Chandalar River Fall Chum Age, Sex, and Length Sampling Evaluation.

R&M# 03-11

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1. **Introduction**:

Summary:

Accurate salmon escapement estimates are necessary for effective salmon management, and concurrent age and sex data from those escapements greatly enhance the value of escapement data (Hilborn and Walters 1992; Parsons and Skalski 2010). Age, sex, and length (ASL) data improves the ability to predict future run strengths, evaluate management decisions, and allows better informed decisions in the future.

Carcass surveys or counts have been used to gather a variety of data, including abundance, biological samples, and demographics, as well as data regarding marine nutrients and other ecological topics (Crawford et al 2007). Several sources of potential biases in data collected from salmon carcass surveys have been identified or proposed. The probability of salmon carcass recovery has been shown to be dependent on size and sex, for example there may be a lower probability of recovering smaller fish and males (Zhou 1999, 2002; Crawford et al 2007). Similarly, differences in behavior of males and females on the spawning grounds may affect the spatial or temporal distribution of carcasses (Neville et al 2006; Crawford et al 2007). Additionally, factors such as the amount of organic debris present in the stream, flow rates, high flow events, and channel morphology can all affect carcass movement and deposition (Cederholm et al; Crawford et al). All these factors should be considered when using data from carcass surveys or counts.

The Chandalar River is a tributary of the Yukon River in interior Alaska and contains the largest population of fall chum salmon *Oncorhynchus keta* in the entire Yukon River drainage, often accounting for 25%–30% of the entire estimated fall chum salmon run entering the Yukon River (JTC 2012; Melegari 2011). Escapement monitoring, using various sonar technologies, has been conducted on the Chandalar River from 1987-1990 and from 1994 – present (Daum et al 1992; Melegari 2011). Throughout these periods ASL data has been intermittently collected using different methods. Early data collected using gill nets at the sonar site were determined to be unreliable due to biases of samples collected with gill nets (Daum et al 1992). More recent efforts have used data collected from carcass surveys on the spawning grounds. While not as demonstrably biased as the samples from gill net catches, there are still concerns regarding potential bias of these samples and the sampling scheme used to collect the samples. Replication of carcass surveys within a season is customary. However, due to the remoteness of the spawning grounds, the often inclement weather conditions, and associated high costs, the samples from the Chandalar River have been collected during a single sampling event. This event was usually scheduled as late as possible, considering weather conditions, to try to arrive during what was expected to be the peak of die off.

1) to collect vertebrae for aging, and sex and length data from fall chum salmon carcasses on the Chandalar River. 2) to collect ASL data over multiple carcass sampling events to investigate the amount of variability within the survey data; and 3) determine if a single sampling event represents the spawning population on the Chandalar River as accurately as multiple sampling events.

***Objectives**:*

The objectives of this project were:

1) To collect vertebrae for age, sex and length (ASL) data from fall chum salmon carcasses on the Chandalar River;

2) to collect ASL data over multiple carcass sampling events to investigate the amount of variability within the survey data; and

3) determine if a single sampling event represents the spawning population on the Chandalar River as accurately as multiple sampling events.

The null hypothesis being that the proportions of sexes and age distributions would be the same for all sampling events.

2. Study Area:

The Chandalar River is a fifth-order tributary of the Yukon River draining the southern slopes of the Brooks Range. It consists of three major branches, the East, Middle, and North Forks (Figure 1). Principal water sources include rainfall, snowmelt, and, to a lesser extent, melt water from small glaciers, and perennial springs (Craig and Wells 1975). Summer water levels and turbidity are highly variable, depending on rainfall, and during the fall water levels usually exhibit a declining trend as headwater areas begin to freeze. The region has a continental subarctic climate characterized by the most extreme temperatures in the state, -41.7° to 37.8° C (U.S. Department of the Interior 1964). Precipitation ranges from 15 to 33 cm annually with the greater amount falling between May and September. The river is typically ice-free by early June and freeze-up begins to occur in late September to early October.

Fall chum salmon are known to spawn in the East Fork and main-stem of the Chandalar River (ADF&G 2012) during late September and October. The ASL sampling from carcasses has occurred in the main-stem Chandalar River just upstream of the village of Venetie, (Figures 1 and 2). The river throughout this area is braided with many channels, gravel islands, and bars. Specific sampling locations during 2012 were; site 1=N 67° 03.937′ W 146° 56.974′ and site 2=N 67° 06.144′ W 147° 07.019′ (Figure 2).

3. Licenses and Permits: State of Alaska Department of Fish and Game Fish Collection Permit #SF2011-084.

4. **Methods:**

***Operation**:*

Three sampling events were scheduled: survey 1= September 28-29, survey 2= October 11-12, and survey 3= October 22-23. To maintain consistency with sample collections during previous years a goal of 180 samples was set for each survey. Samples were collected from the same site during surveys 1 and 3 (site 1); while samples were collected from two sites during survey 2 (site 1 and site 2).

