U.S. Fish and Wildlife Service

Chinook Salmon Age, Sex, and Length Analysis from Selected Escapement Projects on the Yukon River

Alaska Fisheries Technical Report Number 87

Office of Subsistence Management
Fisheries Information Services Division
December 2005

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Abstract

Anecdotal information from fishers along the Yukon River suggests that the length of Chinook salmon harvested and the proportion of female Chinook salmon in the run have decreased over time. To determine whether sex composition, size, age, and size-at-age of Chinook salmon in spawning escapements have experienced a basin-wide decline over time, we examined escapement data from the Andreafsky, Anvik, Gisasa, Salcha, Chena, and Big Salmon rivers. Chinook salmon escapement samples were examined for changes in (1) proportion of female Chinook salmon, (2) proportion of large (≥ 900 mm) Chinook salmon (3) proportion of age-1.4 (6-year-old) and -1.5 (7-year-old) Chinook salmon, and (4) average length of older (age-1.4 and -1.5) Chinook salmon. Of the data sets examined only large (≥ 900 mm) Chinook salmon showed a consistent basin-wide trend. Four of seven time series examined show significant decreases in the relative abundance of large Chinook salmon over time. The estimated odds of sampling a large Chinook salmon decreased 4% per year (95% CI ={2.0%-5.0%}) during Anvik River carcass surveys, 2% per year (95% CI ={2.0%-3.0%}) during Chena River carcass surveys, 2% per year (95% CI ={1.0%-2.0%}) during Salcha River carcass surveys and 7% per year (95% CI ={4.0%-10.0%}) during Big Salmon River carcass surveys. No significant change in the odds of sampling a large Chinook salmon was seen at the Andreafsky and Gisasa rivers weirs or during the Andreafsky River carcass surveys. No basin-wide changes were found in the proportion of female Chinook salmon, the proportion of older (age-1.4 and -1.5) Chinook salmon, and in length-at-age of Chinook salmon in Yukon River escapement data sets. The analysis was not designed to infer cause of the observed trends. The scope of the analysis is limited to a relatively small number of spawning tributaries over a relatively short time period during which both fisheries and environmental changes have occurred confounding the ability to establish the sources of the decreasing size trend in Yukon River Chinook salmon.

Introduction

History

The Yukon River is the largest river in Alaska, draining an area of approximately 330,000 square miles. It originates in British Columbia, Canada and flows over 2,300 miles west across Alaska to the Bering Sea (Alaska Department of Fish and Game (ADF&G) 2002). Chinook salmon *Oncorhynchus tshawytscha* have been harvested in the Yukon River for centuries, predating sustained contact with Euro-American traders in 1833. Currently, 130,000 people live in the U.S. and Canadian portions of the Yukon River drainage. The region is remote, with a limited road system. About 80% of residents live in two communities on the road system, Fairbanks

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and Whitehorse. The remaining 20% reside in over 80 rural villages, which average fewer than 300 people, spread throughout the drainage. Most rural residents are of Yupik Eskimo and Athabascan Indian decent. Chinook salmon provide a crucial subsistence food source for rural residents, who harvested an average of 50,300 Chinook salmon annually during 1991–2000. Chinook salmon is also the primary fish species sought by commercial fishers, who harvested an average of 88,000 Chinook salmon annually during 1991–2000 (ADF&G 2003).

Most Yukon River Chinook salmon harvests occur in commercial and subsistence fisheries, which use similar techniques and gear types. The first recorded commercial harvest in the Yukon River was in 1918. By 1920, the dominant methods of harvest were set gill nets in the lower Yukon River and fishwheels in the upper Yukon River (Wolfe 1984). The commercial fishery was closed from 1925 to 1931 due to concerns of overharvest (ADF&G 2002). By 1950, drift gill nets were commonly used, becoming the dominant harvest method in the Yukon River in the mid-1970s (Wolfe 1984). Gill nets remain the primary technique for harvesting salmon in commercial and subsistence fisheries on the Yukon River. The efficiency of this gear type is controlled by the regulation of fishery timing, mesh size, and the depth and length of the nets.

Annual Yukon River harvests peaked in 1980 at 220,511 Chinook salmon and remained relatively stable through 1997. Beginning in 1998, annual harvests of Chinook salmon in the Yukon River began decreasing and reached a low of 55,066 in 2000. In response to below-average projected returns and low in-river abundances, regulations on fishery timing and gear became progressively more restrictive (ADF&G 2002). The Alaska Board of Fisheries classified Yukon River Chinook salmon as a stock with a yield concern in 2000 (Alaska Sustainable Salmon Fisheries Policy 5 AAC 39.222.(f)(42)). This determination was based on the inability, despite specific management measures, to maintain expected yields or harvestable surpluses above escapement needs since 1998. In 2001, the Alaska Board of Fisheries modified the Yukon River Chinook Salmon Management Plan by adding a fishing schedule for the subsistence fishery and closing the commercial fishery for the first time since 1931 (ADF&G 2004a). Since 2001, harvests and estimated escapements of Chinook salmon on the Yukon River have generally increased. In 2004, the total harvest in the U.S. portion of the Yukon River drainage was over 110,000 Chinook salmon.

Anecdotal evidence from fishers along the Yukon River suggests the length of Chinook salmon harvested and the proportion of female Chinook salmon in the run have decreased over time. Fishers are concerned these changes are due to the large-mesh gill-net fishery that selectively removes larger female Chinook salmon from the population. Potential effects of harvest on phenotypic patterns (especially size and age) are widely acknowledged (Ricker 1980, 1981, 1995, Hankin and Healey 1986, Healey 1986, Riddell 1986, Law and Grey 1989, McAllister et al. 1992, Trippel 1995, Heino 1998, and Hard 2004). Yukon River Chinook salmon stocks have been subjected to gill-net fisheries for over 80 years. Gill nets are size selective (ADF&G 1975, Law 2000, ADF&G 2004b, Bromaghin 2005), and this characteristic has been used in regulation to target specific species. Generally, 8-inch or greater stretched mesh (large mesh) is considered Chinook salmon gear and 6-inch or smaller stretched mesh is considered chum salmon *O. keta* gear.

Bigler et al. (1996) reported a 17.5% decrease in the weight of commercially caught Yukon River Chinook salmon during 1975–1993. He also reported a 3.82% decrease in the length of four-year-old Chinook salmon, but found no change in the length of five- and six-year-old

Chinook salmon caught during the same period. Decreasing trends in size represent potentially large losses in yield. This has important implications for fisheries management because the size selectivity of fishing gear can shift the age composition of spawning runs to younger and smaller fish, impacting productivity and yield (Ricker 1980, McAllister et al. 1992, Hankin et al. 1993, Hard 2004). Age-specific mating experiments conducted on Chinook salmon have shown that parental age has a strong influence on the age of maturity of their progeny (Hankin et al. 1993).

The reproductive value of female Chinook increases with size and age. Larger, older females carry more eggs and dig deeper redds that provide better protection (Healey and Heard 1984, Hankin and Healey 1986). Selective removal of large fish can also reduce variation in spawning timing and egg size within a population (Trippel 1995). In addition, reduction in the body size of Chinook salmon would be a disadvantage for extended upriver migrations (Bigler and Helle 1994).

In developing and testing net selectivity models for Yukon River Chinook salmon test fisheries, Bromaghin (2005) describes the selectivity of gill nets as “the relative probability that a fish that comes into contact with the gear is captured.” Gill nets are most efficient for fish whose head girth is slightly larger than the perimeter of the mesh size. Most fish captured by gill nets are caught as their heads pass into the mesh and the gear catches behind the operculum. The selectivity of the gear decreases for smaller or larger fish. Thorpe (1993) suggests that it is “nearly impossible to exploit a living resource without imparting some genetic change”; gear selectivity implies directional selection.

A concern that selectivity of the large-mesh gill-net fishery through time has removed larger female Chinook salmon from the spawning population was raised during a Yukon River U.S./ Canada Treaty negotiation session in 1997. The U.S./Canada Yukon River Joint Technical Committee (JTC) was tasked to compile available information on Yukon River Chinook salmon age-sex-length (ASL) composition. The JTC examined length-at-age over time in six locations: the Y-1 commercial fishery, Big Eddy test fishery, Andreafsky River escapement, Salcha River escapement, Canadian border fishwheel, and Canadian commercial fishery. The JTC length-at-age data analysis did not show any substantial change in Chinook salmon size (U.S./Canada Yukon River JTC 1998).

Continuing concerns raised by local fishermen about the decline in abundance of large Chinook salmon have heightened managers’ concerns about long-term impacts of gill-net fisheries on Chinook salmon populations in the Yukon River. In 2004, the National Park Service subsistence biologist and the U.S. Fish and Wildlife Service fishery manager for the Yukon River asked the Office of Subsistence Management, Fisheries Information Services Division to further investigate age, sex, and length trends in Yukon Chinook salmon. This report documents findings of that investigation.

Objectives

To determine whether sex composition, size, age, and size-at-age of Chinook salmon in the spawning escapements have declined over time, we examined time series of spawning escapement samples for changes in

1. the proportion of female Chinook salmon,
2. the proportion of large (≥ 900 mm) Chinook salmon,

3. the proportion of age-1.4 (6-year-old) and -1.5 (7-year-old) Chinook salmon, and
4. the lengths-at-age of age-1.4 and -1.5 Chinook salmon.

The intent of this study was to look for Yukon River basin-wide trends in Chinook salmon sex composition, size, age, and size-at-age, and not for trends within individual spawning populations.

Methods

Data Sets

We requested time series ASL data of spawning Chinook salmon populations from both ADF&G and Canadian Department of Fisheries and Oceans (CDFO). In July 2004, ADF&G provided ASL data for five Yukon River tributaries: Andreafsky, Anvik, Gisasa, Salcha, and Chena rivers (Hamner et al. 2002). These rivers represent two lower and three middle Yukon River tributaries. In January 2005, ADF&G provided an additional data set from the Big Salmon River in Canada. Big Salmon River data were collected during ADF&G carcass surveys (Figure 1).

Because we were interested in evaluating phenotypic changes, we needed to examine information from multiple generations. Data sets selected for our analysis represent weir escapement projects and carcass surveys operated in the U.S. portion of the Yukon River for over ten years. The data set from Big Salmon River contained only nine years of data, but was included in the analysis because it represents an upriver stock that may have been subjected to the greatest selective pressures from harvests.

Sample size varied among escapement projects and years, and data sets contained 9 to 28 years of samples. None of the data sets used represented a complete time series; each data set has two or more missing years of data. In all data sets used, salmon lengths were mid-eye-to-fork-of-tail (MEF) measurements in millimeters. Most salmon ages were determined from scales, but a small number were determined from otoliths. Sex was determined from visual inspection of external features.

To ensure sufficient sample sizes, analysis was confined to Chinook salmon spending only one year in fresh water. Analysis was further restricted to individuals spending five years or less in salt water. Although data sets contained information from individuals spending zero and two years in fresh water, and individuals spending more than 5 years in salt water, their numbers accounted for less than 1% of the data.

Andreafsky River Carcass Survey Data—Escapement data from carcass surveys on the East and West forks of the Andreafsky River were pooled for the analysis providing 13 years (1980–1985, 1988–1993, 1996) of usable ASL data (Figure 2).

Andreafsky River Weir Data—The Andreafsky River weir data set used for this analysis provided 11 years (1994–2004) of usable ASL data (Figure 2, Appendix 1).

Anvik River Carcass Survey Data—The Anvik River data set used for this analysis provided 25 years (1976–1978, 1980–1982, 1984–1985, 1988–2004) of usable ASL data (Figure 2).

Gisasa River Weir Data—The Gisasa River data set used for this analysis provided 10 years (1995–2004) of usable ASL data (Figure 2, Appendix 2).

Chena River Carcass Survey Data—The Chena River data set used for this analysis provided 22 years (1975, 1981–1982, 1984–1985, 1988–2004) of usable ASL data (Figure 2).

Salcha River Carcass Survey Data—The Salcha River data set used for this analysis provided 28 years (1970, 1972–1973, 1975–1976, 1978–1979, 1981–1982, 1984–1985, 1988–2004) of usable ASL data (Figure 2).

Big Salmon River Carcass Survey Data—The Big Salmon River data set used for this analysis provided nine years (1980–1985, 1988–1990) of usable ASL data (Figure 2).

Data Analysis

Age, sex and length samples collected at the Andreafsky and Gisasa weirs were collected using weekly stratification (Tobin and Harper 1995, Melegari 1996). To account for the stratified random sampling, ASL samples were weighted. Weights were calculated as

$$w_{ysi} = \frac{N_{ys}}{N_y}\frac{1}{n_{ys}}$$

where

w_{ysi} = weight for fish *i* in stratum *s* during year *y*,
n_{ys} = number of ASL samples collected in stratum *s* during year *y*,
N_{ys} = escapement in stratum *s* during year *y*,
N_y = total escapement during year *y*.

Trends in Proportions—Four variables of interest: (1) proportion of female Chinook salmon, (2) proportion of Chinook salmon ≥ 900 mm MEF, (3) proportion of age-1.4 Chinook salmon, and (4) proportion of age-1.5 Chinook salmon, were modeled as binomial random variables using logistic regression (Hosmer and Lemeshow 1989).

$$Logit(\pi) = Ln(\frac{\pi}{1-\pi}) = B_o + B_1 X \ , \tag{1}$$

where

π = binomial random variable,
B_o = intercept coefficient,
B_1 = slope coefficient for year, and
X = year.

Analysis was completed using PROC LOGISTIC (Allison 1999). Trends in the data sets were considered statistically significant at a p-value ≤ 0.05. Results were presented as odds ratios where an odds ratio greater than one signifies an increase in the probability of sampling a female Chinook salmon over a one-year period; values less than one signify a decrease in the probability of sampling a female Chinook salmon over a one-year period; and values of one signify no change. For example, an analysis of the change in proportions of female Chinook salmon over time might result in an odds ratio of 1.29. This implies that the predicted odds of encountering a female Chinook salmon increases 29% per year (Ramsey 2002).

Proportion of Female Chinook Salmon—The proportion of female Chinook salmon was calculated by combining age-1.3, -1.4 and -1.5 female salmon within an annual sample and dividing this value by the total number of Chinook salmon of both sexes and all ages sampled that year. Age-1.1 and age-1.2 Chinook salmon identified as females were not considered for this analysis because these fish were probably incorrectly sexed. Changes in the proportion of female Chinook salmon over time were modeled using logistic regression (equation 1).

Proportion of Chinook Salmon ≥ 900 mm MEF—The proportion of the largest Chinook salmon in the escapement was defined as the proportion of Chinook salmon ≥ 900 mm within each annual sample. Chinook salmon ≥ 900 mm on average represented the upper 12% of the lengths in the data sets. Changes in this proportion over time were modeled using logistic regression (equation 1).

Proportion of Age-1.4 and -1.5 Chinook Salmon—Trends in the proportion of age-1.4 and -1.5 Chinook salmon were modeled separately using logistic regression (equation 1). The proportion of age-1.4 Chinook salmon in the escapement was calculated as the number of age-1.4 individuals within each escapement sample divided by the total number of Chinook salmon in that sample. The proportion of age-1.5 Chinook salmon in the escapement was calculated as the number of age-1.5 individuals within each escapement sample divided by the total number of Chinook salmon in the sample.

Length-at-Age for age-1.4 and -1.5 Chinook Salmon—Trends in Chinook salmon length-at-age were modeled separately for ages-1.4 and -1.5 by sex over time using linear models (Myers 1990).

$$E(Y) = B_o + B_1 X \quad , \tag{2}$$

where

$E(Y)$ = expected value of length as a function of year,
B_o = intercept coefficient,
B_1 = slope coefficient for year, and
X = year.

Models using length as the response variable and year as the independent variable were completed in PROC GLM (SAS institute Inc. 1990). Trends in the data sets were considered statistically significant at a p-value $\leq$ 0.05.

Results

Proportion of Female Chinook Salmon

The proportion of female Chinook salmon significantly changed over time in four of the seven sampled escapements; however, there was no clear pattern to the direction (increase or decrease) of change.

Andreafsky River Carcass Survey—No significant change was seen in the estimated odds of sampling female Chinook salmon over time during Andreafsky River carcass surveys (Figure 3a, Table 1).

Andreafsky River Weir—No significant change was seen in the estimated odds of sampling female Chinook salmon at the Andreafsky River weir (Figure 3b, Table 1).

Anvik River Carcass Survey—The estimated odds of sampling female Chinook salmon over time during Anvik River carcass surveys significantly decreased 2.0–3.0% per year (95% confidence interval; Figure 3c, Table 1).

Gisasa River Weir—No significant change was seen in the estimated odds of sampling female Chinook salmon at the Gisasa River weir (Figure 3d, Table 1).

Chena River Carcass Survey—The estimated odds of sampling female Chinook salmon over time during Chena River carcass surveys decreased 1.0–3.0% per year (95% confidence interval; Figure 3e, Table 1).

Salcha River Carcass Survey—The estimated odds of sampling female Chinook salmon over time during Salcha River carcass surveys increased 0.0–1.0% per year (95% confidence interval; Figure 3f, Table 1).

Big Salmon River Carcass Survey—The estimated odds of sampling female Chinook salmon over time during Big Salmon River carcass surveys decreased 8.0–11.0% per year (95% confidence interval; Figure 3g, Table 1).

Proportion of Chinook Salmon ≥ 900 mm MEF

The proportion of Chinook salmon ≥ 900 mm MEF significantly decreased over time in four of seven sampled escapements.

Andreafsky River Carcass Survey—No significant change was seen in the estimated odds of sampling Chinook salmon ≥ 900 mm during Andreafsky River carcass surveys (Figure 4a, Table 2).

Andreafsky River Weir—No significant change was seen in the estimated odds of sampling Chinook salmon ≥ 900 mm at the Andreafsky River weir (Figure 4b, Table 2).

Anvik River Carcass Survey—The estimated odds of sampling Chinook salmon ≥ 900 mm during Anvik River carcass surveys decreased 2.0–5.0% per year (95% confidence interval; Figure 4c, Table 2).

Gisasa River Weir—No significant change was seen in the estimated odds of sampling Chinook salmon ≥ 900 mm at the Gisasa River weir (Figure 4d, Table 2).

Chena River Carcass Survey—The estimated odds of sampling Chinook salmon ≥ 900 mm during Chena River carcass surveys decreased 2.0–3.0% per year (95% confidence interval; Figure 4e, Table 2).

Salcha River Carcass Survey—The estimated odds of sampling Chinook salmon ≥ 900 mm during Salcha River carcass surveys decreased 1.0–2.0% per year (95% confidence interval; Figure 4f, Table 2).

Big Salmon Carcass Survey—The estimated odds of sampling Chinook salmon ≥ 900 mm during Big Salmon River carcass surveys decreased 4.0–10.0% per year (95% confidence interval; Figure 4g, Table 2).

Proportion of age-1.4 and -1.5 Chinook Salmon

The proportion of age-1.4 Chinook salmon significantly changed over time in three of seven sampled escapements; and the proportion of age-1.5 Chinook salmon significantly changed over time in two of seven sampled escapements. However, there was no clear pattern to the direction (increase or decrease) of change for any age class.

Andreafsky River Carcass Survey—No significant change was seen in the estimated odds of sampling either age-1.4 or -1.5 Chinook salmon during Andreafsky River carcass surveys (Figure 5a, Tables 3a and 3b).

Andreafsky River Weir—No significant change was seen in the estimated odds of sampling either age-1.4 or -1.5 Chinook salmon at Andreafsky River weir (Figure 5b, Tables 3a and 3b).

Anvik River Carcass Survey—The estimated odds of sampling age-1.4 Chinook salmon decreased 0.0–2.0% per year (95% confidence interval), but no significant change was seen for age-1.5 Chinook salmon during Anvik River carcass surveys (Figure 5c, Tables 3a and 3b).

Gisasa River Weir—No significant change was seen in the estimated odds of sampling either age-1.4 or -1.5 Chinook salmon at Gisasa weir (Figure 5d, Tables 3a and 3b).

Chena River Carcass Survey—No significant change was seen in the estimated odds of sampling age-1.4 Chinook salmon, but the estimated odds of sampling age-1.5 Chinook salmon decreased 3.0–5.0% per year (95% confidence interval) during Chena River carcass surveys (Figure 5e, Tables 3a and 3b).

Salcha River Carcass Survey—The estimated odds of sampling age-1.4 Chinook salmon increased 0.0–0.1% per year (95% confidence interval), but no significant change was seen for age-1.5 Chinook salmon during Salcha River carcass surveys (Figure 5f, Tables 3a and 3b).

Big Salmon River Carcass Survey—The estimated odds of sampling age-1.4 Chinook salmon decreased 7.0–11.0% per year (95% confidence interval) and increased 17.0–27.0% per year (95% confidence interval) for age-1.5 Chinook salmon during Big River carcass surveys (Figure 5g, Tables 3a and 3b).

Length-at-age for age-1.4 and -1.5 Chinook salmon

Significant changes in length-at-age for age-1.4 and -1.5 Chinook salmon were found in 10 of 27 relationships examined.

Andreafsky River Carcass Survey—One of four relationships examined showed a significant trend in length-at-age data for Andreafsky River carcass surveys (Figure 6a, Table 4a). Mean length declined 0.0–2.1 mm per year (95% confidence interval) for age-1.4 females. Overall mean length was 854 mm for age-1.4 females (Appendix 3).

Andreafsky River Weir—Three of four relationships were examined for trends in length-at-age data for the Andreafsky River weir. No analysis was done on age-1.5 males due to the small sample size (n=7). No significant trend was detected in the three relationships examined (Figure 6b, Table 4b and Appendix 4).

Anvik River Carcass Survey—One of four relationships examined showed a significant trend in length-at-age data for Anvik River carcass surveys (Figure 6c, Table 4c). Mean length declined 0.9–1.5 mm per year (95% confidence interval) for age-1.4 females. Overall mean length was 841 mm for age-1.4 females (Appendix 5).

Gisasa River Weir—None of the four relationships examined showed a significant trend in the length-at-age data for Gisasa River weir (Figure 6d, Table 4d and Appendix 6).

