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Characterization of Tuluksak Chinook Salmon Subsistence Harvests, 2008 and 2009

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Characterization of Tuluksak Chinook Salmon Subsistence Harvests, 2008 and 2009

Frank Harris and Ken C. Harper

Abstract

Chinook salmon *Oncorhynchus tshawytscha* are an important species in the Kuskokwim River subsistence fishery and to the overall ecology of the drainage. Harvest pressures are intense with an average of 76,000 Chinook salmon harvested annually by subsistence fishers. There are no restrictions on the gill net mesh size used in the subsistence fishery, and a larger proportion of harvested female Chinook salmon are thought to be captured with large meshed nets. The goal of this study was to characterize the subsistence fishery near the confluence of the Tuluksak and Kuskokwim rivers by separating harvest locations into three zones based on their proximity to the mouth of the Tuluksak River. Age, sex, and length information was collected from subsistence caught fish within each zone during 2008 and 2009. Age-sex compositions and length for each age-sex category were tested for significant differences among zones as well as samples collected from the Tuluksak River weir. Female Chinook salmon comprised 29% and 30% of the total subsistence catch sampled during 2008 and 2009, respectively. In contrast, females comprised 40% of the Chinook salmon passing the weir during 2008 and 44% during 2009. Age-sex composition was not significantly different between the weir escapement and the subsistence fishery ($P = 0.1314$) during 2008 with the exception of zone 1 ($P < 0.001$). Chinook salmon sampled from zone 1 during 2008 were significantly younger and comprised of more males. Significant differences in age-sex composition were detected between the escapement samples and the harvest samples in 2009 ($P = 0.029$). Lengths of subsistence caught fish were significantly larger for age-4 males during 2008 ($P=0.009$) and age-5 males during 2009 ($P=0.022$) than the same sex and age of fish sampled at the weir. Large mesh nets (≥20.3 cm) accounted for only 30% and 31% of fish sampled during 2008 and 2009, respectively.

Introduction

Kuskokwim River returns of Chinook salmon *Oncorhynchus tshawytscha*, chum salmon *O. ke*ta, sockeye salmon *O. nerka*, and coho salmon *O. kitsutch* support one of the largest and most important subsistence fisheries in Alaska (Molyneaux et al. 2005). The annual subsistence harvest in the Kuskokwim River drainage averaged 76,980 Chinook, 57,981 chum, 37,076 sockeye, and 31,729 coho salmon from 1999 to 2008 (Martz and Dull 2006; Simon et al. 2007). Subsistence fishers from Tuluksak River downstream to the mouth of the Kuskokwim River harvest approximately 76% of the annual Chinook salmon for the entire drainage (Fall et al. 2009). More than 2000 households harvest salmon for subsistence use in the Kuskokwim region with many more assisting with the processing. Fish contribute as much as 85% of the total fish and wildlife harvested within the community of Kwethluk (Coffing 1991). Annual harvests are estimated using catch calendars mailed to fishers identified in each village. Between 2002 and

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2006, an average 2,192 Chinook salmon (range 830-3,117) was harvested in the village of Tuluksak, from an average of 49 households sampled (Ward et al. 2003, Whitmore et al. 2005, Fall et al. 2007a, Fall et al. 2007b, Fall et al. 2009).

State and Federal fishery managers have recognized the use and dependence on salmon by Kuskokwim residents and have elevated subsistence use to the highest priority among user groups. Sustained yield management has been used to develop regulations and policies. Beginning in 1985, the commercial fishery was restricted to 15.2-cm stretch mesh as the maximum allowable. A directed commercial fishery for Chinook salmon was closed from 1986 to 2007. Commercial harvests have remained low because of conservative management and poor market conditions for chum salmon (Alaska Department of Fish and Game, 2009). In response to the guidelines established in the Sustainable Salmon Fisheries Policy (5 AAC 39.222), the Alaska Board of Fisheries (BOF) classified the Kuskokwim Chinook and chum salmon as stocks of yield concern in September 2000. This determination was based on the inability to maintain expected yields, or harvestable surpluses above the stock's escapement needs since 1998, despite the use of specific management measures and anticipated low adult salmon returns (Burkey et al. 2001). The Kuskokwim River Salmon Rebuilding Management Plan (5 AAC 07.365) was developed in response to the yield concern classification, adopted by the BOF in January 2001, and amended in January 2004 (Bergstrom and Whitmore 2004). The yield concern classification was also supported by the Federal Subsistence Board through a Special Action and an Interim Memorandum of Agreement at the beginning of the 2001 season. The plan provided guidelines for the rebuilding and management of the Kuskokwim River salmon fishery that would result in the sustained yield of salmon stocks large enough to meet escapement goals, provide fishers with reasonable opportunity to harvest subsistence salmon, and provide for fisheries other than subsistence. The yield concern classification was discontinued in 2007 after chum and Chinook salmon escapements returned to levels above the historical average (Linderman and Reardon 2007).

Managers are concerned with Chinook salmon harvests and the sustainability of the population. Gill net mesh size used by subsistence fishers is not regulated, and there is a propensity to use gill nets with 20.3 cm stretched mesh and larger when targeting Chinook salmon on the Kuskokwim River (Dubois and Molyneaux 2000; Molyneaux et al. 2005). Larger mesh nets are known to be selective for larger and older fish which include a higher proportion of females (Alaska Department of Fish and Game 1981; Dubois and Molyneaux 2000; Molyneaux et al. 2004, Bromaghin 2005). Consequently, intensive selective harvests may result in a decrease in the percentage of large, old, and female fish as the run progresses up the river through the various fisheries (Molyneaux et al. 2005). The percentage of females sampled in the 2004 subsistence fishery on the Kuskokwim River near Bethel increased from 7% with the use of nets less than 15.2 cm mesh, to 12.1% for mesh sizes between 16.5 and 20.0 cm, to 34% for $\geq$ 20.3-cm mesh (Molyneaux et al. 2005).

Potential effects of selective harvest on phenotypic patterns (age and size) are widely acknowledged (Ricker 1980, 1981, 1995; Hankin and Healey 1986; Riddell 1986; Law and Grey 1989; McAllister et al. 1992; Trippel 1995; Heino 1998; Hard 2004). Anecdotal information from fishers along the Kuskokwim River suggests that the length of Chinook salmon harvested and the proportion of female Chinook salmon in the run have decreased over time.

Adequate escapements to individual tributaries and mainstem spawning areas are necessary to provide sustainable harvests and maintain genetic diversity. Salmon migrating to the Tuluksak River are harvested in a large in-river subsistence fishery, and pass through an in-river commercial fishery located between the Kuskokwim Bay and the Tuluksak River. The weir escapement project on the Tuluksak River has collected escapement and age, sex and length information on Chinook salmon returns between 1991 and 1994 and from 2001 to present. Returns of Chinook salmon to the Tuluksak River have ranged from 362 to 2,917 between 1991 and 2009 (Gates and Harper 2002, 2003; Zabkar et al. 2004, 2005, 2006; Plumb et al. 2007, Plumb and Harper 2008; Miller and Harper 2009, 2010). As few as 67 females passed the weir during 2002, with females comprising as low as 14% of the return during 1993. Observations during the 1990's also indicated subsistence fishing activities occurring in and around the mouth of the Tuluksak River. Anecdotal evidence suggests that large mesh gill nets were used in this fishery, which may have negatively impacted the composition of the Chinook salmon returning to the Tuluksak River. To address this concern, the Kenai Fish and Wildlife Field Office conducted a study during 2008 and 2009 to examine the Chinook salmon subsistence fishery near the village of Tuluksak.

Objectives

Specific objectives of this study were to: (1) estimate the age, sex, and length composition of the Chinook salmon subsistence harvest in each of three zones near the confluence of the Kuskokwim and Tuluksak rivers such that simultaneous 95% confidence interval estimates of age-sex proportions have maximum width of 0.20; (2) test the hypothesis that the age, sex, and length composition of the Chinook salmon harvested in the subsistence fishery does not differ among three zones near the confluence of the Kuskokwim and Tuluksak rivers; and, (3) test the hypothesis that the age, sex, and length composition of Chinook salmon harvested in the subsistence fishery near the confluence of the Kuskokwim and Tuluksak rivers does not differ from that observed at the Tuluksak River weir.

Study Area

The Kuskokwim River drainage includes an area of approximately 50,000 square miles (Brown 1983). The Tuluksak River, one of several lower Kuskokwim River tributaries on the Yukon Delta National Wildlife Refuge, drains into the Kuskokwim River approximately 116 river kilometers (rkm) upriver from Bethel, Alaska. The Tuluksak River originates in the Kilbuck Mountains, is approximately 137 rkm in length, and its watershed encompasses approximately 2,098 km^2 (Figure 1). The Fog River, which is its only major tributary, empties into the lower portion of the Tuluksak River. The Tuluksak River is a medium gradient river for the majority of its length, and is characterized by dense overhanging vegetation and cut banks. The lower portion of the river has reduced gradient, silt substrate, and turbid water. The Tuluksak River provides important spawning and rearing habitat for chum, Chinook, pink *O. gorbuscha*, sockeye, and coho salmon (U.S. Fish and Wildlife Service 1991).

Dredging from mineral mining has altered approximately 40 km of the upper Tuluksak River drainage above the refuge boundary. Dredge equipment operating in the floodplain has altered the stream channel and water in some areas flows through dredge tailings and or tailings ponds (Figure 1). Silt transport from these dredging operations may have altered downstream sections

of the river. The mining activity and dredging, which began in 1908 and continued through most of the 20th century, removed approximately 500,000 ounces of gold (Strachan 2005). Mining companies have continued to explore and mine for gold in the drainage, and have conducted an extensive drilling program to define the lode bearing ore bodies. They have also expressed an interest in reworking the old dredge tailings.

