWT application (under separate submission to the Northern Fund) by Snootli Hatchery for SEP (Salmonid Enhancement Program). The objectives for SEP are to produce CWT marked fry and generate the data necessary to estimate the escapement of the marked and unmarked fractions of the chinook returning to the Atnarko River and the data produced by the project are included in the Salmonid Enhancement Program's (SEP) production planning and assessment processes. The data produced are consistent with those required for SEP chinook salmon escapement sampling requirements and contribute to SEP databases.

The Atnarko River is the only chinook rate indicator on the mainland of BC between Kitsumkalum and Harrison River. There are a total of 5 Chinook Conservation Units identified in central BC including Docee, Rivers Inlet, Wannock, Bella Coola-Bentick, and Dean River. Atnarko constitutes the largest complex of chinook salmon in Central BC and is the largest contributor to the Bella Coola-Dean Conservation Unit. The Atnarko chinook population is summer timed with a predominantly ocean-type life history strategy although both stream and ocean-type components are present and this population. The majority of chinook that enter the Bella Coola River spawn in the Atnarko River.

Similarly timed stocks include the Chuckwalla River and Owikeno Lake tributary stocks in Rivers Inlet as well as the Dean River. Although Chuckwalla River chinook are no longer enhanced, historical hatchery marked releases from the Chuckwalla River show tag recoveries in similar fisheries to Atnarko recoveries. In addition, exploitation rates may be well represented with similar summer timing as well as both ocean and stream types life histories present.

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

Finally, the results of this project, an escapement estimate for the 2016 Atnarko River chinook salmon return, supports the Canadian Department of Fisheries & Oceans (DFO) priorities of fish production and conservation. The project supports the development of escapement goals and stock specific exploitation rate management objectives.

1.2 **Study Area**

The Atnarko River feeds the Bella Coola River and is situated in Statistical Area 8 on the Central Coast of B.C. (Figure 1). This system is located north of Cape Caution and resides within the Northern Fund region of the PST. The Atnarko River drains a 2,440 km^2 watershed, merging with the Talchako River to form the Bella Coola River (see Figure 2), approximately 45 km downstream from Knot Lake. 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 Atnarko chinook population is summer timed with a predominantly ocean-type life history strategy. This population is the primary contributor to the Bella Coola-Dean Conservation Unit (Holtby and Ciruna; 2007). Distribution of Atnarko chinook salmon is 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 Atnarko can be divided into three river segments with specific biotic and abiotic attributes. The upper segment has many sections with deep and large holding areas that constitute high quality spawning areas. Overall the spawning habitat is excellent with the exception of the lower part of the upper section where the river gradient decreases, resulting in very slow water velocities and virtually no spawning habitat. The middle segment is characterized by sections with larger substrate, boulders, and increased gradient drops. Higher water velocities result in a generally lower quality spawning habitat. Holding in this section is limited and spawning is generally spread out. The lower segment is characterized by braided sections and dominated by high quality spawning habitat in its middle and lower sections. The upper part of this 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 moderate in size, 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.

1.3 **Objectives**

The primary objectives of this project were to:

1) determine an unbiased total spawning escapement estimate of Atnarko River chinook salmon (*Onchorynchus tshawytscha*) using the Petersen protocol, within the data standard coefficient of variation (CV) of 15% or less.
    a. Stratify estimates by sex and age, as well as by hatchery versus wild production.
    b. Generate sex specific estimates to reduce sex and age bias associated with different capture techniques.

2) estimate the age structure of the population within 5% of the true value.
3) estimate of the hatchery contribution to the escapement within 5% of the true value (conducted by SEP separately).

Additional objectives also included improving study methodology and project efficiency, particularly in regard to improved application of IEH (Independent Encounter History) spawning escapement estimates for future years.

2. METHODS

Chinook salmon abundance was assessed through a mark-recapture experiment that collected the data necessary to provide estimates of the wild and enhanced fractions of the chinook escapement to the Atnarko River. The abundance estimates were sex specific; data on the sex of each chinook were recorded for the mark application and mark recovery portions of the work. Scales were collected to provide the age data necessary to identify the brood year components of the return, and scales matched to the length and sex data.

2.1 **Sampling and Marking**

2.1.1 *Tag application*

A double tagging method was used to mark a minimum of 1,000 Atnarko chinook. Chinook were captured using nylon tangle nets 21-43m long (depending on river morphology) and 20 meshes deep using eight inch Alaskan twist mono mesh. Additionally, a seine net (60m length by 5 m depth) was used in two lower-river locations where river morphology allowed. Crews consisting of Snootli Creek Hatchery and DFO Stock Assessment personnel were present on the Atnarko River for each day of the project. Crews consisted on a minimum of four people; one oarsman, one or two divers/swimmers and net handlers. Larger crews were utilized in reaches where the anticipated catch per set would be higher. The middle reaches are too dangerous for rafts and all work was done on foot with an extra swimmer to replace the raft.

A typical drift net set involved a diver/swimmer who pulled the 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 the chinook and hold them in preparation for tagging. Distressed fish (bleeding gills, pinned gills etc.) were attended to first, secondly any previously tagged fish were recorded as recaptured fish and released, thirdly females were tagged and then remaining chinook were tagged. There were several variations used as dictated by river conditions, including boat to walking shore sets, two person walking sets and two swimmer sets.

In order to achieve a representative portion of the chinook spawning population throughout the chinook spawning area, the Atnarko River has been 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). Divisions are based on accessibility to the river, historical evidence of spawning similarity, and ability to drift each reach in a single day (Figure 3). Tagging occurred along all reaches concurrently by multiple crews. Because of access and fish abundance the majority of fish have traditionally been tagged in the upper and lower reaches (Approx. 40% Upper, 20% Middle, 40% Lower). Changes to river system since 2010 and varying release strategies by Snootli hatchery have resulted in variable fish distribution within the three reaches. This variability has resulted in a significantly higher representation of chinook in the lowest reach.

Each Chinook was marked with an individually numbered metal #3 Kurl-Lock tag applied to the right operculum and a secondary mutilation mark consisting of a hole punched through the operculum. Opercular punches were applied using a heavy duty paper punch. 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 record: crew initials, set #, date, reach, location, sex, tag #, punch scheme, and nose fork length, and adipose fin presence (see Section 10a) was recorded. If previously tagged fish were recaptured the date, reach, location, sex, tag#, punch location and observer was recorded on a recapture sheet (see Section 10c).