Sampling procedures during each survey, with the exception noted below, were the same as previous years. An R-44 helicopter was used to survey the spawning area for concentrations of spawned out fish. Upon location of concentrations of spawned out fish, all dead or dying fish near the shoreline at that site were sampled to reduce possible sampling bias. The exception was during survey 2 when the carcass sampling survey and an effort by Alaska Department of Fish and Game to collect genetic samples were combined. During this combined trip some live fish were snagged to obtain adequate genetic samples. The intention was that the genetic samples from the snagged fish would be in addition to the normal carcass collections for ASL data. However, miscommunications resulted in a portion of the ASL samples being collected from the snagged fish, although the exact number was not recorded, and the snagged samples were not identified. Fish were measured to the nearest 5 millimeters, mid-eye to the fork of the tail (METF). The sex of specimens was determined by external morphology or by dissection of the carcass and visual identification of reproductive organs if sex was not obvious from external morphology. Vertebrae were collected, cleaned, and provided to the Alaska Department of Fish and Game for aging.

***Data Analysis*:**

A Chi-Square test using Minitab® (State College PA) software was used to compare the variability in the sex ratios and age classes among the three sampling events.

5. Results:

The three sampling events were successfully completed: survey 1= September 28, survey 2= October 11-12, and survey 3= October 22. The sample goal of 180 carcasses during each of the three surveys was achieved, for a total of 540 samples. Overall, samples were collected from 277 females and 263 males, resulting in an overall sample sex ratio of 51% female (Table 1), which was similar to previous years. Sex ratios (percent female) of samples for each individual survey were 53, 43, and 58% for surveys 1, 2, and 3 respectively. Ages were determined for 531 (98%) of the samples (Table 1). There were two primary age classes in the samples, 0.3 from brood years 2007, and 0.4, from brood years 2006. Age class 0.3 was predominant overall, accounting for 52% of the combined samples, with values of 57% for survey 1, 41% for survey 2, and 59% for survey 3. Age class 0.4 accounted for 41% of the combined samples, and accounted for 38, 49, and 37% of the samples for surveys 1, 2, and 3 respectively. Other age classes present were 0.5 and 0.2 (Table 1). The female samples were predominantly age class 0.3 (59%; range 48% to 64% for the individual surveys) followed by age class 0.4 (34%; range 30% to 43% for the individual surveys). Male samples were more evenly distributed between age classes 0.3 and 0.4, with 0.4 being slightly predominant (48%; range 45% to 53% for the individual surveys) followed by age class 0.3 (45%; range 35% to 51% for the individual surveys). Female samples ranged from 500 to 670 mm METF and males ranged from 510 to 695 mm METF (Table 2). For length-at-age measurements, mean lengths of male fish were generally larger than females.

Samples from survey 2 had a higher proportion of males than the other surveys (Figure 3). The Chi-Square test indicated the proportions of males and females differed significantly from expected values among all three surveys (χ^2 = 8.954, df = 2, P = 0.011), but results were not significant between surveys 1 and 3 (χ^2 = 1.125, df = 1, P = 0.289).

Similarly, age structure was found to be significantly different than expected values among all three surveys (χ^2 = 22.199, df = 6, P = 0.001), but not significant between surveys 1 and 3 (χ^2 = 0.166, df = 3, P = 0.983). Survey 2 had higher than expected counts for the older age classes (0.4 and 0.5) and lower than expected for the younger age classes (0.2 and 0.3; Figure 4). When grouped by sex, females had no significant difference in age structure detected among all three surveys (χ^2 = 7.194, df = 6, P = 0.303). However, for males, age structure was found to be significantly different among all three surveys (χ^2 = 14.544, df = 4, P = 0.006), but not significant between surveys 1 and 3 (χ^2 = 0.512, df = 2, P = 0.774; Figure 5).

To evaluate the influence of the sampling inconsistency during survey 2 several tests with a subsample from survey 2 were conducted. While records of which samples came from carcasses and which came from snagged live fish during survey 2 were not kept, all 30 samples collected on the second day were from carcasses, and the other 150 samples were a mix, with some carcasses, but mostly snagged fish. When this subsample of 30 known carcasses was compared to the 150 mixed samples the proportion of males and females did not differ significantly from expected values (χ^2 = 0.113, df = 1, P = 0.736). Similarly age structure did not differ significantly (χ^2 = 3.545, df = 2, P = 0.170) between the carcass subsample and the mixed sample. Meanwhile, significant differences in age structure were found between the carcass subsample and surveys 1(χ^2 = 14.605, df = 2, P = 0.001) and 3 (χ^2 = 17.061, df = 2, P < 0.001). However, no significant differences in the proportion of males and females were found when the carcass subsample was compared with surveys 1 (χ^2 = 1.680, df = 1, P = 0.195) and 3 (χ^2 = 3.503, df = 1, P = 0.061)

Also during survey 2, samples were collected from two different sites, site 1 (the same site where all samples for surveys 1 and 3 were collected) and site two, approximately 11 rkm upriver from site 1. During survey 2, 130 samples were collected from site 1 and 50 were collected from site 2. Chi-square tests showed no significant difference between the sample sites for both the proportion of sexes (χ^2 = 0.646, df = 1, P = 0.422) and age structure (χ^2 = 4.755, df = 2, P = 0.093). At the same time, significant differences in age structure were found between those samples collected at site 1 during survey 2 and both survey 1 (χ^2 = 12.075, df = 4, P = 0.002) and survey 3 (χ^2 = 14.722, df = 2, P = 0.001). For the proportion of sexes, a significant difference was found between those samples collected at site 1 during survey 2 and survey 3 (χ^2 = 5.697, df = 1, P = 0.017), but not for survey 1 (χ^2 = 2.012, df = 1, P = 0.156).