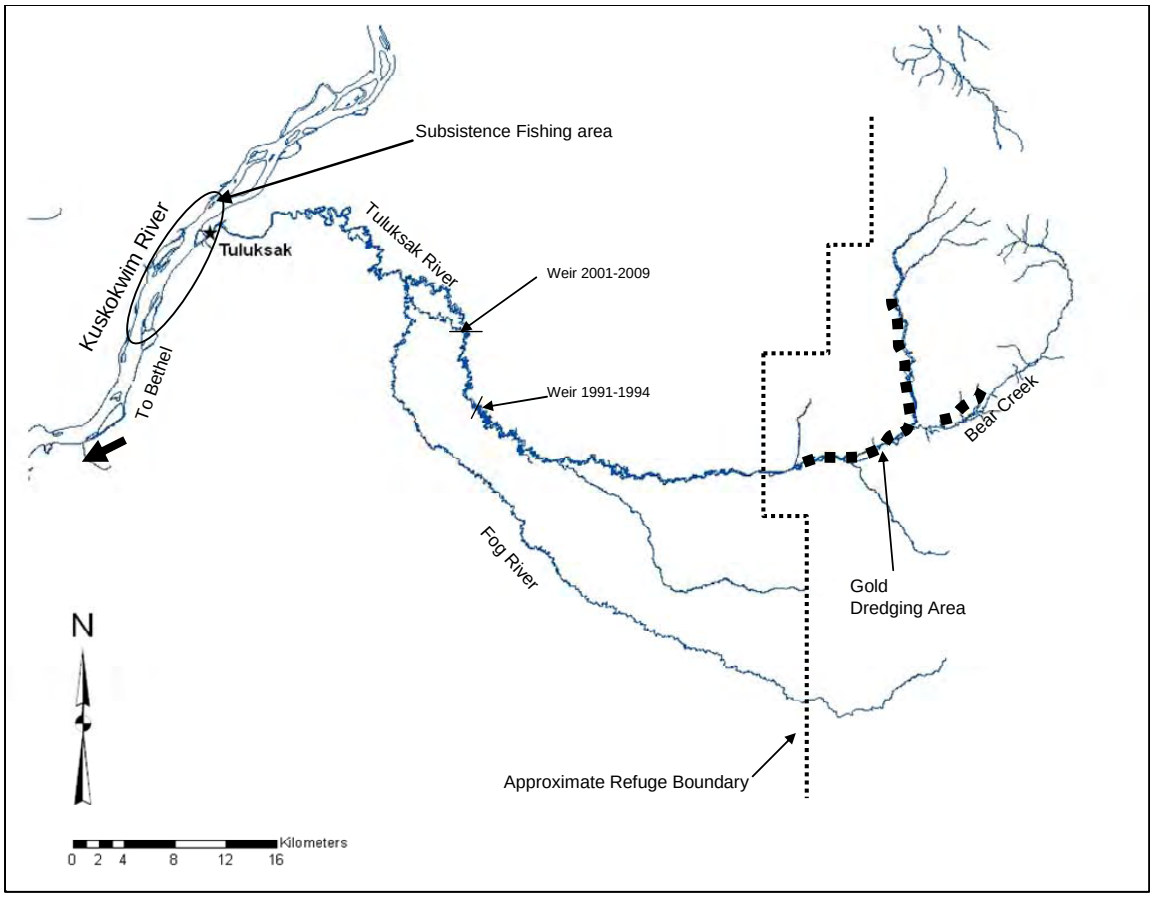

FIGURE 1.—The Tuluksak River watershed showing locations of the weir site and the subsistence fishing area near the confluence of the Tuluksak and Kuskokwim rivers.

Methods

Fishing Zones

The Tuluksak village subsistence fishery was divided into three zones based on the hypothesis that differential harvest rates may occur within the fishery for separate Chinook salmon stocks (Figure 2). Harvest rates may differ due to the location of fishery in relation to the mouth of the Tuluksak River. Among the three zones, zone 3 was thought to comprise the highest proportion of Tuluksak River Chinook salmon. In addition, zones were established to identify potential differences in age, sex, and length of harvested fish due to location of harvest and gear types used in the fishery.

Sample Sizes

The statistical criteria identified in Objective 1 can be satisfied with complete age and sex information from190 fish from each zone (Bromaghin 1993). The power analysis included both males and females with ages 1.1, 1.2, 1.3, 1.4, and 1.5. To account for the average percent (15%) of unreadable scales, the sample size of 190 per zone was adjusted upward to 225.

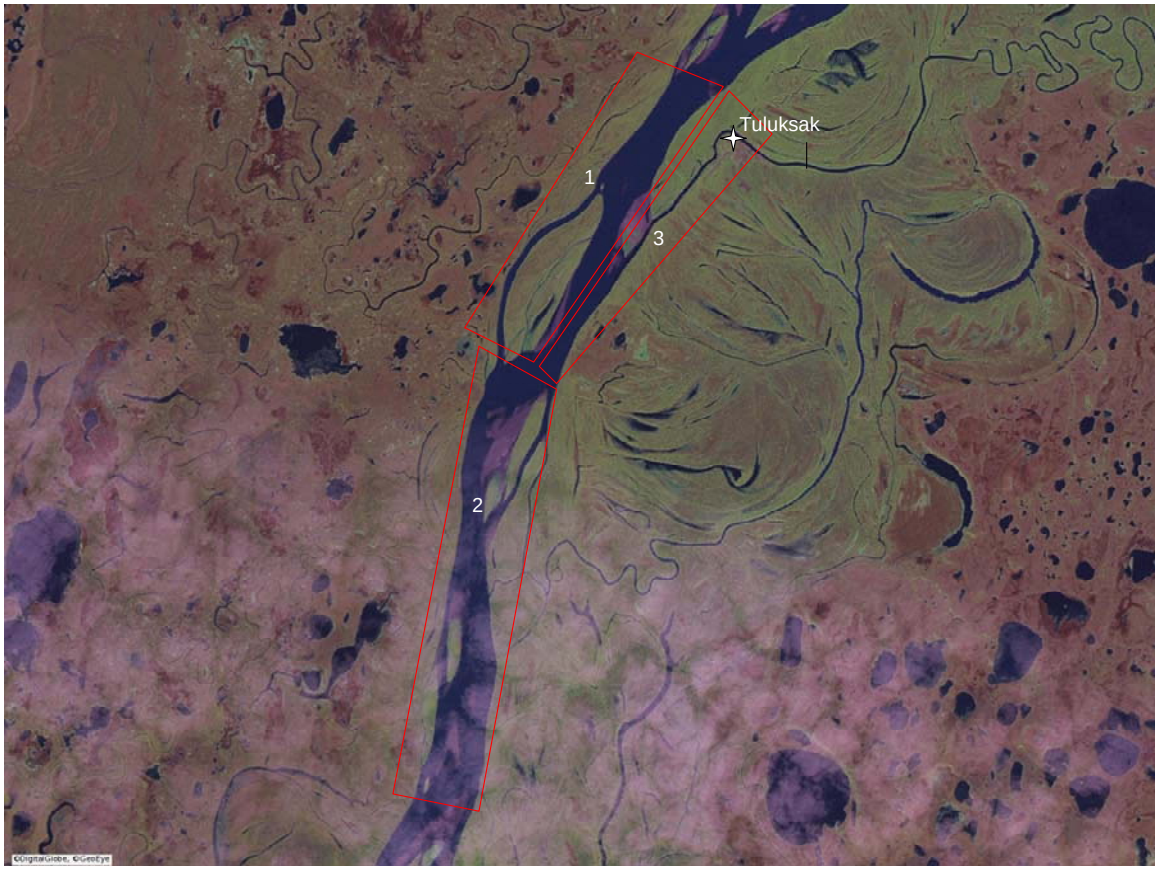

FIGURE 2.—Satellite photo with designated subsistence fishing zones near the village of Tuluksak. Zone 3 is the reach within the Tuluksak River down to the island below the confluence. Zone 1 encompasses the river right bank from above the village to the island below the confluence. Zone 2 encompasses the mainstem Kuskokwim River below zones 1 and 3.

The sample size necessary to achieve the power criteria identified in Objectives 2 and 3 can only be approximated. A two-stage process was used to explore the needed sample size. We first assumed the age-sex composition of the escapement in 2008 and 2009 was similar to that observed in 2006 (Plumb et al. 2007), the last complete data set. For any particular sample size, we modified the corresponding proportions for the harvest to minimize the chi-square test statistic for a test of homogeneity using Excel Solver, under the constraints that each proportion must be at least 0.01 and the maximum difference between any two proportions was 0.10 (Objective 3). The resulting proportions, which represent a worst-case scenario with respect to the power of the test, are presented in Table 1. Overall, the test statistic was minimized by selecting the difference of 0.10 to occur at the age-sex category with the largest proportion, and making all other differences as small as possible. The sample size in the harvest was then modified until the power of the test was 0.65, which was achieved at a sample size of 665.

Assuming this combined sample is distributed equally among zones, a sample size of 219 per zone is required. The sample size of 225 fish per zone necessary to achieve the criteria of Objective 1 is also adequate to achieve the criteria of Objectives 2 and 3. We note that greater power will be achieved if the observed proportions vary from the worst-case scenario presented by Table 1.

TABLE 1.—Age and sex proportions that reflect a worst case scenario for the statistical power of a chi-square test of homogeneity.

