Validation of Chinook salmon Age, Sex, and Length sampling on the East Fork Andreafsky River weir, and East Fork Andreafsky River Chinook salmon ASL carcass survey.

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Summary:

1. **Introduction**: Chinook salmon ASL information has been collected in the Yukon River drainage for decades and is used by managers to track changes in the age, sex, and length (ASL) composition of the Chinook salmon runs. On the East Fork Andreafsky River, Chinook salmon ASL data was collected via carcass surveys by Alaska Department of Fish & Game (ADFG) from 1980 through 1994 and again in 1996. Since 1994 the U.S. Fish & Wildlife Service (USFWS) has collected Chinook salmon data via a resistance board weir. The combined data set is valuable for tracking long term ASL trends in this system; however, these trends are difficult to analyze because of the biases associated with each of the different sampling techniques (Zhou 2002, Murdoch et al. 2002). For example, carcass surveys have been shown to be biased towards larger fish, which are generally female Chinook salmon. Conversely, data from weirs are assumed to be unbiased (Cousens et al 1982), and the sampling method and size (160) adequate to estimate the population characteristics (Cochrane 1977, Symons and Waldichuk 1984).
In 2009, an effort to census the Chinook salmon population of the E. F. Andreafsky River was undertaken by attempting to capture, sample, and mark all Chinook salmon passing through the weir, followed by a multi-day carcass survey at the end of the spawning season. It was speculated this would allow us to understand the true population parameters for ASL data which could then be used to evaluate the degree of associated biases at this location. Overall, this project was initiated to evaluate the direction and magnitudes of these biases (Objective 1 and 2) and determine if a conversion factor could be created that would allow these two data sets (weir and carcass) to be analyzed together (Objective 4). It was hypothesized that if a conversion factor could be created then the two data sets could be analyzed together and used to estimate parameters of past escapements to the E.F. Andreafsky River. We were unable to address Objective 4 due to the limitations of the data that was collected.

A computer sampling model was created using the programming language R (R development core team, Vienna, Austria) to simulate the sample method used at the weir. This model was then applied to the census data collected in 2009 by strata. Model results were evaluated to understand how the weir sampling methodology performed. Statistical analyses were performed on hourly

and daily counts of ASL data from the weir, to look for significant trends that could influence ASL composition estimates. We hypothesized that if the current sampling design were adequate, there would be no significant difference between the results of the computer simulated sample and that of the known population (census).

Objectives:

1. Estimate the bias of the weir's current Chinook salmon Age, Sex, and Length (ASL) composition estimators.
2. Estimate the bias of alternative weir Chinook salmon ASL composition estimators.
3. Estimate the bias of carcass sampling ASL composition estimators.
4. Estimate the functional relationship between carcass and weir ASL composition estimators.

2. Study Area: The Andreafsky River is located in the lower Yukon River drainage, northeast of the Village of St. Mary's, Alaska (Figure 1). The Andreafsky is one of the three largest Yukon River tributaries within the Yukon Delta National Wildlife Refuge (Refuge) boundaries (USFWS 1991) and drains a watershed of approximately 5,450 km^2. The main stem Andreafsky River and the East Fork Andreafsky River parallel each other flowing in a southwesterly direction for more than 200 river-kilometers (rkm) and converge 7 rkm above their confluence with the Yukon River. The mouth of the Andreafsky River is approximately 160 rkm upstream from the mouth of the Yukon River. The main stem Andreafsky River and East Fork Andreafsky River flow through the Andreafsky Wilderness and the portions of each river within Refuge boundaries are designated as Wild and Scenic Rivers. The weir is located 43 rkm above the confluence of the Yukon and Andreafsky rivers (62° 07' N, 162° 48.4' W).