6. Discussion:

Survey 2 was found to be significantly different than surveys 1 and 3. Survey 2 was also the survey where a sampling inconsistency occurred, and many of the samples came from snagged live fish. This presents the question of was the difference due to the sampling inconsistency or to some other reason. If the difference was due to the change in sampling then a difference between the samples collected with the two different methods would be expected. Since there was no difference detected in either the proportions of sexes or age structure between those samples from survey 2 that were known to be from carcasses and the samples that were mostly snagged fish, this could indicate that the detected differences between survey 2 and the other surveys were not due to the inconsistency in sampling. Additionally, the fact that significant differences in age structure were found between those samples from survey 2 that were known to be carcasses and thus were collected consistently with both survey 1 and 3 also supports this conclusion. The lack of any significant difference being detected for the proportion of males and females between the survey 2 carcass subsample and the other surveys would seem to refute this conclusion. However, in both cases the proportion of males in the subsample from survey 2 was higher than expected values. Furthermore, considering the smaller sample size of the subsample, coupled with the relatively small variation in sex ratios, ratios only varied from 43 to 58% over all three surveys, it seems reasonable to assume that this conflicting result is due to the test not having the power to detect the small difference in the proportions of sexes.

An additional component to consider was the addition of a second sampling site during sample 2. No significant differences were found between the samples collected at the two different sites during that time. However, significant differences were found between samples collected during survey 2 at site1 and surveys 1 and 3 (when all samples were collected at site 1).These data indicate the addition of the second site had no detectable influence.

The significant differences that were found in both sex ratio and age structure in survey 2 leads to the rejection of the null hypothesis that the proportions of sexes and age distributions are the same for all sampling events, and implies that a single sampling event would be more susceptible to bias, and therefore less likely to be representative of the entire population than multiple sampling events. However, a multiple event sampling scheme would have some other concerns that would need to be addressed. For example, simply pooling all the sampling events would require the assumption that each sampling event represented a nearly equal proportion of the run. Otherwise samples should be weighted to account for the proportion of the run that they represent, data that may be difficult to acquire. Additionally, besides costs, one of the other reasons we have done a single survey in the past is because of the inclement weather that often occurs during that time of year. While weather was good and we were able to do all three surveys as scheduled in 2011, in the past we have had to cancel and reschedule surveys sometimes multiple times in a single year to complete one survey.

One thing to keep in mind is that while the data indicate that the differences detected in survey 2 were not due to the inconsistency in sampling, whether the difference is due to an actual change over time in the spawning population or to some other sampling bias is still unknown. Even if data from all three sampling events were the same, it would still be possible that there was a bias that remained consistent over the sample events and it wouldn't necessarily mean that the samples were not biased. Therefore, whether it is a single or a multiple event sampling scheme, without additional information, how well the samples represent the spawning population is unknown.

Recommendations:
While the data show that the sampling inconsistencies had no significant effect on the data, it does cloud the issue slightly. Repeating the study being sure to closely follow the sampling protocol could clear this issue up. Additionally repeating a multiple sampling event over several

years could lead to the discovery of any patterns that may exist, which could improve our understanding of sampling biases. However, conducting a multiple surveys without knowing how to or if the data should be weighted, or without additional data to help evaluate possible biases, a multiple event sample may not be more representative than a single sample. Ultimately, it comes down to is the quality and value to managers of the data worth the cost of obtaining it.

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Table 1. — Age and sex of fall chum salmon carcasses sampled on the spawning grounds in the Chandalar River, Alaska, 2011. Vertebrae were aged by Alaska Department of Fish and Game, unknown age indicates numbers of samples that could not be aged and were not included in age calculations.