Category		Proportion	
Sex	Age	Weir	Harvest
Male	1.1	0.000	0.010
Male	1.2	0.362	0.462
Male	1.3, 2.2	0.260	0.207
Male	1.4, 2.3	0.095	0.076
Male	1.5, 2.4	0.006	0.010
Female	1.1	0.000	0.010
Female	1.2	0.006	0.010
Female	1.3, 2.2	0.066	0.053
Female	1.4, 2.3	0.187	0.149
Female	1.5, 2.4	0.018	0.014
Total		1.000	1.000

Biological Sampling

Subsistence harvest sampling was designed to gather representative harvest information. Prior to the Chinook salmon season, each fish camp with a fish drying rack was identified. Families associated with those camps were contacted to solicit their participation. Participating families would call or wave down passing crews prior to cutting their fish. In order to encompass the majority of the fishing season, surveys were conducted from 10 June through 16 July 2008 and 12 June through 10 July 2009. Sampling was considered representative of the total village harvest. Similar to subsistence studies completed by the Alaska Department of Fish and Game (ADFG), mesh sizes were categorized into three size ranges: ≤15.2 cm, >15.2 cm and <20.3 cm, and ≥20.3 cm (Molyneaux et al. 2003, and 2004).

Age, sex, and length (ASL) data were collected for Chinook salmon caught by subsistence fishers for comparison among zones and with escapement samples collected at the Tuluksak River weir. Length was measured to the nearest 5 mm from the middle of the eye to the fork of the tail (MEF). Four scales were collected from each fish according to methods described by Koo (1962) and Mosher (1968) and forwarded to ADFG for aging using standard methods (Jearld 1983). Sex was determined for each subsistence-harvested fish by visual observation of gametes within the body cavity.

Salmon ages were reported according to the European Method (Koo 1962) where numerals preceding the decimal denote freshwater annuli and numerals following the decimal denote marine annuli. Total years of life at maturity are determined by adding one year to the sum of

the two digits on either side of the decimal of the European designation (e.g. age 1.4 and 2.3 are 6 year-old fish). Due to different age designations having the same overall age, fish were pooled by total age (1.4 and 2.3 were grouped as age 6) for the age-sex composition tests. Since the majority of growth occurs during the saltwater residence period for salmon, only saltwater ages were used for the length at age-sex analysis. When displaying saltwater ages, an "x" was used to denote the freshwater annuli (e.g. x.3 or x.4).

Data Analysis

Harvest ASL —Individual catches were recorded and keyed to a unique identifier assigned to each fish camp for possible post-season stratification. Samples collected from actual harvests were compared to catch calendars issued by ADFG, and recorded by individual fishers. Sampling in proportion to harvests through time was evaluated using our samples and data provided on harvest calendars returned to ADFG post-season. Samples were collected on an opportunistic basis, corresponding with the daily harvest of participating fishers. Since the harvest data was collected as randomly as possible and was relatively proportional to overall harvests, data that was homogeneous for each zone was pooled to form a single sample for each zone. Non-homogeneous data was post stratified by location. Each year's data were analyzed independently, with no statistical comparison between years.

The age-sex composition of the harvest in each zone was estimated using standard estimators of proportions and variances based upon the multinomial probability model (Cochran 1977). Similar methods were used to estimate the age-sex composition of fish at the Tuluksak River weir, though estimation is temporally stratified (e.g., Plumb et al. 2007). Simultaneous 95% confidence intervals for the age-sex proportions were constructed using the methods of Goodman (1965) and Bromaghin (1993).

The hypothesis that the age-sex composition does not differ among zones was tested with a chi-square test of homogeneity (Greenwood and Nikulin 1996) using bootstrapping techniques with 10,000 replications. These techniques were employed to compensate for small sample sizes in two of the three zones. The chi-square test was performed in software program R (RCDT 2009, version 2.10.1). If no differences were found, all the samples were pooled to compare to the escapement. Significant differences between zones were further examined for differences in fishing locations and gear (e.g. majority of fish caught in one of the three mesh sizes). If a zone had considerable differences in techniques, locations and gear, it was not pooled with the remaining zones, and tested against the escapement individually.

The mean and variance of length was estimated for sex, and age in each zone. If $x_{sai|z}$ is the length of the ith fish in the zone z sample of sex s and age a, the mean and the variance of the mean were estimated as

$$\bar{x}_{sa|z} = \frac{\sum_{i=1}^{n_{sa|z}} x_{sai|z}}{n_{sa|z}}$$

and

$$\hat{v}\left(\overline{x}_{sa|z}\right) = \frac{\sum_{i=1}^{n_{sa|z}}\left(x_{sai|z} - \overline{x}_{sa|z}\right)^2}{n_{sa|z}\left(n_{sa|z} - 1\right)},$$

respectively. Lengths for each age-sex category were tested for normality, and analyzed with a box plot to determine if data were normally distributed. Where data were parametric, analysis of variance (ANOVA; Montgomery 1984) was used to test the hypotheses that mean length does not differ among zones for each age and sex category. Kruskal-Wallis One Way Analysis of Variance on Ranks was used to test this hypothesis for non-parametric data. If significant differences were not detected, samples were pooled across zones to represent the harvest. All ANOVA and Kruskal-Wallis tests were executed in the statistical program Sigma plot for windows version 11.0.

Comparing Harvest and Escapement ASL —When significant differences were detected between the zones, chi-square tests were used to determine which zone was different. Each zone that was significantly different was not pooled, and was tested against the escapement samples individually. The remaining zones were pooled and treated as a simple random sample and were likewise compared to the Tuluksak River escapement.

Chinook salmon sampled from the Tuluksak River escapement were pooled into a single sample and treated as a simple random sample. However, these fish were collected within the structure of a temporally stratified random sampling design (e.g., Plumb et al. 2007). To compensate for the difference between the actual and assumed sampling design, the stratum sample sizes and the stratum weights were used to construct a weight for each fish in the combined escapement sample. The weights were then scaled so that they sum to the total number of fish in the combined sample.

A chi-square test of homogeneity (Greenwood and Nikulin 1996) with 10,000 replications was used to test the hypothesis that the age-sex compositions of the harvest and weir escapement were not different. Lengths for each age-sex category were tested for normality, and analyzed with a box plot to determine if data were normally distributed. For parametric data, an ANOVA was used to test the hypotheses that mean length does not differ among pooled zones and weir escapement for each age and sex category. A Kruskal-Wallis One Way Analysis of Variance on Ranks was used to test this hypothesis for non-parametric data.

Results

Preseason mapping revealed 32 subsistence fish camps within the study area. Zone 3 had the highest number of fish camps (N=25) followed by zone 1 (N=7). No fish camps were located in zone 2 (Figure 2). No new fish camps were built between years; however, two camps were abandoned and two camps were rebuilt from years of neglect. The location of fishing effort during 2008 or 2009 did not coincide with the location of fish camps. Fish camps that used drift nets fished primarily in zone 2 and camps that used set nets primarily fished within the zone camps were located. The maximum distance traveled by subsistence fishers from fish camps to harvest areas was approximately 14 rkm.

Samples were collected from 25 of the 32 known fish camps during 2008 and 2009. Catch calendar data was not collected during the 2008 season; however, 17 of the 25 families sampled during 2009 were contacted for catch data. Of the contacted families, five filled out the calendars, six never received a calendar, three lost their calendars, and three did not fill them out. The five calendars that were filled out followed the same patterns as the harvest sampling, although the calendars did report 33% fewer Chinook salmon than what was actually sampled from those families with matching records. The 2009 catch calendar data and observations made during the collection of harvest samples during 2008 and 2009 support our assumption that sampling was in proportion to the harvest.

The number of Chinook salmon sampled from the subsistence harvest during 2008 (*N*=723) and 2009 (*N*=1,037) exceeded our annual goal of 675 samples (Figure 3). After unreadable scales were removed, samples sizes were reduced to 577 in 2008 and 895 in 2009. The goal of 225 samples per zone was not met in zones 1 and 3 during either year. Despite shortfalls in reaching sample goals for these two zones, samples were in relative proportion to the fishing effort within each zone.

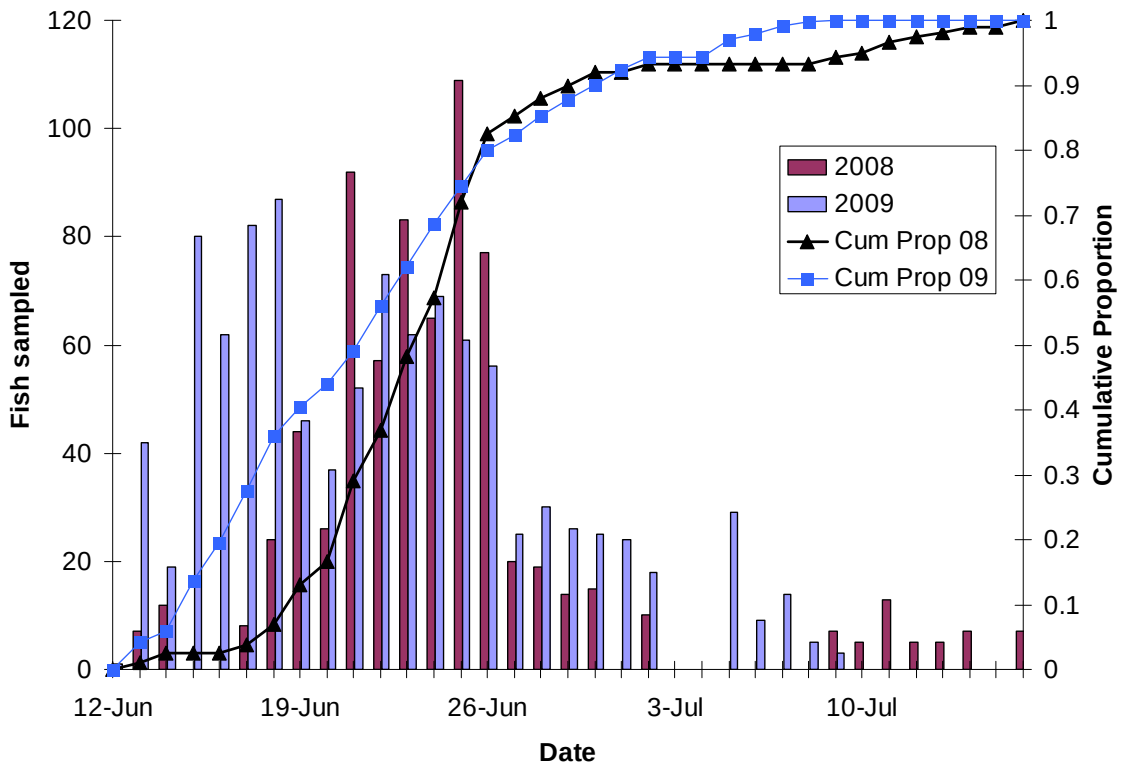

FIGURE 3.—Daily number of fish sampled and cumulative proportion of the Chinook salmon subsistence harvest samples at the village of Tuluksak, Alaska during 2008 (*N*=723) and 2009 (*N*=1,037).