Chena River Carcass Survey—One of four relationships examined showed a significant trend in length-at-age data for Chena River carcass surveys (Figure 6e, Table 4e). Mean length of Chinook salmon increased 0.1–0.8 mm per year (95% confidence interval) for age-1.4 females. Overall mean length was 865 mm for age-1.4 females (Appendix 7).

Salcha River Carcass Survey—Three of four relationships examined showed a significant trend in length-at-age data for Salcha River carcass surveys (Figure 6f, Table 4f). Mean length of Chinook salmon decreased 1.1–2.2 mm per year (95% confidence interval) for age-1.4 males, 0.2–2.7 mm per year (95% confidence interval) for age-1.5 males, and 0.5–1.9 mm per year (95% confidence interval) for age-1.5 females. Overall mean length was 864 mm for age-1.4 males, 980 mm for age-1.5 males, and 927 mm for age-1.5 females (Appendix 8).

Big Salmon River Carcass Survey—All four relationships investigated showed a significant decrease in length-at-age for Big Salmon River carcass surveys (Figure 6g, Table 4g). Mean length of Chinook salmon decreased 6.2–12.8 mm per year (95% confidence interval) for age-1.4 males, 2.4–14.0 mm per year (95% confidence interval) for age-1.5 males, 3.3–5.9 mm per year (95% confidence interval) for age-1.4 females, and 1.0–5.3 mm per year (95% confidence interval) for age-1.5 females. Overall mean length was 827 mm for age-1.4 males, 964 mm for age-1.5 males, 872 mm for age-1.4 females, and 927 mm for age-1.5 females (Appendix 9).

Discussion

Data Quality

Hard (2004) developed an age-structured model that predicted harvest-imposed directional selection on Chinook salmon size would lead to modest reductions in age-specific size within five generations (approximately 25 years). However, Pacific salmon ASL data sets of sufficient quality for analyses extending 25 years or farther are uncommon (Bigler and Helle 1994; Healey 1986). This report documents the analysis of ASL information collected from six Yukon River tributary projects that represent the longest time series of escapement data available for Chinook salmon within this drainage (Figure 2). Three of seven ASL data sets analyzed for this report contained over 20 years of data—those for Salcha (28 years), Anvik (25 years), and Chena (22 years) river carcass surveys. The remaining three data sets analyzed contained 13 or fewer years—those for Andreafsky (13 years) and Big Salmon (9 years) river carcass surveys, and Gisasa (10 years) and Andreafsky River (11 years) weirs. These data were collected over a 35-year period by several agencies using various techniques under variable field conditions. Therefore, all these data sets contain unknown variation introduced by differences in time series, sampling strategies, measurement error, crew experience, and environmental conditions.

Yukon River Chinook salmon escapements are shaped by changes in fisheries management regimes, including the selectivity of fishing gear in commercial and subsistence fisheries. Recent time series of escapement data were collected during a particularly dynamic period in Chinook salmon fishery management. In 2001, no commercial fishing was allowed. In subsequent years, windowed openings for the subsistence fishery were implemented in attempts to improve harvest quality and allow portions of the run to enter spawning tributaries without being subjected to fisheries. Current salmon management is based on stock-recruitment theory, and managers strive to maintain a constant escapement that is thought to achieve maximum or high sustained yield for fisheries. While ASL data analyzed for this report are thought to represent Chinook salmon populations from several spawning areas, these data do not represent the total run.

When judging these data sets, trends over time must be considered with the knowledge that none of the time series are continuous. The gaps represent years in which escapement samples were not collected or for which data have not been processed, as well as years eliminated due to suspected coding errors. In addition, the data sets represent different time periods. No ASL information has been collected from Big Salmon River in the last 14 years, so these Canadian data do not substantially overlap with any of the more recent U.S. data. For example, the Big Salmon and Gisasa river time series do not overlap at all, since Big Salmon River data were collected prior to 1991 and Gisasa River data were collected after 1994 (Figure 2).

Interpretation of Results

Results were interpreted within the context of basin-wide spawning trends rather than population-specific spawning trends.

Has the proportion of spawning female Chinook salmon declined over time? No. Results showed no discernible basin-wide trend in the proportion of females in the spawning escapement (Table 1). We assumed Chinook salmon from drainages in close proximity would be exposed to similar environmental and fisheries pressures, and that populations in adjacent tributaries would show similar trends. However, results from Tanana River tributaries showed different trends. The proportion of female Chinook salmon in the Chena River decreased slightly through time, while the proportion in the nearby Salcha River increased slightly. The geographic pattern of results makes it difficult to conclude that there was a drainage-wide trend over the study years.

Has the proportion of large (≥ 900 mm) spawning Chinook salmon declined over time? Yes. Results showed a decrease in the proportion of large Chinook salmon sampled through time in four of the six tributaries examined (Table 2). Escapement data from the Anvik, Chena, Salcha, and Big Salmon rivers showed a significant decrease in the proportion of large Chinook salmon, although no significant trends were found in the Andreafsky or Gisasa rivers.

Have the proportions of age-1.4 and -1.5 spawning Chinook salmon declined over time? No. Results showed no clear basin-wide trend in the proportion of age-1.4 or -1.5 Chinook salmon in spawning populations (Tables 3a and 3b). The proportion of age-1.4 Chinook salmon decreased in the Anvik and Big Salmon rivers, and increased in the Salcha River; the proportion of age-1.5 Chinook salmon decreased in the Chena River and increased in the Big Salmon River.

Have the lengths of age-1.4 and -1.5 spawning Chinook salmon declined over time? With fewer than half of the tests (10 of 27) showing a significant decline, it is difficult to conclude that the lengths of older spawning Chinook salmon have consistently declined basin-wide

(Tables 4 a–g). The most significant changes were seen for age-1.4 female Chinook salmon, which showed a length decrease in three of the six tributaries—Andreafsky (carcass data), Anvik, and Big Salmon rivers—and an increase in the Chena River. Age-1.4 male, -1.5 male, and -1.5 female Chinook salmon all showed a length decrease in the Salcha River. All age-1.4 and -1.5 Chinook salmon showed a decrease in length in the Big Salmon River.

The magnitude of changes within the six tributaries was largest within the nine years of ASL data collected prior to 1991 on the Big Salmon. One would expect to see the greatest changes in upriver stocks, such as the Big Salmon River spawning population, since they typically have earlier run timing and are exposed to the combined effects of commercial and subsistence fisheries for a longer period of time than lower-river stocks (Figure 1).

Application of Results

One trend was identified, a decrease in the proportion of large (≥ 900 mm) Chinook salmon spawning in a majority of the sampled tributaries. Although this analysis was initiated because of concerns about size-selective harvests of large-mesh gill nets, the study could not be designed to assign a cause to any identified trends. Several other studies of Pacific salmon have documented declining trends in the size of all five species (Ricker 1980, 1981, 1995, Healey 1986, Beamish and Bouillon 1993, Ishida et al. 1993, Bigler and Helle 1994, Bigler et al. 1996, Cox and Hinch 1997, Ratner and Lande 2001). The two primary explanations for these declines have been selective fisheries, and long-term variation in the ocean environment.

The commercial fishery has operated on the Yukon River for 87 years, and gill nets have been the primary gear used for commercial as well as subsistence salmon harvests since the 1970s. Studies have shown gill nets to be size selective for Chinook salmon (ADF&G 1975, ADF&G 2004b, Bromaghin 2005), and selective harvest of fishes favors genotypes with slower growth and earlier age of maturity (Conover and Munch 2002). Other studies have shown that a size-selective harvest is likely to alter size, age of maturity, and fecundity of exploited populations (Ricker 1980, Kaitala and Getz 1995, Heino 1998, Ratner and Lande 2001, Hankin et al. 1993, and Hard 2004). However, direct evidence linking harvesting practices and evolution of either size or life history in natural stocks is limited (Ratner and Lande 2001). One of the few studies to measure heritability of size in the wild was conducted on sea-ranched Atlantic salmon *Salmo salar* parr (Jonasson et al. 1997). The investigators showed that declines in body size would be expected on a decadal scale and acknowledged the difficulty in disentangling nongenetic causes of change from directional change due to fishing. Riddell (1986) cautioned that fishing is only one source of adult mortality, and suggested that the response to selective pressures could be reduced if natural selection favored larger fish or might be masked by environmental conditions.

The scope of our analysis is somewhat limited, since we could examine only a relatively small number of spawning population samples obtained over a relatively short time period during which both fisheries and environmental changes have occurred. Without accurate baseline data on the age, sex, and length composition of Yukon River Chinook salmon stocks prior to the widespread use of large-mesh gill nets, or comparable data on unfished stocks, it is not possible to determine whether any of the trends we found were due to selectivity of the gill-net fishery. Changing environmental conditions could have caused these trends or confounded our ability to discern selectivity effects of the fishery. For example, Beamish and Bouillon (1993) correlated patterns of the Aleutian low-pressure system with salmon abundance and copepod production, and found that recent increases in Bering Sea temperature have led to a shrinking of the ice pack, fewer nutrients in the upper water layers, and a shift in the phytoplankton community, including coccolithiphore blooms of unprecedented size (Stabeno et al. 1998). At the same time, changes have been documented in the zooplankton communities that serve as food for salmon (Napp et al. 1998). Earlier studies by Ricker (1981, 1995), however, indicated that trends in Pacific salmon size could not be completely explained by sea surface temperature or salinity. Finally, another potential factor affecting the size and age of wild salmon stocks is the presence of hatchery-produced salmon, which directly compete for forage with wild salmon in the Bering Sea and Gulf of Alaska (Ishida et al. 1993, Bigler and Helle 1994, Bigler et al. 1996).

It is possible that the documented change in relative abundance of large Chinook salmon represents effects of many factors. It is unclear if these phenotypic changes are a result of genetic selection for smaller size and early age at maturation. Phenotypic variation in Yukon River Chinook salmon is confounded by environmental influences as well as by biotic changes to stocks caused by fishing pressure. The magnitude and pattern of phenotypic changes may be a poor measure of actual genetic changes (Conover 2000).

Recommendations

To continue exploring changes in Yukon River Chinook salmon sex, age, size, and size-at-age composition, we recommend the following:

1. Reinstate collection of spawning escapement data from main Yukon River spawning tributaries located in Canada, to monitor future trends in Yukon Chinook salmon upper river populations.
2. Examine Yukon River Chinook salmon commercial harvest ASL data for trends over time, and compare changes to those found in the spawning escapement ASL data.
3. Incorporate yearly project-specific contextual and environmental information that fully describes data quality in the Arctic-Yukon-Kuskokwim Salmon Database.
4. Systematically document Yukon River Chinook salmon subsistence harvests and ASL composition.
5. Explore ways to better document gear types and mesh sizes used in commercial and subsistence fisheries.
6. Explore new collection technologies to improve the accuracy of ASL data, and standardize data collection, analysis, and storage across agencies.

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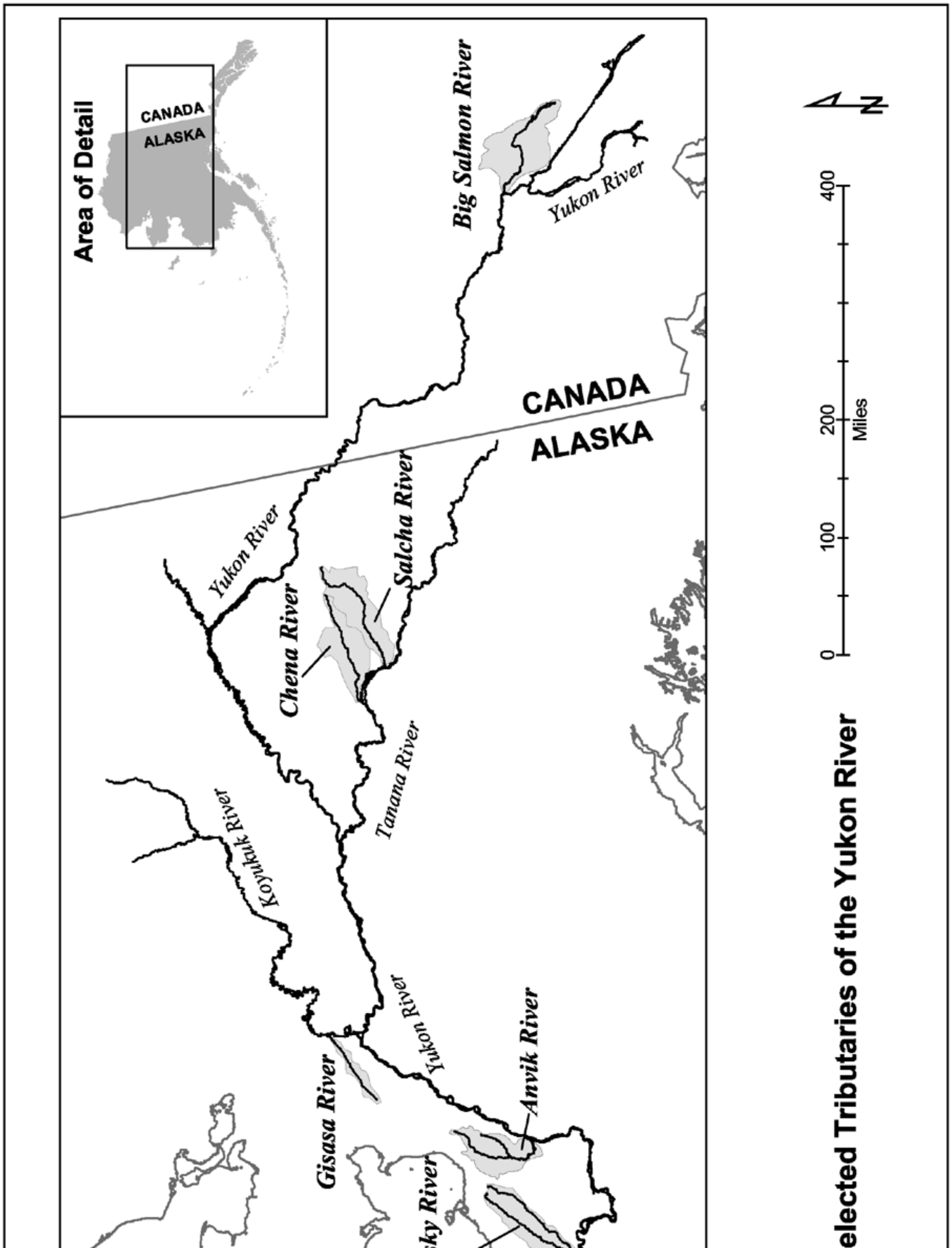


Figure 1. Locations of the six tributaries with long-term ASL monitoring data, located within the Yukon River drainage.

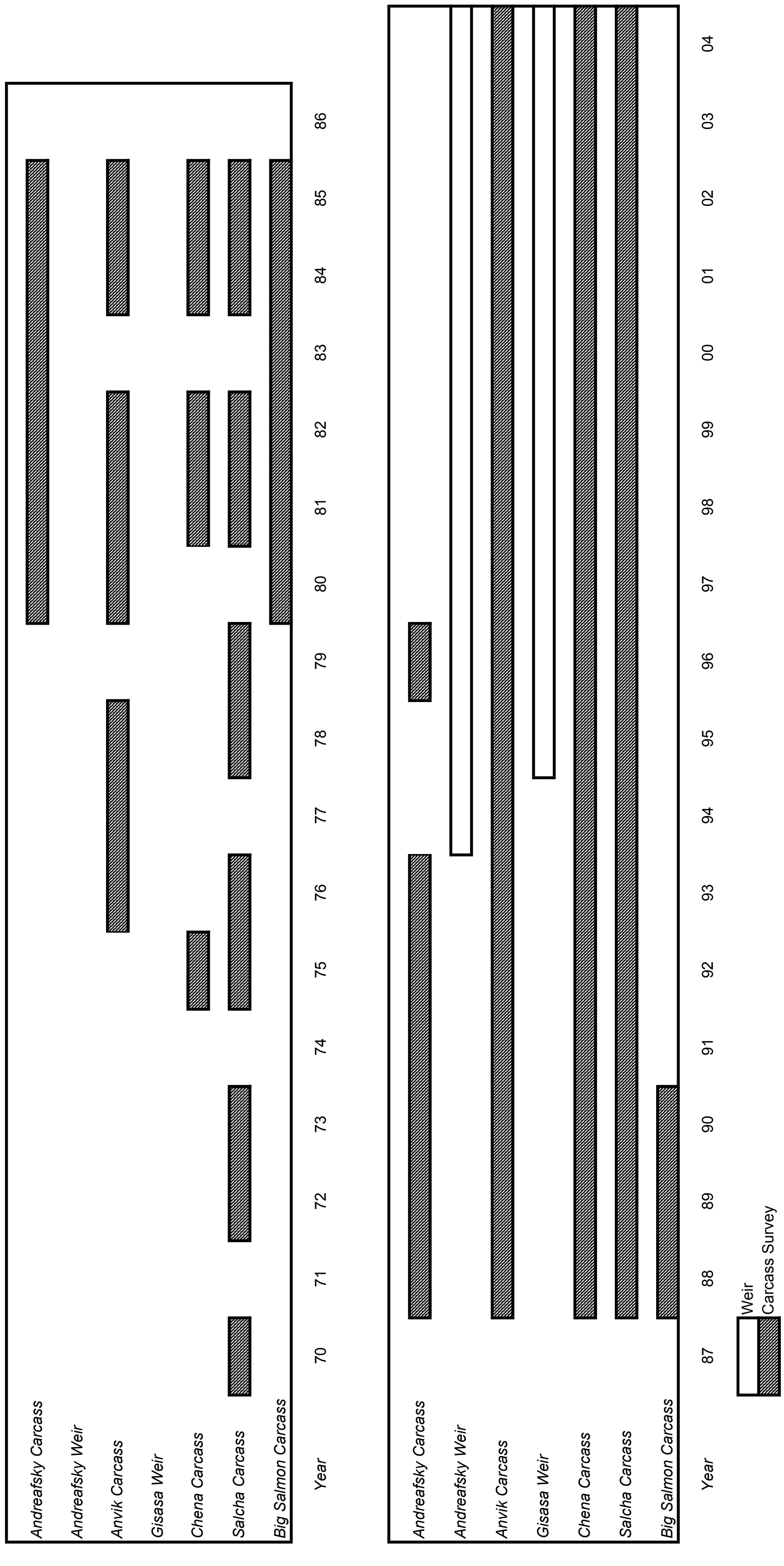
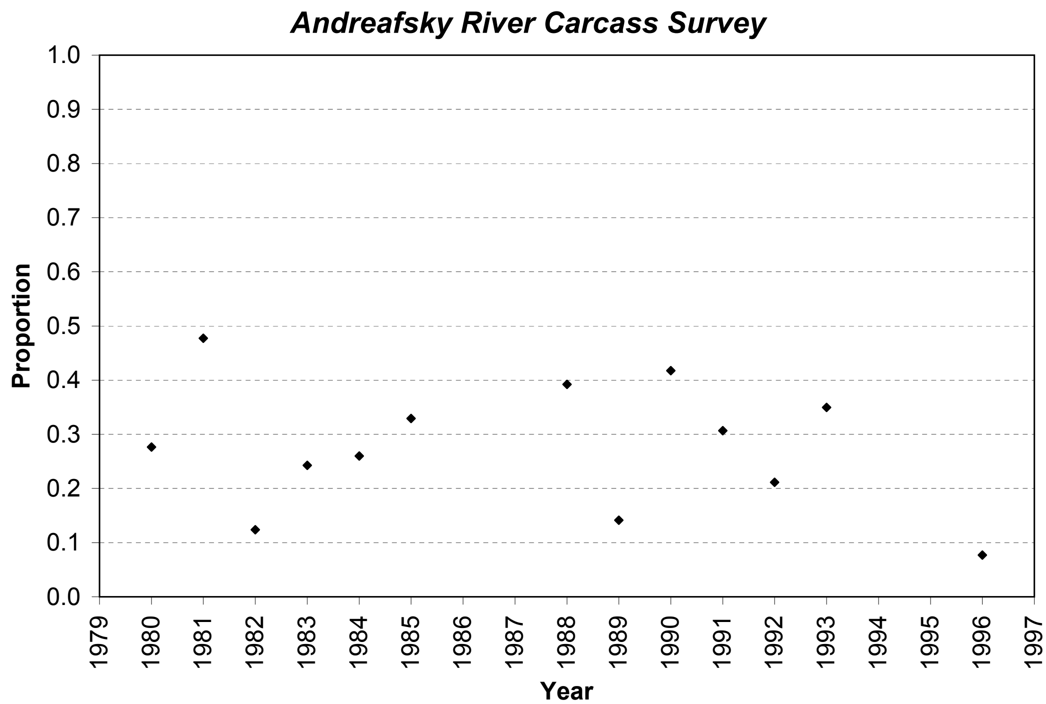
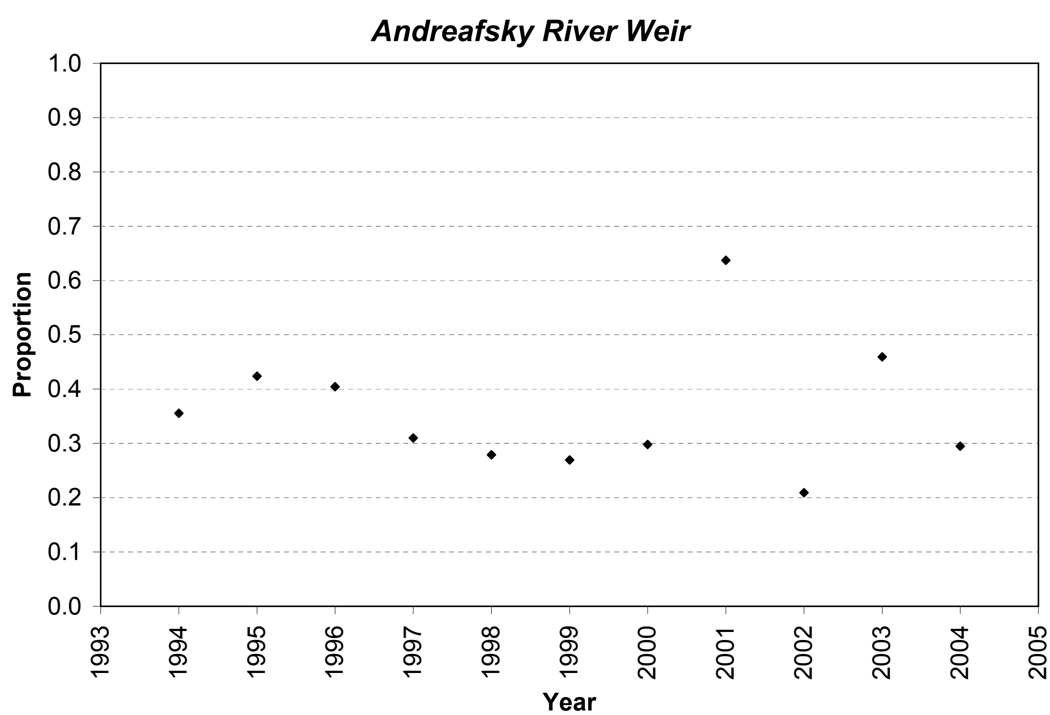


Figure 2. Primary sampling methods and years of collection for ASL data from six Yukon River tributaries 1970–2004.