				Brood year and age			
		Sample	Unknown	2008	2007	2006	2005
Sample dates		size	age	0.2	0.3	0.4	0.5
Sept. 28	Female	95 (53%)	4 (5%)	1 (1%)	58 (64%)	27 (30%)	5 (5%)
	Male	85 (47%)	1 (1%)	2 (2%)	42 (50%)	39 (46%)	1 (1%)
	Total	180 (100%)	5 (3%)	3 (2%)	100 (57%)	66 (38%)	6 (3%)
Oct. 11-12	Female	77 (43%)	0 (0%)	1 (1%)	37 (48%)	33 (43%)	6 (8%)
	Male	103 (57%)	1 (1%)	0 (0%)	36 (35%)	54 (53%)	12 (12%)
	Total	180 (100%)	1(<1%)	1 (<1%)	73 (41%)	87 (49%)	18 (10%)
Oct. 22	Female	105 (58%)	2 (2%)	2 (2%)	66 (64%)	32 (31%)	3 (3%)
	Male	75 (42%)	1 (1%)	1 (1%)	38 (51%)	33 (45%)	2 (3%)
	Total	180 (100%)	3 (2%)	3 (2%)	104 (59%)	65 (37%)	5 (3%)
Combined	Female	277 (51%)	6 (2%)	4 (1%)	161 (59%)	92 (34%)	14 (5%)
	Male	263 (49%)	3 (1%)	3 (1%)	116 (45%)	126 (48%)	15 (6%)
	Total	540 (100%)	9 (2%)	7 (1%)	277 (52%)	218 (41%)	29 (5%)

Table 2. — Length at age of female and male fall chum salmon carcasses sampled on Chandalar River spawning grounds, Alaska, 2011.

		Female					Male				
			Mid-eye to fork length (mm)					Mid-eye to fork length (mm)			
Sample dates	Age	N	Mean	SE	Median	Range	N	Mean	SE	Median	Range
Sept 28	0.2	1	525	—	—	—	2	573	37.5	573	535-610
	0.3	58	570	4.2	568	515-670	42	601	4.5	605	510-660
	0.4	27	587	4.6	585	545-640	39	606	3.7	610	560-650
	0.5	5	587	13.8	585	550-635	1	600	—	—	—
	Total	91					84				
Oct 11-12	0.2	1	535	—	—	—	0	—	—	—	—
	0.3	37	561	4.1	560	505-615	36	604	5.1	608	530-660
	0.4	33	587	5.2	595	505-645	54	623	3.2	625	575-685
	0.5	6	606	15.6	615	555-650	12	622	10.1	625	565-695
	Total	77					102				
Oct 22	0.2	2	533	27.5	533	505-560	1	530	—	—	—
	0.3	66	556	3.1	558	500-610	38	595	5.2	600	510-650
	0.4	32	573	4.0	573	525-615	33	608	4.9	605	555-695
	0.5	3	582	13.0	580	560-605	2	558	27.5	558	530-585
	Total	103					74				
Combined	0.2	4	531	11.4	530	505-560	3	558	25.9	535	530-610
	0.3	161	562	2.2	560	500-670	116	600	2.9	605	510-660
	0.4	92	582	2.7	580	505-645	126	614	2.3	615	555-695
	0.5	14	594	8.7	588	550-650	15	612	10.3	620	530-695
	Total	271					260				