A variety of techniques and mesh sizes were used by subsistence fishers to harvest Chinook salmon. Drift gill nets captured 80% (*N*=463) and 89% (*N*=794) of the Chinook salmon sampled during 2008 and 2009, respectively (Figure 4). Set nets were used with less frequency

and accounted for 17% (2008, *N*=99) and 8% (2009, *N*=73) of the Chinook salmon harvested. Another 3% (*N*=15) of the Chinook salmon harvest in 2008 and 3% (*N*=28) in 2009 could not be assigned a capture method because catches from both drift and set gill nets were mixed prior to sampling. The smallest mesh size (≤15.2 cm) caught the largest proportion of Chinook salmon during 2009 (*N*=349) (Figure 4; Appendices 1 and 2), but also captured the lowest number of females for both years of this study (2008, *N*=26; 2009, *N*=78). Gill nets with mesh sizes >15.2 cm and <20.3 cm caught the most fish during 2008 (*N*=225) including the highest percentage of females (38%). The ≥20.3 cm mesh size captured the smallest number of Chinook salmon during 2008 (2008 *N*=175); however, catch with this mesh size increased to 280 fish during 2009. Females represented 34% and 36% of the harvest with this mesh size in 2008 and 2009, respectively.

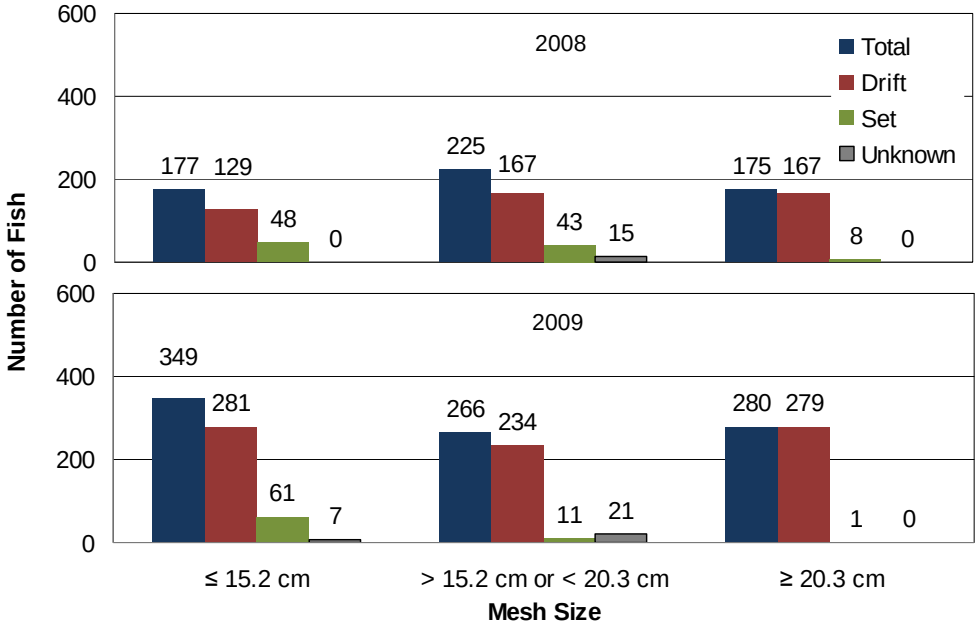

FIGURE 4.— Number of Chinook salmon sampled by mesh size and gear type from the subsistence fishery at the village of Tuluksak, Alaska during 2008 and 2009.

2008

Age, sex and length were obtained from 577 Chinook salmon sampled from the subsistence harvest from 10 June to 16 July, 2008. Peak weekly samples from the harvest (*N*=345) occurred between 22 June and 29 June and the median cumulative harvest date occurred on 24 June. Females comprised an estimated 29% of the total Chinook salmon subsistence harvest (Appendix 1). Harvest was predominately from zone 2 (*N*=446, 77%), followed by zone 1 (*N*=78, 14%) and zone 3 (*N*=53, 9%).

Harvest Age-Sex Composition —Five age groups (3, 4, 5, 6, and 7) and 7 age classes (1.1, 1.2, 1.3, 1.4, 2.3, 1.5, and 2.4) were identified from the Chinook salmon harvested in the Tuluksak subsistence fishery during 2008 (Appendix 3). Ages 1.3 (49%) and 1.4 (28%) dominated the harvest. Age composition differed between sexes. Males were primarily age-1.3 (57%) and age-1.2 (29%), whereas females were predominantly age-1.4 (68%) and age-1.3 (29%).

Tuluksak River Weir Escapement —Four age groups (4, 5, 6, and 7) and six age classes (1.2, 1.3, 2.2, 1.4, 2.3, and 1.5) were identified from Chinook salmon passing the Tuluksak River weir (Appendix 4). Age-1.3 (49%) and age-1.4 (31%) dominated the escapement, but age compositions differed between sexes. The predominant ages were 1.3 (65%) and 1.2 (25%) for males, and 1.4 (68%) and 1.3 (25%) for females. Females comprised 40% of the Chinook salmon escapement.

Data Analysis

Lengths of Chinook salmon were significantly different among the three harvest zones for age-x.3 females (Table 2). No significant difference in length was detected among the three zones for age-x.2, and age-x.3 males, and age-x.4 females. No significant difference in length was detected in any age group with zone 1 removed from the analysis (Table 3). Insufficient numbers of age-x.4 males and age-x.5 females were available for testing.

TABLE 2.—Statistical comparison of length by age-sex category among the three harvest zones for Chinook salmon sampled in the Tuluksak subsistence fishery during 2008. Statistical analysis required the use of mean length for ANOVA and median length for Kruskal-Wallis (KW).

Age-Sex	Zone 1			Zone 2			Zone 3				
Category	*N*	Length	Range	*N*	Length	Range	*N*	Length	Range	Test	*P*
M Age x.2	36	550	490 - 650	79	554	455 - 808	4	571	522 - 646	KW	0.534
M Age x.3	22	680	562 - 799	184	695	534 - 847	26	716	643 - 891	ANOVA	0.127
F Age x.3	5	720	560 - 788	39	795	650 - 853	6	825	697 - 840	KW	0.039
F Age x.4	9	817	612 - 960	91	870	742 - 982	16	836	779 - 947	KW	0.269

TABLE 3.—Statistical comparison of length by age-sex category between zones 2 and 3 for Chinook salmon sampled in the Tuluksak subsistence fishery during 2008. Statistical analysis required the use of mean length for ANOVA and median length for Kruskal-Wallis (KW).

Age-Sex	Zone 2			Zone 3				
Category	*N*	Length	Range	*N*	Length	Range	Test	*P*
M Age x.2	79	554	455 - 808	4	571	522 - 646	KW	0.366
M Age x.3	184	695	534 - 847	26	716	643 - 891	ANOVA	0.101
F Age x.3	39	795	650 - 853	6	825	697 - 840	KW	0.559
F Age x.4	91	870	742 - 982	16	836	779 - 947	KW	0.387

Age-sex composition was significantly different among the three harvest zones during 2008 ($\chi 2$ = 58.487, df = na, $P < .001$). Each zone was independently tested against the other zones to determine which zone differed. The age-sex composition was not significantly different for zones 2 and 3 ($\chi 2$ = 11.3461, df = na, P = 0.2173). Zone 1 was significantly different from zone 2 ($\chi 2$ = 41.5922, df = na, P <0.001) and zone 3 ($\chi 2$ = 33.3554, df = na, P <0.001). Therefore, zones 2 and 3 were pooled together for testing against the escapement samples and zone 1 was tested separately against the escapement.

Age-sex compositions from zones 2 and 3 were not significantly different from the Tuluksak River weir escapement ($\chi 2$ = 17.2171, df = na, P = 0.1175). However, there was a significant difference between zone 1 and the weir escapement ($\chi 2$ = 212.6164, df = na, $P < 0.001$). Residuals from chi-square test indicated more young males (age-4) and fewer old (age-7 females and age-6 males) Chinook salmon in the harvest than the escapement.

Lengths were not significantly different for age-x.3 and x.4 female Chinook salmon, and age-x.3 and x.4 males when comparing zones 2 and 3 to the escapement samples (Table 4). Significant differences were detected in age-x.2 males (Kruskal-Wallis, H = 6.874, df = 1, P = 0.009). Insufficient numbers of age-x.5 males were available to perform the test. Zone 1 was tested independently against the escapement, and no significant difference in length was detected in age-x.3 and x.4 males and age-x.4 females (Table 5). However, significant differences were detected in age-x.2 males (ANOVA, F = 7.341, df = 59, P = 0.009), and age-x.3 females (Kruskal-Wallis, H = 6.212, df = 1, P = 0.013).

TABLE 4.—Statistical comparison of length by age-sex category between the Tuluksak weir escapement and harvest samples collected from zones 2 and 3 in the Tuluksak subsistence fishery during 2008. Statistical analysis required the use of mean length for ANOVA and median length for Kruskal-Wallis (KW).