3a.

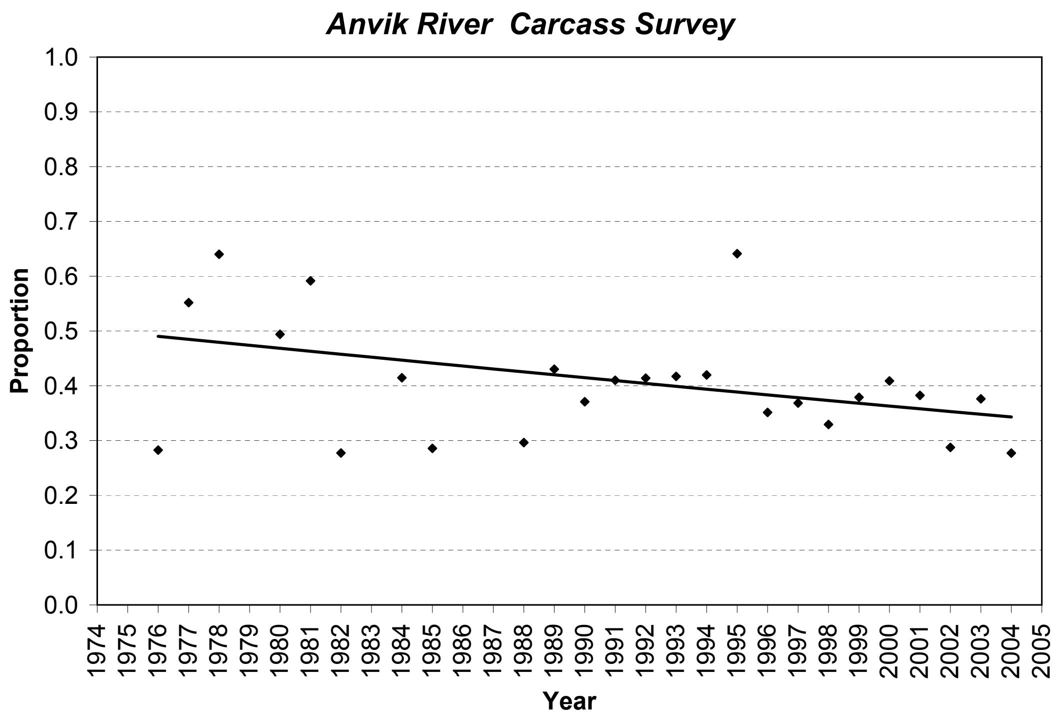


3b.

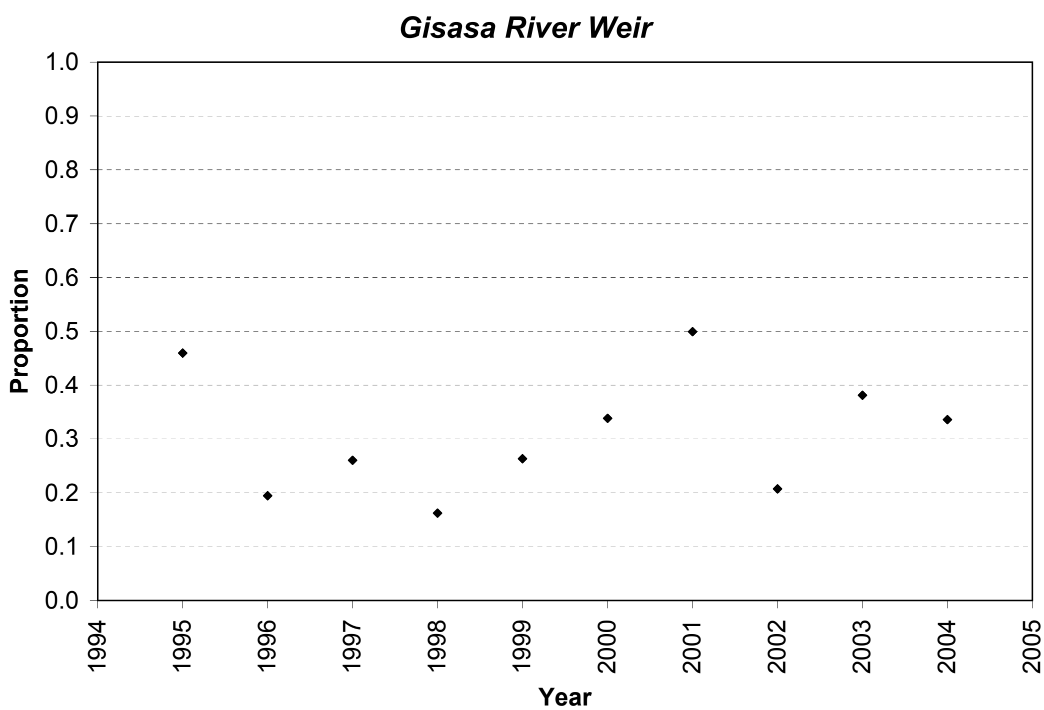


Figures 3a and 3b. Proportions of female Chinook salmon from the Andreafsky River.

3c.

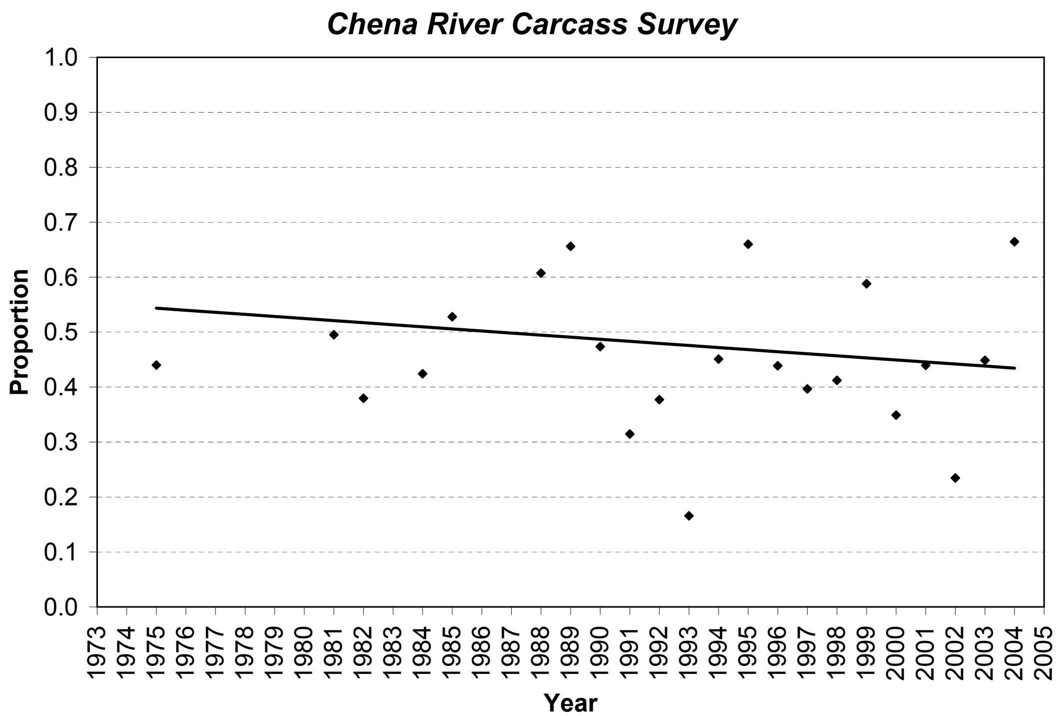


3d.

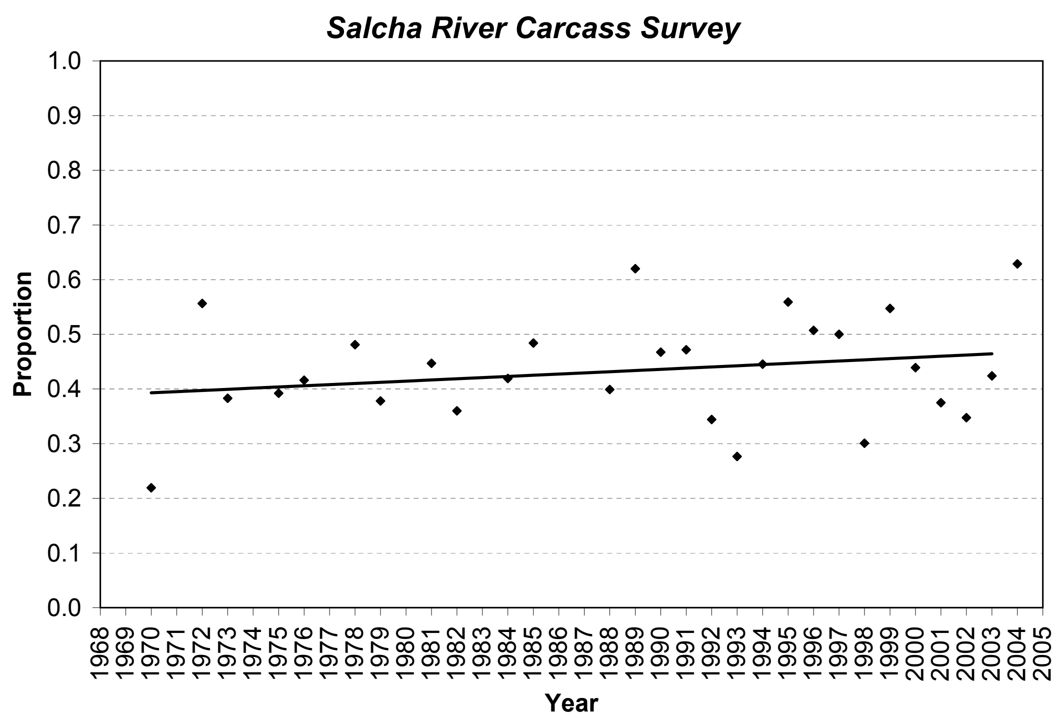


Figures 3c and 3d. Proportions of female Chinook salmon from the Anvik and Gisasa rivers. Regression line indicates a significant change in the proportion of females through time.

3e.



3f.



Figures 3e and 3f. Proportions of female Chinook salmon from the Chena and Salcha rivers. Regression line indicates a significant change in the proportion of females through time.

3g.

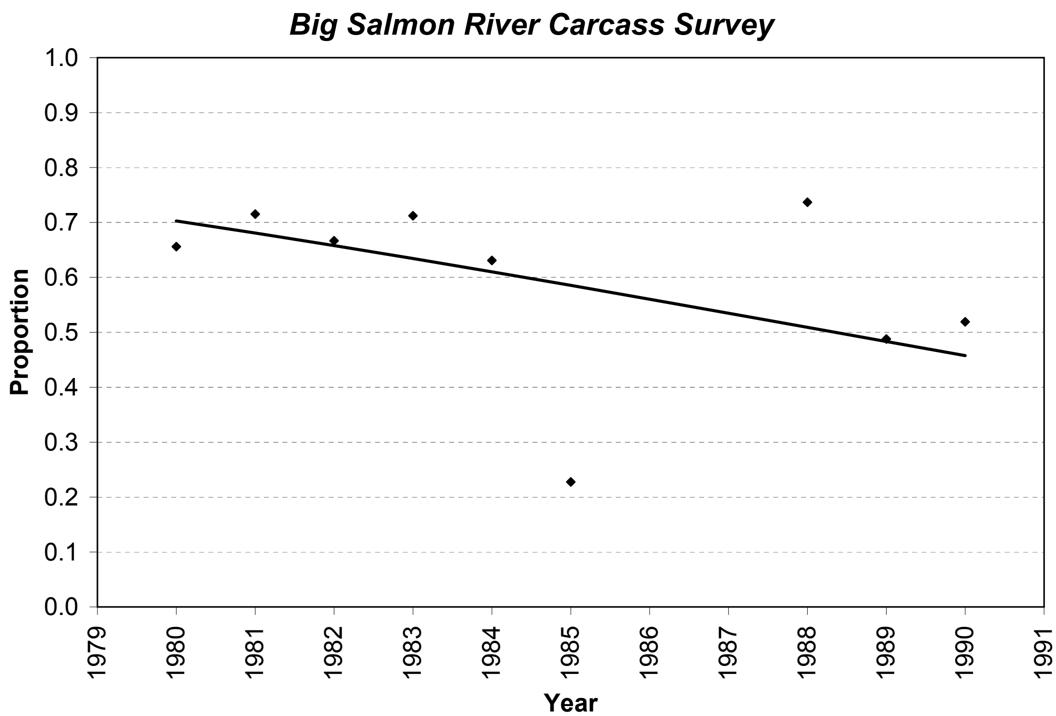
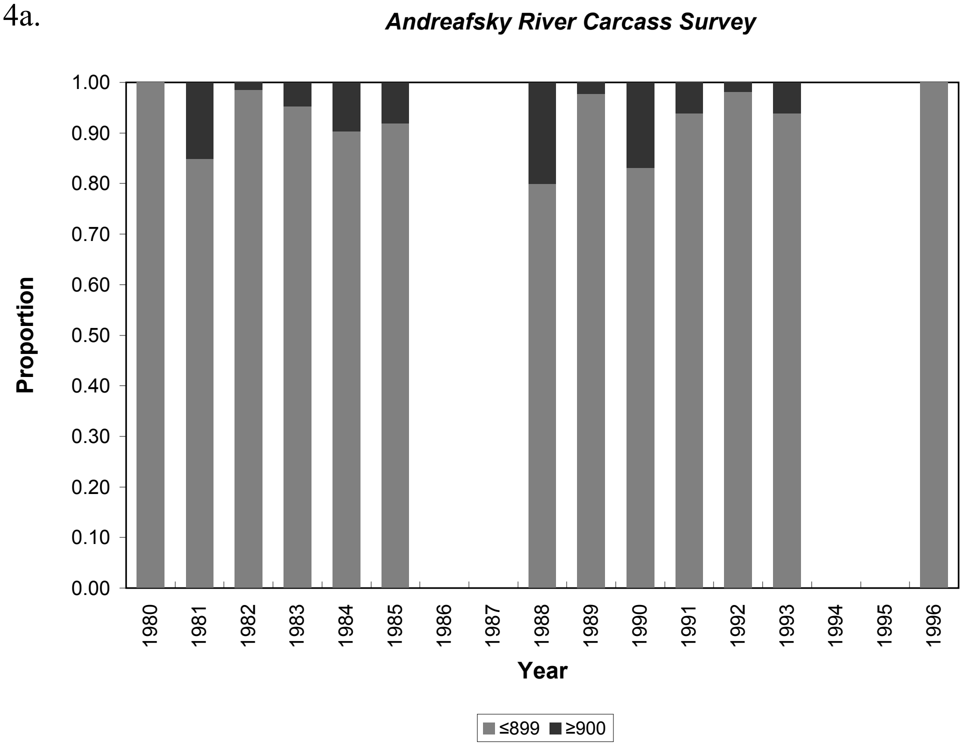
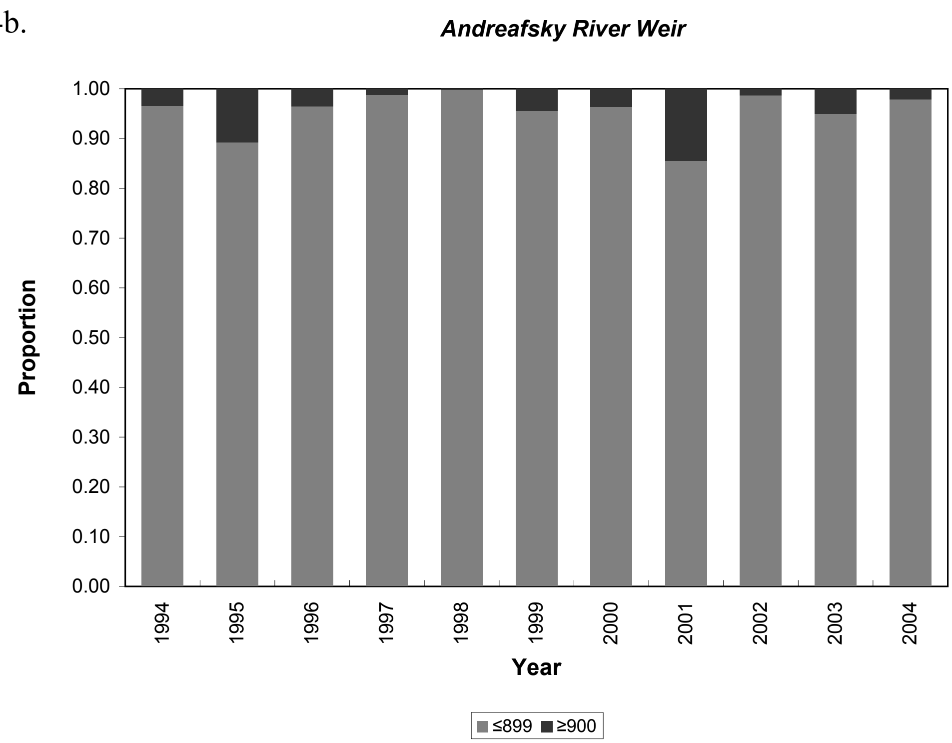


Figure 3g. Proportion of female Chinook salmon from the Big Salmon River. Regression line indicates a significant change in the proportion of females through time.

4a.

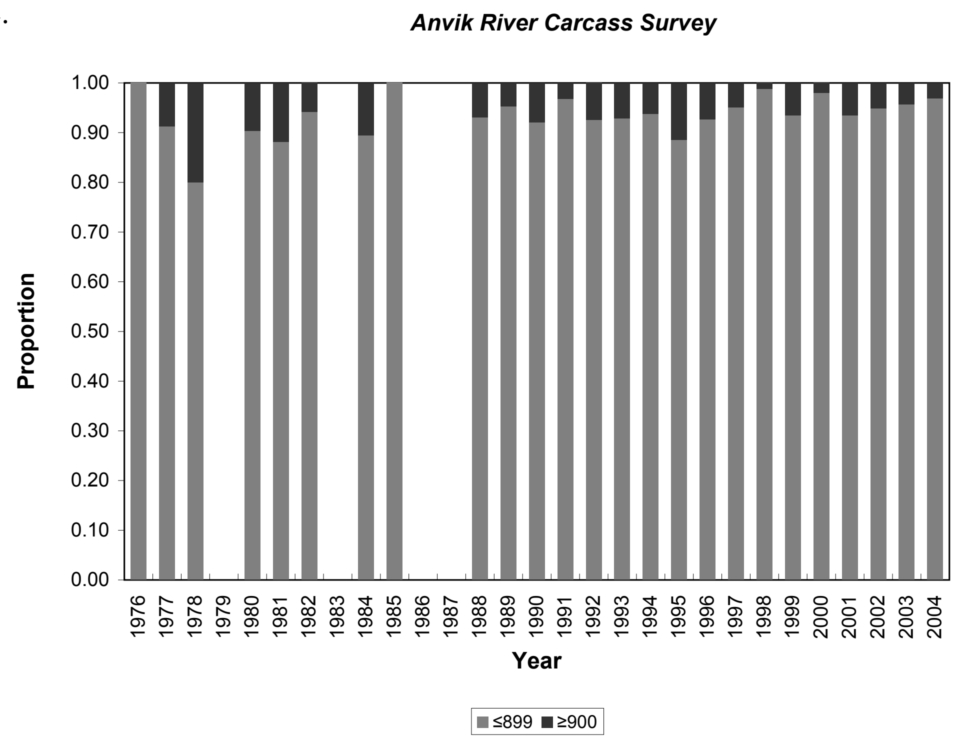


4b.



Figures 4a and 4b. Proportions of Chinook salmon ≤ 899 mm and ≥ 900 mm from the Andreafsky River.

4c.