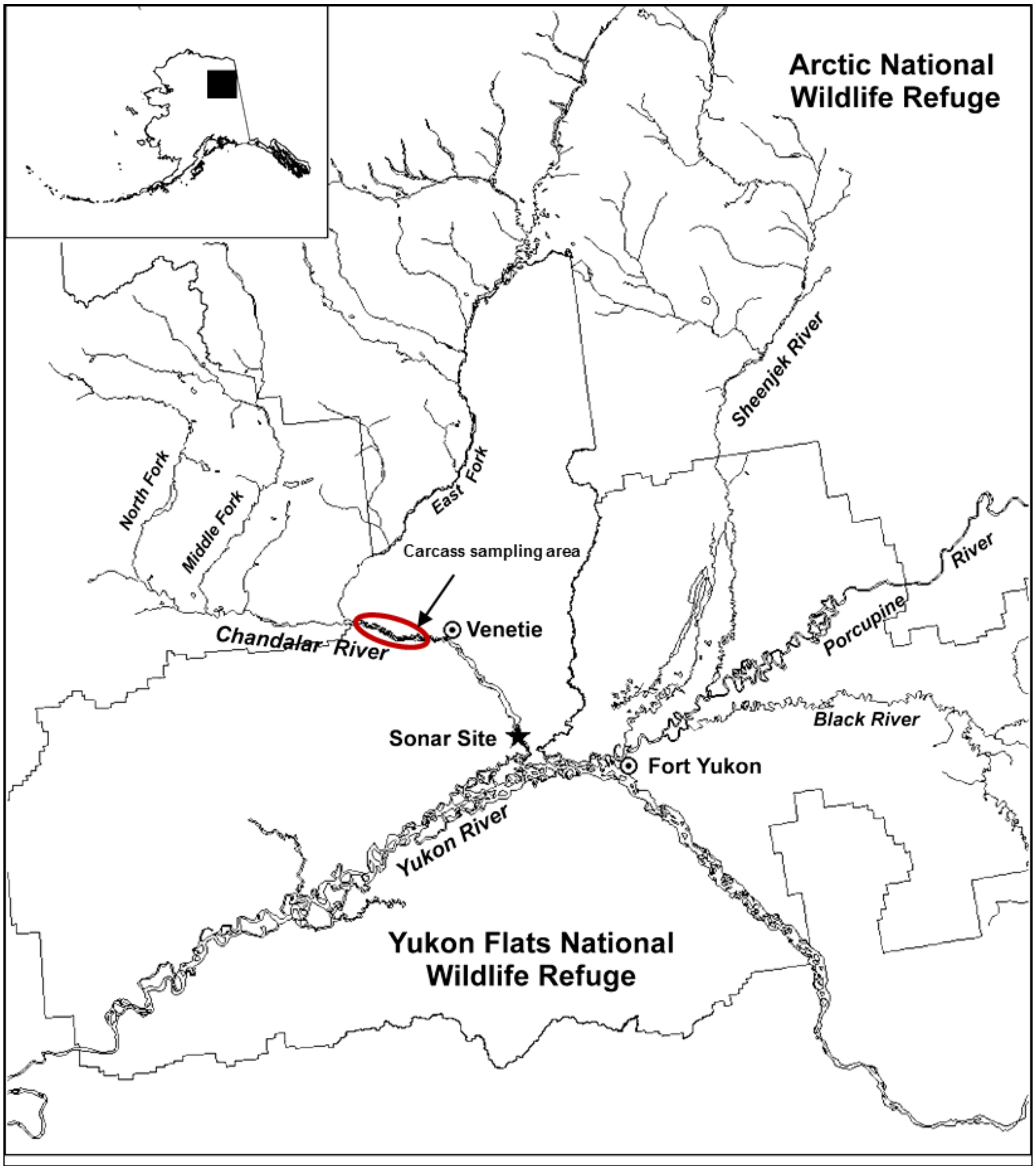

Figure 1. — Map of the Chandalar River, showing carcass sampling area and the location of the Chandalar river sonar escapement project site.

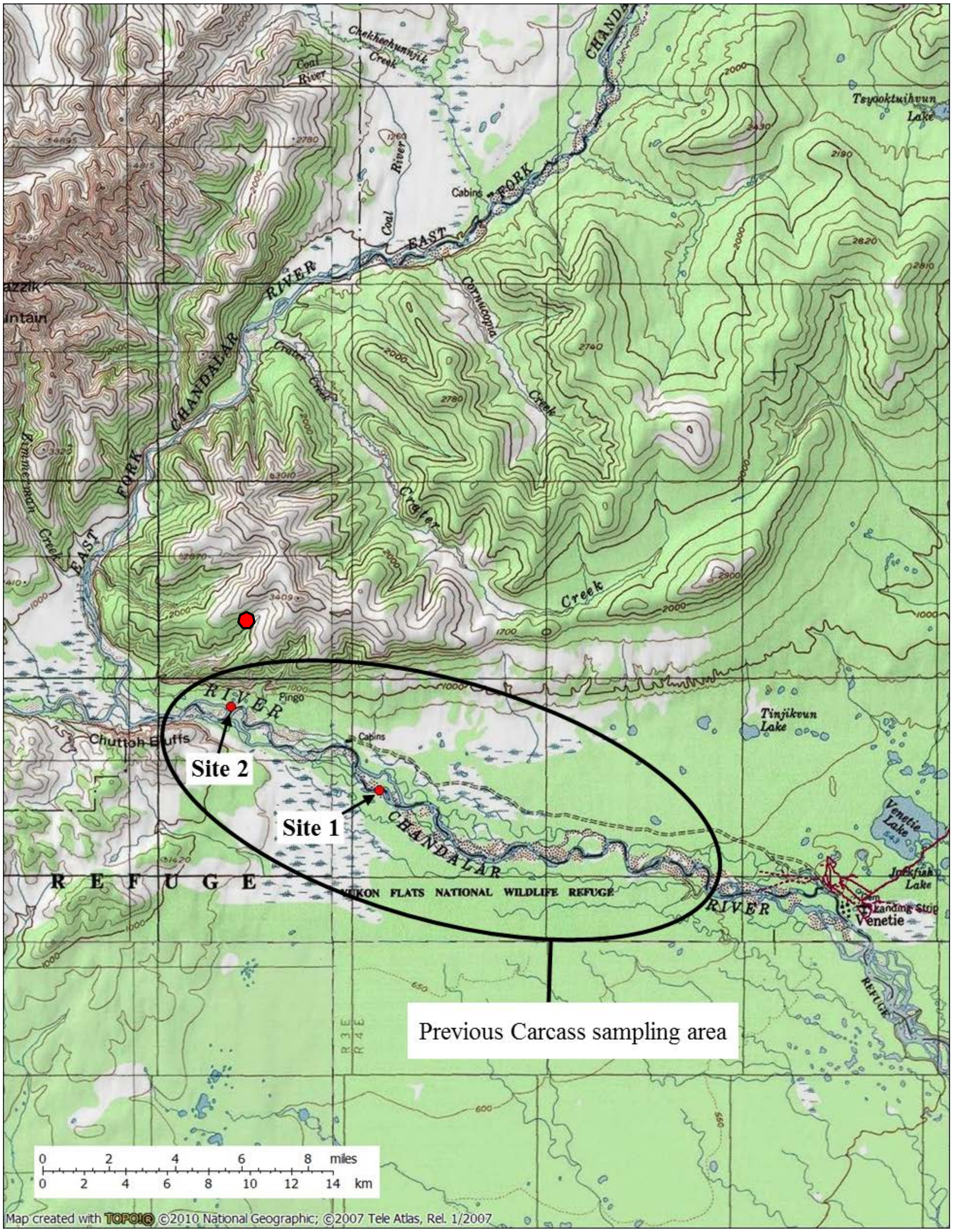

Figure 2. — Map showing the 2011 carcass sampling sites and denoting the area where previous carcass sampling has occurred.