Age-Sex	Harvest Zones 2 & 3			Weir				
Category	*N*	Length	Range	*N*	Length	Range	Test	*P*
M Age x.2	83	554	455 - 808	24	525	420 - 600	KW	0.009
M Age x.3	210	697	534 - 891	79	714	470 - 905	ANOVA	0.059
M Age x.4	46	789	580 - 1077	13	746	410 - 920	ANOVA	0.183
F Age x.3	45	797	650 - 873	42	795	700 - 890	KW	0.970
F Age x.4	107	859	742 - 982	86	858	750 - 970	ANOVA	0.843

TABLE 5.—Statistical comparison of length by age-sex category between the Tuluksak weir escapement and the harvest samples collected from zone 1 in the Tuluksak subsistence fishery during 2008. Statistical analysis required the use of mean length for ANOVA and median length for Kruskal-Wallis (KW).

Age-Sex	Harvest Zone 1			Weir				
Category	*N*	Length	Range	*N*	Length	Range	Test	*P*
M Age x.2	36	552	490 - 650	24	520	420 - 600	ANOVA	0.009
M Age x.3	22	680	462 - 799	79	714	470 - 905	ANOVA	0.064
M Age x.4	13	746	410 - 920	3	796	544 - 975	ANOVA	0.601
F Age x.3	5	720	560 - 788	42	795	700 - 890	KW	0.013
F Age x.4	9	817	612 - 960	86	960	750 - 970	KW	0.149

2009

Age, sex and length were obtained from 895 Chinook salmon sampled from the subsistence harvest from 12 June to 9 July, 2009. Peak weekly samples from the harvest (N=355) occurred from 21 June to 27 June. The median cumulative harvest date occurred on 22 June. Harvest was predominately from zone 2 (N=663, 74%), followed by zone 3 (N=129, 14%) and zone 1 (N=103, 12%). Females comprised an estimated 30% of the total Chinook salmon harvest (Appendix 2).

Harvest Age-Sex Composition —Six age groups (3, 4, 5, 6, 7, and 8) including nine ages classes (1.1, 1.2, 1.3, 2.2, 1.4, 2.3, 1.5, 2.4, and 1.6) were identified from the Chinook salmon harvested in the Tuluksak subsistence fishery during 2009 (Appendix 5). Age-1.4 (44%) and age-1.3 (31%) dominated the harvest and the age composition differed between sexes. Males were primarily age-1.3 (39%) and age-1.2 (32%), whereas females were predominantly age-1.4 (84%).

Tuluksak River Weir Escapement —Four age groups (4, 5, 6, and 7) including five ages classes (1.2, 1.3, 2.2, 1.4, and 1.5) were identified from Chinook salmon passing the Tuluksak weir during 2009 (Appendix 6). Similar to the harvest, ages 1.4 (44%) and 1.3 (35%) dominated the

escapement and age composition differed between sexes. The predominant ages for males were 1.3 (45%) and 1.2 (33%). Females were again dominated by age 1.4 (74%) and 1.3 (23%) fish (Appendix 6). The total Chinook salmon escapement was composed of 44% females during 2009 (Miller and Harper 2010).

Data Analysis

Lengths of Chinook salmon were not significantly different among the three harvest zones regardless of age with the exception of age-x.2 males (ANOVA, F = 3.694, df = 204, *P* = 0.024, Table 6). Sample sizes were too small to perform a valid test for age-x.3 and x.5 females.

TABLE 6.—Statistical comparison of length by age-sex category among the three harvest zones for Chinook salmon sampled in the Tuluksak subsistence fishery during 2009. Statistical analysis required the use of mean length for ANOVA and median length for Kruskal-Wallis (KW).

Age-Sex	Zone 1			Zone 2			Zone 3				
Category	*N*	Length	Range	*N*	Length	Range	*N*	Length	Range	Test	*P*
M Age x.2	24	570	455 - 645	135	586	425 - 735	43	561	450 - 660	ANOVA	0.024
M Age x.3	22	683	515 - 795	191	694	495 - 885	35	689	520 - 860	ANOVA	0.779
M Age x.4	18	774	515 - 875	133	792	650 - 1010	20	780	630 - 950	ANOVA	0.569
F Age x.4	32	838	720 - 970	168	860	715 - 980	28	845	690 - 930	KW	0.305

Age-sex composition was not significantly different among the three harvest zones ($\chi 2$ = 22.8993, df = na, *P* = .1314). Therefore, all zones were pooled for comparison with the age-sex composition of the escapement sample.

Age-sex composition from the harvest was significantly different from the Tuluksak River weir escapement during 2009 ($\chi 2$ = 26.0426, df = na, *P* = 0.0293). Residuals from the test showed that age-5 females were harvested at a lower rate than expected. Because of this difference, each zone was individually tested against the escapement to determine if a particular zone had a major influence on the overall results. When tested individually, no significant differences were detected between the weir escapement and zone 1 or 2 ($\chi 2$ = 11.4563, df = NA, *P* = 0.9756 for zone 1 and $\chi 2$ = 21.08, df = NA, *P* = 0.3322 for zone 2). A significant difference was detected between the escapement and zone 3 ($\chi 2$ = 21.72, df = NA, *P* = 0.0007). Residuals from the test conducted on zone 1 showed more age-4 males and fewer age-5 females than would be expected in the harvest.

Lengths of Chinook salmon were not significantly different for age-x.3 and x.4 females and age-x.2 and x.4 males when samples from the three harvest zones were compared to the escapement (Table 7). The mean length of age-x.3 males was significantly different (ANOVA, F = 8.217, df = 302, *P* =.004) between the three harvest zones and the escapement. The number of age-x.5 females in the escapement and the subsistence harvest were too small to perform a valid test.

TABLE 7.—Statistical comparison of length by age-sex category between the Tuluksak weir escapement and harvest samples collected in the Tuluksak subsistence fishery during 2009. Statistical analysis required the use of mean length for ANOVA and median length for Kruskal-Wallis (KW).

Age-Sex	Harvest			Weir				
Category	*N*	Length	Range	*N*	Length	Range	Test	*P*
M Age x.2	202	585	425 - 735	40	584	460 - 995	KW	0.795
M Age x.3	248	692	495 - 895	55	663	501 - 800	ANOVA	0.004
M Age x.4	171	789	515 - 1010	26	764	550 - 955	ANOVA	0.135
F Age x.3	34	793	675 - 855	25	790	700 - 876	ANOVA	0.782
F Age x.4	228	851	690 - 980	72	858	720 - 1010	ANOVA	0.391

Discussion

This project began with the expectation that subsistence fishers in the village of Tuluksak harvested Chinook salmon primarily with large mesh nets (≥20.3) resulting in harvests that were selective toward larger and older fish which are primarily females. The data collected during 2008 and 2009 indicated that only 31% of the fish were harvested with large mesh nets (≥20.3 cm). A larger proportion (36%; Figure3) was harvested with small mesh nets (≤15.2 cm) and the majority (69%) was harvested using nets with mesh sizes ≤20.3 cm. This is in contrast with the subsistence fishery that occurs near Bethel where the majority (91%) of the Chinook salmon were harvested using gill nets with mesh sizes ≥20.3 cm (Molyneaux et al. 2005).

There are a couple possible explanations why Tuluksak residents favored the use of small meshed nets. Subsistence fishers may only have enough money to purchase one net, and a smaller mesh net (≤15.2 cm) is more versatile. Smaller meshed nets can be used to target four species of salmon (chum, Chinook, sockeye, and coho) and other species including whitefish. This mesh size is also legal for use in the commercial salmon fisheries that occur in the Kuskokwim River, which limits commercial fishers to mesh ≤15.2 cm, except during an emergency order, which can allow mesh sizes up to 20.3 cm (Alaska Department of Fish and Game Commercial Fishing Regulations, 5AAC 07.331). Another possible explanation was the efficiency of the smaller mesh nets. One subsistence fisher commented that he could catch more fish (Chinook, chum or sockeye) in a shorter period of time using gill nets with the smaller mesh size (Justin Napoka, Tuluksak, personal communication). The ability to catch more fish in a shorter period of time also saves money by burning less fuel. Fuel was not readily available in the village during June of 2008 or 2009, requiring subsistence fishers to travel 28 km downstream to the nearest fuel supply. Therefore, subsistence fishers were interested in maximizing their catches with a minimum number of drifts to reduce costs (Johnny Owens, Tuluksak, personal communication).

There was a significant difference between the age-sex composition of Chinook salmon in the harvest and that observed at the Tuluksak River weir during 2009. Due to the use of nets with smaller mesh size, subsistence fishers caught fewer old females and more young males. This was especially evident in 2009 when fishers in zone 3 caught a higher proportion of young males near the mouth of the Tuluksak River than was sampled at the escapement project. The percent of female Chinook salmon harvested in the Tuluksak subsistence fishery followed a pattern which decreased during mid-season and increased toward the end of the harvest period (Figure 5). Molyneaux et al. (2003) did not find any discernable pattern in the sex ratio of Chinook

salmon harvested in the lower Kuskokwim River during 2002. The average age of Chinook salmon in the Tuluksak subsistence fishery followed a trend very similar to the number of females observed. The lower incidence of females in the subsistence harvest during mid-season coincided with a decrease in age and corresponding large increase in the harvest during each year of the study. One possible explanation for this observation could be selective harvest of Chinook salmon downstream of Tuluksak. The lower percentage of females observed in the harvest during mid-season also coincided with the bulk of the harvest from zone 3 during 2009. The majority (56%) of Chinook salmon harvested in zone 3 were harvested during this decline in percent females, along with 66% of the harvest occurring with the smaller mesh (≤15.2 cm) gill nets. Intense use of small mesh gill nets during the period when fewer females were available for harvest may have caused the age-sex composition in zone 3 to be significantly different from the escapement.