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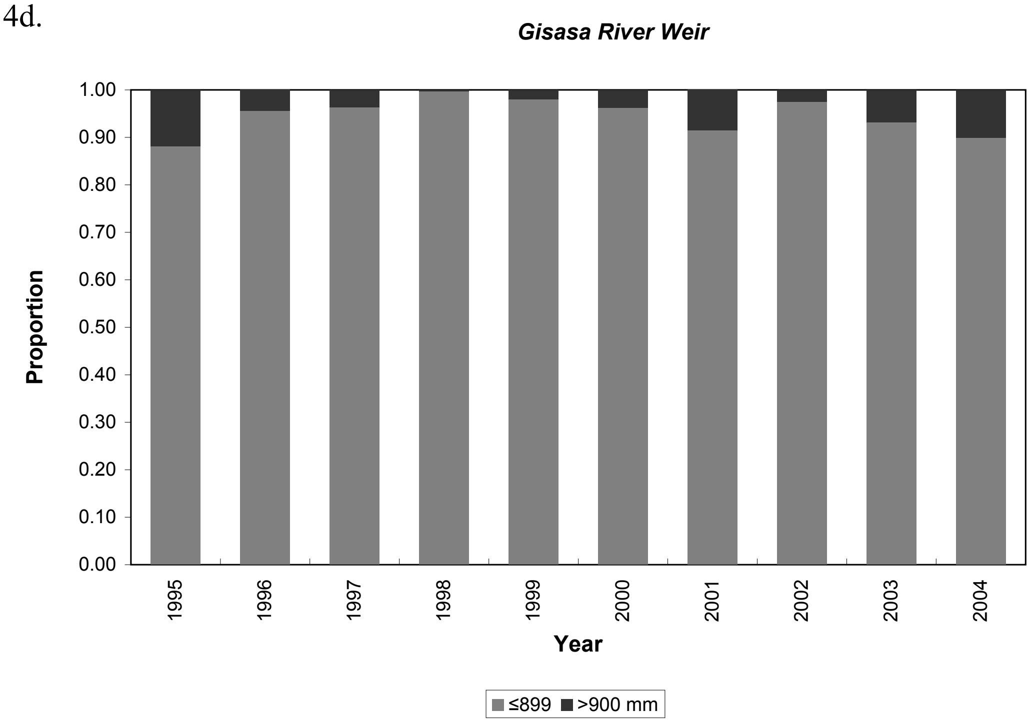
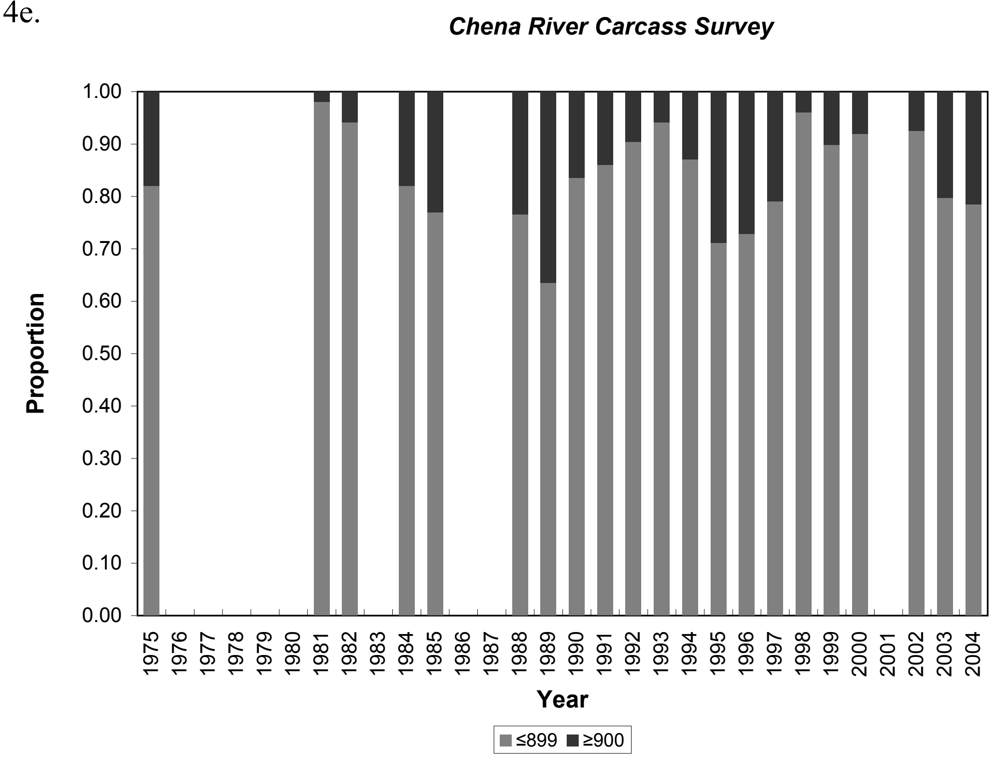


Figures 4c and 4d. Proportions of Chinook salmon ≤ 899 mm and ≥ 900 mm from the Anvik and Gisasa rivers.

4e.



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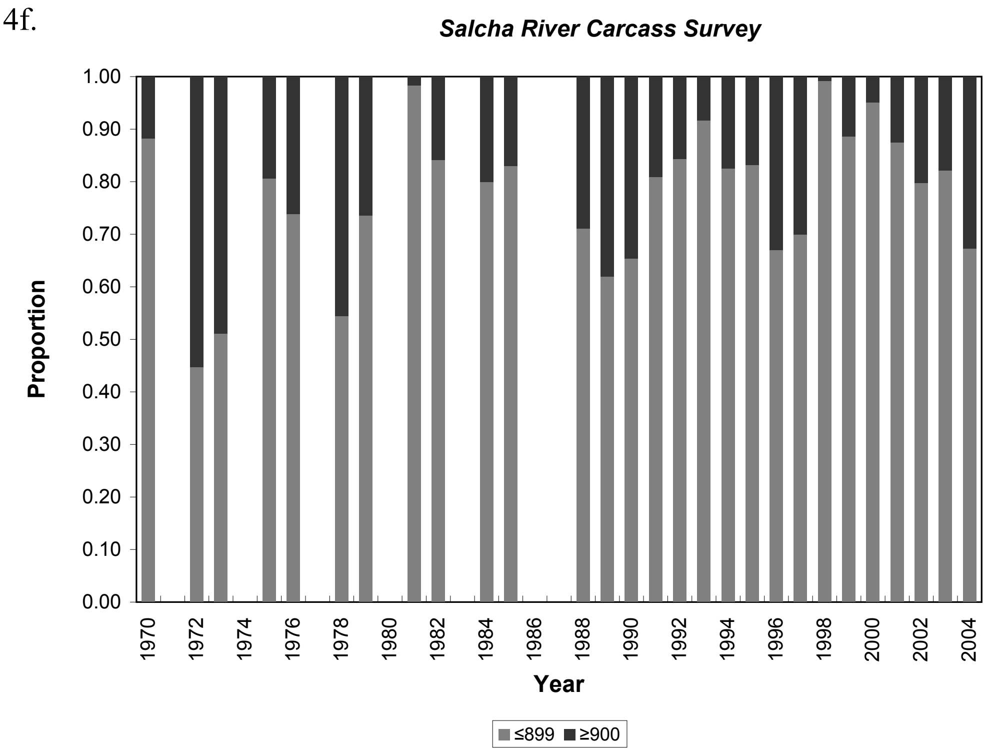


Figures 4e and 4f. Proportions of Chinook salmon ≤ 899 mm and ≥ 900 mm from the Chena and Salcha rivers.

4g.

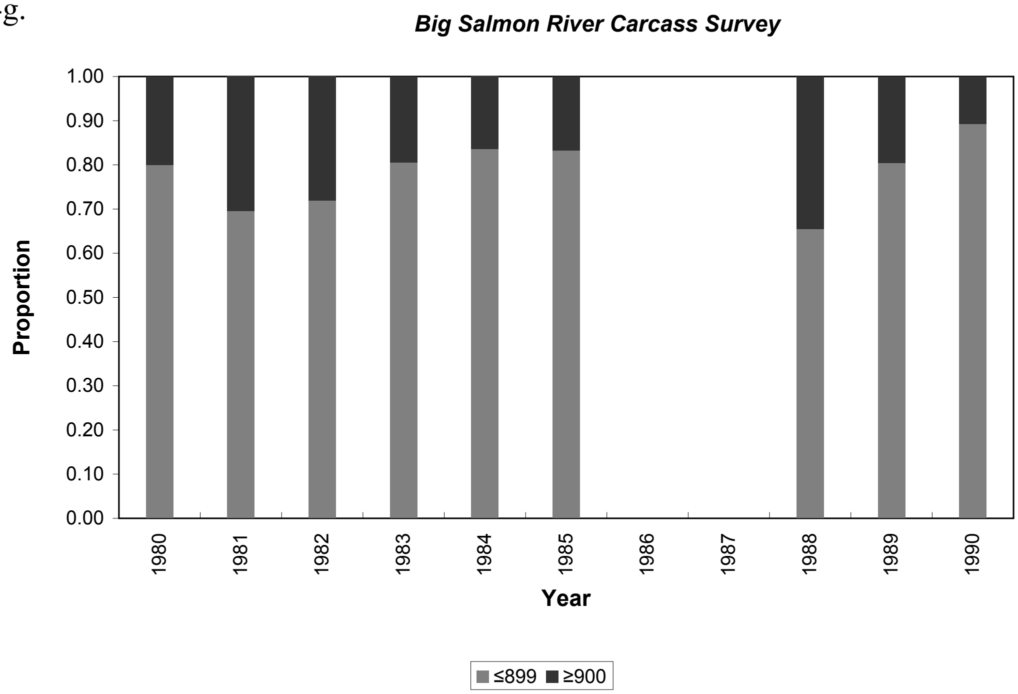
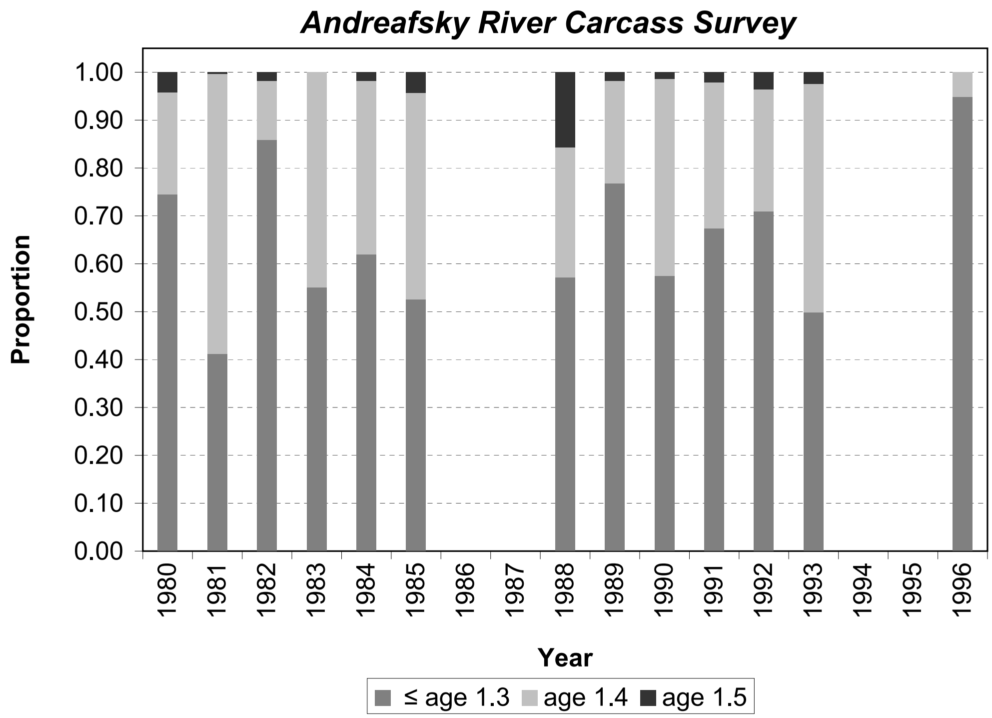
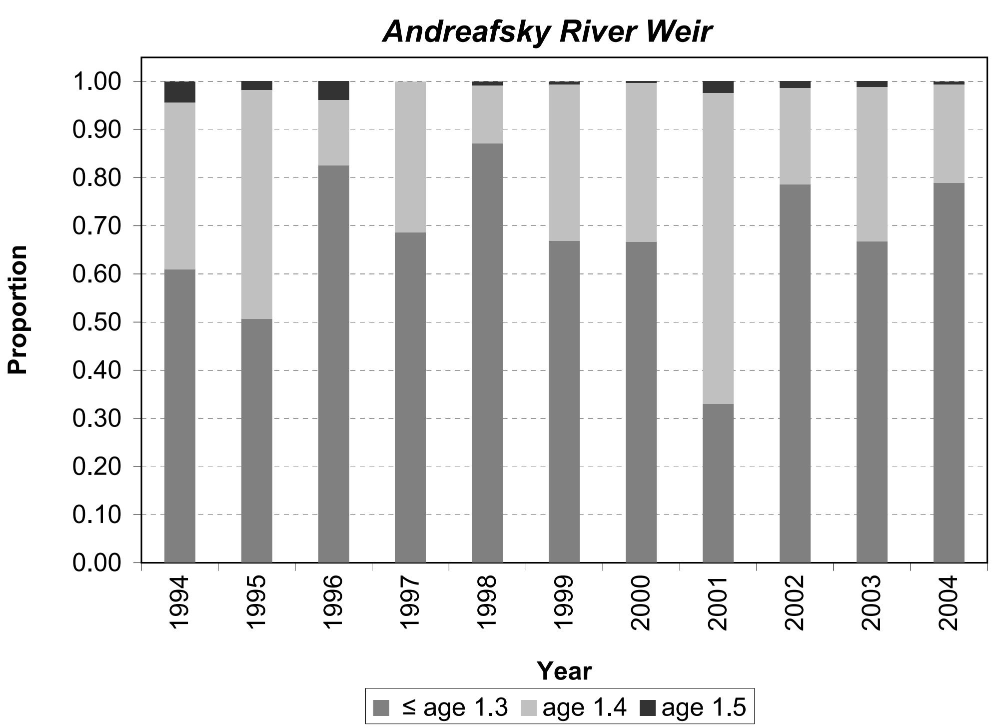


Figure 4g. Proportions of Chinook salmon ≤ 899 mm and ≥ 900 mm from the Big Salmon River.

5a.

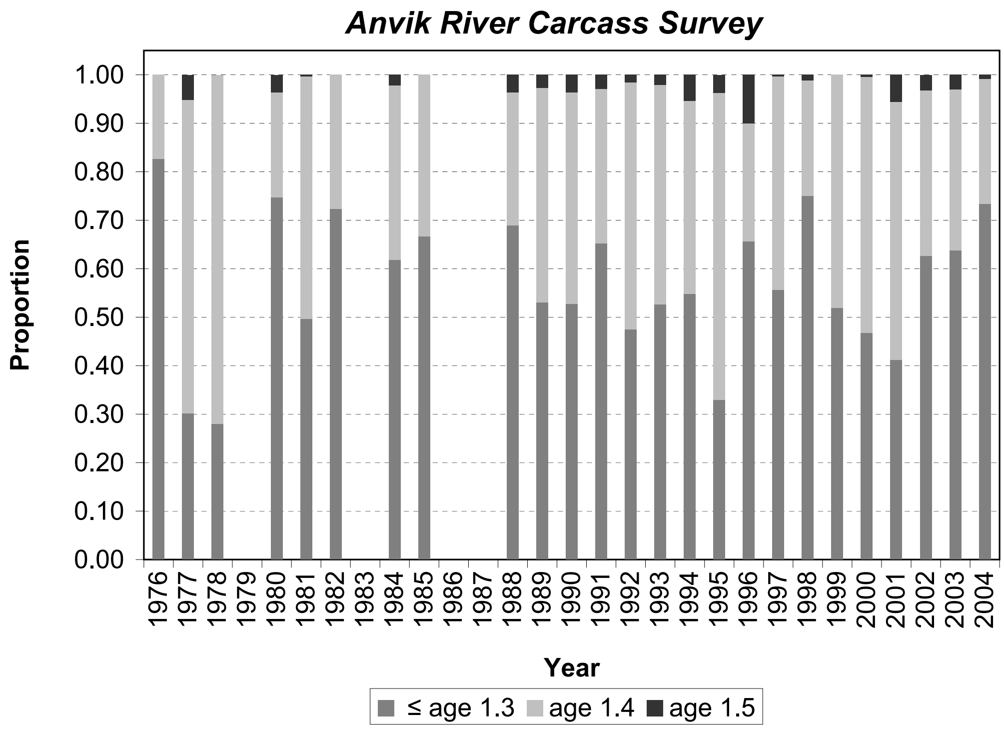


5b.



Figures 5a and 5b. Proportions of Chinook salmon ≤ age 1.3, age 1.4, and age 1.5 from the Andreafsky River.

5c.



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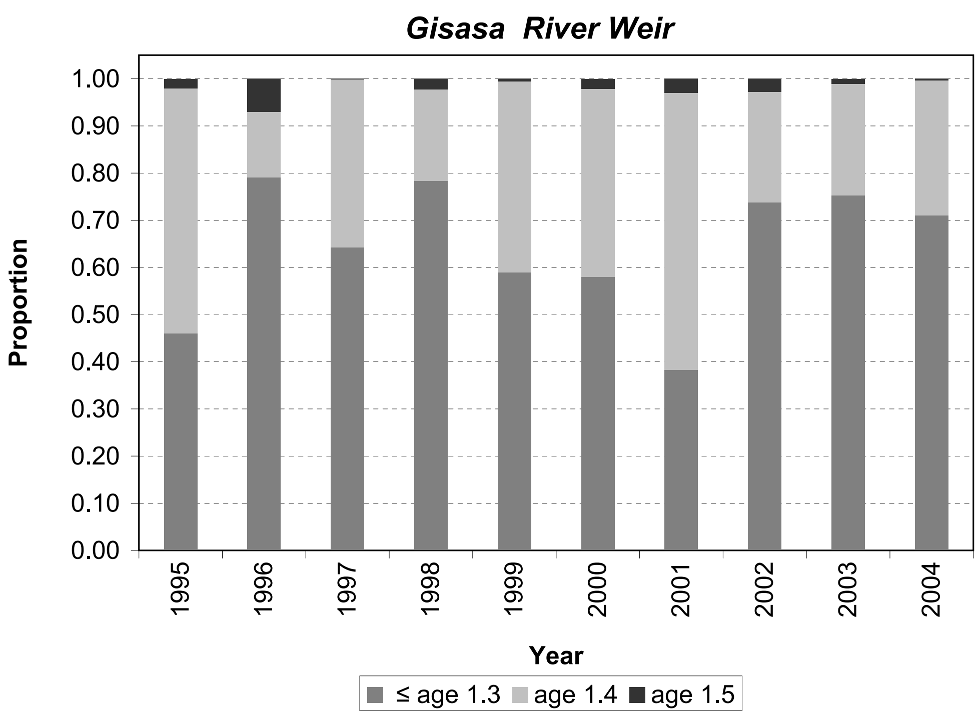
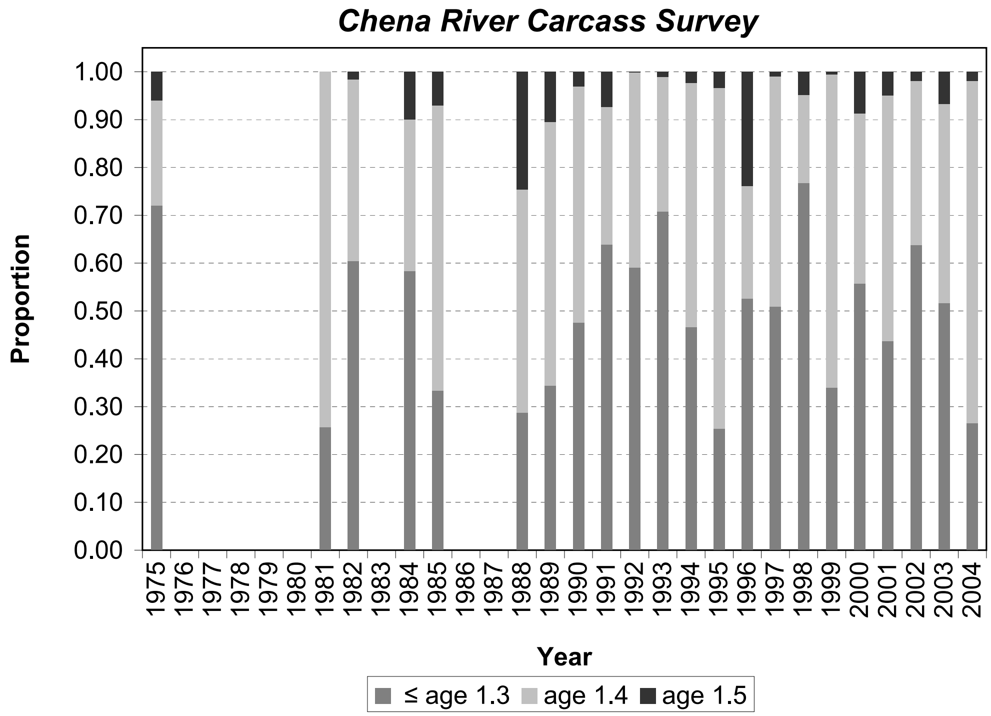


Figures 5c and 5d. Proportions of Chinook salmon ≤ age 1.3, age 1.4, and age 1.5 from the Anvik and Gisasa rivers.

5e.



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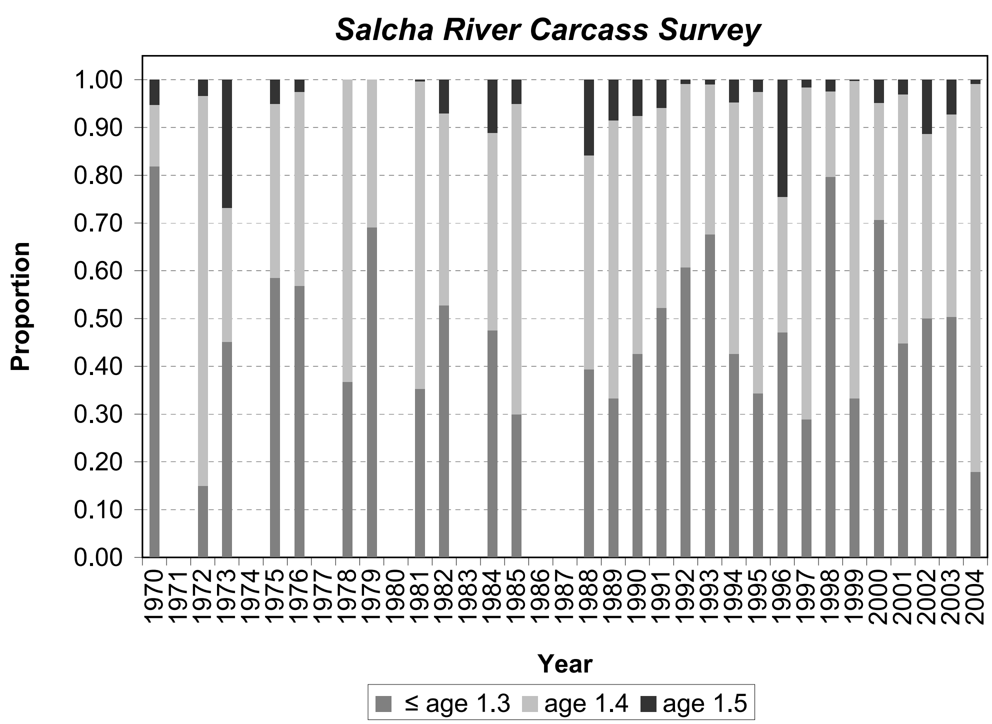


Figures 5e and 5f. Proportions of Chinook salmon ≤ age 1.3, age 1.4, and age 1.5 from the Chena and Salcha rivers.