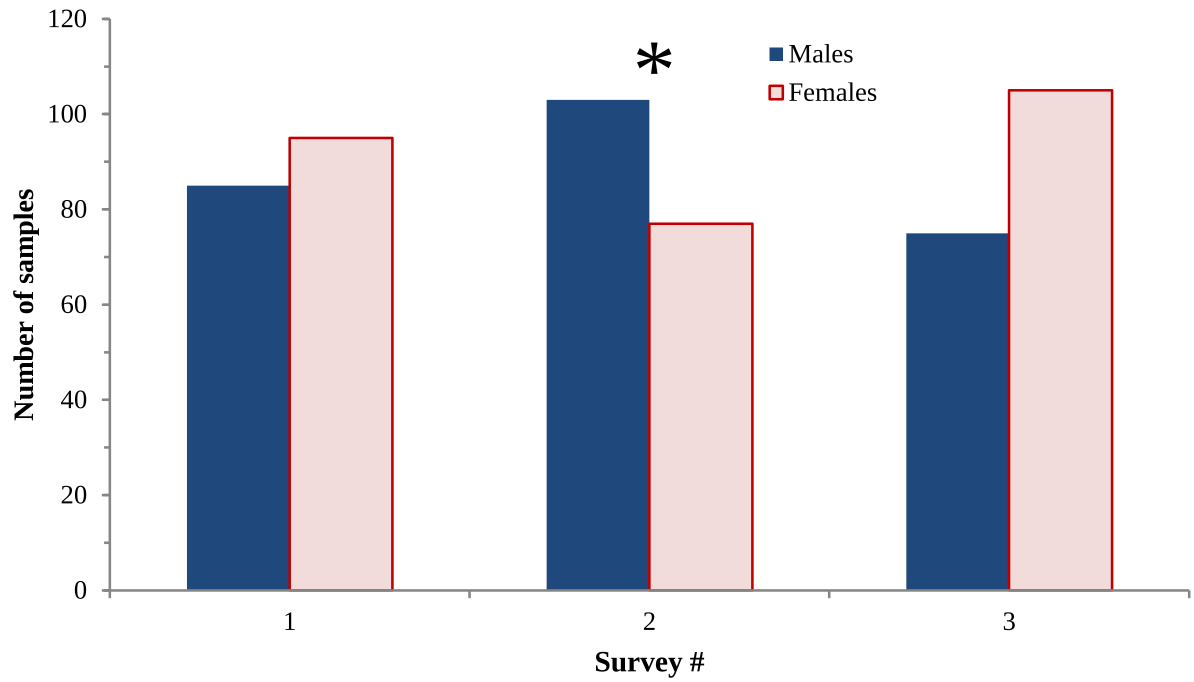

Figure 4. — Numbers of fall chum salmon male and female samples from each survey event on the Chandalar River. Asterisk denotes survey(s) determined to be significantly different.