Scale samples were collected from live non-adipose fin clipped (AFC) chinook during tagging. A maximum target of 500 scales was set although 300-400 was considered sufficient. Five scales were taken from each fish into a small individually numbered scale envelope for transfer to scale books at a later date, envelope # was recorded on the tagging form (Appendix C). This step ensures quality scale samples, Atnarko chinook scales are difficult to read accurately and good quality samples are required. Scale samples were randomly taken to represent all stream reaches. (Scales samples were transferred to scale sample books and shipped to the Fish Ageing Laboratory at the Pacific Biological Station immediately following the dead pitch portion of the project.

Additionally, the program recorded all fish encountered with an adipose fin clip which identifies the presence of a cwt. This was recorded for every fish on the tagging form although heads were only collected during dead pitch and brood-stock, no adipose fin clip fish are sacrificed during tagging.

2.1.2 *Brood Stock Collection:*

This section provides methodology for the brood stock collection as related to escapement estimation for this project. (See *Operational Guide – Atnarko Chinook Mark Recapture Project.; Winther and Krimmer, 2016* for detailed description of Brood stock collection as related to Snootli Hatchery and SEP operations.)

Brood stock collection was coordinated by Snootli Hatchery with support from Stock Assessment staff. The brood stock portion of the project involved collection and transport of unripe chinook from the Upper and Lower sections of the Atnarko River to Snootli Hatchery to reach full maturity. Fishing methods were the same as those used in the marking phase of the project.

Male chinook specimens were collected 'as needed' corresponding to the number of females collected. If a female chinook was not ripe for spawning and there was nearby road access (in the lower river) for a transport tank equipped truck, the fish would be removed from the river with accompanying male fish and taken to ponds at Snootli Hatchery to ripen at a later date. The project also involved on-river spawning of ripe fish.

In addition to collection of brood stock and egg take activities (Appendix D), efforts were made to record detail for every fish handled during this time. Recaptures were noted and recorded (Appendix E), as well as all fish removed from the Atnarko River. This information is required for IEH methodologies for escapement estimation which was first introduced in the 2009. Several samples were also taken during brood stock collection for DNA analysis, and some tissue samples were collected for bacterial kidney disease screening (data for these two elements of the program is maintained by Snootli Hatchery).

2.1.3 *Dead Pitch and Sampling:*

The final phase of the mark recapture program was the dead pitch of carcasses. 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, collection continued until no new carcasses became available.

All carcasses recovered were examined for tags, opercular punches and adipose clips. Carcasses were also checked for pre-spawn mortality and egg retention, sex, primary and secondary marks, and adipose clipped fins (AFC) indicating a fish of hatchery origin and probably an inserted coded wire tag (CWT).

Data recorded for each carcass recovered included recorders initials, date, reach, location, sex, nose fork length, and post orbital-hypural length. Presence or absence of adipose clips

and Kurl-Lock tags were recorded, and opercular punch (if present record punch scheme). Carcasses were pitched high onto the banks into areas that they would not be reintroduced below the high water mark to be counted twice.

Adipose-clipped fish (CWT) were sampled which involved removing the snout (cut snout off one cm behind the eyes) and attaching a barcoded E-label to the head with a Swiftachment gun. To insure the label was well attached, a minimum of three Swiftachers was used. Length measurements and scale samples were also taken from these fish.

Upon return to the hatchery, CWT heads were frozen individually before bagging and boxing according to date and river reach. Heads were shipped to J.O. Thomas and Associates for dissection immediately after the dead pitch portion of the project has concluded.

Scale samples and length measurements were randomly collected, with a target of 500 non-adipose fin-clipped (AFC) chinook and 200 AFC fish. Five scales from each fish were placed into a small individually numbered scale envelope for transfer to scale books at a later date and envelope # was recorded. Effort was made to sample fish with uniform spatial randomness. All fish were recorded and then disposed of according to protocol.
All scales were transferred to scale books and submitted to the Fish Ageing Laboratory at the Pacific Biological Station after the dead pitch portion of the project has concluded.

2.2 **Analyses**

Preliminary escapement estimate was calculated using the Chapman modification of the Petersen estimator (Ricker 1975). In addition, estimates based on Individual Encounter History (IEH) methods described in Velez-Espino et al. 2010 Can MS Rep 2930 were carried out. IEH provides an additional estimation process that takes place parallel to the Petersen estimation, using the latest analytical and computational developments. The IEH results are provided for informational purposes.

2.2.1 Petersen Estimate

Chinook salmon escapement estimates will be determined using the Chapman modification of the Petersen estimator (Ricker 1975):

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

where *P* is the population estimate, *C* is the total number of fish recovered, *M* is the total number of fish tagged, and *R* is the number of tagged fish recovered and includes fish with missing tags (secondary marks only). The subscript *i* is the sex stratum and the subscript r is the river stratum.

Population estimates for sex and river strata will be summed to obtain a total in-river population estimate:

$$P_t = \sum_{i=1}^{n}\sum_{r=1}^{m} P_{i,r} \qquad (2)$$

where *n* is the total number of sex strata and *m* is the total number of river strata.

2.2.2 Bias Assumptions

Several assumptions made within the Peterson mark-recapture method:

- All fish have an equal probability of capture (application) and recapture (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
- Closed Population Assumption - there is no immigration or emigration between marking and recovery
- Fish do not lose their marks, all marks are recognizable and reported upon encounter

All fish have an equal probability of capture (application) and recapture (recovery):
This assumption was addressed throughout the program with spatial and temporal standards. During tagging and dead pitch, multiple crews operated in separate reaches each day, each reach was sampled on a consistent schedule on alternating weekdays.
The tangle nets used do not discriminate between larger fish and capture method does not discriminate between marked and unmarked fish assuming their behaviour does not differ. It should be noted however that the larger size of the mesh used in the tangle nets does select against fish smaller than approximately 460mm POH length, most often jacks. This has been a consistent bias within the program for the past several years because a small mesh seine net

is generally not used. The net and capture methods used do not discriminate between marked and unmarked fish assuming their behaviour does not differ.

The fishing methods employed attempt to encounter and capture all fish within the river system of pools, riffles and glides. In areas of the river such as log jams or deep pools, which cannot be accessed by the net, crews use various methods to scare fish out of these areas. Additional crew members at the bottom of the set will prevent fish from escaping downstream; the intention is to capture all fish within the sample area.

Marked fish mix completely with unmarked fish between marking and recovery:
Multiple tagging locations improve the mixing of marks throughout the population.
Tagging effort was kept constant to ensure all chinook were targeted, a comparison of tagged and untagged recoveries would indicate if the tagging and recovery efforts were random.

Marked fish suffer the same mortality rate as unmarked fish:
In order to address this assumption, measures were taken during tagging and recapture events to ensure that the handling associated with tagging and recapture did not result in increased mortality.

All fish were handled with care and the handling time was kept to a minimum. All fish were observed to ensure were fully upright and appeared in good condition prior to release; if fish were in in poor condition or exhibited signs of stress they were revived and monitored by one of the divers until they swam away on their own. Record was made of any fish which required revival or appeared to be in less than good condition upon release.