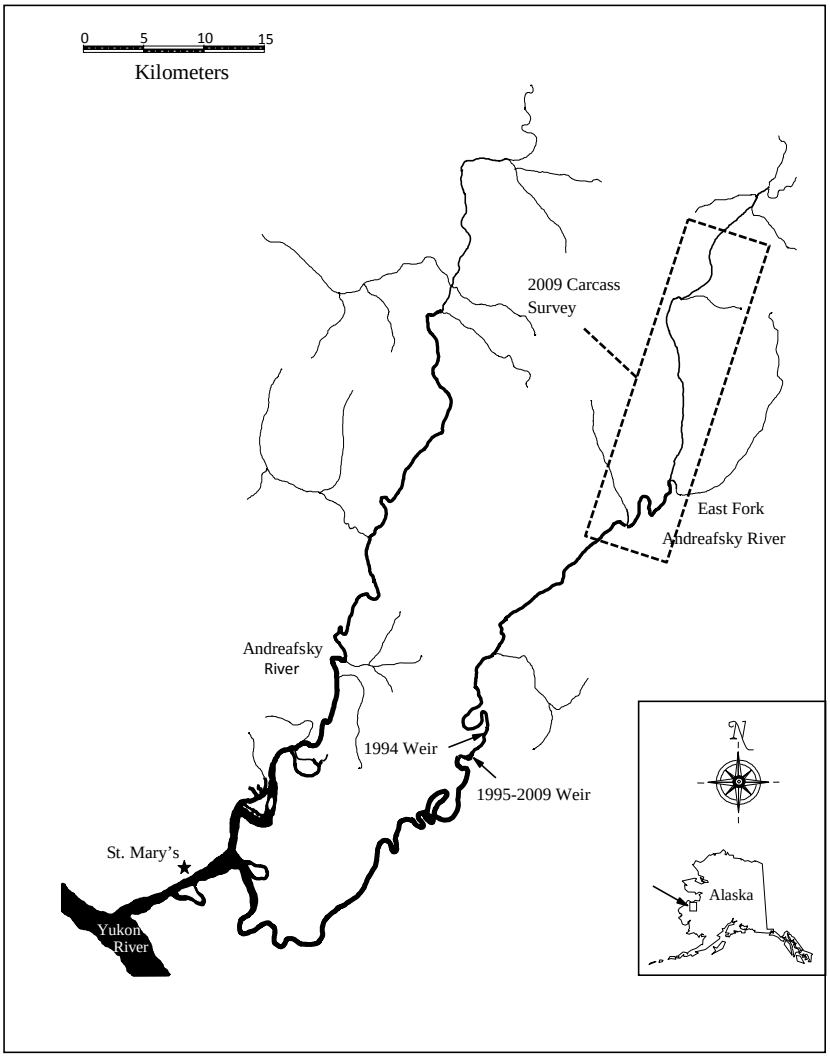

Figure 1. Weir location and carcass survey area on the East Fork Andreafsky River, Alaska.

3. Licenses and Permits: Land use permit #LAS 18,885 has been executed by the Alaska Dept. of Natural Resources for the field camp location, and a sample collection permit was issued by the Alaska Dept. of Fish and Game prior to the beginning of field data collection.

4. **Methods:**

Operation:

Fish Weir: A resistance board weir was used to sample Chinook salmon for ASL and escapement data between June 20 and August 3, 2009. For the analyses conducted in this project the weir operation time period was divided into four strata: Strata 1 = July 1 to July 11(n= 226), Strata 2= July 12 to July 18(n=554), Strata 3=July 19 to July 25(n=748), and Strata 4 =July 26 to August 3(n=1053). A stratified random sampling design is currently used at the E. F. Andreafsky River weir. A target of 160 fish is sampled for ASL in each week (strata) according to Cochran

(1977). Data is then weighted and used to characterize the run. This sampling method was designed so that simultaneous 90% interval estimates of the sex and age will have maximum widths of 0.20 for each week (strata). All Chinook salmon passing through the weir were marked with an adipose fin clip for identification during the subsequent carcass surveys. For more specific information regarding the sampling methodology, refer to Maschmann 2010a.

Carcass Survey: The carcass survey began on August 15, twenty-three days after the midpoint of the run at the weir, and ended on August 21. The carcass survey occurred as two strata; 260 carcasses were sampled for ASL data in the first strata running from August 15-18, and 140 carcasses were sampled for ASL data during the second strata running from August 20-21. The Chinook salmon spawning grounds on the East Fork Andreafsky River begin approximately 40 rkm upstream of the weir (figure 1). Adequate sample size was determined to be 400 carcasses (pers. comm. Larry du Bois ADF&G). Detailed methods for the carcass survey are described in Maschmann 2010b.

***Data Analysis*:**

We used the statistical package R to analyze and estimate biases within and between the fish weir data (census), simulated sample, and carcass survey data. The assumptions while modeling the weir data were:

1) The stratified random sample taken at the weir is spread out evenly through the course of the run and each day, and can be approximated using a random sample without replacement within the computer model.

2) In strata where the cumulative run total for the period was below 160, all fish will be included in that strata, or sample size must be adjusted within the model for that strata.

3) The procedures used at the weir minimize sampler bias that cannot be accounted for with this model, e.g. during a sample draw from the cage, all individuals of the target species (Chinook) are sampled.

4) There are no significant temporal trends in ASL characteristics over the course of the run, or day, which could bias sampling that could not be adequately controlled by random sampling.

5) No fish are allowed to pass the weir un-sampled. (Note: This assumption was not met; however the information and implications are addressed.)

We began by having the model divide the Chinook salmon sampled during the census by strata. The model then randomly sampled 160 fish from each stratum without replacement. The model compiled counts of the samples drawn from each stratum into a matrix and then returned the desired ASL characteristic that was being assessed for that test. For each test the model would perform 1,000 iterations, and then calculated the proportion of these results which fell within a specified percent of the known population. The results were given logical values of 1 or 0 in each

iteration; one if the value was within the specified range, and zero if it was not. The results were then summed and divided by 1000 to calculate the percent of time 1000 iterations were within specified range. The model was also manipulated to adjust the number of samples drawn from each stratum. For this study, the performance of the sampling protocol was determined at the strata level.

Weir Efficiency and Relationship to Carcass Survey:

To estimate the efficiency of the run, and the functional relationship between the weir and carcass ASL composition estimators we evaluated four specific population parameters within the model.

1) *Age class distribution by sample size and by strata from fish weir*. The sample size was adjusted within the model for a range of values above and below the current 160 samples collected at the weir during routine sampling, (50, 100, 160, 200, 250, and 300). The performance measure was the percent of the iterations that returned a value that was within a percentage (10, 20, and 30 %) of the known population determined with the census, in each strata. Error bars are presented as the percent of un-ageable scales applied to the data as a maximum possible error measure, for example if 10 percent of the male census scales could not be aged and were applied to a single age class.

   Each sex per strata was also tested at the current 160 sample size too see how often the result of each iteration was within a percentage (10, 20, and 30%) of the known population determined with the census. This question addresses quality of escapement passing the weir, and the confidence we have in evaluating this parameter.

2) A*ge composition and* s*ex ratio between sampling methods*. To test if the age composition and sex ratio were different between the carcass sample and the weir census (known population), a chi-square goodness of fit test was used. Binomial hypothesis tests were to be used if the carcass survey differed from the census data.

3) *Temporal trends in sex ratio.* Logistic and linear regression models were used to look at temporal variation in the run as a whole and for each sex. Logistic models looked at the probability of capture for male Chinook salmon by date and time of day. Linear models looked at time of day by ranking the 24 hours in a day, by light conditions on the river and ranking from 1 through 6, Both Cumulative and daily counts were assessed.