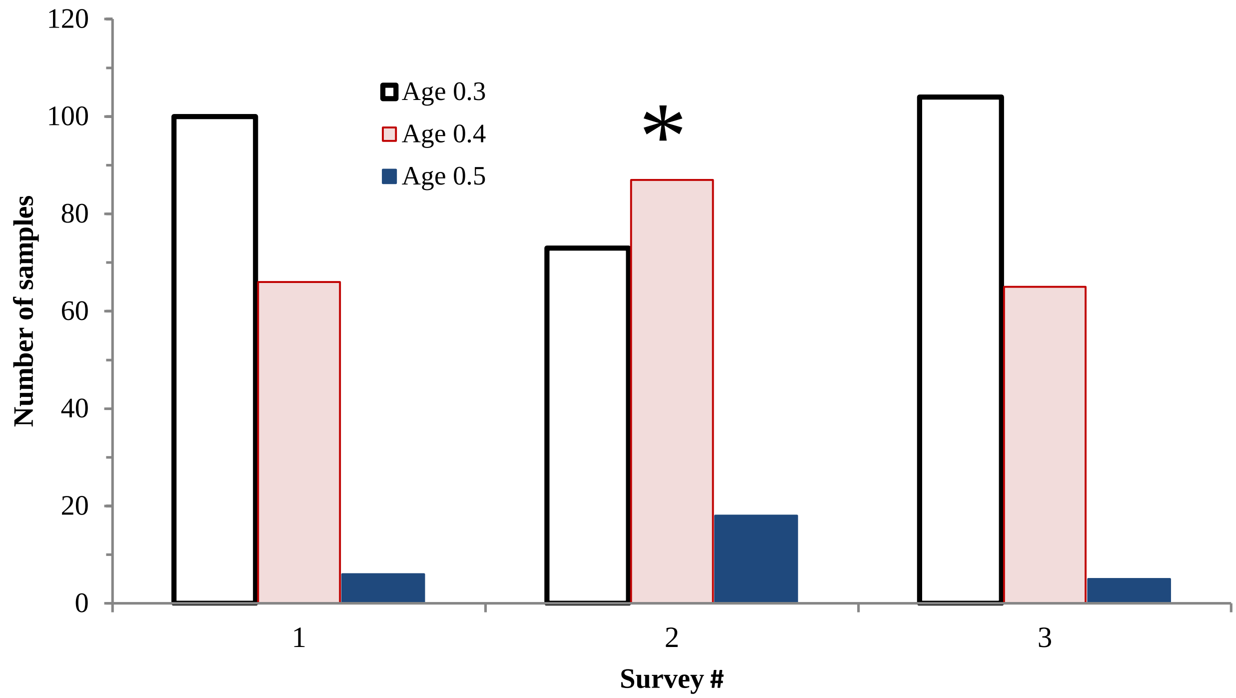

Figure 5. — Numbers of fall chum salmon samples in each age group from each survey event on the Chandalar River. Asterisk denotes survey(s) determined to be significantly different.

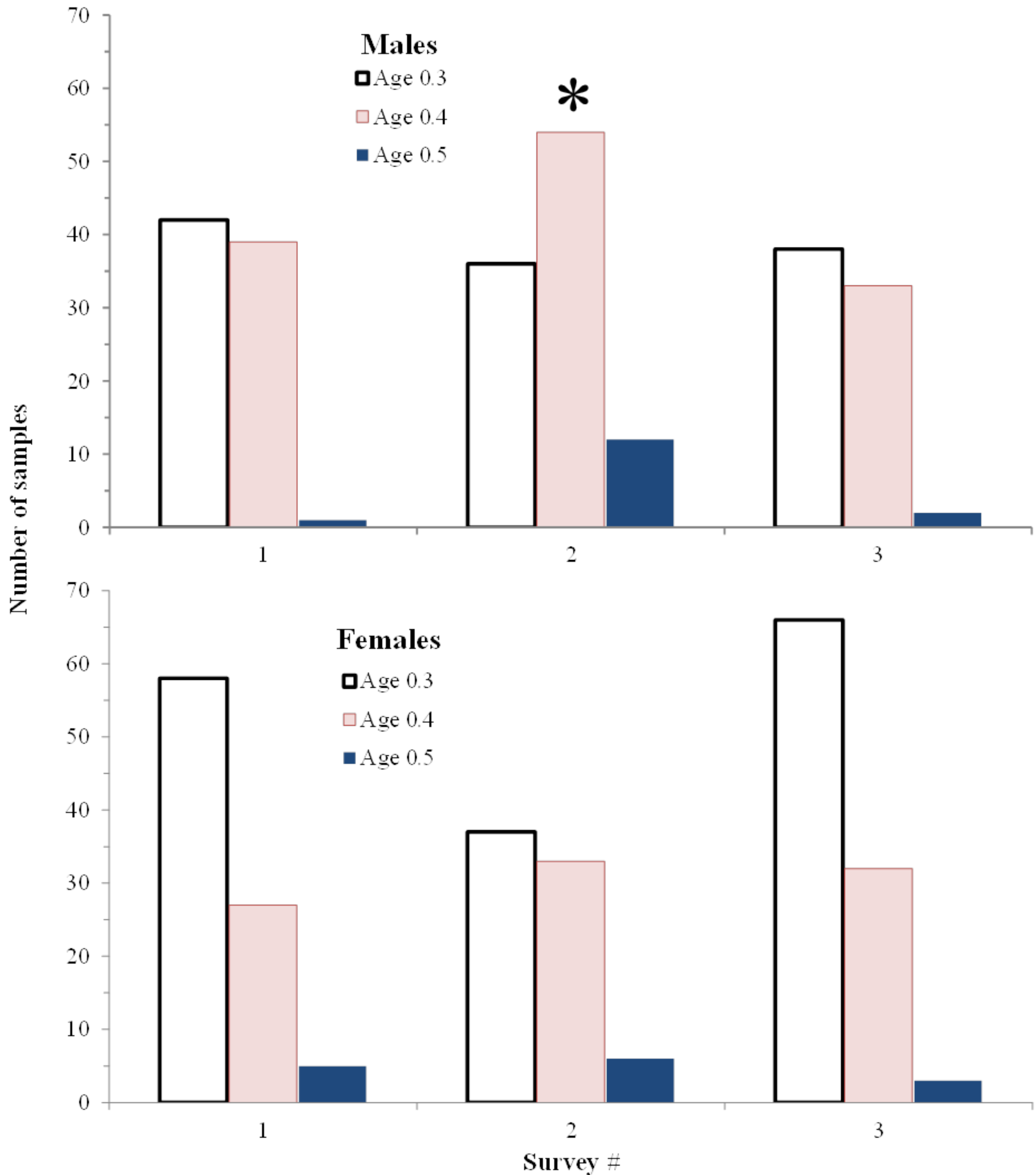

Figure 5. — Age structure composition of fall chum salmon sampled during three various throughout the migration period on the Chandalar River, 2011. Asterisk indicates lack of significant difference in age composition of male chum in survey 1 and 3.