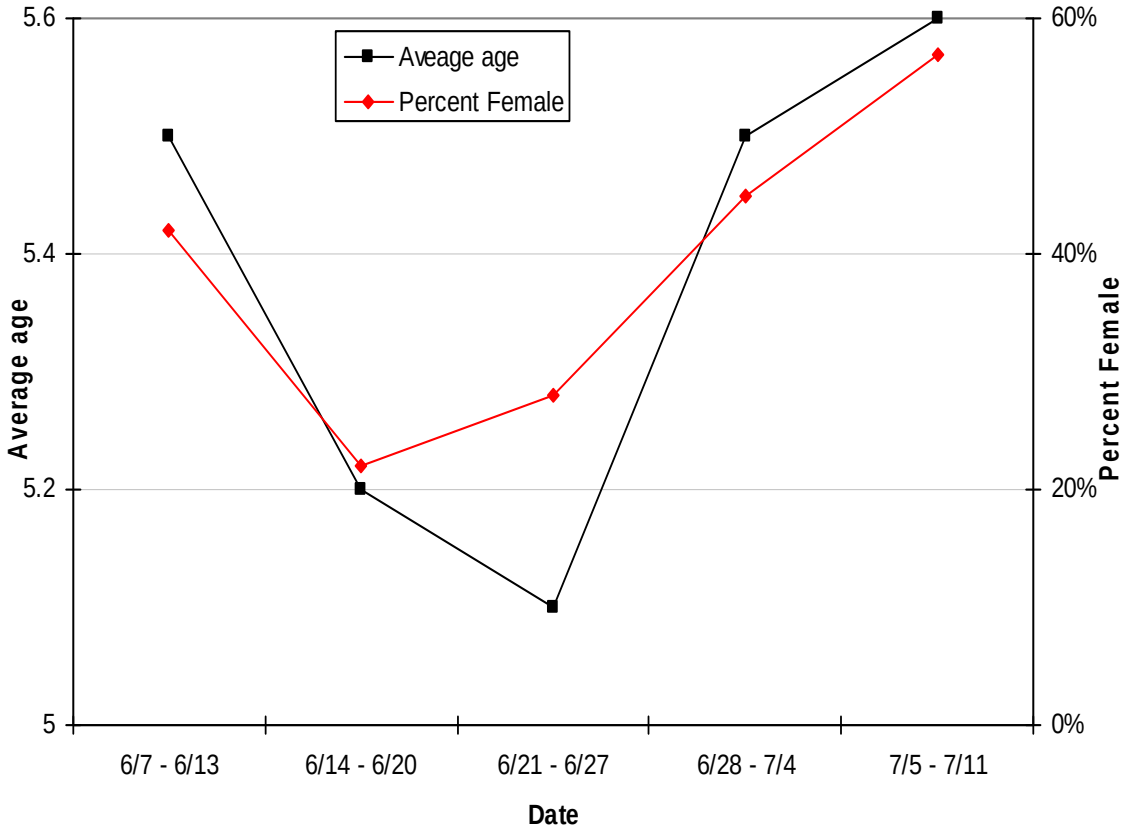

FIGURE 5.—Age and sex composition by week for Chinook salmon sampled in the Tuluksak subsistence fishery during 2009. A very similar pattern was observed during 2008.

A comparison of age-sex composition between the subsistence harvest and the weir escapement revealed no significant difference for the majority of age groups. The only age groups that were significantly different were age-x.2 and x.3 males and x.3 females from zone 1 in 2008. No significant difference in length for the older age-sex categories would suggest that harvest methods were proportionate to the weir escapement for these categories. The significant difference in length detected for the younger age fish may be directly related to the use of

smaller mesh gillnets. In general, gillnet mesh sizes are selective for various sizes of fish (Bromaghin 2005, Hyer and Schleusner 2005). Younger Chinook salmon are smaller on average than older Chinook, and can have a wide range of lengths in each age group. Bromaghin (2005) calculated optimal net selectivity curves for salmon on the Yukon River to be approximately a length of 3.8 times the stretch-mesh size of a gillnet. Using this formula, a 15.2 cm stretch mesh gill net would have peak efficiency for a fish in the 580 mm range. Age-x.2 males caught in a gill net with 15.2 cm or larger stretch mesh would likely be larger than the average length for age-x.2 males in the escapement, as was the case in 2008. We suspect that this also happened with age-x.3 females in 2008 and age-x.3 males during 2009.

Fishing methods and locations varied between years and may have affected the results. Zone 1 was not pooled with zones 2 and 3 in 2008 due to the differences in fishing methods. The majority (83%) of the fish harvested in zone 1 during 2008 were captured using small mesh gill nets (≤15.2 cm), biasing the catch towards younger and smaller fish. The bulk of the harvest (81%) in zone 1 during 2008 was from two families that used small mesh nets (≤15.2 cm). One of these families stopped fishing in zone 1 entirely during 2009. The other family continued fishing their set net in zone 1, but also drifted in zone 2. Set nets were the preferred method in zone 1 during 2008, harvesting 55% of the fish. Several subsistence fishers switched methods in 2009 and the majority of fish (83%) were harvested by drifting nets. Changing fishing locations and methods is a yearly event in dynamic areas. Stumps and logs create snags that can destroy nets, while channels can fill with sand making them less productive fishing locations. In the past, subsistence fishers would drift the straight section of the Tuluksak River located just downstream from the village (Peter Gregory, Tuluksak, personal communication). No subsistence fishing for Chinook salmon was observed in the Tuluksak River during this study. Seasonal employees with the USFWS reported set nets inside the mouth of the river during the 2003–2005 field seasons. River conditions have changed dramatically near the mouth since these reports, but these fishing patterns may return as river condition change.

The estimated number of female Chinook salmon counted past the Tuluksak River weir has declined from an overall average of 378 during the operational years (1991-1994 and 2002-2009) to an average of 201 during the past three years (2007-2009) (Harper 1995a, 1995b, 1995c, 1997, Gates and Harper 2002, 2003, Zabkar et al. 2004, 2005, 2006, Plumb and Harper 2007, 2008, Miller and Harper 2009, 2010). Although fewer females have passed the weir during the past three years, the percentage of females in the escapement samples has been above 40% (Figure 6). Two of the four lowest years on record occurred during the last three years, concurrent with the two lowest years of escapement. The lowest estimated number of females in the escapement occurred during 2002 (N=67). Because this run is comprised of so few females, use of large mesh gillnets in the Tuluksak River could capture a significant portion of females headed to the spawning ground, jeopardizing this stock.

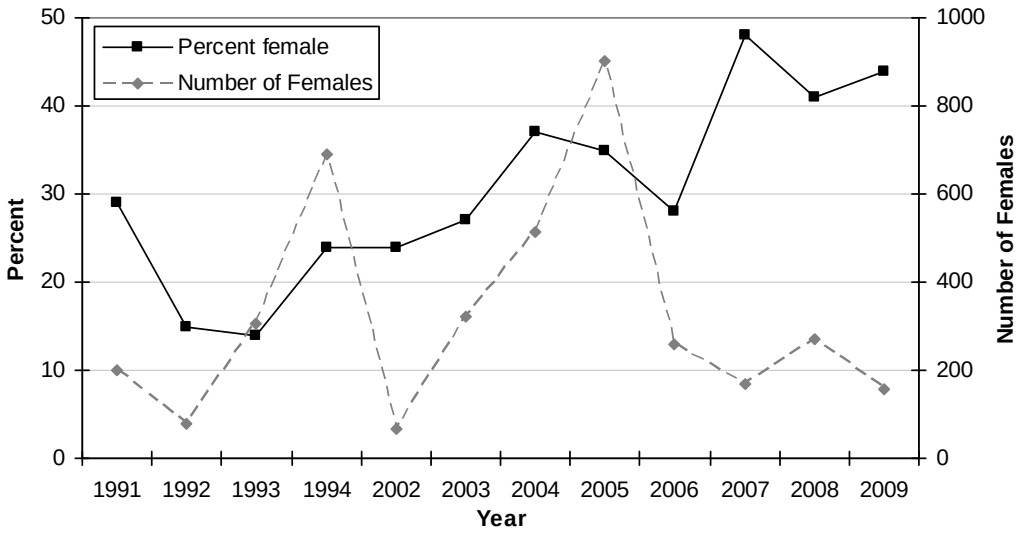

FIGURE 6.—Estimated percent and number of female Chinook salmon in the escapement at the Tuluksak River weir, 1991-1994 and 2002-2009.

Conclusions and Recommendations

Findings from this study suggest that subsistence fishers in the village of Tuluksak harvest a greater proportion of Chinook salmon with smaller mesh gear than was previously assumed. Fishing locations varied and no Chinook salmon were harvested in the Tuluksak River during the duration of the study. Limited data from Bethel subsistence harvest surveys indicate that many subsistence fishers from this community use large mesh nets for their subsistence harvest. Because fishers in the Bethel area constitute the majority of subsistence fishers in the Kuskokwim River drainage, a similar study is warranted to accurately quantify the size of nets used and the age, sex, and length structure of fish harvested in and around Bethel.

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References

Alaska Department of Fish and Game. 1981. A review of gillnet mesh selectivity studies as related to Chinook salmon fisheries of Cook Inlet, Alaska, a report to the Alaska Board of Fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Anchorage, Alaska.

Alaska Department of Fish and Game. 2009. Alaska Department of Fish and Game staff comments on subsistence, personal use, sport, and commercial finfish regulatory proposals for the Arctic-Yukon-Kuskokwim Management Area, Alaska Board of Fisheries meeting, Fairbanks, Alaska January 26-31, 2010. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report Number 3A09-05, Anchorage, Alaska.

Bergstrom, D.J., and C. Whitmore. 2004. Kuskokwim River Chinook and chum salmon stock status and action plan, a report to the Alaska Board of Fisheries. Alaska Department of Fish and Game, Commercial Fisheries Division, Regional Information Report Number 3A04-02, Anchorage, Alaska.

Bromaghin, J.F. 1993. Sample size determination for interval estimation of multinomial probabilities. The American Statistician 47(3):203-206

Bromaghin, J.F. 2005. A versatile net selectivity model, with application to Pacific salmon and freshwater species of the Yukon River, Alaska. Fisheries Research 74: 157-168.