Marked and unmarked fish behave the same:
Chinook salmon were tagged with an uncoloured #3 Ketchum Kurl-Lock operculum tag and secondary mutilation punch. The tag does not noticeably change their behaviour. Tags and marks are small and placed in the mid-operculum area to reduce the likelihood that the marked fish would be targeted by predators or by sampling crews. Furthermore, the tag does not stick out and is unlikely to snag or catch on structures in the river.

Closed Population Assumption:
The study area was limited to the Atnarko River. The Atnarko River may not meet the strict definition of a closed system as there is potential for immigration or emigration from the Talchako or Bella Coola Rivers. However, spawning in the Bella Coola River and tributary creeks occurs earlier than the Atnarko and is completed before the Atnarko chinook start to spawn. Based on observations made by Snootli Hatchery staff over several decades, chinook spawn is almost non-existent in the Talchacko River which shares its confluence with the Atnarko River (J Willis, pers.com).

Fish do not lose their mark, all marks are recognizable and reported upon encounter:
Kurl-Lock tags do not appear to make carcasses more obvious to samplers during any parts off the program, each live fish or carcass required close inspection in order to detect a tag. During tagging and brood stock collection each net set is examined by multiple crew members; first for distressed fish and then for tagged fish which are then removed and processed. During processing of the remaining fish each one is also examined for tag and secondary operculum punch (indicating a lost tag).
During dead pitch each carcass is examined for tag and operculum punch by hand, each side of the head is examined. Double tagging allows identification of a tagged fish if the tag has been lost throughout the duration of the program. All fish that are encountered are diligently observed and information properly recorded.

2.2.3 Hatchery Contribution

Atnarko hatchery chinook production has averaged around 2 million annually with 150,000 of released fry having been adipose fin clipped and marked at the Snootli Hatchery with coded-wire tags. This enhancement has continued since the mid 1980's, usually splitting the release of juvenile fish between upper and lower Atnarko in an attempt to cover potential differences in outmigration timing between the areas. Release timings are structured to match the various life history strategies present. Direct hatchery contributions are measured and compared using several methods, the annual chinook dead pitch program is believed to be the least biased of the methods.

A random portion of adipose-fin-clipped dead pitch recoveries were sampled for scales and heads taken for CWT reading.

Estimates of the contribution of hatchery-reared chinook to the total escapement are calculated by expanding the percentage of CWTs in escapement counts by tag code. The number of successfully decoded CWT chinook in the escapement are estimated and stratified by age and sex. Percent hatchery contributions by sex and age are then calculated using the best population estimates for adult males, jacks, and females.

Historical mark presence data suggests an average hatchery contribution of approximately 40% of the spawning runs. Completed data will be analyzed by SEP but are unavailable at the time of this report. Preliminary analysis for 2016 suggests the hatchery contribution at approximately 60% for the project. This increased rate may reflect reduced survival of wild chinook resulting from flood events of 2010 and 2011.

3. RESULTS

3.1 **Petersen Estimate**

With an overall tag recovery rate of 14.6%, the pooled-Petersen procedure yielded 9,414 (95% CI: 7,716 – 11,481) females, 12,288 (95% CI: 9,936– 15,189) males and 270 (95% CI: 55– 281) jacks for a total spawning escapement of 21,971 fish (95% CI: 18,765 – 25,178). The coefficient of variation (CV) was 9.9%, 10.5%, and 68.3% for females, males and jacks respectively, and 7.3% for the entire population.

3.1.1 Tagging/Marking and Sampling:

Tagging was initiated August 19, 2016 and continued exclusively until August 31, 2016. Between September 1 and September 9 a combination of brood stock collection and tagging activities occurred. The majority of tagging (marking) was conducted using gill nets, however a seine net was used in two locations within the lower reach. The seine net results in more efficient capture of fish and reduced visible stress to fish as compared to gill nets, it is also less size selective against small fish than gill nets. The very low number of jacks encountered in tagging is likely due to the fact that larger mesh size is biased against capturing jack sized fish, and also the smaller mesh seine nets can only be used in two pools during tagging.

Suitable brood stock was transported to Snootli Hatchery and those fish not suitable for brood stock were tagged and released.

Tagging continued into the brood stock collection phase with tags applied to all fish. Some were taken to the hatchery and removed from the sample population (but useful in the IEH analysis); most females were taken for brood stock purposes and those fish not taken as brood stock were predominantly males and released to be river after tags were applied.

A total of 1,318 chinook (480 females, 821 males, 17 jacks) were tagged. As required recording for IEH (Independent Encounter History) protocol 96 chinook (38 females, 58 males, 0 jacks) were removed for Snootli Hatchery brood stock. This left a total of 1,222 chinook (442 females, 763 males, 17 jacks) respectively available for dead pitch recovery.

Scale samples were collected from 537 (239 female, 293 male, 5 jacks) live non-adipose fin clipped (AFC) chinook during tagging. Additionally, scale samples were collected from 2 (1 female, 1 male) adipose fin clipped chinook during tagging.

3.1.2 Tag Distribution and Retention:

Tagging distribution is subject to change depending on fish population densities throughout the Atnarko River; since 2013 the upper reach has not proven as productive as in previous years. The distribution of tags applied by reach for 2016 was 32.9% upper (433/1318), 18.0% middle (237/1318) and 49.2% lower (648/1318) reaches.

In past years tag loss has been a problem; caused by various reasons including poor tag placement, malfunctioning tags, opercular deterioration or physical damage in nets during recapture. For 2016 a total of 10 fish (4 female and 6 male) were identified without tags but bearing secondary markings during the dead pitch; the secondary marking provided sufficient information to allow inclusion in the Petersen population estimate.

Tagging distribution for 2016 was 32.8% Upper (433/1318), 18.0% Middle (237/1318) and 49.2% Lower (648/1318). Because of historical river access and fish abundance the majority of fish have traditionally been tagged in the upper and lower reaches (Approx. 40% Upper, 20% Middle, 40% Lower).

3.1.3 Recaptures:

A total of 147 (24 female, 123 male) separate capture events occurred between August 22 and September 9 where chinook were recaptured and released to the river. Twenty fish were recaptured once and two fish were recaptured twice over the course of the study.

3.2 Brood Stock and Sampling:

Brood stock collection where adults are removed from the river and transported to Snootli Hatchery started September 1 and continued until September 21, 2016.

A total of 1146 chinook (616 females, 521 males, 9 jacks) were spawned as part of the brood stock collection program. Of this total, 352 chinook (313 females and 39 males) were removed from the Atnarko River to Snootli Hatchery before spawning and 794 fish (303 females, 482 males, 9 jacks) were spawned on the Atnarko River.