4) *Length frequency distribution.* A Kolmogorov-Smirnov test for equality in length frequency distribution was used to examine the difference in length distribution between the carcass survey and the known population. Data from male and female Chinook salmon were analyzed separately. A two-sided test was performed for each sex; then one-sided tests were performed to test whether or not biases seen in other studies persisted in the 2009 carcass study.

5. Results and Discussion:

***Fish Weir Data*:**

In 2009, the estimated total run of Chinook salmon through the weir was 3,004, of which, 2,582 were sampled for ASL data, approximately 86% of the returning population. The remaining 14% were allowed to pass un-sampled during times when passage rates were extremely high to reduce stress to the fish. Dates on which fish passed un-sampled were: July 12 (n=49), July 14 (n=74), July17 (n=66), July28 (n=96), July29 (n=18), July31 (n=15), and August 1(n=66) however, fish were still counted as they passed to build the census, and efforts were made to record the sex of those fish which passed un-sampled. The scale cards for one day were lost on July25 (n=22). Of 2,582 Chinook salmon that were sampled at the weir, age information was available for 90% of the scale samples. Therefore, of the 3,004 counted Chinook at the weir, 77% were aged. Of the 1,065 aged female Chinook samples, 16 were age class 1.2 (Age $_4$), 57 were age class 1.3 (Age $_5$) and 982 were age class 1.4 (Age$_6$). Of the 1,401 aged males, 555 were age class 1.1 (Age $_3$), 305 were age class 1.2 (Age $_4$), and 380 were age class 1.3 (Age $_5$). The number of un-ageable males and females were 156 and 114 respectively. The ratio of male to female of un-ageable samples were within 10% of the weir census sex ratio; 58% of the un-ageable scales were from males, 42% were female, the census was 67% male and 33% female for the 2582 sampled. In years where high numbers of scales are unreadable, it may be beneficial to create length at age key for each sex, and apportion those fish appropriately. The sample size is large enough to accommodate this technique. Chinook that were sampled in 2009 for which an age could not be determined are included in the dataset (available by request). The method used was the semi random technique described by Isermann and Knight (2005).

All Chinook salmon sampled at the weir were marked. However, due to discrepancies between the ratio of marked to unmarked Chinook salmon recovered in the carcass survey, it appears that fish passed the weir un-sampled (Figure 2). The high percentage (41%) of unmarked fish in the carcass survey suggest that more Chinook passed the weir than were counted, or the survey was biased towards those individuals that passed in the highest numbers during times when fish were not being sampled at the weir. Also, the run in 2009 was later than average and Chinook were still moving past the weir when it was removed possibly adding to the number of unmarked fish seen in the carcass survey (Figure 5). The final sample stratum was the largest of the four sample strata in 2009 (Appendix A).

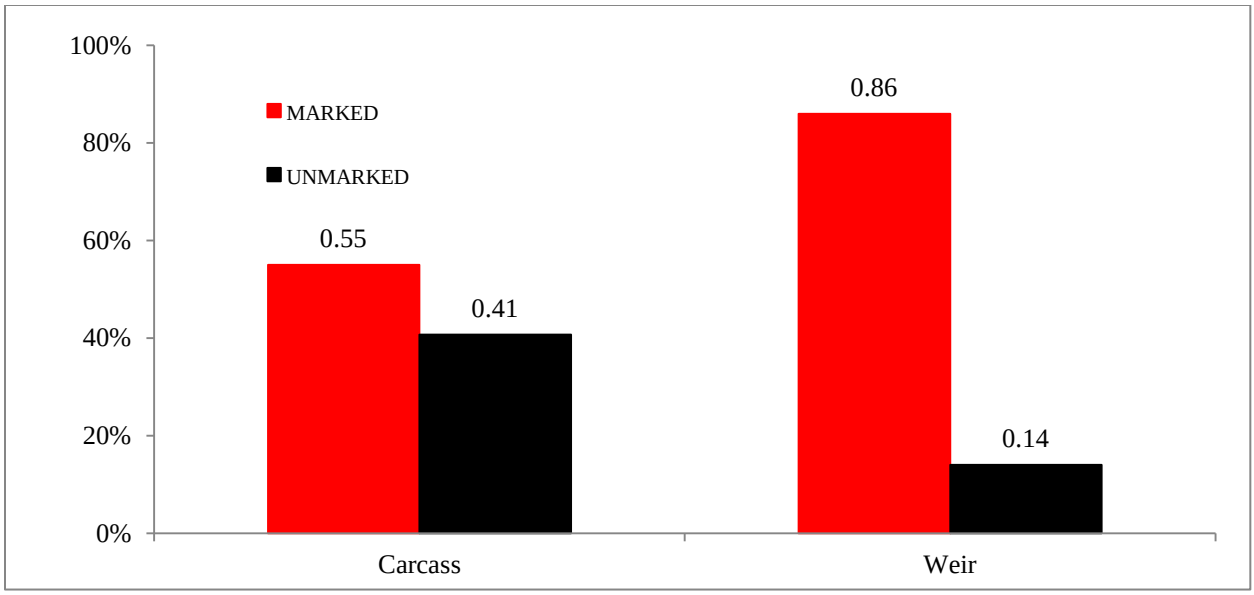

Figure 2. Percent of MARKED to UNMARKED Chinook salmon sampled in the carcass survey and during the census at the weir. UNMARKED at the weir are based on the 3,004 counted versus 2,582 sampled and counted during the census. Carcass sample marks are not estimated, this graph reflects the actual proportion of the 400 carcasses sampled. The ratio of MARKED to UNMARKED did not vary significantly between male and female in the carcass survey.