Appendix

Appendix A. — Historical age and sex of fall chum salmon carcasses sampled on the spawning grounds in the Chandalar River, Alaska. Vertebrae were aged by Alaska Department of Fish and Game, unknown age indicates numbers of samples that could not be aged and were not included in age calculations.

Year		Sample size	Unknown age	Age (brood year) n (%)				
2006				0.2 (2003)	0.3 (2002)	0.4 (2001)	0.5 (2000)	0.6 (1999)
	Female	72(41%)	0 (0%)	8 (11%)	45 (63%)	16 (22%)	3 (4%)	0 (0%)
	Male	103(59%)	0 (0%)	6 (6%)	69 (67%)	28 (27%)	0 (0%)	0 (0%)
	Total	175(100%)	0 (0%)	14 (8%)	114 (65%)	44 (25%)	3 (2%)	0 (0%)
2008				0.2 (2005)	0.3 (2004)	0.4 (2003)	0.5 (2002)	0.6 (2001)
	Female	102(56%)	2 (2%)	4 (4%)	45 (44%)	41 (40%)	7 (7%)	3 (3%)
	Male	79(44%)	1 (1%)	2 (3%)	28 (35%)	42 (53%)	6 (8%)	0 (0%)
	Total	181(100%)	3 (2%)	6 (3%)	73 (41%)	83 (47%)	13 (7%)	3 (2%)
2009				0.2 (2006)	0.3 (2005)	0.4 (2004)	0.5 (2003)	0.6 (2002)
	Female	104(58%)	0 (0%)	10 (10%)	70 (67%)	23 (22%)	1 (1%)	0 (0%)
	Male	76(42%)	0 (0%)	6 (8%)	43 (57%)	23 (30%)	3 (4%)	1 (1%)
	Total	180(100%)	0 (0%)	16 (9%)	113 (63%)	46 (26%)	4 (2%)	1 (<1%)
2010				0.2 (2007)	0.3 (2006)	0.4 (2005)	0.5 (2004)	0.6 (2003)
	Female	124(70%)	0 (0%)	30 (24%)	70 (56%)	19 (15%)	4 (3%)	1 (1%)
	Male	53(30%)	0 (0%)	7 (13%)	33 (62%)	11 (21%)	2 (4%)	0 (0%)
	Total	177(100%)	0 (0%)	37 (21%)	103 (58%)	30 (17%)	6 (3%)	1 (<1%)

Appendix B — Historical length at age of female and male fall chum salmon carcasses sampled on Chandalar River spawning grounds, Alaska.

		Female					Male				
			Mid-eye to fork length (mm)					Mid-eye to fork length (mm)			
Year	Age	N	Mean	SE	Median	Range	N	Mean	SE	Median	Range
2006											
	0.2	8	542	13.2	540	480-590	6	573	15.6	585	510-620
	0.3	45	551	3.5	550	500-600	69	583	3.8	580	500-655
	0.4	16	564	5.6	560	530-600	28	604	6.1	600	550-660
	0.5	3	607	18.6	–	570-630	–	–	–	–	–
	0.6	0	–	–	–	–	–	–	–	–	–
	Total	72					103				
2008											
	0.2	4	543	19.3	545	500-580	2	540	10	540	530-550
	0.3	45	552	3.3	550	510-610	28	575	5.9	570	520-640
	0.4	41	578	4.0	580	530-630	42	608	4.3	605	560-700
	0.5	7	560	11.1	560	520-610	6	595	4.3	595	580-610
	0.6	3	593	8.8	590	580-610	0	–	–	–	–
	Total	100					78				
2009											
	0.2	10	553	8.8	555	505-590	6	575	14.1	585	510-610
	0.3	70	557	2.9	558	500-600	43	584	4.3	580	540-650
	0.4	23	565	6.6	570	470-620	23	615	4.8	620	560-660
	0.5	1	590	–	590	–	3	607	16.7	590	590-640
	0.6	0	–	–	–	–	1	660	–	660	–
	Total	104					76				
2010											
	0.2	30	545	4.6	543	490-610	7	599	6.6	600	575-630
	0.3	70	558	3.2	560	500-650	33	605	7.7	610	530-720
	0.4	19	568	8.2	570	500-630	11	586	12.1	580	540-670
	0.5	4	585	11.9	585	560-610	2	595	15.0	595	580-610
	0.6	1	630	–	630	–	0	–	–	–	–
	Total	124					53				