IEH protocol requires their fate of all fish is the same; all tagged fish captured during the brood stock portion of the program were killed, spawned and removed from the study group.

Samples were taken from 86 AFC chinook (26 females, 59 males, 1 jack) on the river and from 52 AFC chinook (43 females, 9 males) harvested at Snootli Hatchery

A total of 2.15 million Atnarko chinook eggs were planted at Snootli Hatchery; close to their target of 2.3 million.

3.3 Dead Pitch and Sampling:

The first carcass was encountered on August 26 and was a pre-spawn female, the first post spawn carcass was encountered on September 7 and dead pitch activities continued until

October 6, 2016. A total of 3,403 carcasses were recovered (2,039 female, 1,350 male, 14 jack). Of the 3,403 carcasses recovered a total of 178 were tagged chinook (95 female, 83 male); 4 of the recovered carcasses (4 male) were missing their tag but were identified as tagged fish by their secondary mark. A total of 471 AFC chinook (328 female, 140 male, 3 jack) were recovered within the pitched carcasses.

Length measurements were taken from a total of 1,005 carcasses (641 females, 361 males, 3 jacks); 457 of those fish were adipose clipped (318 females, 136 males and 3 jacks) and 548 were not adipose clipped (323 females and 225 males).

Scale samples and length measurements were randomly collected from 546 non-adipose fin-clipped (323 females and 223 males) chinook and 157 Adipose-clipped fish (114 female, 40 male, 3 jack) during the dead pitch phase.

3.3.1 Recovery Distribution:

Of the 3,403 dead pitch recoveries 413 (12.1%) were from the upper section, 589 (17.3%) were from the middle section and 2,401 (70.6%) were from the lower section.

Within the upper section 233 (56.4 %) were females, 180 (43.6%) were males and 0 (0%) were jacks. Within the middle section 305 (51.8%) were females, 281 (47.7%) were males and 3 (0.5%) were jacks. Within the lower section 1,501 (62.5 %) were females, 889 (37.0%) were males and 11 (0.5%) were jacks.

Several reasons exist for this significant bias in recovery location; a 150 year flood event occurred in 2010 and washed out the only bridge accessing the upper Atnarko River; it was not replaced until the 2013 season. In 2011 and 2012, Snootli Hatchery was forced to release upper river juvenile chinook into the lower river reaches. Analysis of the 2015 CWT recovery data indicated significant straying within the upper groups to the lower, preliminary analysis indicates similar straying in 2016.

3.3.2 Egg Retention:

Visual inspection and ventral compression was applied as appropriate to all female carcasses to investigate whether individuals died after or before spawning. 2,039 females inspected during the dead pitch only two females showed 100% retention. Neither of these fish were adipose clipped, nor had they been tagged during the tagging portion of the program.

3.4 Bias Assessment

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.

3.4.1 Potential Biases in Tagging and Carcass Recovery:

Within a stratum, Petersen estimates using tagging and recovery are subject to bias depending on the extent to which these assumptions are violated (Andrew et al. 1988; Bocking et al. 1990). Tests which may be used to evaluate bias of the Petersen estimate in this study are also presented and discussed.

3.4.2 Period bias:

Temporal bias was assessed in both the marking and recovery samples. Marking bias was examined by comparing the mark occurrence in each of the recovery periods. Differences among periods were compared using the Chi-square test (Sokal and Rohlf, 1981). No significant difference was found in either the marking or recovery samples.

3.4.3 Age bias:

Size-related bias in age structure was assessed by comparing the age frequency distributions of scale samples taken during sampling phase and the dead pitch recovery phase. Scales were compared using the Kolmogorov-Smirnov two-sample test (Kolmogorov-Smirnov two-sample test: $p < 0.01$). Age frequency analysis indicated no significant differences in location or shape of frequency distributions in combined male and female groups.

Application bias was assesses by comparing NF length frequency distributions in marked and unmarked fish in the recovery sample. (Kolmogorov-Smirnov two-sample test: $p < 0.01$). Length frequency analysis indicated no significant differences in location or shape of frequency distributions of the groups.

3.4.4 Location bias:

Spatial bias was assessed using Chi-square tests.

Bias in the application sample was assessed by comparing the differences in mark incidence among recovery strata. Results showed no significant difference.

3.4.5 Fish size bias:

Size-related bias was assessed using the Kolmogorov-Smirnov two sample test (Sokal and Rohlf, 1981).

Recovery bias was assessed by comparing NF length frequency distributions in the marked and unmarked samples. (Kolmogorov-Smirnov two-sample test: $p < 0.01$). No significant bias was found.

Application bias was assessed by comparing NF length frequency distributions in tagged and untagged fish in the recovery sample (Kolmogorov-Smirnov two-sample test: $p < 0.01$). The results showed no significant difference.

3.4.6 Fish sex bias:

Sex-related recovery bias was assessed using Chi-square tests.

Recovery bias was assessed by stratifying the application sample into recovered and non-recovered components and comparing the male and female proportions in each. Results showed there was bias toward females.

Application bias was assessed by comparing the sex ratio in the marked and unmarked carcasses in the recovery sample. Results showed np significant difference.

3.5 Tagging Stress:

Mark-application stress was assessed by comparing the categorical spawn retention data for the marked and unmarked females in the carcass recovery sample using Chi-square tests.

Visual inspection and/or ventral compression was applied to 2,039 female carcasses; 1,944 (95.3%) untagged and 95 (4.7 %) tagged to investigate whether individuals died after or before spawning.

Only 2 of the total 2,037 females inspected (99.37%) were noted as 100% retention and the rest were not recorded as having any lesser level of retention. In past seasons lower levels of retention were noted and allowed analysis of partial retention levels, for 2016 it is not possible to determine the amount of partial retention for 2016. However, chi-square test indicated that egg retention, as an indicator of pre-spawning mortality was independent of tag status.

3.6 Age-Specific Spawning Escapement

Scale Age Structure-

Atnarko chinook scales are difficult to read for age. A total of 1,406 chinook scales were submitted to the laboratory and 1,138 individual fish were successfully aged. This analysis

indicated that 0.9 % of samples corresponded to age-2 fish, 17.0 % to age-3 fish, 49.8 % to age-4 fish, 31.3 % to age-5 fish and 1.0 % to age-6 fish.

The analysis of freshwater versus marine annulus indicated that 92.4% of the sample corresponded to ocean-type fish while 7.6% corresponded to stream-type fish. At the age-specific level 100% of the age-2 fish, 98.4% of the age-3 fish, 94.9% of the age-4 fish, 87.1% of the age-5 fish and 33.3% of the age-6 fish exhibited ocean-type life history.