Carcass Survey:

The target goal of 400 Chinook salmon carcasses was reached during 2009, approximately 13% of the fish counted through the weir (3,004). Forty six percent of the carcasses sampled were male and 54% were female. Efforts were made in both 2010 and 2011 to repeat the carcass survey. However, in both years high-water led to low carcass recovery and produced results which were unusable for comparison. With paired data from only one year a conversion factor could not be created due to the statistical limitations of the dataset. However, the carcass survey data from 2009 is useful in assessing how well it characterized the 2009 census at the weir. With 86% of the estimated passage sampled, approximately 14% of the carcasses should be unmarked. The actual percent of unmarked carcasses is 41%. This leaves open scenarios of fish passing un-sampled or counted during or after the weir census, or reflects the bias of carcass surveys in general. By using a Chapman modification Peterson estimate we can derive the following population estimate.

$$N = \left(\frac{\frac{2{,}582 + 1}{240 + 1}}{400 + 1}\right) - 1 = \sim 4{,}298\ Chinook$$

Where 2,582 fish were marked at the weir, 400 were subsequently sampled in the carcass survey and of that 400, 240 were marked. The count from the weir was 3,004 Chinook salmon and our Peterson estimate is 4,298, a difference of 1,294 salmon. As stated previously the weir was removed before the run had stopped, and some salmon were allowed to pass un-sampled, but counted. This makes our estimate of 3,004 conservative, but it is unlikely that 1,294 salmon

passed during or after the census. The Peterson estimate likely represents the combined effects of carcass sample bias and uncounted/un-sampled Chinook salmon; unfortunately it is not possible to assess the magnitude to which each contributes to inflated population estimate derived from the Peterson model. A common bench mark for carcass surveys is to sample 20% of the population of interest, in this case 600 Chinook salmon. Or, we could refer to Thompson's (1987) guidelines for sampling multinomial distributions and choose a significance level of 0.10 and then use a finite population correction to arrive at the desired sample size of 355, then adjust for the precision of our carcass sample aging results, on average 85% ageable, which gives us a age error adjusted sample size of 418 carcasses. This is a difference of 18 carcasses between the actual number collected and the calculated sample needed, and theoretically should be adequate to represent the population. It is important to note that this sample size should accurately represent the distribution of the population being sampled but does not have the ability to make any assumption about size of the population being sampled. In fact, without the data from the weir count it would be impossible to use the finite population correction. Subsequent statistical analysis back up these results and show that we have captured the distribution of the weir census for both sexes in terms of males and females individually, however, we did not accurately represent the length frequency distribution of males or the proportion of each sex in a given age class. It does however suggest that an adequate sample was collected in the 2009 Carcass survey for the estimated census population of 3,004 Chinook. The disagreement in terms of length frequency distribution is likely a violation of the sampling assumption of equal probability of recovery for carcasses favoring larger males (Zhou 2002). This suggested the bias was size and not behavior related.

Age Characterization

Weir Efficiency and Relationship to Carcass Survey:

Age class distribution by sample size and by strata from fish weir for Female Chinook.

Age class 1.4 (Age $_6$) was the only age class that was consistently characterized accurately for the test at all sample sizes (Table 1). At the lowest sample size (50), the model was within 10% of the known population 83% of the 1,000 iterations. Error estimates are not included as they followed a normal distribution around the known population due to the nature of random sampling used in the computer model. Age classes 1.3(Age 5) and 1.2(Age 4) were consistently inaccurate, being within 10% of the known population less than 30% of the time, and within 20% of the known population less than 58% of the time. This suggests that we should have some confidence in our ability to accurately estimate the dominant age class(es), in this case Age $_6$ female Chinook salmon, but careful about the degree of accuracy for smaller age classes. While this may complicate our understanding of the smaller age classes it is important to note that better than 90% of all the females sampled were age class 1.4(Age 6). Furthermore, the performance of the modeled sub-sampling across the range of sample sizes suggests that the current sample size performs as well at 160 fish per strata and in some cases better, than it does with larger sample sizes for the smaller age classes (Table 1). For males, where age classes are more evenly distributed, the sampling model is more accurate for all the age classes (Table 2).

The even distribution likely limits the number of results that are easily skewed. In table 2 for males at the 20% level we can see that we meet the goal of being within 20% of the actual value approximately 94% of the time for age class 1.1 (Age $_3$) males, however accuracy dropped as sample size increased.

Table 1. Percent of time sample method performed within a given percent of the known population value by age class for female Chinook salmon. Currently the sampling regime at the weir collects data from 160 fish (*). Numbers in bold signify results that were within a known proportion at least 90% of the time.

	10%			**20%**			**30%**		
n=	**Age 4**	**Age 5**	**Age 6**	**Age 4**	**Age 5**	**Age 6**	**Age 4**	**Age 5**	**Age 6**
50	0.00	0.07	0.83	0.00	0.23	**1.00**	0.00	0.34	**1.00**
100	0.00	0.18	**0.94**	0.00	0.39	**1.00**	0.00	0.56	**1.00**
160*	0.19	0.18	**0.99**	0.27	0.49	**1.00**	0.30	0.66	**1.00**
200	0.09	0.30	**0.99**	0.25	0.50	**1.00**	0.46	0.71	**1.00**
250	0.12	0.28	**0.99**	0.23	0.58	**1.00**	0.33	0.86	**1.00**
300	0.16	0.27	**0.99**	0.25	0.56	**1.00**	0.39	0.80	**1.00**

Table 2. Accuracy in distribution of age classes in strata test results. Cell values indicate the percent of the 1,000 iterations that were within the given percentage by age class, sex, and strata. Numbers in bold signify results that were within a known proportion at least 90% of the time.