Brown, C.M. 1983 (draft). Alaska's Kuskokwim River region: a history. Bureau of Land Management, Anchorage, Alaska.

Burkey, C., M. Coffing, J. Menard, D. Molyneaux, P. Salomone, and C. Utermohle. 2001. Annual management report for the subsistence and commercial fisheries of the Kuskokwim Area, 2000. Alaska Department of Fish and Game, Division of Commercial Fisheries of the Kuskokwim Area, Regional Information Report Number 3A01-34, Anchorage, Alaska.

Cochran, W.G. 1977. Sampling techniques, 3rd edition. John Wiley and Sons, New York.

Coffing, M.W. 1991. Kwethluk subsistence: contemporary land use patterns, wild resource harvest and use, and the subsistence economy of a Lower Kuskokwim River Area community. Alaska Department of Fish and Game, Division of Subsistence Technical Paper Number 157, Juneau, Alaska.

DuBois, L., and D.B. Molyneaux. 2000. Salmon age, sex and length catalog for the Kuskokwim Area, 1999 Progress Report. Alaska Department of Fish and Game, Division of Commercial Fisheries, AYK Region, Regional Information Report Number 3A00-18, Anchorage, Alaska.

Fall, J. A., D. Caylor, M. Turek, C. Brown, T. Krauthoefer, B. Davis, and D. Koster. 2007a. Alaska subsistence salmon fisheries 2004 report. Alaska Department of Fish and Game, Division of Subsistence, Technical Paper Number 317, Juneau, Alaska.

Fall, J.A., D. Caylor, M. Turek, C. Brown, T. Krauthoefer, J. Heltzel, and D. Koster. 2007b. Alaska subsistence salmon fisheries 2005 report. Alaska Department of Fish and Game, Division of Subsistence, Technical Paper Number 318, Juneau, Alaska.

Fall, J.A., C. Brown, M.F. Turek, N. Braem, J.J. Simon, A. Russell, W. E. Simeone, D. L. Holen, L. Naves, L. Hutchinson-Scarbrough, T. Lemons, V. Ciccone, T. M. Krieg, and D. Koster.

2009. Alaska subsistence salmon fisheries 2006 annual report. Alaska Department of Fish and Game Division of Subsistence, Technical Paper Number 344, Anchorage, Alaska.

Gates, K.S., and K.C. Harper. 2002. Run timing and abundance of adult Pacific salmon in the Tuluksak River, Yukon Delta National Wildlife Refuge, Alaska, 2001. U.S. Fish and Wildlife Service, Kenai Fish and Wildlife Field Office. Alaska Fisheries Data Series Number 2002-6, Kenai, Alaska.

Gates, K.S., and K.C. Harper. 2003. Run timing and abundance of adult Pacific salmon in the Tuluksak River, Yukon Delta National Wildlife Refuge, Alaska, 2002. U.S. Fish and Wildlife Service, Kenai Fish and Wildlife Field Office. Alaska Fisheries Data Series Number 2003-1, Kenai, Alaska.

Goodman, L.A. 1965. On simultaneous confidence intervals for multinomial proportions. Technometrics 7:247-254.

Greenwood, P.E., and M.S. Nikulin. 1996. A guide to chi-squared testing. John Wiley & Sons, New York, New York.

Hankin, D.G., and M.C. Healey. 1986. Dependence of exploitation rates for maximum yield and stock collapse on age and sex structure of Chinook salmon (Oncorhynchus tshawytscha). Canadian Journal of Fisheries and Aquatic Sciences 43: 1746–1759.

Hard J. J. 2004. Evolution of Chinook salmon life history under size-selective harvest. Pages 315–337 *in* P.A. Hendry and S. C. Stearns, editors. Illuminated salmon and their relatives. Oxford University Press, New York.

Hard J.J. 2004. Evolution of Chinook salmon life history under size-selective harvest. Pages 315–337 *in* P.A. Hendry and S. C. Stearns, editors. Illuminated salmon and their relatives. Oxford University Press, New York.

Harper, K.C. 1995a. Run timing and abundance of adult salmon in the Tuluksak River, Yukon Delta National Wildlife Refuge, Alaska, 1991. U.S. Fish and Wildlife Service, Kenai Fishery Resource Office, Alaska Fisheries Progress Report 95-1, Kenai, Alaska.

Harper, K.C. 1995b. Run timing and abundance of adult salmon in the Tuluksak River, Yukon Delta National Wildlife Refuge, Alaska, 1992. U.S. Fish and Wildlife Service, Kenai Fishery Resource Office, Alaska Fisheries Progress Report 95-3, Kenai, Alaska.

Harper, K.C. 1995c. Run timing and abundance of adult salmon in the Tuluksak River, Yukon Delta National Wildlife Refuge, Alaska, 1993. U.S. Fish and Wildlife Service, Kenai Fishery Resource Office, Alaska Fisheries Progress Report 95-2, Kenai, Alaska.

Harper, K.C. 1997. Run timing and abundance of adult salmon in the Tuluksak River, Yukon Delta National Wildlife Refuge, Alaska, 1994. U.S. Fish and Wildlife Service, Kenai Fishery Resource Office, Alaska Fisheries Technical Report 41, Anchorage, Alaska.

Heino, M. 1998. Management of evolving fish stocks. Canadian Journal of Fisheries and Aquatic Sciences 55: 1971–1982.

Hyer, K.E., and C.J. Schleusner. 2005. Chinook salmon age, sex, and length analysis from selected escapement projects on the Yukon River. U.S. Fish and Wildlife Service, Alaska Fisheries Technical Report Number 87, Anchorage, Alaska.

Jearld, A. 1983. Age determination. Pages 301-324 *in* L.A. Nielson and D.L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Koo, T.S.Y. 1962. Age determination in salmon. Pages 37-48 *in* T.S.Y. Koo, editor. Studies of Alaskan red salmon. University of Washington Press, Seattle, Washington.

Law, R., and D.R. Grey. 1989. Evolution of yields from populations with age-specific cropping. Evolutionary Ecology 3: 343–359.

Linderman, J. C., and M. Rearden. 2007. Kuskokwim Bay Salmon Fishery News Release #1, 2007 Kuskokwim Area regulatory changes, salmon outlook, and management strategies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Kuskokwim Area Office, Bethel, Alaska.

Martz, M., and B.S. Dull. 2006. Lower Kuskokwim River inseason subsistence salmon catch monitoring, 2005. Alaska Department of Fish and Game, Fishery Management Report Number 06-44, Anchorage, Alaska.

McAllister, M.K., R.M. Peterman, and D.M. Gillis. 1992. Statistical evaluation of a large-scale fishing experiment designed to test for a genetic effect of size-selective fishing on British Columbia pink salmon (Oncorhynchus gorbuscha). Canadian Journal of Fisheries and Aquatic Sciences 49: 1294–1304.

Miller, S.J., and K.C. Harper. 2009. Abundance and run timing of adult Pacific salmon in the Tuluksak River, Yukon Delta National Wildlife Refuge, Alaska, 2008**.** U.S. Fish and Wildlife Service, Kenai Fish and Wildlife Field Office, Alaska Fisheries Data Series Number 2009-5, Kenai, Alaska.

Miller, S.J., and K.C. Harper. 2010. Abundance and run timing of adult Pacific salmon in the Tuluksak River, Yukon Delta National Wildlife Refuge, Alaska, 2008**.** U.S. Fish and Wildlife Service, Kenai Fish and Wildlife Field Office, Alaska Fisheries Data Series Number 2010-2, Kenai, Alaska.

Molyneaux, D.B., D.L. Folletti, L. Dubois, G. Roczicka, and W. Morgan. 2003. Age, sex, and length composition of Chinook salmon from the 2002 Kuskokwim River subsistence fishery. Alaska Department of Fish and Game, Regional Information Report Number 3A04-13, Anchorage, Alaska.

Molyneaux, D.B., D.L. Folletti, L.K. Brannian, and G. Roczicka. 2004. Age, sex, and length composition of Chinook salmon from the 2003 Kuskokwim River subsistence fishery. Alaska Department of Fish and Game, Regional Information Report Number 3A04-23, Anchorage, Alaska.

Molyneaux, D.B., D.L. Folletti, L.K. Brannian, and G. Roczicka. 2005. Age, sex, and length composition of Chinook salmon from the 2004 Kuskokwim River subsistence fishery. Alaska Department of Fish and Game, Fishery Data Series Number 05-45, Anchorage, Alaska.

Montgomery, D.C. 1984. Design and analysis of experiments, 2nd edition. John Wiley & Sons, New York, New York.

Mosher, K. H. 1968. Photographic atlas of sockeye salmon scales. U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Fishery Bulletin Number 2: 243-274.

Plumb, M.P., K.C. Harper, and D.G. Spencer. 2007. Abundance and run timing of adult Pacific salmon in the Tuluksak River, Yukon Delta National Wildlife Refuge, Alaska, 2006**.** U.S. Fish and Wildlife Service, Kenai Fish and Wildlife Field Office, Alaska Fisheries Data Series Number 2007-4, Kenai, Alaska.

Plumb, M.P., and K.C. Harper. 2008. Abundance and run timing of adult Pacific salmon in the Tuluksak River, Yukon Delta National Wildlife Refuge, Alaska, 2007**.** U.S. Fish and Wildlife Service, Kenai Fish and Wildlife Field Office, Alaska Fisheries Data Series Number 2008-4, Kenai, Alaska.

RDCT (R Development Core Team). 2009. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Ricker, W.E. 1980. Causes of the decrease in age and size of Chinook salmon (Oncorhynchus tshawytscha). Canadian Technical Report of Fisheries and Aquatic Sciences 944.

Ricker, W.E. 1981. Change in the average size and average age of Pacific salmon. Canadian Journal of Fisheries and Aquatic Sciences 38:1636-1656.