CWT Age Structure –
Analysis of the age structure of 587 total CWT sampled fish indicated that 0.68% (4/587) of the sample corresponded to age-2 fish, 4.1% (24/587) corresponded to age-3 fish, 42.4% (249/587) corresponded to age-4 fish, 50.3% (295/587) corresponded to age-5 fish and 2.6% (15/587) to age-6 fish.

Analysis of freshwater versus marine annulus indicated that 90.6% of the sample corresponded to ocean-type fish while 9.4% corresponded to stream-type fish. At the age specific level 100% of the age-2, age-3 and age-4 fish, 85.8% of the age-5 fish and 13.3% of the age-6 fish exhibited ocean-type life history.

3.7 Hatchery Contribution

Hatchery contribution was calculated at approximately 61% from expanded CWT results.

The incidence of AD clipped fish encounter throughout the project varied; 15.7% (207/1,319) during tagging, 13.7% (273/1,988) during brood stock and 13.8% (471/3,403) during dead pitch.

4. DISCUSSION

4.1 **Evaluation of Results**

The purpose of this study was to provide an estimate of the 2016 Atnarko River Chinook spawning escapement using modified Petersen Mark Recapture techniques with a CV of 15% or less and the results for the experiment, a combined escapement of escapement of 21,971 chinook (95% CI: 18,765 – 25,178) and a CV = 7.3% met that objective.

Several sources of error have been addressed over the past 7 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 brood stock, recaptures and losses-on-capture have been eliminated to the greatest extent possible. Additional refinements such as those applied in 2016 provide better results in both the Petersen estimates and the application of IEH analysis.

The Atnarko operational protocol requires collection of data in addition to that required by Petersen method, it requires detailed record of every fish encountered and results in extra work for field crews. However, the extra effort involved is offset by the benefits these additional modelling techniques and subsequent data analysis provide; estimation of survival and immigration rates, analysis of migration phenology and stream residence times and unbiased estimates of spawning escapement. Thus, the use of mark-recapture experiments based on individual encounter histories offers great opportunities for optimization of both information and cost (Velez Espino 2009).

Preliminary escapement estimate was calculated using the Chapman modification of the Petersen estimator (Ricker 1975). In addition to the population estimation using the Petersen estimator, analysis based on Individual Encounter History (IEH) methods (described in Velez-Espino et al. 2010 Can MS Rep 2930) were carried out in conjunction with this project. The continued calibration of the IEH methodology is made for interest sake as some of the data collection and field methods are tailored to ensure proper collection of these data.

4.2 **Escapement into the Bella Coola watershed**

The majority of chinook that enter into the Bella Coola River swim upstream to spawn in the Atnarko River. However, a small group of lower Bella Coola tributary spawners are enumerated, these Bella Coola Chinook are believed to make up a very small component (~ 300 fish on average) of the overall system. When one considers that the Bella Coola River Nuxalk Fishery caught an estimated 2,319 chinook in 2016 and the estimated sport river fishery catch of 1,000 chinook (D. Wagner pers. com) the number of Atnarko chinook escaping ocean fisheries and commercial net fisheries into the Bella Coola River is estimated to be approximately 25,000 when using the spawning escapement produced by the Petersen model.

4.3 **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. Several recommendations implemented in 2015 proved successful and seem to have addressed the majority of issues. Consequently only a small number of recommendations were brought forward for the 2016 season, all were successfully implemented.

List of recommendations for 2016:

1) *The use of opercular tags on brood stock held at Snootli hatchery is problematic, a significant portion of fish experience tag loss in the concrete raceways. Recommendation was to use different tag such as Floy 'spaghetti' tag near dorsal area.*
2) *Revisit and update Program Safety Plan, acquire additional safety and First Aid equipment and EMS protocol.*

Both of the recommendations were successfully introduced for 2016 and will continue to be applied into the future.

1) *Individually numbered Floy T-bar Anchor Tags were applied to all chinook returned to Snootli hatchery and tag loss was negligible using this approach.*
2) *The EMS Safety Plan was updated with better communication and evacuation protocols for each reach. Level 3 First Aid kits with oxygen systems and spine boards were purchased and kept at predefined muster stations in Reaches 1 and 3 that allowed access for any crew. An additional Level 2 First Aid kit and spine board was kept at the local West Coat Helicopter base for incidents within Reach 2. Emergency response and evacuation protocols were strengthened for all crews and areas.*

There are a few specific challenges for the 2017 season; specifically the building at the Atnarko Spawning Channel was destroyed by fire in February 2017. This building is used as a muster point for First Aid and evacuation response as well as a point for communication.

5. ACKNOWLEDGEMENTS

Thank you to Pacific Salmon Commission for financial support, BC Parks and local property owners for access to the Atnarko River. We would like to thank A. Krimmer and DFO stock assessment staff, J. Willis and the field crews of the Snootli Hatchery for their continued co-operation and hard work to make this project successful. Thanks to C. Masson, I. Winther, and A. Velez-Espino for biological and scientific support in the ongoing improvement of field techniques and data analysis protocols.

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7. FIGURES

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

Figure 2. The Atnarko River drainage.