5g.

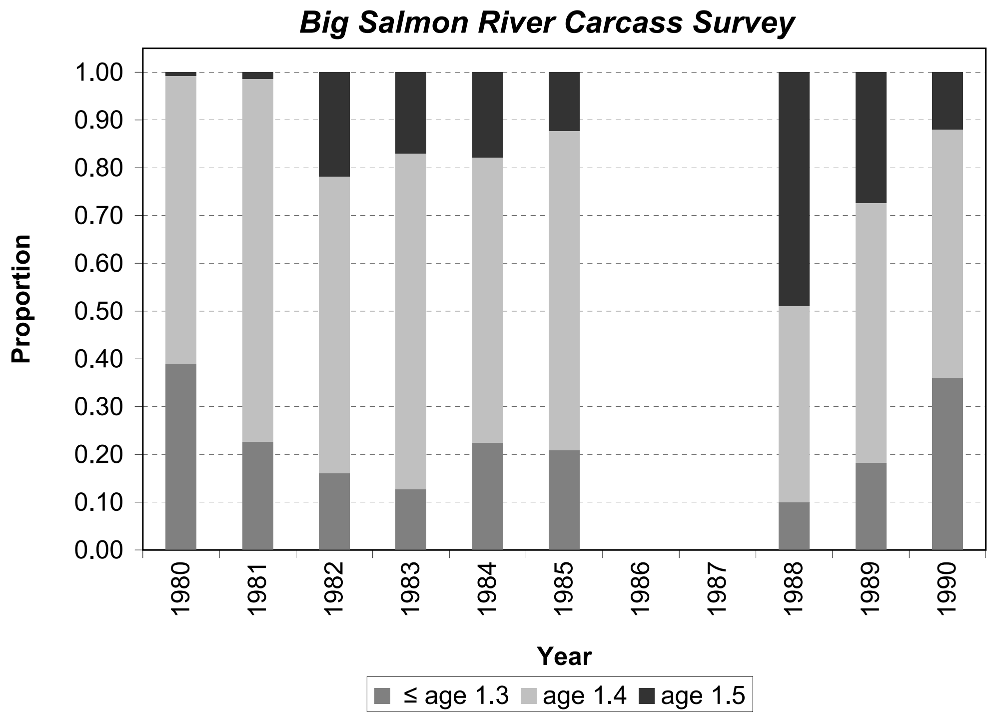
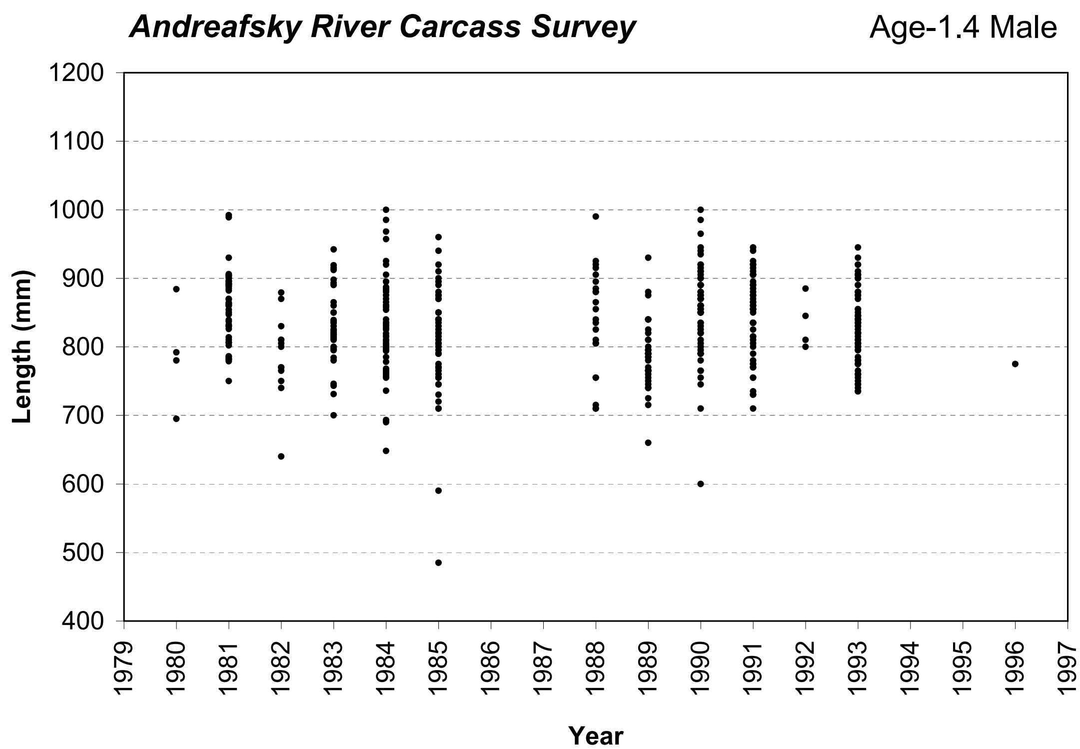


Figure 5g. Proportions of Chinook salmon ≤ age 1.3, age 1.4, and age 1.5 from the Big Salmon River.



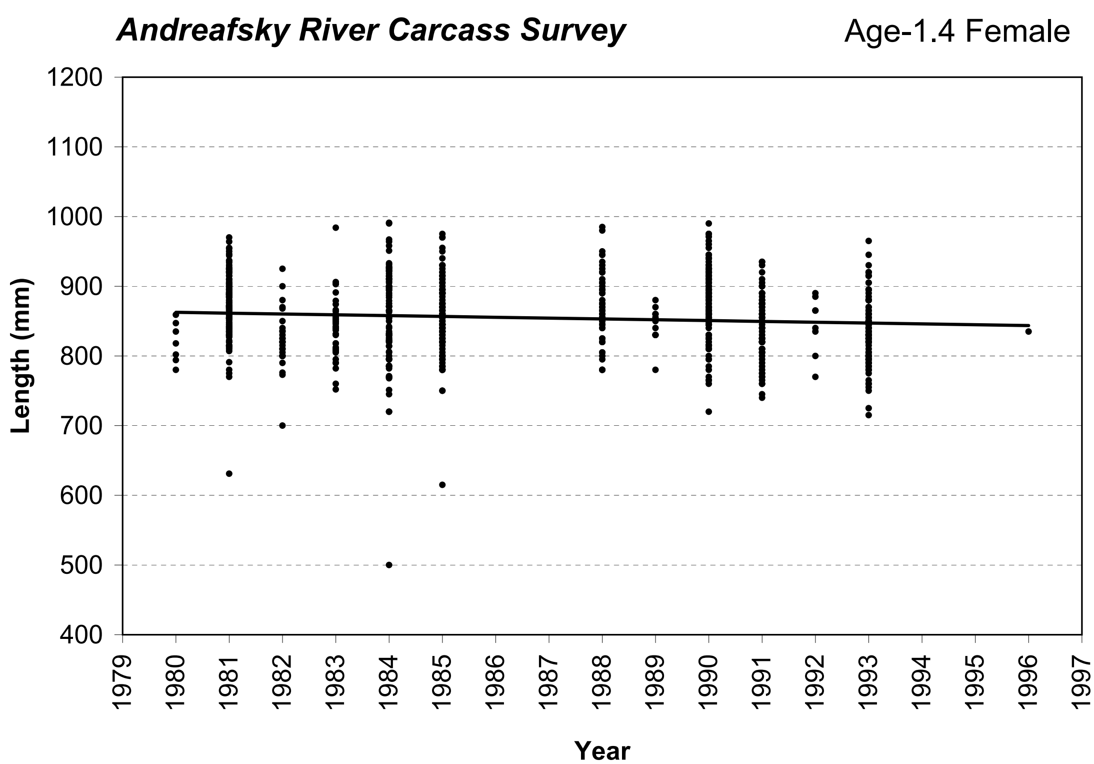
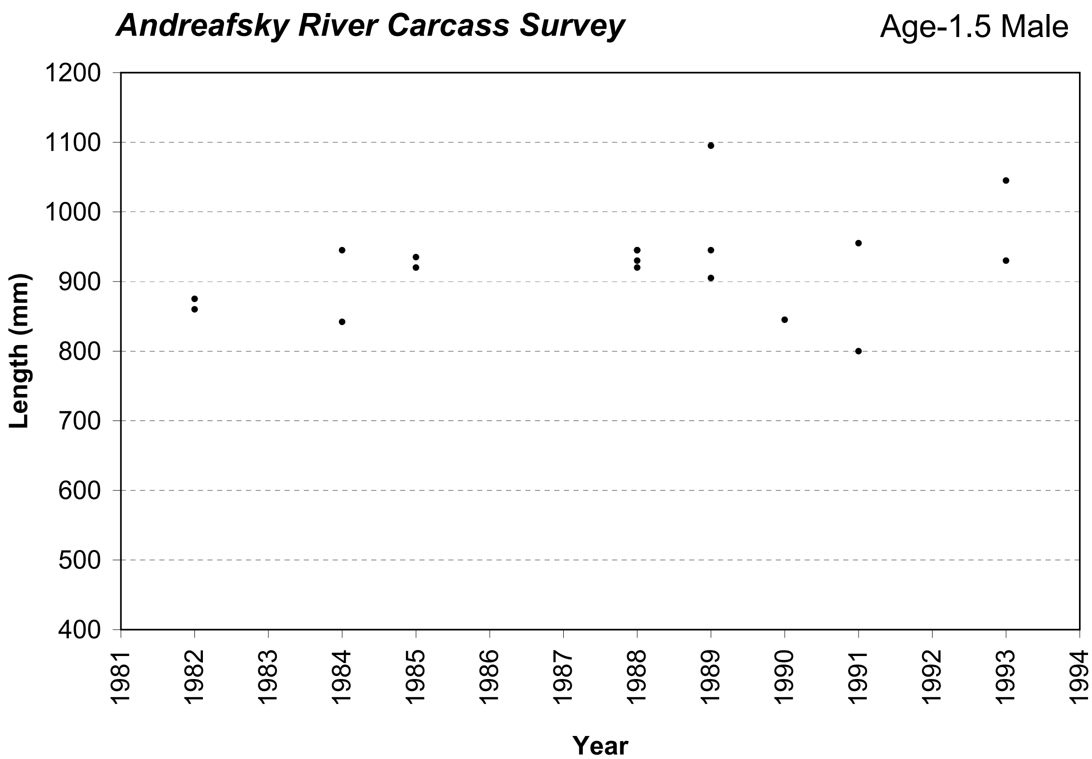


Figure 6a. Length data for age-1.4 male and female Chinook salmon from the Andreafsky River carcass survey. Regression line indicates a significant change in length through time.



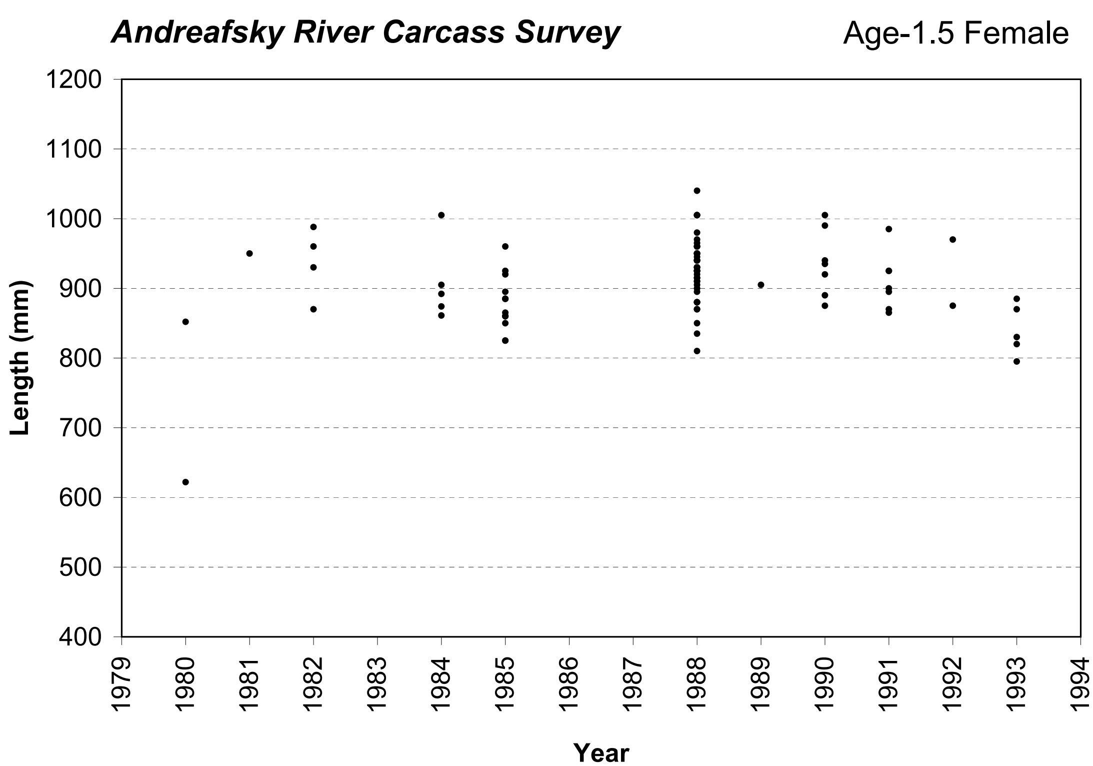
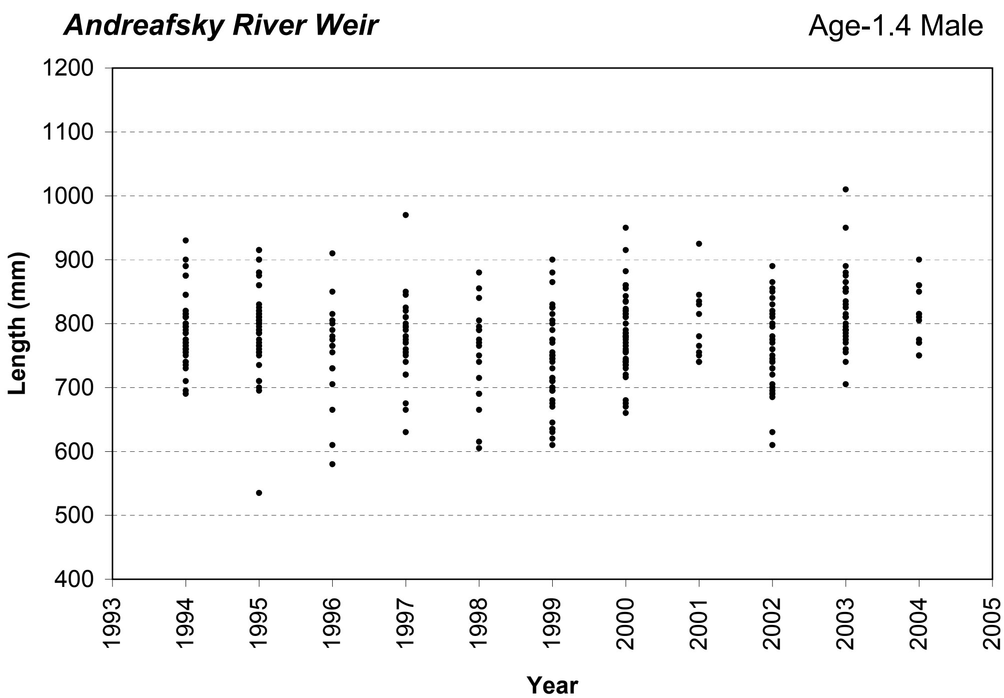


Figure 6a *(Continued)*. Length data for age-1.5 male and female Chinook salmon from the Andreafsky River carcass survey.



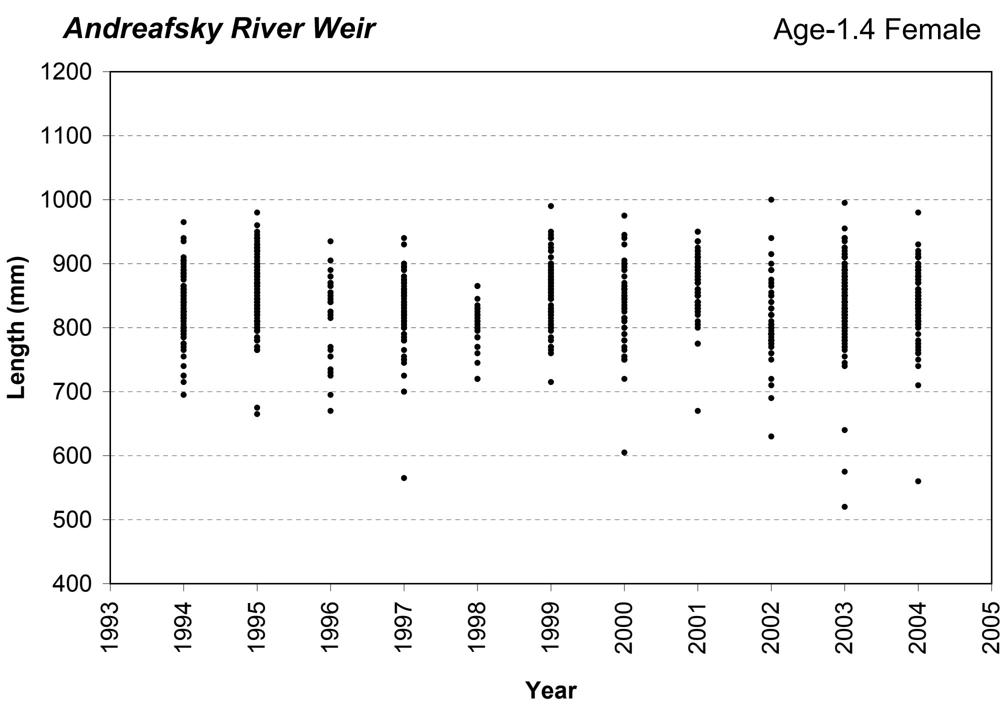
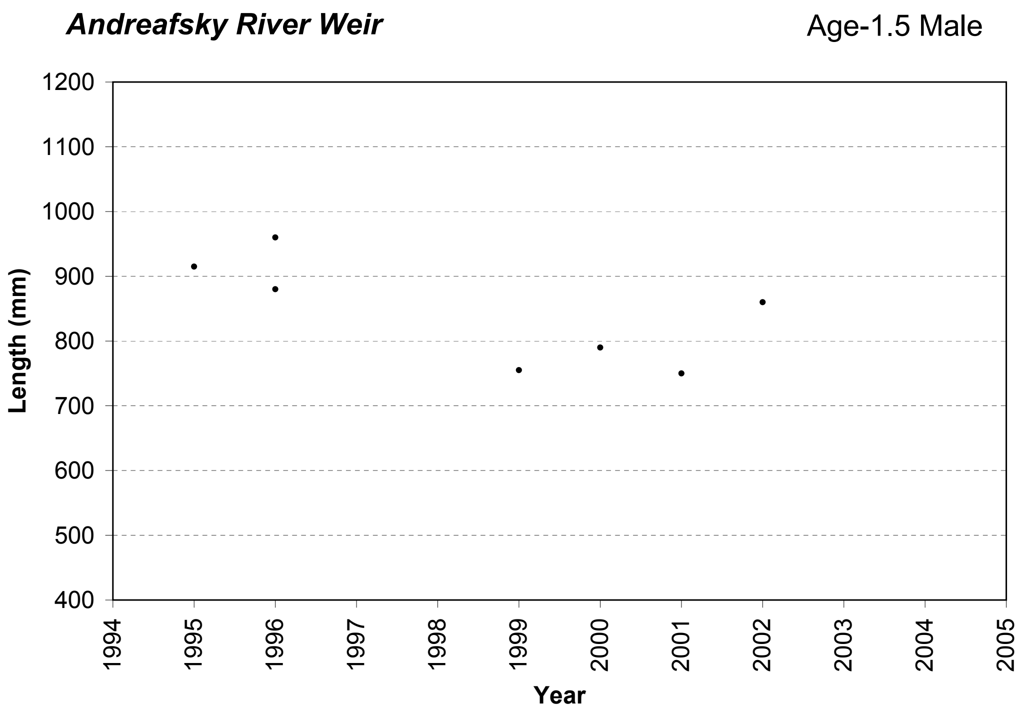


Figure 6b. Length data for age-1.4 male and female Chinook salmon from the Andreafsky River weir.