Ricker. W.E. 1995. Trends in the average size of pacific salmon in Canadian catches. Pages 593–602 *in* R.J. Beamish, editor. Climate change and northern fish populations. Canadian Special Publication Fisheries Aquatic Science 121.

Riddell, B.E. 1986. Assessment of selective fishing on the age at maturity in Atlantic salmon (Salmo salar): A genetic perspective. Pages 102–109 *in* D. J. Meerburg, editor. Salmonid age at maturity. Canadian Special Publication Fisheries Aquatic Science 89.

Simon, J., T. Krauthoefer, D. Koster, and D. Caylor. 2007. Subsistence salmon harvest monitoring report, Kuskokwim Fisheries Management Area, Alaska, 2004. Alaska Department of Fish and Game, Division of Subsistence Technical Paper Number 313. Juneau, Alaska.

Strachan, D.G. 2005. 2005 soil geochemistry with recommendations for 2006 Nyac Gold District, Tintina Gold Province, Southwest Alaska.

Trippel, E.A. 1995. Age at maturity as a stress indicator in fisheries. BioScience 45: 759–771.

U.S. Fish and Wildlife Service. 1992. Fishery management plan for the Yukon Delta National Wildlife Refuge. U.S. Fish and Wildlife Service, Anchorage, Alaska.

Ward, T.C., M. Coffing, J. Estenson, R. Fisher, and D. Molyneaux. December 2003. Annual management report for the subsistence and commercial fisheries of the Kuskokwim Area, 2002. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A03-27, Anchorage, Alaska.

Whitmore, C., M. Martz, D.G. Bue, J.C. Linderman, and R. Fisher. 2005. Annual fishery management report for the subsistence and commercial fisheries of the Kuskokwim area 2003. Alaska Department of Fish and Game, Fisheries Management Report Number 05-72, Anchorage, Alaska.

Zabkar, L., F. Harris, and K. C. Harper. 2004. Abundance and run timing of adult Pacific salmon in the Tuluksak River, Yukon Delta National Wildlife Refuge, Alaska, 2003. U.S. Fish and Wildlife Service, Kenai Fishery Fish and Wildlife Service Office, Alaska Fisheries

Data Series Number 2004-6, Kenai, Alaska.

Zabkar, L., F. Harris, and K.C. Harper. 2005. Abundance and run timing of adult Pacific salmon in the Tuluksak River, Yukon Delta National Wildlife Refuge, Alaska, 2004. U.S. Fish and Wildlife Service, Kenai Fishery Fish and Wildlife Service Office, Alaska Fisheries Data Series Number 2005-6, Kenai, Alaska.

Zabkar, L.M., F. Harris, and K.C. Harper. 2006. Abundance and run timing of adult Pacific salmon in the Tuluksak River, Yukon Delta National Wildlife Refuge, Alaska, 2005. U.S. Fish and Wildlife Service, Kenai Fishery Fish and Wildlife Service Office, Alaska Fisheries Data Series Number 2006-8, Kenai, Alaska.

APPENDIX 1.—Number of Chinook salmon sampled by zone, sex, and gill net mesh size from the Tuluksak subsistence fishery during 2008.

2008									
		≤15.2 cm		>15.2 cm and <20.3 cm		≥20.3 cm		Total per Zone	
Zone	Sex	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1	Male	54	83%	9	69%	0	0%	63	77%
1	Female	11	17%	4	31%	0	0%	15	19%
2	Male	96	86%	101	63%	116	66%	313	70%
2	Female	15	14%	59	37%	59	34%	133	30%
3	Male	1	100%	30	58%	0	0%	31	58%
3	Female	0	0%	22	38%	0	0%	22	42%
Total	Male	151	85%	140	62%	116	66%	407	71%
Total	Female	26	15%	85	38%	59	34%	170	29%

APPENDIX 2.—Number of Chinook salmon sampled by zone, sex, and gill net mesh size from the Tuluksak subsistence fishery during 2009.

2009									
		≤15.2 cm		>15.2 cm and <20.3 cm		≥20.3 cm		Total per Zone	
Zone	Sex	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1	Male	49	74%	14	50%	4	44%	67	65%
1	Female	17	26%	14	50%	5	56%	36	35%
2	Male	158	80%	130	67%	174	64%	462	70%
2	Female	39	20%	65	33%	97	36%	201	30%
3	Male	64	74%	34	79%	0	0%	98	77%
3	Female	22	26%	9	21%	0	0%	31	24%
Total	Male	271	78%	178	67%	178	64%	627	70%
Total	Female	78	22%	88	33%	102	36%	268	30%

APPENDIX 3.—Age composition of the subsistence harvest collected from the Kuskokwim River near Tuluksak, Alaska during 2008.

		Brood Year and Age Group								
		2005	2004	2003	2003	2002	2002	2001	2001	
		1.1	1.2	1.3	2.2	1.4	2.3	1.5	2.4	Total
Sampling Dates:	06/26 - 07/12									
Male:	Number in Sample:	5	119	231	0	49	1	2	0	407
	% Males in Age Group:	1.2	29.2	56.8	0.0	12.0	0.2	0.5	0.0	100.0
	% in Harvest Sample:	0.9	20.6	40.0	0.0	8.5	0.2	0.3	0.0	70.6
	Samples From Harvest:	5	119	231	0	49	1	2	0	407
Female	Number in Sample:	0	1	50	0	115	0	3	1	170
	% Females in Age Group:	0.0	0.6	29.4	0.0	67.6	0.0	1.8	1	100.0
	% in Harvest Sample:	0.0	0.2	8.7	0.0	19.9	0.0	0.5	0	29.4
	Samples From Harvest:	0	1	50	0	115	0	3	1	170
Total:	Number in Sample:	5	120	281	0	164	1	5	1	577
	% in Harvest Sample:	0.9	20.8	48.7	0.0	28.4	0.2	0.9	0.2	100.0
	Total Samples From Harvest:	5	120	281	0	164	1	5	1	577

APPENDIX 4.—Estimated age and sex composition of weekly Chinook salmon escapements through the Tuluksak River weir, Alaska, 2008 (Miller and Harper, 2009).

		Brood Year and Age Group						
		2004	2003	2003	2002	2002	2001	
		1.2	1.3	2.2	1.4	2.3	1.5	Total
Strata 1 - 8:	06/29 - 08/23							
Sampling Dates:	07/01 - 08/19							
Male:	Number in Sample:	23	76	1	12	1	1	114
	% Males in Age Group:	25.4	65.1	0.3	6.3	2.7	0.3	100.0
	Estimated % of Escapement:	15.2	39.1	0.2	3.8	1.6	0.2	60.1
	Estimated Escapement:	107	274	1	26	11	1	421
Female	Number in Sample:	0	43	0	87	1	10	141
	% Females in Age Group:	0.0	25.3	0.0	67.8	0.5	6.5	100.0
	Estimated % of Escapement:	0.0	10.1	0.0	27.0	0.2	2.6	39.9
	Estimated Escapement:	0	71	0	190	1	18	280
Total:	Number in Sample:	23	119	1	99	2	11	255
	Estimated % of Escapement:	15.2	49.2	0.2	30.8	1.8	2.8	100.0
	Estimated Escapement:	107	345	1	216	13	20	701

APPENDIX 5.—Age composition of subsistence harvest collected from the Kuskokwim River near Tuluksak, Alaska 2009.

		Brood Year and Age Group									
		2006	2005	2004	2004	2003	2003	2002	2002	2001	
		1.1	1.2	1.3	2.2	1.4	2.3	1.5	2.4	1.6	Total
Sampling Dates:	06/26 - 07/12										
Male:	Number in Sample:	3	205	250	3	171	4	2	0	0	638
	% Males in Age Group:	0.5	32.1	39.2	0.5	26.8	0.6	0.3	0.0	0.0	100.0
	% in Harvest Sample:	0.3	22.6	27.5	0.3	18.8	0.4	0.2	0.0	0.0	70.3
	Samples From Harvest:	3	205	250	3	171	4	2	0	0	638
Female	Number in Sample:	0	0	34	0	228	0	5	2	1	270
	% Females in Age Group:	0.0	0.0	12.6	0.0	84.4	0.0	1.9	1	0.4	100.0
	% in Harvest Sample:	0.0	0.0	3.7	0.0	25.1	0.0	0.6	0	0.1	29.7
	Samples From Harvest:	0	0	34	0	228	0	5	2	1	270
Total:	Number in Sample:	3	205	284	3	399	4	7	2	1	908
	% in Harvest Sample:	0.3	22.6	31.3	0.3	43.9	0.4	0.8	0.2	0.1	100.0
	Total Samples From Harvest:	3	205	284	3	399	4	7	2	1	908

APPENDIX 6.—Estimated age and sex composition of weekly Chinook salmon escapements through the Tuluksak River weir, Alaska, 2009 (Miller and Harper, 2010).

		Brood Year and Age					
		2005	2004	2004	2003	2002	
		1.2	1.3	2.2	1.4	1.5	Total
Strata 2 – 9:	06/28 – 08/22						
Sampling Dates:	06/30 – 08/06						
Male:	Number in Sample:	39	55	1	26	0	121
	% Males in Age Group:	33.1	44.7	0.9	21.3	0.0	100.0
	Estimated % of Escapement:	18.6	25.2	0.5	12.0	0.0	56.4
	Estimated Escapement:	67	91	2	44	0	204
Female:	Number in Sample:	0	24	0	72	2	98
	% Females in Age Group:	0.0	23.3	0.0	74.3	2.3	100.0
	Estimated % of Escapement:	0.0	10.2	0.0	32.4	1.0	43.6
	Estimated Escapement:	0	37	0	117	4	158
Total:	Number in Sample:	39	79	1	98	2	219
	Estimated % of Escapement:	18.6	35.4	0.5	44.4	1.0	100.0
	Estimated Escapement:	67	128	2	161	4	362