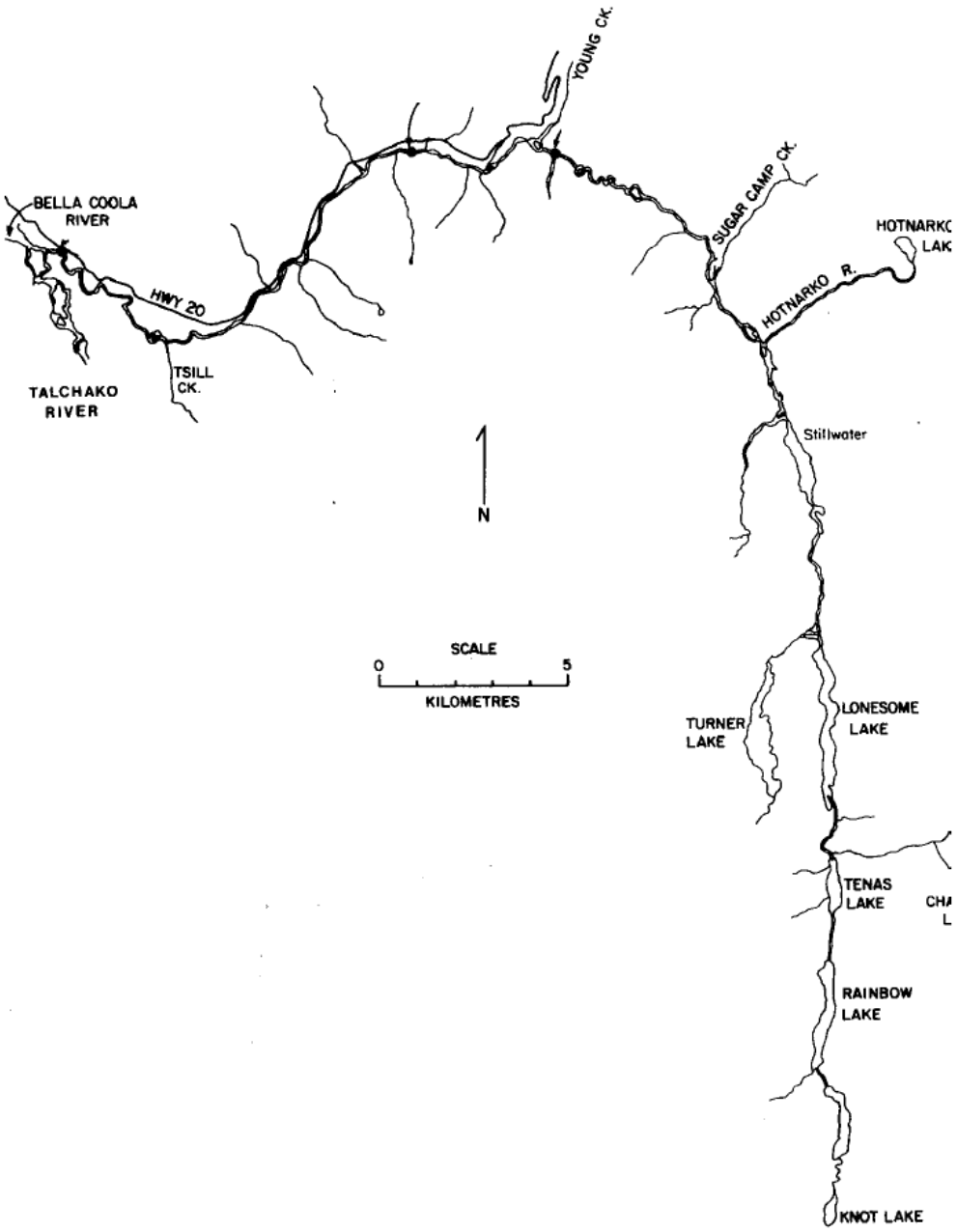


Figure 3. Map showing Atnarko River project sample area.

8. TABLES

Table 1. Atnarko Chinook Mark Recapture Results 2001-2003, 2009-2016.

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%

Table 2. Petersen Escapement Estimation 2016

ATNARKO RIVER MARK RECAPTURE 2016

Petersen Calculations

	Recovered	Deadpitch Carcasses	Tags in Broodstock	Tagged (original)	Tagged (corrected)
F	95	2036	38	480	442
M	83	1353	58	821	763
J	0	14	0	17	17
	178	3403	96	1318	1222

	Marked	Recovered	Carcasses	Modified Peterson	95% lower limit	95% upper limit	CV	Variance	Standard Deviation
F	442	95	2039	9414	7716	11481	9.9%	870602.0	933.1
M	763	83	1350	12288	9936	15189	10.5%	1665870.3	1290.7
J	17	0	14	270	55	281	68.3%	34020.0	184.4
Total (F+M+J)	1222	178	3403	21971	18765	25178	7.3%	2570492.3	1603.3
F+M	1205	178	3389	21701	18516	24887	7.3%	2536472.3	1592.6

Table 3. Summary of tagging effort for the Atnarko River 2016 Mark Recapture experiment.

Count of marks applied by reach												
	Lower Reach			Lower Reach Total	Middle Reach		Middle Reach Total	Upper Reach			Upper Reach Total	Grand Total
Date	Female	Jack	Male		Female	Male		Female	Jack	Male		
19-Aug-16	44	2	34	80								80
22-Aug-16	64	3	64	131								131
23-Aug-16								12		29	41	41
24-Aug-16	11	1	18	30				12		21	33	63
25-Aug-16	23		17	40	10	7	17					57
26-Aug-16	19		26	45	11	16	27					72
29-Aug-16					16	22	38	9	1	12	22	60
30-Aug-16	34	1	35	70	15	14	29	30		39	69	168
31-Aug-16	15	1	17	33	12	19	31	4		1	5	69
1-Sep-16		2	51	53				20		49	69	122
2-Sep-16									3	76	79	79
6-Sep-16									1	81	82	82
7-Sep-16					24	32	56		1	32	33	89
8-Sep-16	73	1	81	155	19	20	39					194
9-Sep-16	3		8	11								11
Grand Total	**286**	**11**	**351**	**648**	**107**	**130**	**237**	**87**	**6**	**340**	**433**	**1318**

Table 4. Summary of recapture effort for the Atnarko River 2016 Mark Recapture experiment; recaptures released to river.

Recaptures Released to River										
	Lower Reach		Lower Reach Total	Middle Reach		Middle Reach Total	Upper Reach		Upper Reach Total	Grand Total
Date	Female	Male		Female	Male		Female	Male		
19-Aug-16	1	2	3							3
22-Aug-16	1	8	9							9
24-Aug-16		1	1				4	2	6	7
26-Aug-16		3	3		1	1				4
29-Aug-16					1	1				1
30-Aug-16				1	2	3	4	2	6	9
31-Aug-16	2	4	6	4	5	9				15
1-Sep-16		4	4				2	11	13	17
2-Sep-16							1	21	22	22
6-Sep-16								26	26	26
7-Sep-16					3	3		16	16	19
8-Sep-16				4	4	8				8
9-Sep-16		1	1					6	6	7
Grand Total	**4**	**23**	**27**	**9**	**16**	**25**	**11**	**84**	**95**	**147**

Table 5. Summary of recapture effort for the Atnarko River 2016 Mark Recapture experiment; recaptures taken to Snootli Hatchery.

Recaptures to Hatchery							
	Lower Reach		Lower Reach Total	Upper Reach		Upper Reach Total	Grand Total
Date	F	M		F	M		
1-Sep-16	6		6				6
2-Sep-16				3		3	3
6-Sep-16				3		3	3
8-Sep-16	2		2				2
9-Sep-16	1		1				1
16-Sep-16		1	1		1	1	2
Grand Total	**9**	**1**	**10**	**6**	**1**	**7**	**17**

Table 6. Summary of recapture effort for the Atnarko River 2016 Mark Recapture experiment; recaptures killed as brood stock.