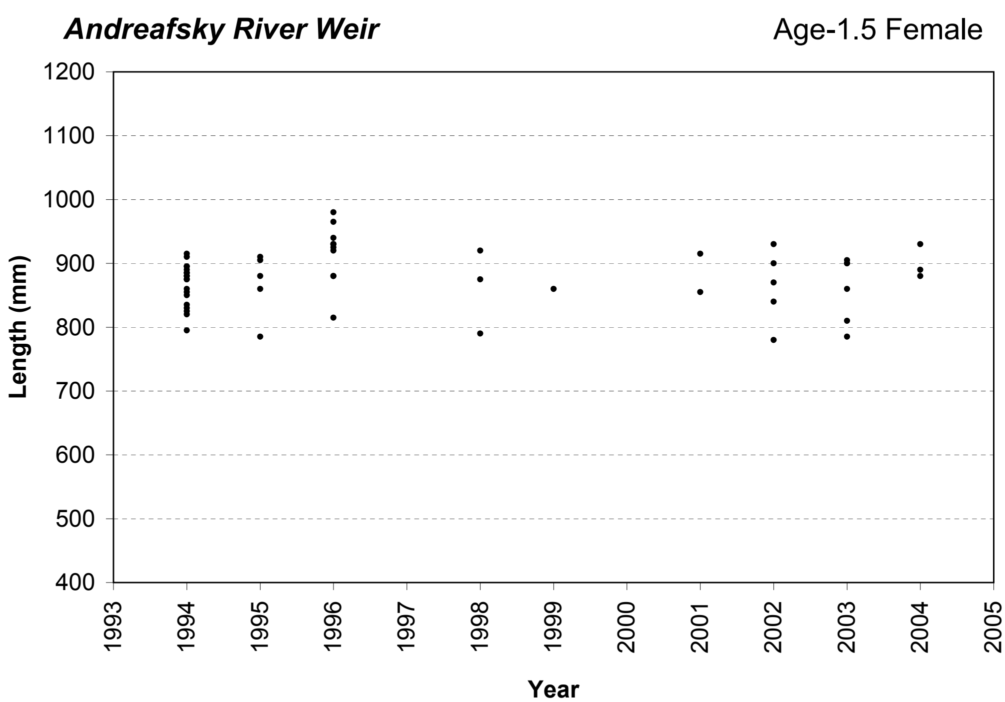
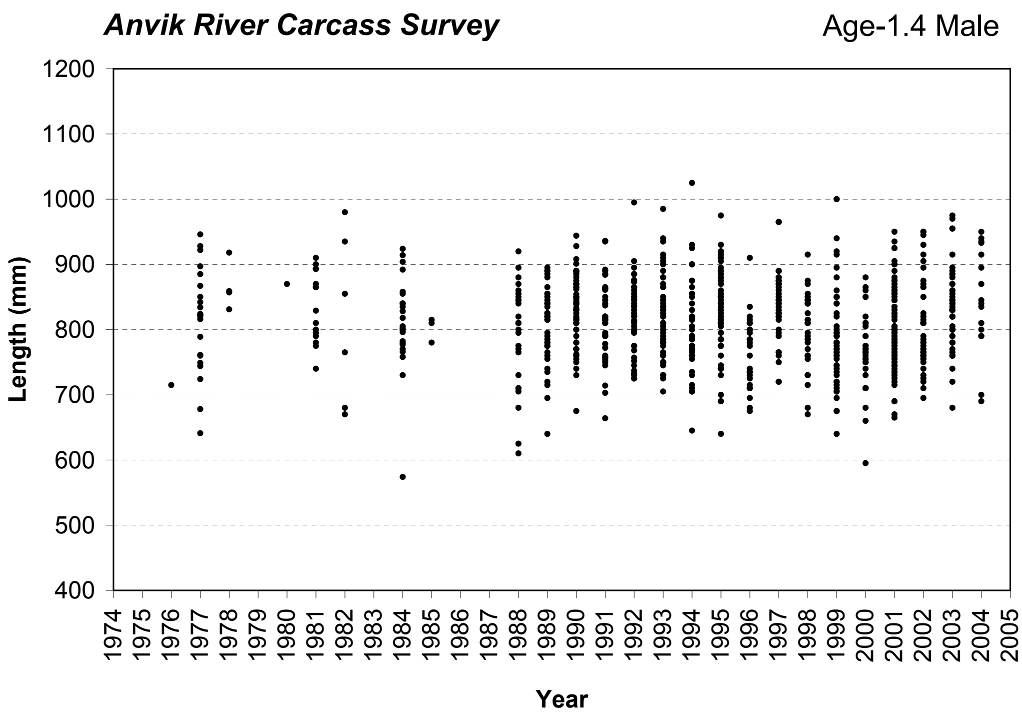


Figure 6b *(Continued)*. Length data for age-1.5 male and female Chinook salmon from the Andreafsky River weir.



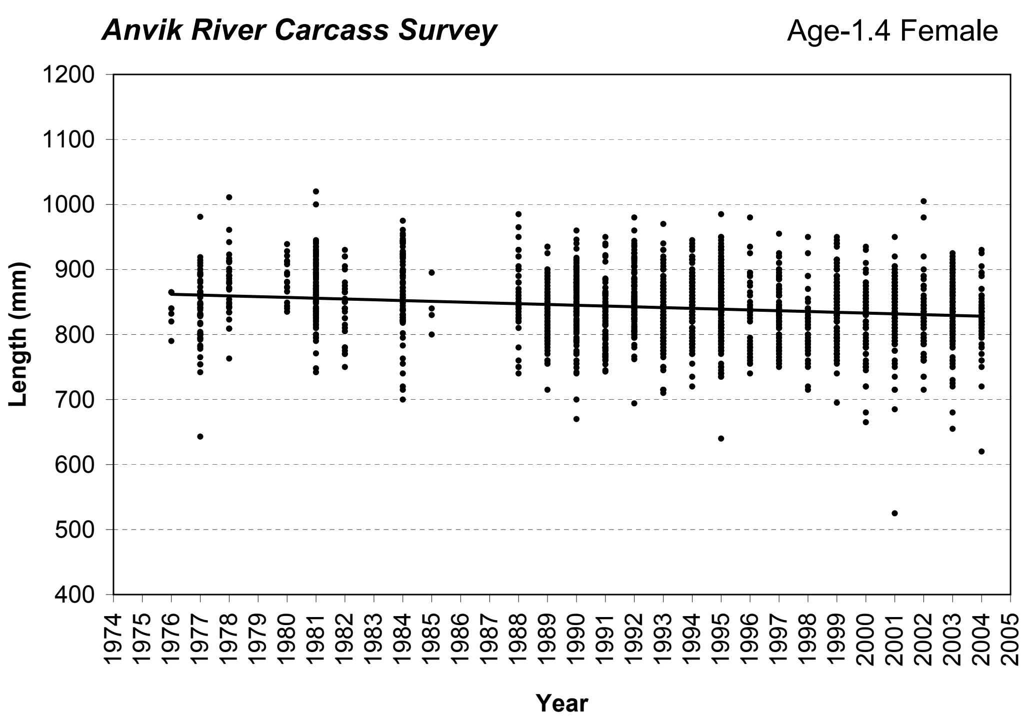
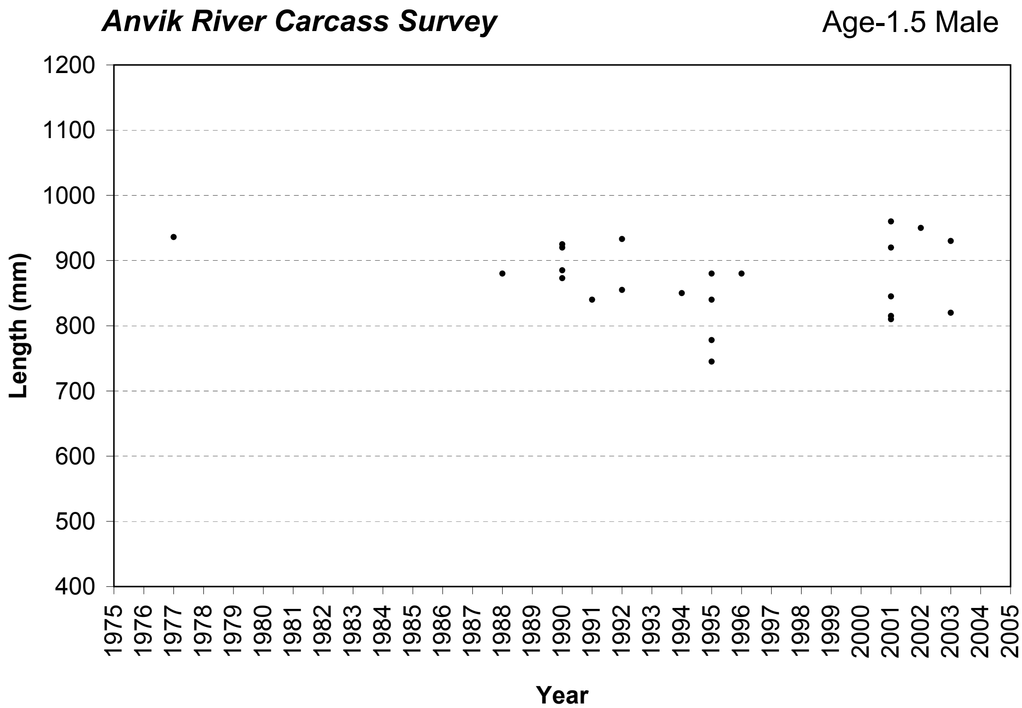


Figure 6c. Length data for age-1.4 male and female Chinook salmon from the Anvik River carcass survey. Regression line indicates a significant change in length through time.



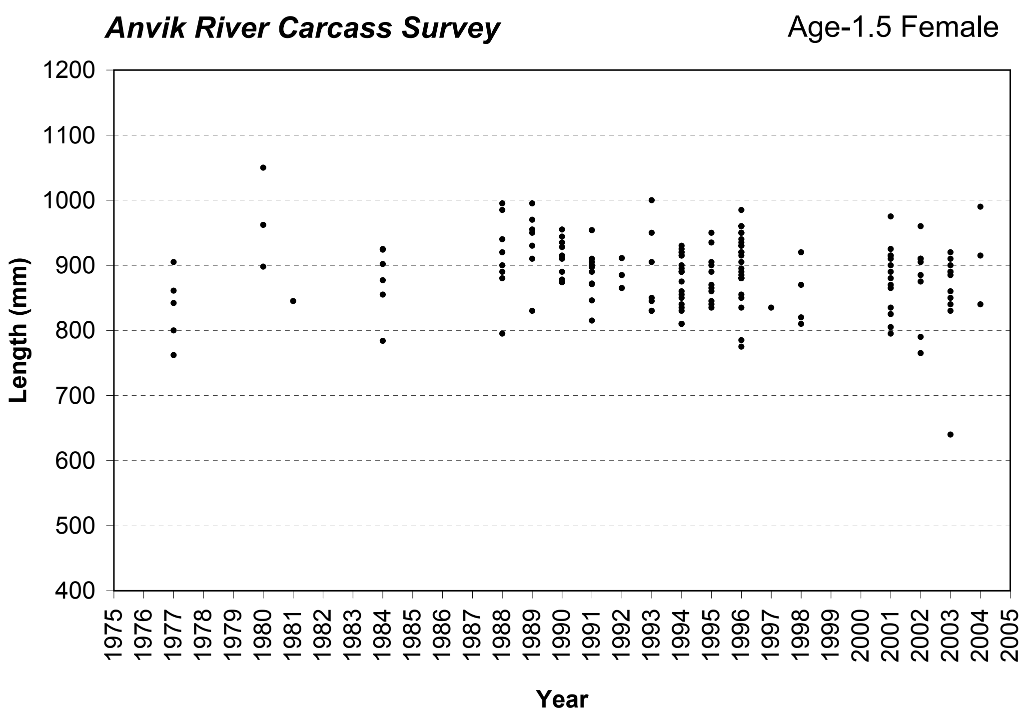
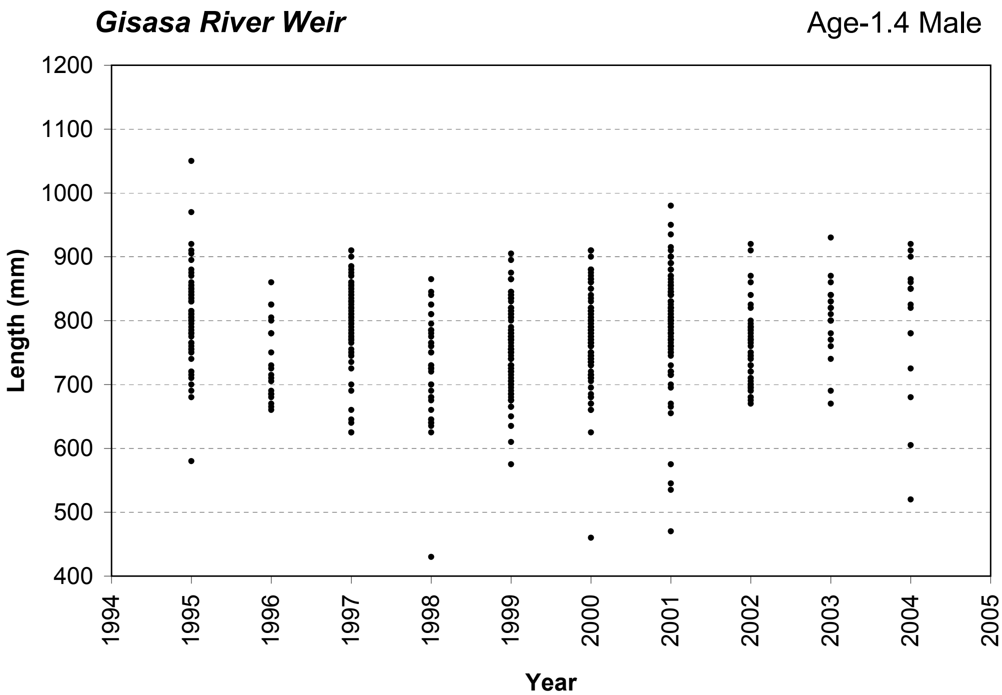


Figure 6c *(Continued)*. Length data for age-1.5 male and female Chinook salmon from the Anvik River carcass survey.



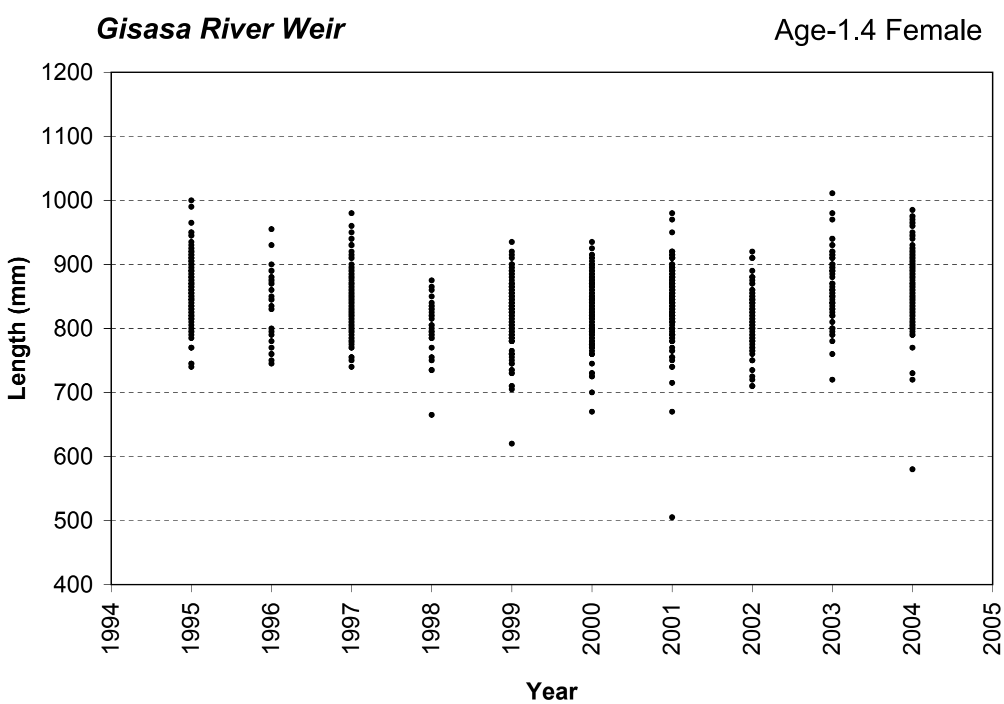
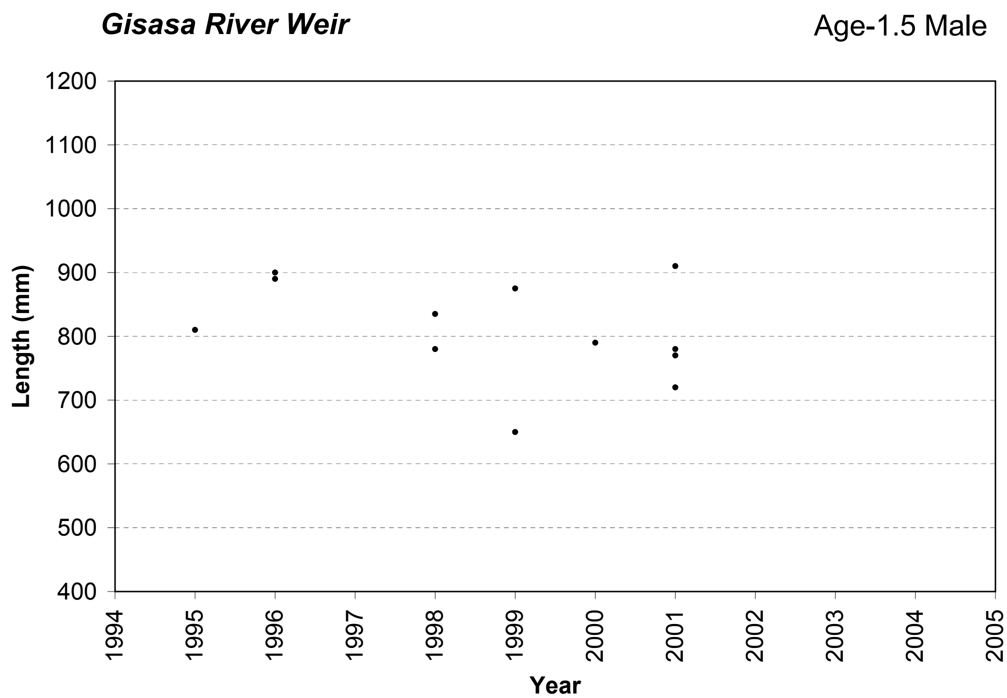


Figure 6d. Length data for age-1.4 male and female Chinook salmon from the Gisasa River weir.



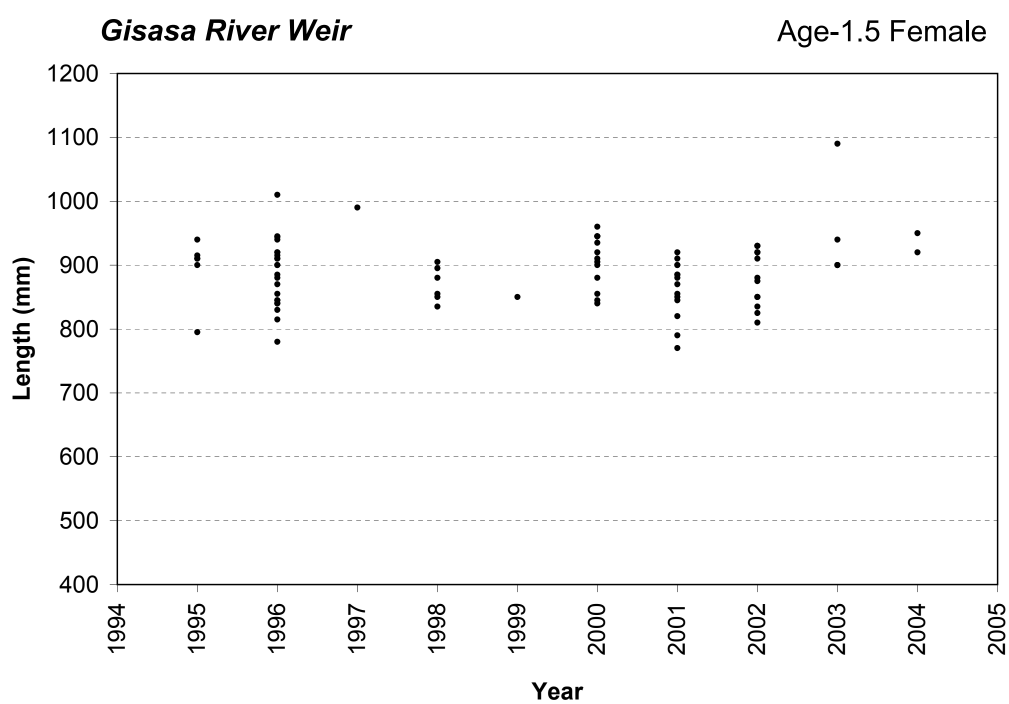
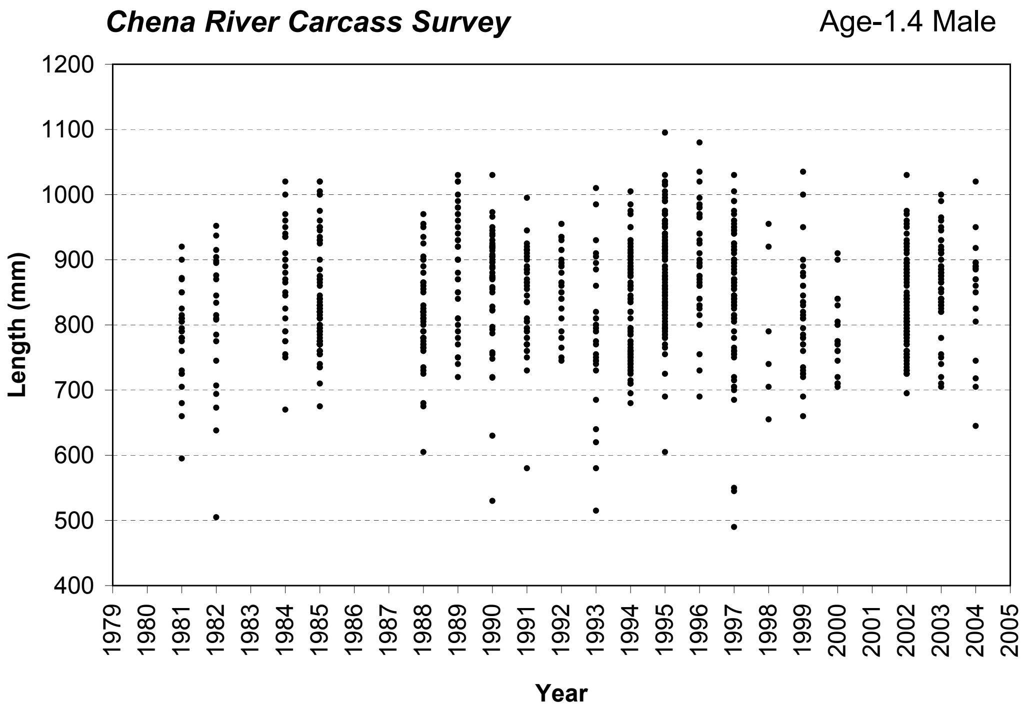


Figure 6d (Continued). Length data for age-1.5 male and female Chinook salmon from the Gisasa River weir.