			Strata 1	**Strata 2**	**Strata 3**	**Strata 4**
10%	**Female**	**Age 4**	35.5	11.1	0	0
		Age 5	00.1	09.1	20.4	17.3
		Age 6	**100**	**99.9**	**100**	**99.7**
	Male	**Age 3**	88.4	76.1	65.9	52.7
		Age 4	60.1	40.6	38.7	45.6
		Age 5	75.4	46.7	48.5	49.2
20%	**Female**	**Age 4**	63.5	28.2	0	0
		Age 5	01.6	27.5	31.3	34.6
		Age 6	**100**	**100**	**100**	**100**
	Male	**Age 3**	**99.6**	**97.8**	**93.7**	83.4
		Age 4	**90.6**	71.4	71	79.1
		Age 5	**97.7**	79.3	81.5	79.2
30%	**Female**	**Age 4**	84.9	40.1	0	0
		Age 5	30.7	48	35.5	53.6
		Age 6	**100**	**100**	**100**	**100**
	Male	**Age 3**	**100**	**99.9**	**99.8**	**96.4**
		Age 4	**98.3**	**90**	89.5	**92.8**
		Age 5	**100**	**94**	**95.5**	**96.2**
		N=	226	554	748	1053

Age composition and sex ratio between sampling methods.

Overall, the age compositions from the carcass survey and the known population were not significantly different for males (Male: X^2 =5.47, DF=3, P value = 0.14), or females (Female: X^2 =5.23, DF=2, P value= 0.073). The general pattern of age class distribution for both males and females was similar between the known population and the carcass survey (Figure 3 and 4).

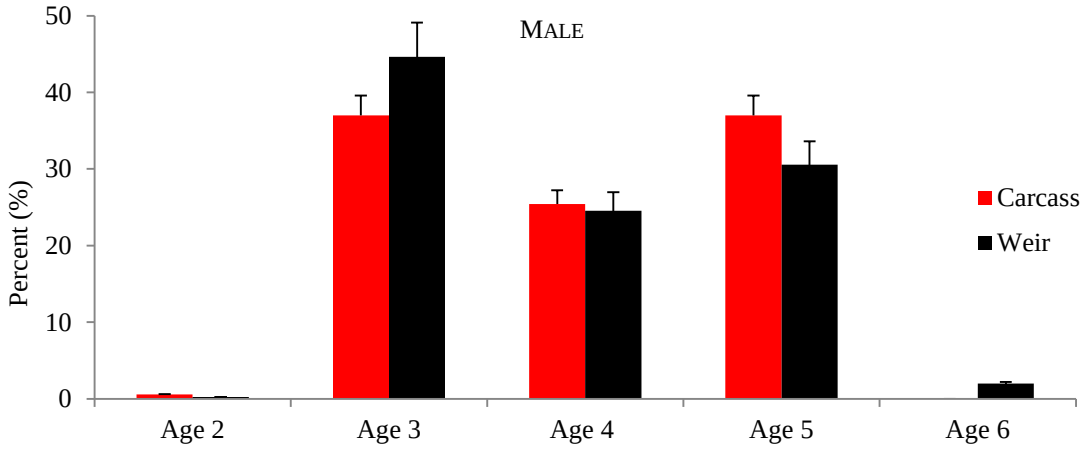

Figure 3. MALE Chinook salmon age class by percent for the weir census and the carcass survey. Error bars indicate the percent of possible error due to un-ageable scales

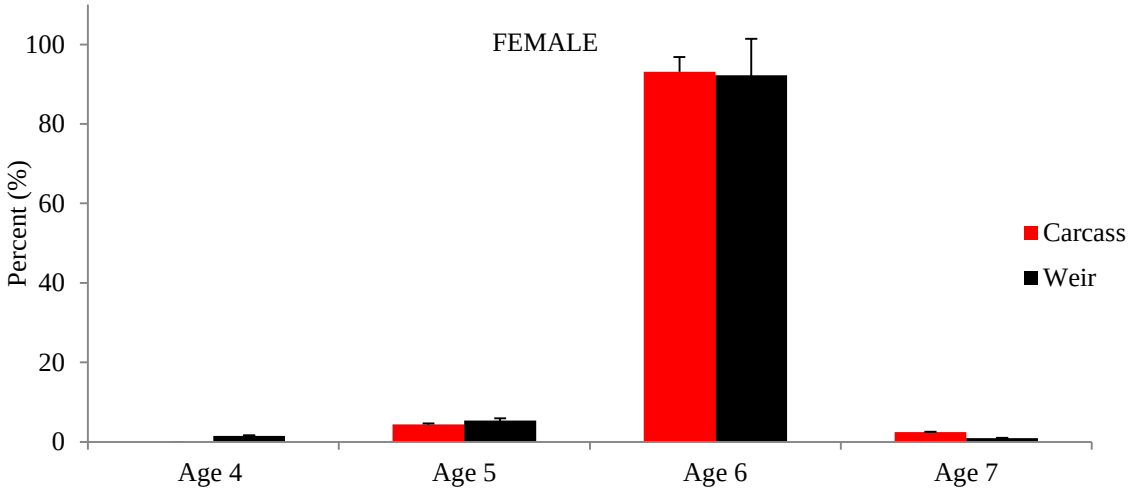

Figure 4. FEMALE Chinook salmon age class structure for weir census and carcass survey estimate. Error bars indicate the .percent of possible error due to un-ageable scales