Recaptures killed as Brood Stock							
	Lower Reach		Lower Reach Total	Upper Reach		Upper Reach Total	Grand Total
Date	F	M		F	M		
9-Sep-16	1	1	2		3	3	5
12-Sep-16	4	5	9		5	5	14
13-Sep-16				1	1	2	2
14-Sep-16	1	6	7		9	9	16
15-Sep-16				1	2	3	3
16-Sep-16	1	8	9		10	10	19
19-Sep-16		1	1		4	4	5
21-Sep-16				1		1	1
Grand Total	**7**	**21**	**28**	**3**	**34**	**37**	**65**

Table 7a. Summary of brood stock effort by tag/no tag for Atnarko River 2016 Mark Recapture

Count of Brood Stock by Tag/No Tag									
	Lower Reach			Lower Reach Total	Upper Reach			Upper Reach Total	Grand Total
Date	Female	Jack	Male		Female	Jack	Male		
1L	24		24	48					48
1R					12		33	45	45
2L	1			1	1		1	2	3
NP							3	3	3
Untagged	287	5	248	540	291	4	212	507	1047
Grand Total	**312**	**5**	**272**	**589**	**304**	**4**	**249**	**557**	**1146**

Table 7b. Summary of brood stock effort by date for Atnarko River 2016 Mark Recapture

Count of Brood Stock by Date									
Date	Lower Reach Female	Jack	Male	Lower Reach Total	Upper Reach Female	Jack	Male	Upper Reach Total	Grand Total
2016-09-09	33	1	26	60	22		19	41	101
2016-09-12	56	1	52	109	31		26	57	166
2016-09-13	42		18	60	20		18	38	98
2016-09-14	63	1	67	131	53	3	43	99	230
2016-09-15					28		21	49	49
2016-09-16	67	2	54	123	63		57	120	243
2016-09-19	43		35	78	58	1	43	102	180
2016-09-21	5		15	20	21		17	38	58
2016-09-23					1		2	3	3
2016-09-26			1	1	1		1	2	3
(blank)	3		4	7	6		2	8	15
Grand Total	**312**	**5**	**272**	**589**	**304**	**4**	**249**	**557**	**1146**

Table 8. Summary of dead pitch effort for the Atnarko River 2016 Mark Recapture experiment

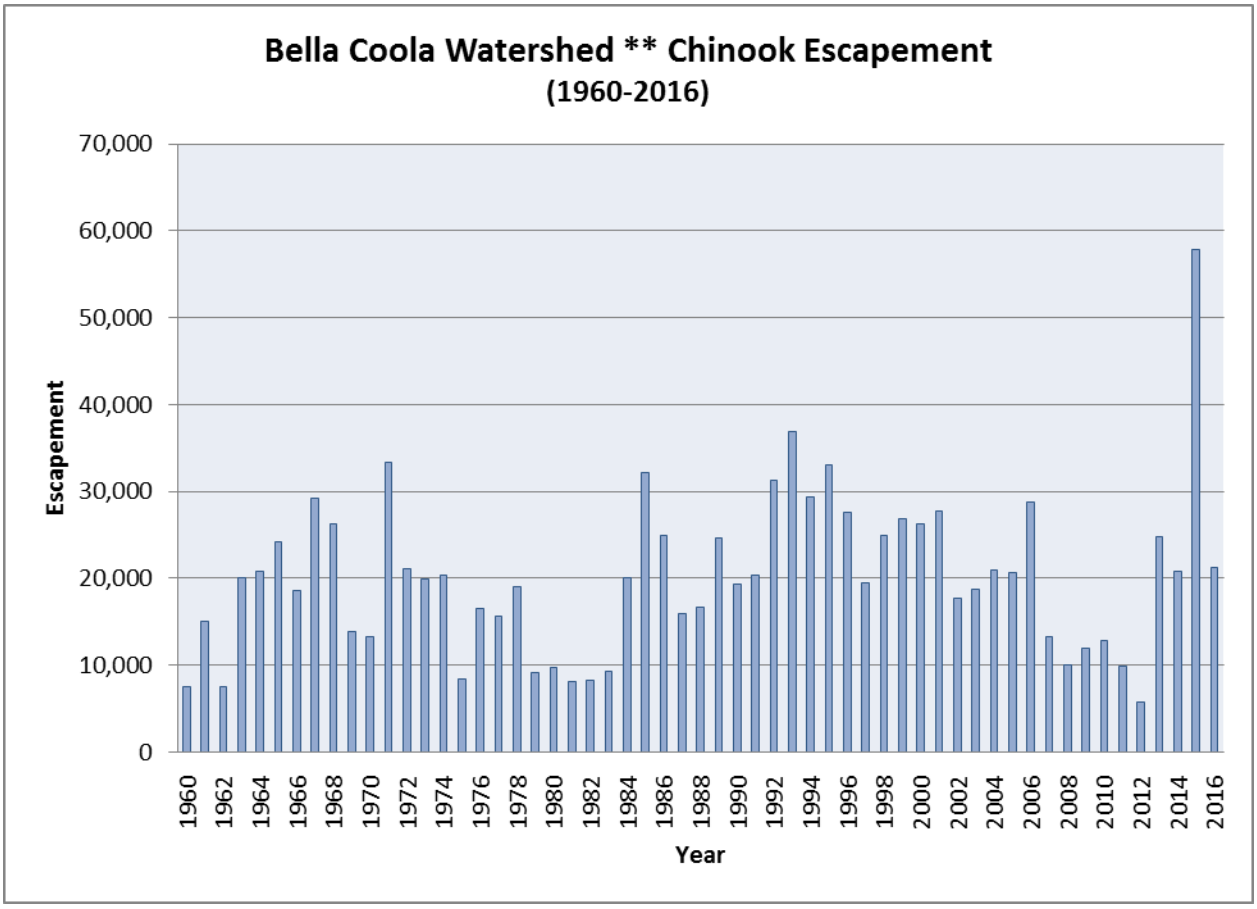
Count of Carcass Recovery by Sex												
	Lower Reach			Lower Total	Middle Reach			Middle Total	Upper Reach		Upper Total	Grand Total
Date	Female	Jack	Male		Female	Jack	Male		Female	Male		
26-Aug-16	1			1								1
7-Sep-16										1	1	1
12-Sep-16	2			2								2
13-Sep-16	6			6					1		1	7
14-Sep-16	3		1	4								4
15-Sep-16									4	1	5	5
16-Sep-16	5		2	7					7	3	10	17
19-Sep-16	65	1	24	90					20	15	35	125
20-Sep-16	101	1	61	163	43		43	86	11	14	25	274
21-Sep-16	128		49	177	49		32	81	24	18	42	300
22-Sep-16	180		81	261	51	2	46	99	43	43	86	446
23-Sep-16	217		159	376	48		26	74				450
26-Sep-16	180	4	123	307	67	1	77	145	32	19	51	503
27-Sep-16	124	1	74	199	35		42	77				276
28-Sep-16	275	3	155	433								433
29-Sep-16	39	1	28	68					37	20	57	125
30-Sep-16	40		33	73					33	29	62	135
3-Oct-16	89		61	150					5	1	6	156
4-Oct-16	31		16	47	2		3	5				52
5-Oct-16					10		12	22	16	16	32	54
6-Oct-16	15		22	37								37
Grand Total	**1501**	**11**	**889**	**2401**	**305**	**3**	**281**	**589**	**233**	**180**	**413**	**3403**