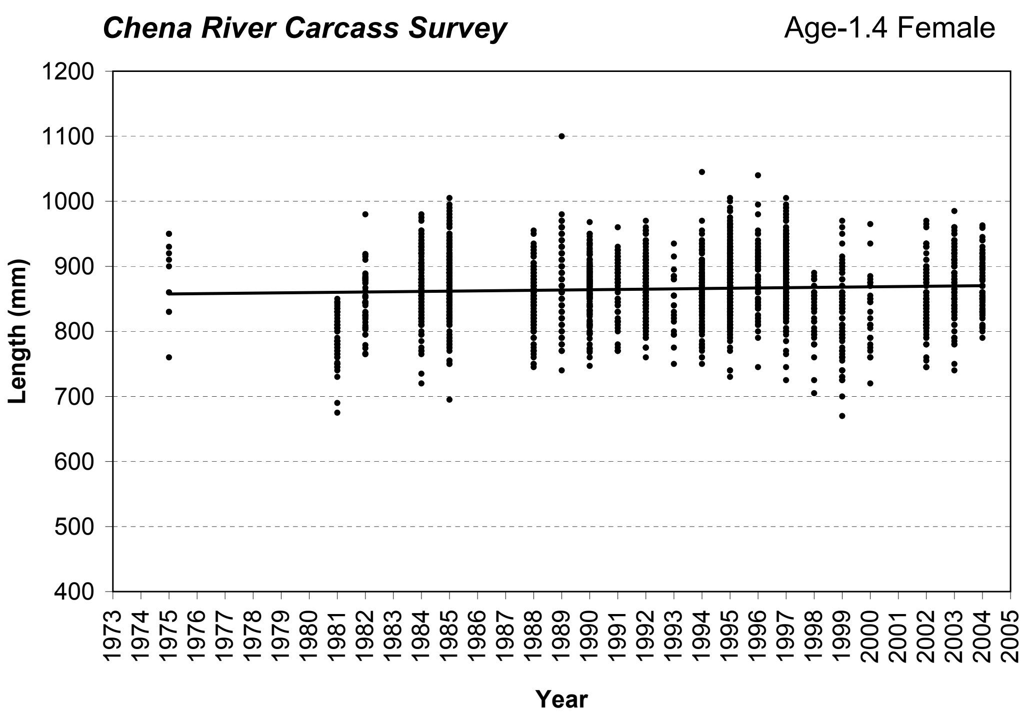
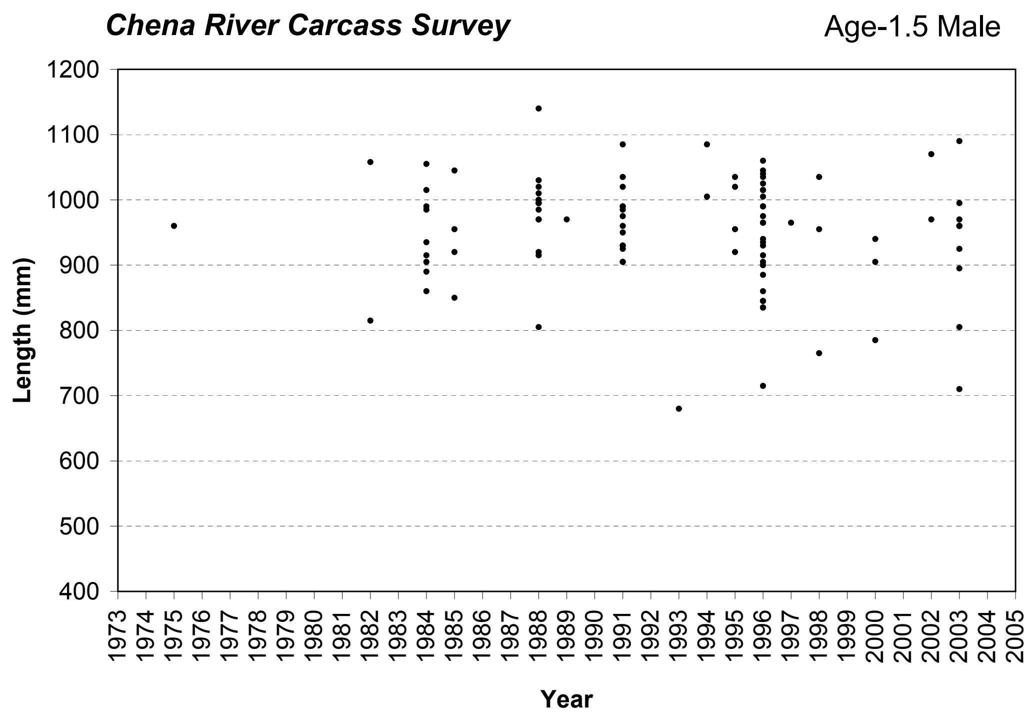


Figure 6e. Length data for age-1.4 male and female Chinook salmon from the Chena River carcass survey. Regression line indicates a significant change in length through time.



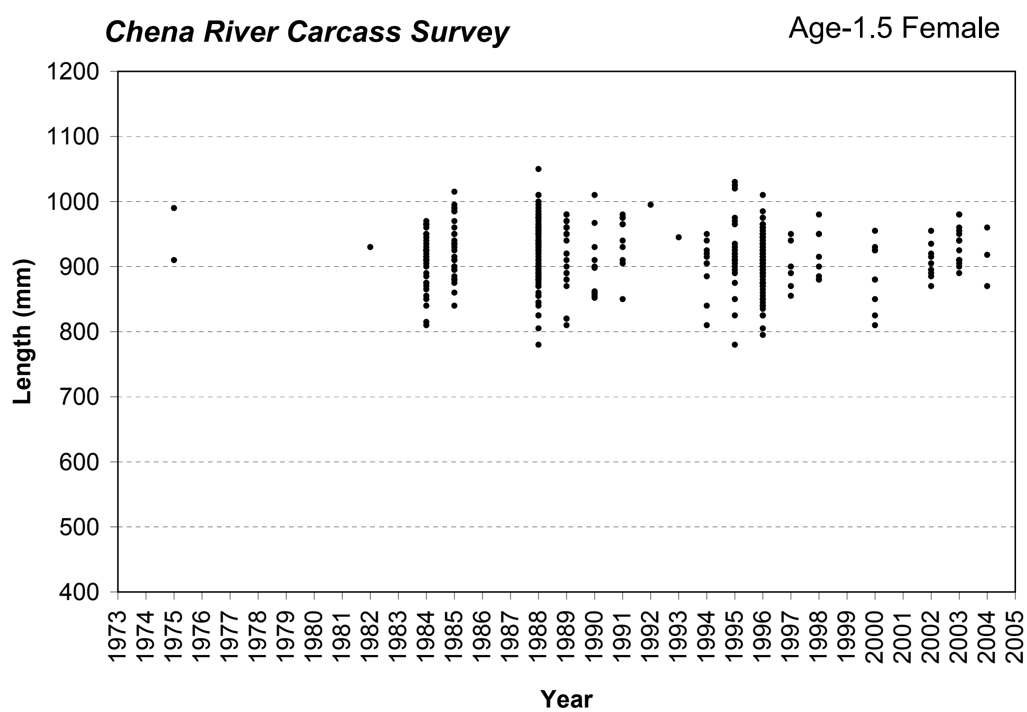
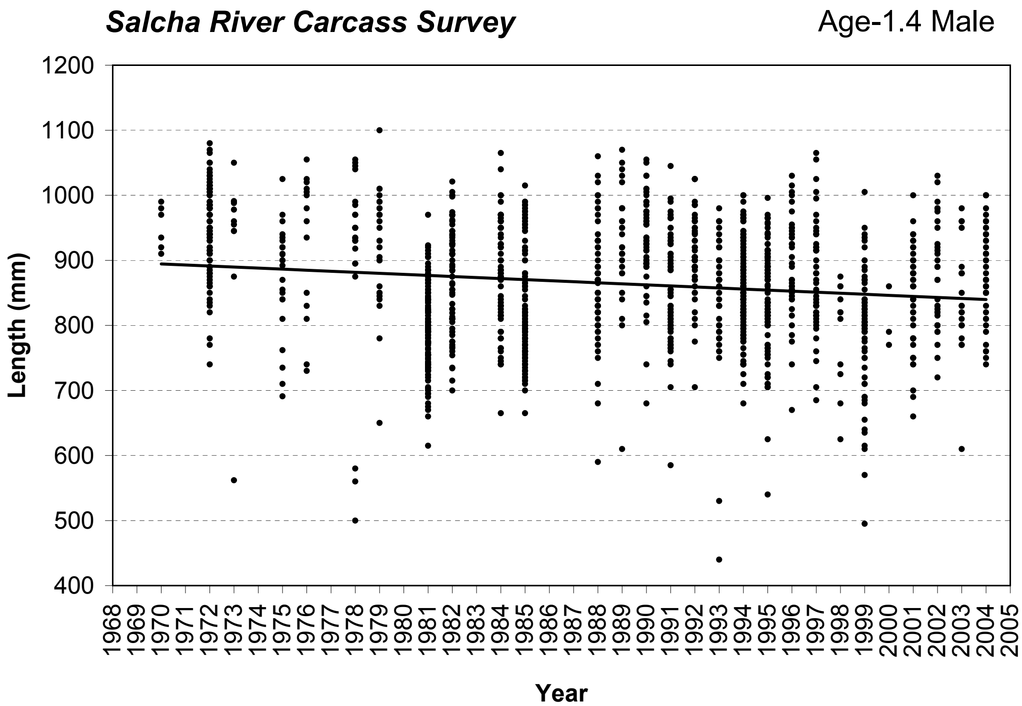


Figure 6e *(Continued)*. Length data for age-1.5 male and female Chinook salmon from the Chena River carcass survey.



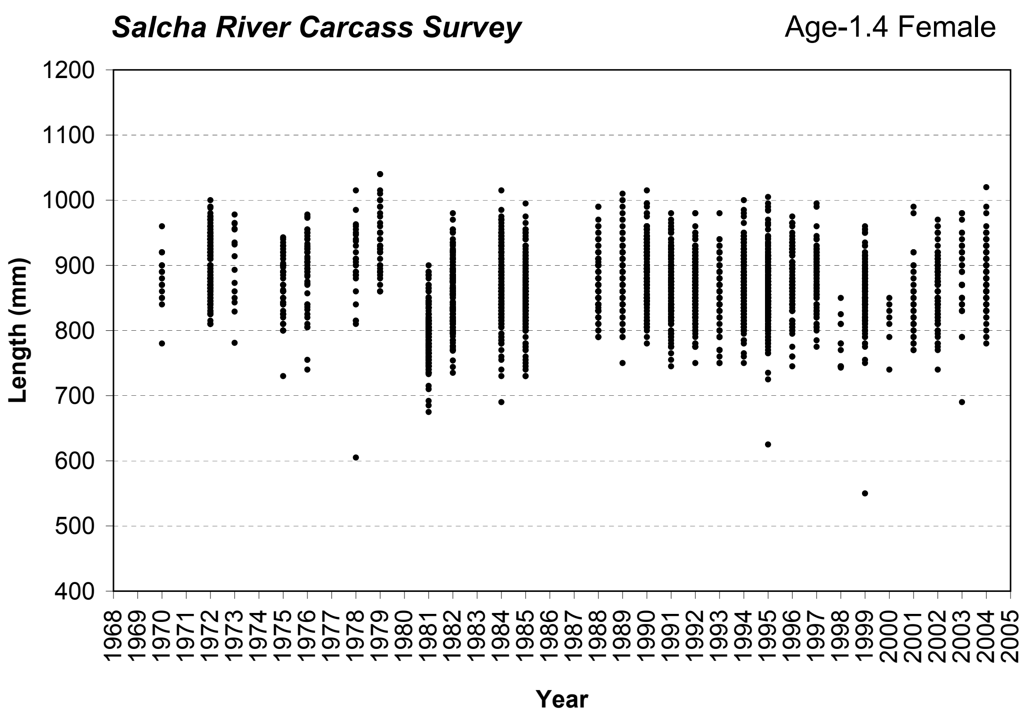
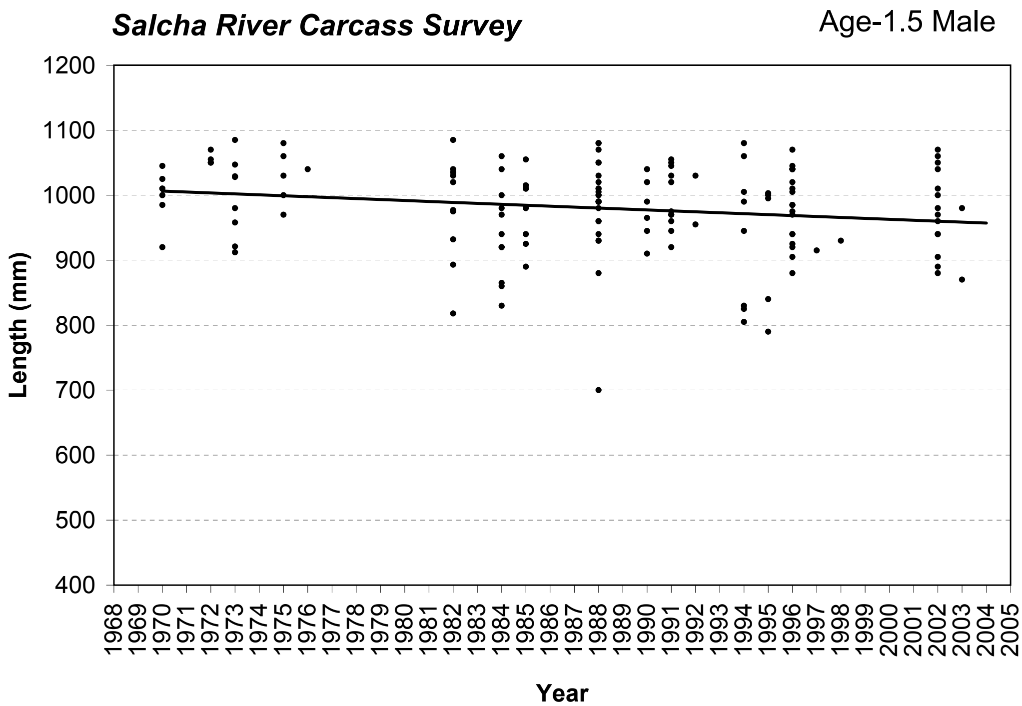


Figure 6f. Length data for age-1.4 male and female Chinook salmon from the Salcha River carcass survey. Regression line indicates a significant change in length through time.



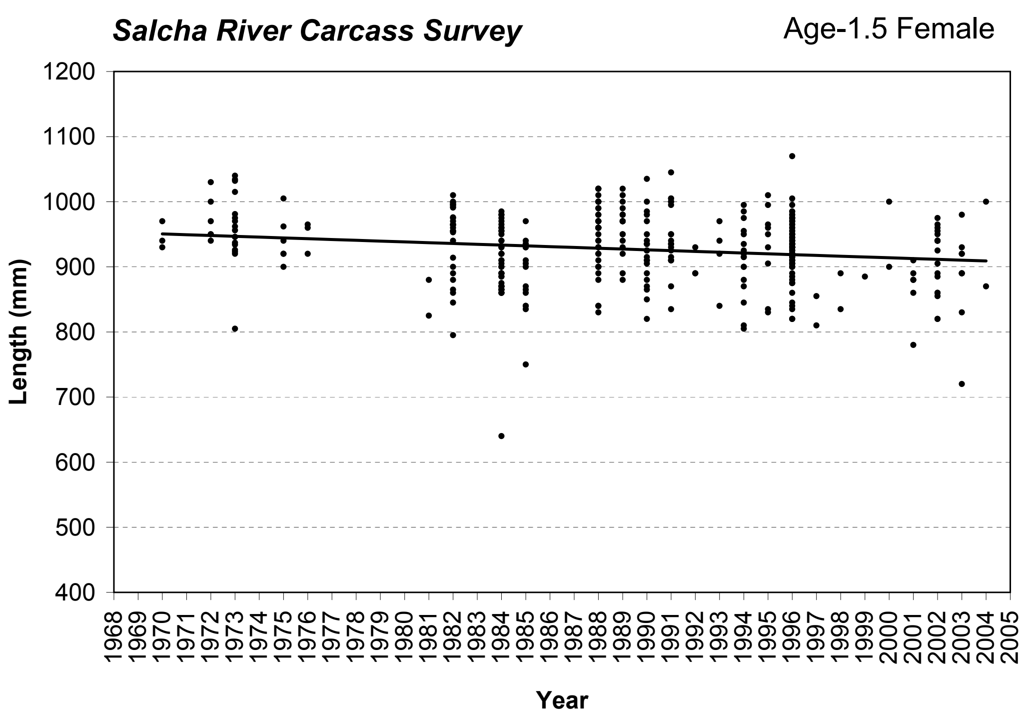
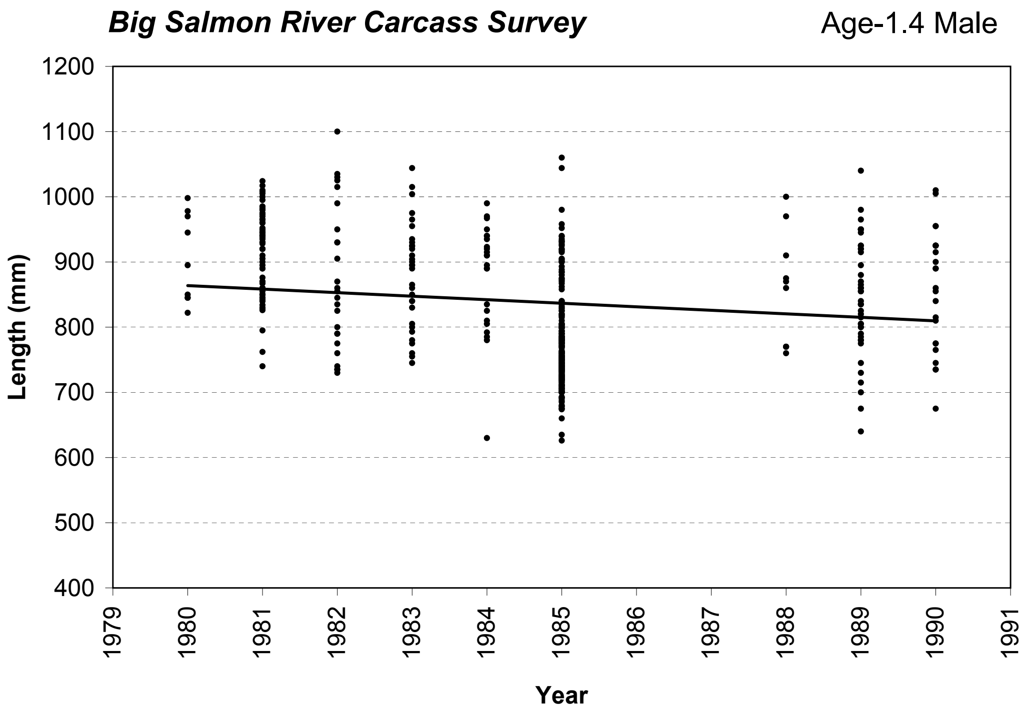


Figure 6f *(Continued)*. Length data for age-1.5 male and female Chinook salmon from the Salcha River carcass survey. Regression lines indicate a significant change in length through time.