The largest discrepancy between carcass and weir sample data was in the Chinook salmon sex ratio (Figure 5). Throughout the four strata, and when the four strata are combined, the sex ratio in the known population has a higher male contribution. Conversely, the carcass survey had a sex ratio skewed toward females. This overrepresentation of females in the carcass survey highlights one of the key areas where this sampling method misrepresents a population parameter. In short, the carcass survey was able to provide an adequate estimate of age class structure for each sex, but the numbers of individuals per sex significantly deviated from the known population. From

these results, we suggest that data from carcass surveys can provide researchers information on population characteristics within each sex, but does not provide adequate information to gain an understanding of sex ratios without accurate counts. Expanding on this, we can report the percent by which the carcass sample deviated from the census. The carcass survey was 53% female (n=213) and 47% male (n=187); The weir census was 33%female (n=846) and 67% male (n=1,736). Therefore in 2009, males were underrepresented in the carcass survey by 14%, and females were overrepresented 20% (figure 3). For this to be turned into a functional relationship by which we could reconstruct past runs based on carcass data we would need to know that adequate sample sizes had been collected; in reviewing data from past carcass surveys (1980-2011, n=18) for the East Fork Andreafsky River, sample sizes range from 25 to 400, with an average of 177 carcasses recovered; 2009 was the largest Chinook carcass sample ever collected on the East Fork. This average is well below the sample size necessary at the 0.10 significance level, but could be acceptable for a 0.20 significance level for infinite population per Thompson's (1987) recommendations. However, there are still no reliable run estimates, which leave between sex comparisons unreliable. Multiple years of side by side comparisons to see if this relationship is repeated are needed to create a valid functional relationship, if possible.

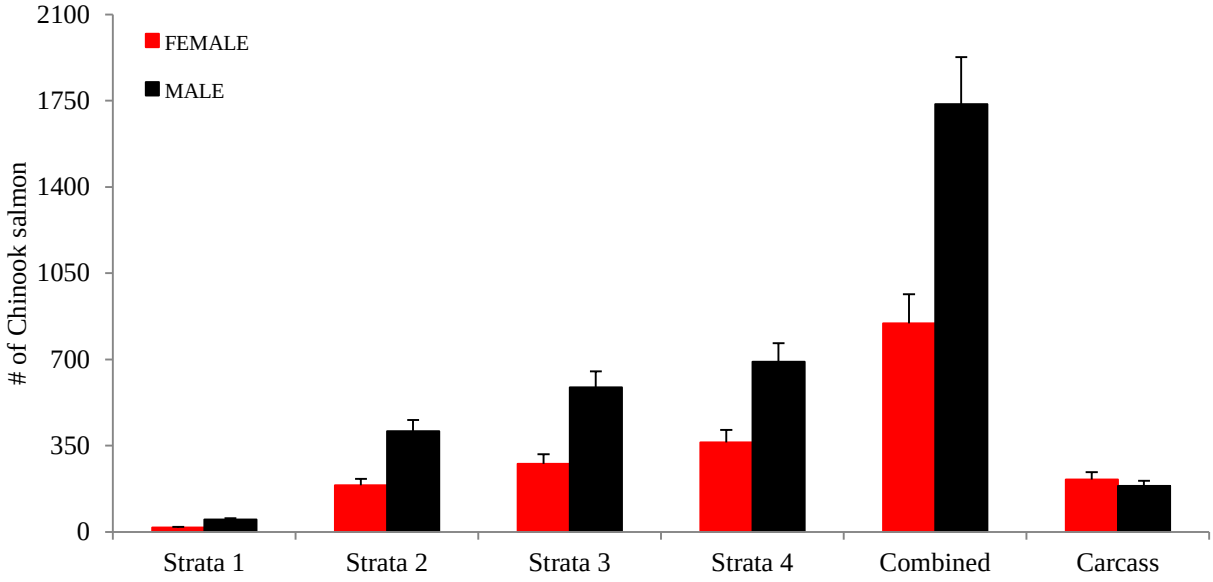

Figure.**5**. Number of MALE and FEMALE Chinook salmon by sample strata from the weir sampling and from the 2009 carcass survey, E.F. Andreafsky River. Strata 1-4 are actual counts of Chinook salmon that were sampled and sexed. The error bars indicate the percent of the run which was allowed to pass without sampling but was counted.

3) Temporal trends in sex ratio.

A multiple logistic regression was used to look at hourly (Time) and daily (Date) trends for males and females passing the weir. "Male" or "Not Male" was defined as the nominal (dependent) variable, and time of day, and day in the run, were the continuous independent variables. Overall, there was a significant downward trend over the course of the run (Date) resulting in the decreased odds of capturing males as the season progressed by a factor of 0.97 on day to 0.46 on day 32 (Table 3; Figure 6 and 7). However, hourly (Time) trends were not

significant, meaning there was no clear pattern over the course of a 24 hour sample period where the probability of capturing a particular sex was higher. This satisfied the assumption that there was no trend for male and female percent in hourly capture from any time of the day that could not be accounted for using a stratified random sample. Linear regression models varied widely however, no combination of variables led to significant R^2 Values. There was an increase in weir passage during the evening between 8pm-12am for both males and females. The most important trend documented was characteristics of the male to female ratio of the pulses. During the pulses the percent of female increased as the pulse passed. The second half of all 4 pulses was dominated by females and the returned to being male dominated in the troughs and buildup of each pulse (figure6). In figure 6 each of the pulses is approximately 4 days long; It is important to spread the sampling over the entire statistical week to ensure that large portions of pulses do not pass un-sampled.

Table 3. Results from the multiple logistic regression examining the number of male Chinook salmon caught with date and time of day as the independent variables in the model. The model was reduced to the single variable of day in run from which the stated odds are presented.