Table 9. Summary of tag recovery in dead pitch for the Atnarko River 2016 Mark Recapture Experiment

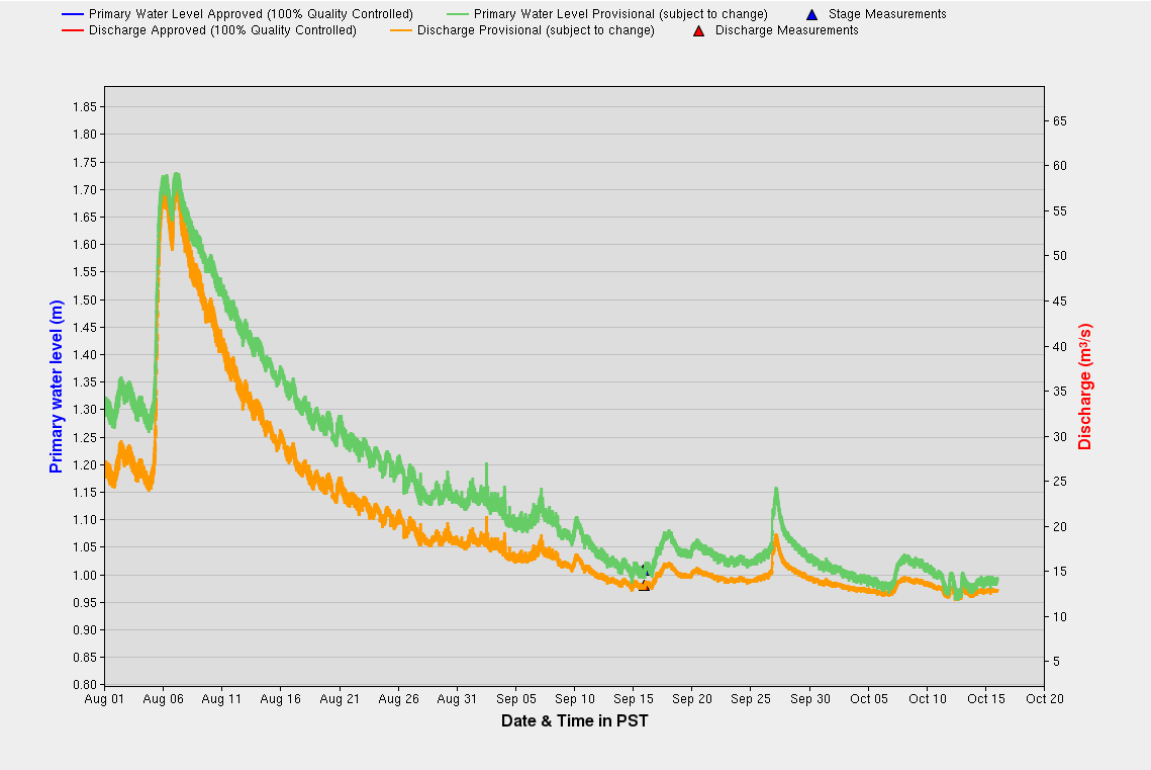
Tag Recovery	Column Labels										
	Lower Reach			Lower Reach Total	Middle Reach			Middle Reach Total	Upper Reach		Upper Reach Total	Grand Total
Date	Female	Jack	Male		Female	Jack	Male		Female	Male		
26-Aug-16												
7-Sep-16												
12-Sep-16	1			1								1
13-Sep-16									1		1	1
14-Sep-16												
15-Sep-16									1	1	2	2
16-Sep-16										1	1	1
19-Sep-16	5		1	6						6	6	12
20-Sep-16	3			3	2		4	6		2	2	11
21-Sep-16	10		3	13	4		1	5		4	4	22
22-Sep-16	12		9	21	3		1	4	1	7	8	33
23-Sep-16	13		7	20	5		2	7				27
26-Sep-16	4		9	13	1		1	2	3		3	18
27-Sep-16	1		6	7	1		2	3				10
28-Sep-16	10		6	16								16
29-Sep-16	4		1	5						1	1	6
30-Sep-16	5		3	8					1	2	3	11
3-Oct-16	2			2					1		1	3
4-Oct-16	1			1								1
5-Oct-16										3	3	3
6-Oct-16												
Grand Total	**71**		**45**	**116**	**16**		**11**	**27**	**8**	**27**	**35**	**178**

9. APPENDIXES

Appendix A. Bella Coola Watershed (Atnarko River) Chinook Escapement 1960-2016.



Appendix B. Time series of Atnarko River water level and discharge for the period of August 1, 2016 - October 15, 2016, Station 08FB006 [BC]. Source: https://wateroffice.ec.gc.ca



Appendix C. Tagging/Dead Pitch Form

Atnarko Chinook Tagging or Deadpitch — 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)	E -label	Egg-Ret. (%)	Comments

Appendix D. Brood Stock 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 2016

Atnarko Chinook Recapture*

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

* These fish are all released alive

Appendix F. Yearly Program Changes and Events 2010 to 2015

a. 2010

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

b. 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 Rd) were only assessable via ATV because of road damage that occurred in the 2010 flood.

c. 2012

- During brood stock 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.
- Bio sampling will occur on live Chinook as they are being tagged. In past years bio sampling was only performed on dead Chinook.
- The upper two river reaches (along the Tote Rd), are again, 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.

d. 2013

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

e. 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.

f. 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.

g. 2016

- Fish taken to Snootli hatchery were marked with a unique Floy T-bar Anchor Tag. This allowed the fish to be tracked until the day they were spawned and did not incur the higher loss rate found using Aluminum Kurlock opercular tags.

Appendix G. Tagging effort for the Atnarko River 2016 Mark Recapture experiment.
(.pdf file attachment)

Appendix H. Recapture effort for the Atnarko River 2016 Mark Recapture experiment.
(.pdf file attachment)

Appendix I. Brood stock effort for the Atnarko River 2016 Mark Recapture experiment.
(.pdf file attachment)

Appendix J. Dead pitch effort for the Atnarko River 2016 Mark Recapture experiment.
(.pdf file attachment)

Appendix K. Sampling effort, scale and age results for Atnarko River 2016 Mark Recapture experiment.
(.pdf file attachment)

Appendix L. Hatchery Contribution Summary from Coded Wire Tag Head Samples 2016
(.pdf file attachment)