	Estimate	SE	z-value	p-value
Intercept	858.61	238.96	3.59	<0.001
Date	-0.021	0.01	-3.59	<0.001
Time	-0.005	0.01	-0.79	0.43

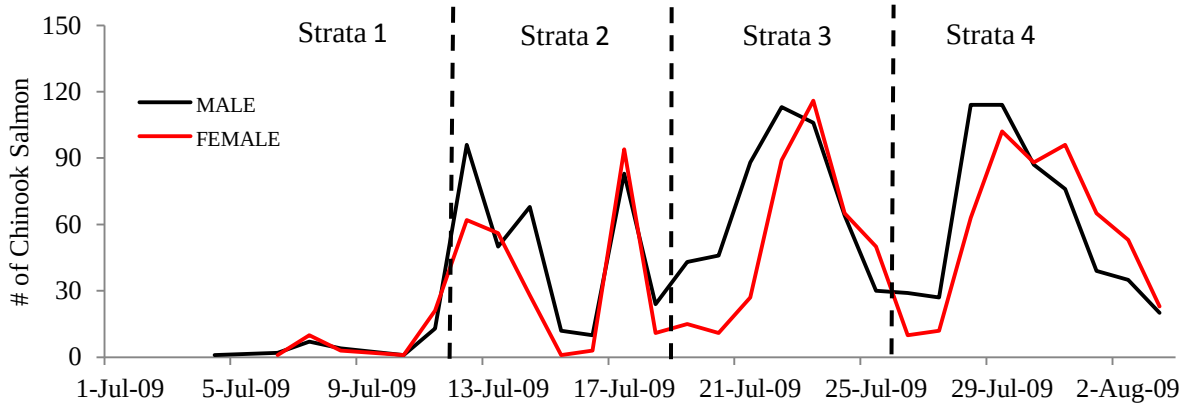

Figure 6. Line plot of MALE and FEMALE Chinook salmon counts by date at the E.F. Andreafsky River weir, 2009.

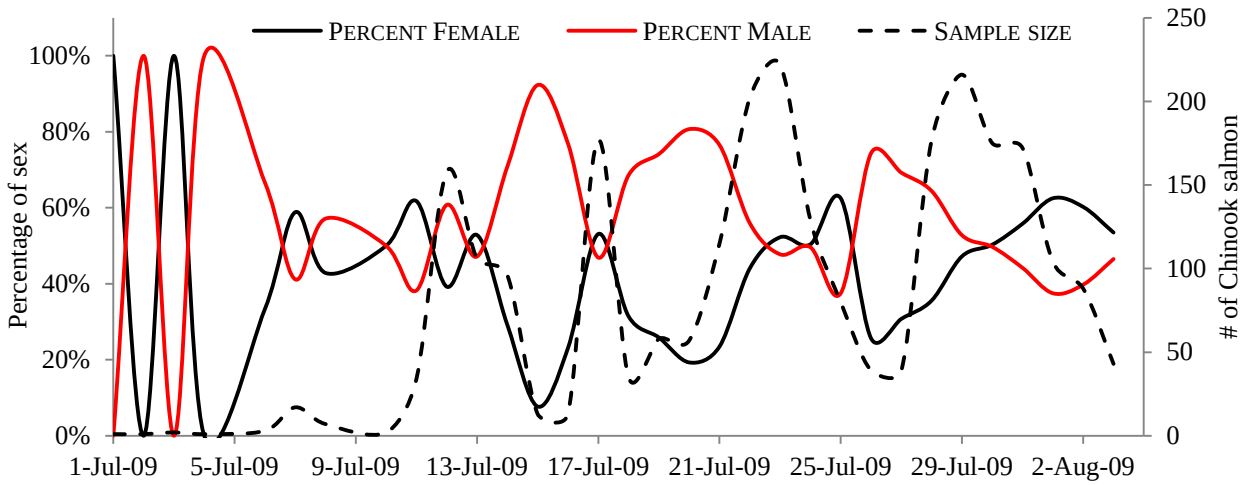

Figure 7. Percent MALE and FEMALE Chinook salmon by date and number passing the E.F. Andreafsky weir by date.

4) Length frequency distribution.

The length distributions for males and females sampled from the carcass survey were tested with population (census) using a Kolmogorov-Smirnov test. Males were significantly different, but not females. (Length $_{male}$, D= 0.1088, P= 0.0412; Length $_{Female}$, D=0.0411, P =0.921). Furthermore, the Kolmogorov-Smirnov test has the ability to test the hypothesis of one sampling methodology being biased high or low. We tested the hypothesis that males sampled in the carcass survey were longer in length than that of the known population. Results were significant (Length $_{male}$, D^{-}= 0.11, P= 0.02006) and support the findings of previous studies that have suggested that carcass surveys are biased towards larger fish. Table 4 presents the mean lengths for both male and female Chinook and supports the results of the of the statistical tests; mean length for males in all age classes was larger for the carcass survey than for weir census.

Table 4. Average total lengths (MEFL) from Chinook salmon sampled during the 2009 weir and carcass surveys, E. F. Andreafsky River, Alaska.

		Female			Male		
Age		**Mean Length (mm)**	**n**	**STD DEV**	**Mean Length (mm)**	**n**	**STD DEV**
3	**Carcass**	-	-	-	340	1	-
	Weir	-	-	-	397	3	83
4	**Carcass**	-	-	-	595	64	45
	Weir	597	16	91	579	555	48
5	**Carcass**	783	9	41	724	44	64
	Weir	774	57	58	707	306	58
6	**Carcass**	829	189	48	807	64	56
	Weir	833	982	43	797	380	53
7	**Carcass**	837	5	56	-	-	-
	Weir	868	10	31	880	2	71

Conclusion:

Results of this project suggest that the current weir sampling regime of collecting of 160 samples per strata is useful for looking at the most abundant age classes, but performance decreases with small age classes or closely proportioned age classes as seen in male portion of the 2009 census. The associated biases that occur appear to be random and driven by smaller sample size rather than biases which occur from a selective bias created by samplers or run characteristics. The strength of our sampling design is fully dependent on technicians not drawing all samples in short windows of opportunity. Given that the majority of samples for males and females come from the well represented age classes, the sample size is appropriate. Furthermore, a full census should be performed again with strict protocols in place to tie hourly count data to individual fish ASL data. This would eliminate some error when combining hourly escapement data to ASL data. It would also allow for a direct comparison between two data sets as opposed to just one example (2009 census). The outcome of this effort suggests that we should be confident in estimates of our dominant and most productive age classes age 1.4 (Age $_6$) females and age class 1.2 (Age $_4$) males, in 2009, yet inferences drawn from age classes which are not well represented should be viewed as being at best within 30% of the actual value for males and females. Efforts made to decrease sampling bias at the weir will help to alleviate problems associated with disproportionate age classes. Sampling at the weir should be conducted 7 days a week or be distributed in a truly random fashion, in a way where concurrent days are not skipped (e.g. four day sampling/ three day off schedules). Special attention should also be paid to times when large pulses of fish are moving through the weir; any disruption where large pulses of fish pass the weir un-sampled should be documented as well as possible and sex recorded. This would be insightful in terms of the quality of escapement.

In a year where the weir is not in operation or becomes inoperable, it may be useful to utilize a carcass survey; however, age structure of the population would be the only statistically sound data collected. We could assume that female length could also be inferred, but Zhous' 2002 study of carcass survey data demonstrates that recovery is based on size and flow; we do not have adequate flow data for 2009 to develop this sort of relationship. The outcome of this project suggests that a reasonable conversion factor between carcass data and census data is not appropriate at this time. The carcass survey portrayed the age class distribution well, but was unable to provide any information regarding the quality (i.e., sex ratio or length distribution) of the escapement in past years without an accurate count of the runs. Further , it is imperative that future carcass surveys follow strict protocols and enhanced marking techniques to truly understand bias.

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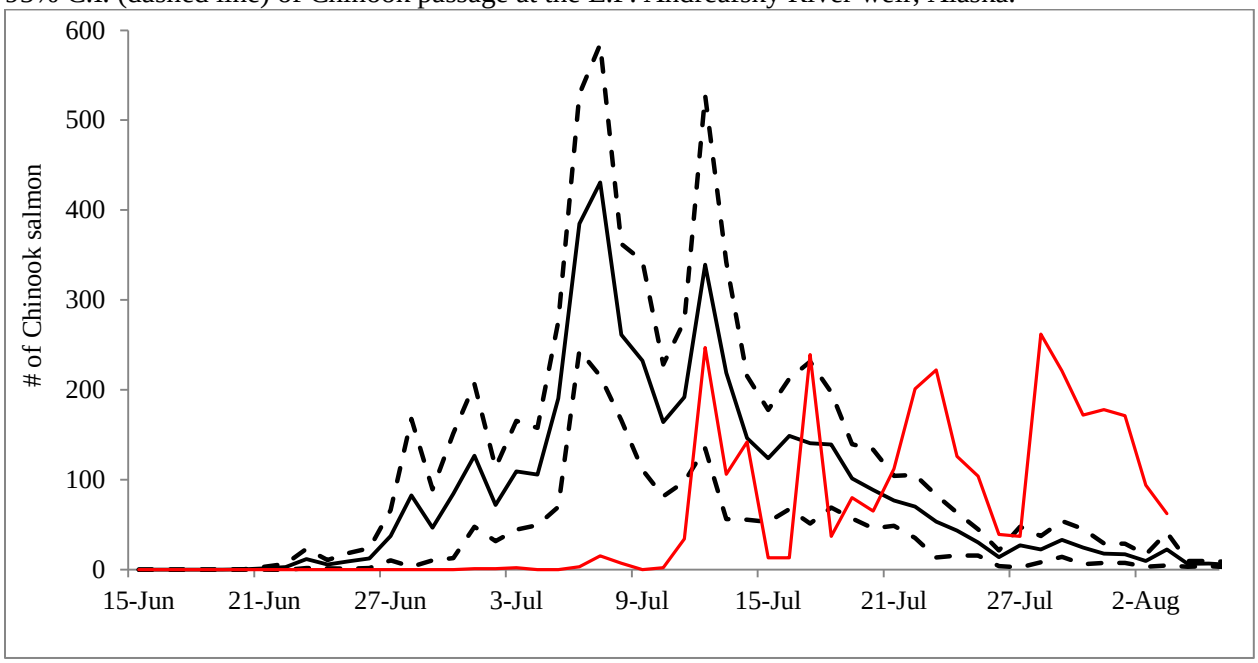
Appendices:

Appendix A. 2009 daily (red line) and historic daily average run size (1994-2008; bold black line) with 95% C.I. (dashed line) of Chinook passage at the E.F. Andreafsky River weir, Alaska.



Appendix B. Chinook Carcass survey sample size 1980-2011(ADF&G/AYKDBMS)

Year	Sample Size
1980	35
1981	228
1982	237
1983	199
1984	277
1985	136
1986	104
1987	207
1988	202
1989	88
1990	363
1991	275
1992	28
1993	313
1996	42
2009	400
2010	25
2011	31