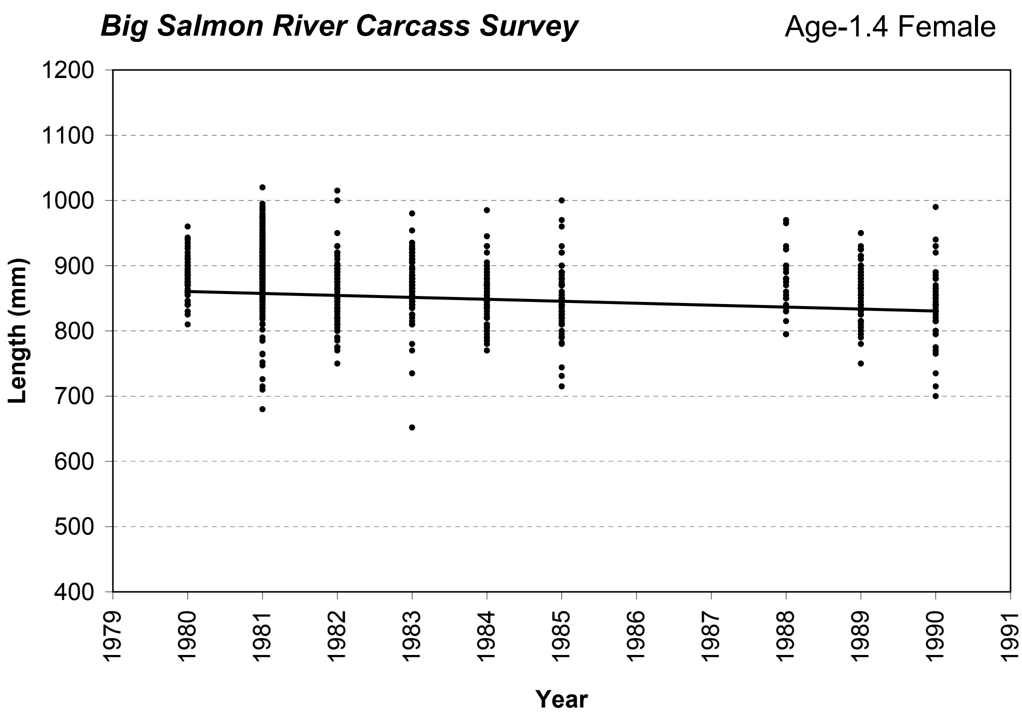
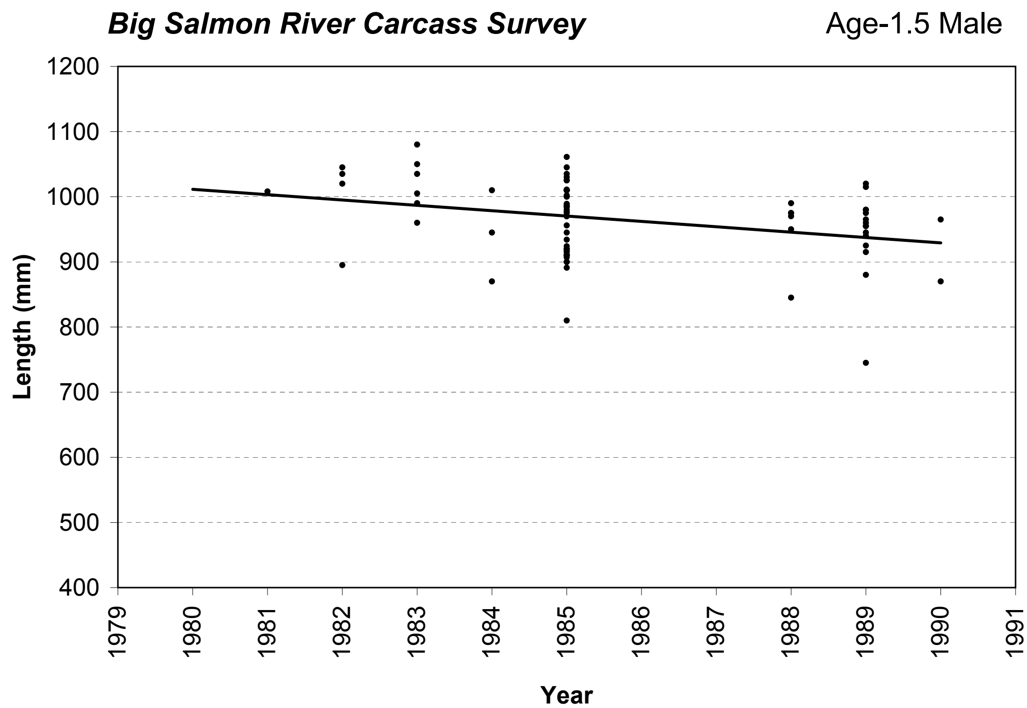


Figure 6g. Length data for age-1.4 male and female Chinook salmon from the Big Salmon River carcass survey. Regression lines indicate a significant change in length through time.



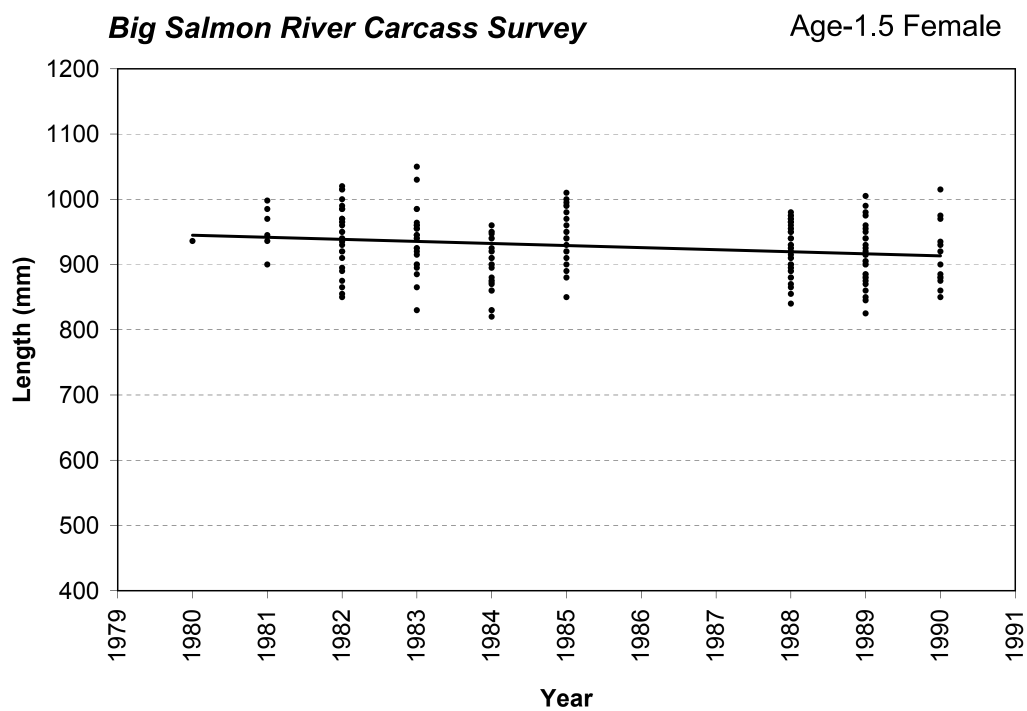


Figure 6g *(Continued)*. Length data for age-1.5 male and female Chinook salmon from the Big Salmon River carcass survey. Regression lines indicate a significant change in length through time.

Table 1. Parameter estimates for logistic regression models of the proportion of female Chinook salmon encountered during escapement sampling.

River	Parameter	Regression Coefficient	Standard Error	P-Value	Sample Size	Odds Ratio
Andreafsky						
Carcass	Intercept	-34.22	17.49	0.0504		
	Year	0.02	0.01	0.0559	3621	1.02
Weir	Intercept	-11.71	423.70	0.9780		
	Year	0.01	0.21	0.9792	4025	1.01
Anvik						
Carcass	Intercept	43.04	7.13	< 0.0001		
	Year	-0.02	0.00	< 0.0001	6555	0.98
Gisasa						
Weir	Intercept	-18.94	496.60	0.9696		
	Year	0.01	0.25	0.9710	4823	1.01
Chena						
Carcass	Intercept	30.00	7.11	< 0.0001		
	Year	-0.02	0.00	< 0.0001	8229	0.99
Salcha						
Carcass	Intercept	-17.83	5.06	0.0004		
	Year	0.01	0.00	0.0005	8831	1.01
Big Salmon						
Carcass	Intercept	204.8	18.53	< 0.0001		
	Year	-0.10	0.01	< 0.0001	4487	0.90

Table 2. Parameter estimates for logistic regression models of the proportion of Chinook salmon ≥ 900 mm encountered during escapement sampling.

River	Parameter	Regression Coefficient	Standard Error	P-Value	Sample Size	Odds Ratio
Andreafsky						
Carcass	Intercept	-16.71	28.11	0.5522		
	Year	0.01	0.01	0.6077	3523	1.01
Weir	Intercept	75.16	1075.80	0.9443		
	Year	-0.04	0.54	0.9419	4158	0.96
Anvik						
Carcass	Intercept	69.67	13.65	< 0.0001		
	Year	-0.04	0.01	< 0.0001	6555	0.96
Gisasa						
Weir	Intercept	-11.30	1030.70	0.9913		
	Year	0.00	0.52	0.9935	4834	1.00
Chena						
Carcass	Intercept	48.23	9.37	< 0.0001		
	Year	-0.03	0.01	< 0.0001	8263	0.98
Salcha						
Carcass	Intercept	30.77	6.09	< 0.0001		
	Year	-0.02	0.00	< 0.0001	8853	0.98
Big Salmon						
Carcass	Intercept	143.70	33.24	< 0.0001		
	Year	-0.07	0.02	< 0.0001	1981	0.93

Table 3a. Parameter estimates for logistic regression models of the proportion of Chinook salmon age 1.4 encountered during escapement sampling.

River	Parameter	Regression Coefficient	Standard Error	P-Value	Sample Size	Odds Ratio
Andreafsky						
Carcass	Intercept	2.43	16.77	0.8848		
	Year	-0.00	0.01	0.8579	3651	1.00
Weir	Intercept	45.10	444.50	0.9192		
	Year	-0.02	0.22	0.9174	4158	0.98
Anvik						
Carcass	Intercept	17.68	7.08	0.0125		
	Year	-0.01	0.00	0.0108	6596	0.99
Gisasa						
Weir	Intercept	51.72	152.50	0.7346		
	Year	-0.03	0.07	0.7315	4838	0.97
Chena						
Carcass	Intercept	-0.42	7.08	0.9525		
	Year	0.00	0.00	0.9693	8263	1.00
Salcha						
Carcass	Intercept	-10.70	4.98	0.0317		
	Year	0.01	0.00	0.0330	8933	1.01
Big Salmon						
Carcass	Intercept	199.90	30.57	< 0.0001		
	Year	-0.10	0.02	< 0.0001	2056	0.90

Table 3b. Parameter estimates for logistic regression models of the proportion of Chinook salmon age 1.5 encountered during escapement sampling.

River	Parameter	Regression Coefficient	Standard Error	P-Value	Sample Size	Odds Ratio
Andreafsky						
Carcass	Intercept	-59.01	46.73	0.2067		
	Year	0.03	0.02	0.2343	3651	1.03
Weir	Intercept	278.30	1996.70	0.8892		
	Year	-0.14	0.99	0.8874	4158	0.87
Anvik						
Carcass	Intercept	-18.88	21.49	0.3795		
	Year	0.01	0.01	0.4754	6596	1.01
Gisasa						
Weir	Intercept	194.60	203.20	0.3383		
	Year	-0.10	0.10	0.3288	4838	0.91
Chena						
Carcass	Intercept	78.93	13.96	< 0.0001		
	Year	-0.04	0.01	< 0.0001	8263	0.96
Salcha						
Carcass	Intercept	-6.48	10.51	0.5377		
	Year	0.00	0.01	0.7232	8933	1.00
Big Salmon						
Carcass	Intercept	-396.10	41.58	< 0.0001		
	Year	0.20	0.02	< 0.0001	2056	1.22

Table 4a. Parameter estimates for linear regression models of Andreafsky River carcass survey Chinook salmon length over time by age group and sex.

Age	Sex	Parameter	Regression Coefficient	Standard Error	P-Value	Sample Size
1.4	Male	Intercept	-275.38	1342.28	0.8375	
		Year	0.56	0.68	0.4108	445
	Female	Intercept	2951.77	1064.27	0.0057	
		Year	-1.06	0.54	0.0491	809
1.5	Male	Intercept	-12015.39	9648.31	0.2309	
		Year	6.51	4.85	0.1986	18
	Female	Intercept	-4066.22	4247.68	0.3410	
		Year	2.50	2.14	0.2446	90

Table 4b. Parameter estimates for linear regression models of Andreafsky River weir Chinook salmon length over time by age group and sex.

Age	Sex	Parameter	Regression Coefficient	Standard Error	P-Value	Sample Size
1.4	Male	Intercept	-2577.78	2329.26	0.2692	
		Year	1.68	1.17	0.1503	337
	Female	Intercept	2306.04	1281.38	0.0723	
		Year	-0.73	0.64	0.2521	854
1.5	Female	Intercept	1496.36	3800.60	0.6954	
		Year	-0.31	1.90	0.8709	55

Table 4c. Parameter estimates for linear regression models of Anvik River carcass survey Chinook salmon length over time by age group and sex.

Age	Sex	Parameter	Regression Coefficient	Standard Error	P-Value	Sample Size
1.4	Male	Intercept	1797.80	743.96	0.0159	
		Year	-0.49	0.37	0.1849	783
	Female	Intercept	3236.74	346.23	< 0.0001	
		Year	-1.20	0.17	< 0.0001	1872
1.5	Male	Intercept	3687.67	3896.54	0.3547	
		Year	-1.41	1.95	0.4780	23
	Female	Intercept	2564.51	1399.27	0.0687	
		Year	-0.84	0.70	0.2325	160

Table 4d. Parameter estimates for linear regression models of Gisasa River weir Chinook salmon length over time by age group and sex.

Age	Sex	Parameter	Regression Coefficient	Standard Error	P-Value	Sample Size
1.4	Male	Intercept	623.32	2576.98	0.8090	
		Year	0.08	1.29	0.9526	554
	Female	Intercept	50.57	1091.47	0.9631	
		Year	0.40	0.55	0.4673	1127
1.5	Male	Intercept	32797.08	20999.18	0.1494	
		Year	-16.01	10.51	0.1586	12
	Female	Intercept	2126.63	3854.52	0.5826	
		Year	-0.62	1.93	0.7488	85

Table 4e. Parameter estimates for linear regression models of Chena River carcass survey Chinook salmon length over time by age group and sex.

Age	Sex	Parameter	Regression Coefficient	Standard Error	P-Value	Sample Size
1.4	Male	Intercept	-441.62	977.94	0.6517	
		Year	0.65	0.49	0.1888	931
	Female	Intercept	-11.50	346.17	0.9735	
		Year	0.44	0.17	0.0114	2511
1.5	Male	Intercept	4309.04	2762.48	0.1221	
		Year	-1.68	1.39	0.2271	99
	Female	Intercept	1996.70	812.82	0.0145	
		Year	-0.54	0.41	0.1846	401

Table 4f. Parameter estimates for linear regression models of Salcha River carcass survey Chinook salmon length over time by age group and sex.

Age	Sex	Parameter	Regression Coefficient	Standard Error	P-Value	Sample Size
1.4	Male	Intercept	4065.24	564.47	< 0.0001	
		Year	-1.61	0.28	< 0.0001	1337
	Female	Intercept	966.80	260.64	0.0002	
		Year	-0.05	0.13	0.7018	2881
1.5	Male	Intercept	3858.94	1235.98	0.0022	
		Year	-1.45	0.62	0.0212	147
	Female	Intercept	3355.68	705.67	< 0.0001	
		Year	-1.22	0.36	0.0006	381

Table 4g. Parameter estimates for linear regression models of Big Salmon River carcass survey Chinook salmon length over time by age group and sex.

Age	Sex	Parameter	Regression Coefficient	Standard Error	P-Value	Sample Size
1.4	Male	Intercept	19748.61	3330.77	< 0.0001	
		Year	-9.53	1.68	< 0.0001	470
	Female	Intercept	10062.31	1319.40	< 0.0001	
		Year	-4.63	0.67	< 0.0001	812
1.5	Male	Intercept	17297.83	5785.46	0.0038	
		Year	-8.23	2.92	0.0061	75
	Female	Intercept	7209.66	2188.07	0.0012	
		Year	-3.16	1.10	0.0046	193

Appendix 1. Daily Chinook salmon counts from the Andreafsky River weir for the years 1994–2004.
Data set obtained from Fairbanks Fish and Wildlife Field Office, May 2005

Date	1994		1995		1996		1997		1998		1999		2000		2001		2002		2003		2004	
15-Jun							0	0														
16-Jun			0	0			0	0														
17-Jun			0	0			0	0			0	0										
18-Jun			0	0			0	0			0	0										
19-Jun			0	0	0	0	0	0			0	0					0	0	0	0		
20-Jun			1	1	0	0	0	0			0	0					0	0	0	0		
21-Jun			0	1	10	10	0	0			0	0					1	1	0	0		
22-Jun			1	2	0	10	0	0			0	0					20	21	0	0		
23-Jun			0	2	33	43	14	14	0	0	0	0			[a]11	11	0	21	4	4	25	25
24-Jun			2	4	6	49	21	35	0	0	0	0			[a]6	17	0	21	2	6	26	51
25-Jun			0	4	0	49	59	94	0	0	0	0			[a]13	30	3	24	7	13	15	66
26-Jun			0	4	59	108	0	94	0	0	0	0			[a]14	44	1	25	3	16	55	121
27-Jun			41	45	42	150	101	195	1	1	0	0			[a]36	80	26	51	12	28	181	302
28-Jun			48	93	19	169	11	206	0	1	0	0			[a]12	92	314	365	19	47	534	836
29-Jun	1	1	67	160	6	175	1	207	10	11	0	0			[a]11	103	119	484	4	51	290	1126
30-Jun	188	189	104	264	8	183	0	207	34	45	47	47	9	9	[a]29	132	27	511	0	51	461	1587
1-Jul	141	330	81	345	72	255	75	282	93	138	19	66	16	25	[a]62	194	319	830	176	227	582	2169
2-Jul	54	384	71	416	21	276	24	306	17	155	9	75	39	64	[a]23	217	105	935	295	522	25	2194
3-Jul	222	606	17	433	205	481	29	335	36	191	0	75	89	153	[a]62	279	230	1165	22	544	375	2569
4-Jul	156	762	55	488	124	605	49	384	75	266	12	87	74	227	[a]61	340	5	1170	6	550	353	2922
5-Jul	651	1413	107	595	309	914	98	482	336	602	97	184	38	265	[a]181	521	20	1190	83	633	263	3185
6-Jul	225	1638	678	1273	258	1172	356	838	373	975	42	226	407	672	[a]286	807	356	1546	136	769	1187	4372
7-Jul	1,156	2794	433	1706	280	1452	227	1065	386	1361	114	340	18	690	[a]252	1059	307	1853	336	1105	878	5250
8-Jul	108	2902	155	1861	244	1696	123	1188	204	1565	197	537	71	761	[a]175	1234	130	1983	469	1574	463	5713
9-Jul	351	3253	260	2121	186	1882	49	1237	129	1694	216	753	17	778	[a]150	1384	178	2161	823	2397	503	6216
10-Jul	375	3628	250	2371	111	1993	64	1301	167	1861	256	1009	30	808	[a]149	1533	191	2352	48	2445	368	6584
11-Jul	288	3916	382	2753	72	2065	69	1370	255	2116	507	1516	57	865	[a]222	1755	264	2616	107	2552	122	6706
12-Jul	581	4497	1022	3775	52	2117	88	1458	138	2254	214	1730	35	900	[a]217	1972	166	2782	345	2897	315	7021
13-Jul	779	5276	697	4472	100	2217	15	1473	62	2316	331	2061	55	955	[a]185	2157	191	2973	311	3208	106	7127
14-Jul	433	5709	375	4847	96	2313	16	1489	61	2377	97	2158	18	973	[a]99	2256	158	3131	340	3548	105	7232
15-Jul	352	6061	292	5139	62	2375	124	1613	91	2468	22	2180	90	1063	169	2425	140	3271	2	3550	53	7285
16-Jul	389	6450	97	5236	95	2470	274	1887	197	2665	33	2213	[b]	1063	87	2512	210	3481	7	3557	58	7343
17-Jul	144	6594	46	5282	110	2580	91	1978	263	2928	75	2288	[b]	1063	41	2553	119	3600	25	3582	54	7397
18-Jul	285	6879	38	5320	55	2635	25	2003	184	3112	63	2351	[b]	1063	196	2749	94	3694	235	3817	29	7426
19-Jul	161	7040	25	5345	42	2677	70	2073	240	3352	65	2416	[b]	1063	71	2820	75	3769	158	3975	40	7466
20-Jul	53	7093	37	5382	69	2746	264	2337	67	3419	302	2718	22	1085	107	2927	50	3819	28	4003	57	7523
21-Jul	66	7159	74	5456	51	2797	148	2485	129	3548	55	2773	12	1097	175	3102	29	3848	10	4013	40	7563
22-Jul	62	7221	33	5489	26	2823	35	2520	117	3665	67	2840	21	1118	66	3168	12	3860	2	4015	13	7576
23-Jul	209	7430	24	5513	2	2825	103	2623	57	3722	15	2855	6	1124	15	3183	32	3892	23	4038	17	7593
24-Jul	149	7579	7	5520	4	2829	57	2680	66	3788	54	2909	11	1135	5	3188	16	3908	58	4096	12	7605
25-Jul	25	7604	78	5598	6	2835	0	2680	12	3800	24	2933	10	1145	17	3205	7	3915	31	4127	19	7624
26-Jul	51	7655	21	5619	3	2838	11	2691	8	3808	5	2938	9	1154	7	3212	3	3918	4	4131	5	7629
27-Jul	92	7747	12	5631	6	2844	3	2694	8	3816	34	2972	7	1161	17	3229	6	3924	22	4153	14	7643
28-Jul	20	7767	15	5646	16	2860	29	2723	11	3827	6	2978	3	1164	10	3239	3	3927	108	4261	23	7666
29-Jul	10	7777	9	5655	13	2873	58	2781	23	3850	159	3137	57	1221	41	3280	4	3931	28	4289	19	7685
30-Jul	13	7790	5	5660	7	2880	144	2925	31	3881	80	3217	4	1225	16	3296	2	3933	4	4293	7	7692
31-Jul	10	7800	1	5661	10	2890	2	2927	17	3898	[b]	3217	20	1245	11	3307	46	3979	0	4293	15	7707
1-Aug	1	7801	8	5669	4	2894	8	2935	20	3918	[b]	3217	12	1257	8	3315	55	4034	2	4295	13	7720
2-Aug			2	5671	2	2896	4	2939	4	3922	18	3235	4	1261	12	3327	48	4082	5	4300	4	7724
3-Aug			13	5684	2	2898	128	3067	11	3933	42	3277	24	1285	4	3331	10	4092	1	4301	3	7727
4-Aug			5	5689	5	2903	2	3069	1	3934	11	3288	[b]	1285	8	3339	3	4095	1	4302	6	7733
5-Aug			6	5695	6	2909	1	3070	7	3941	5	3293	[b]	1285	6	3345	3	4098	4	4306	5	7738
6-Aug			6	5701	2	2911	0	3070	9	3950	2	3295	[b]	1285	1	3346	4	4102	0	4306	10	7748
7-Aug			19	5720	7	2918	1	3071	10	3960	1	3296	4	1289	11	3357	4	4106	1	4307	8	7756

Appendix 1. *Continued*

Date	1994		1995		1996		1997		1998		1999		2000		2001		2002		2003		2004	
8-Aug			20	5740	3	2921	2	3073	3	3963	4	3300	7	1296	0	3357	0	4106	3	4310	6	7762
9-Aug			25	5765	2	2923	2	3075	5	3968	0	3300	10	1306	4	3361	0	4106	1	4311	13	7775
10-Aug			25	5790	5	2928	1	3076	7	3975	1	3301	3	1309	2	3363	0	4106	0	4311	39	7814
11-Aug			7	5797	2	2930	1	3077	1	3976	2	3303	8	1317	1	3364	4	4110	1	4312	17	7831
12-Aug			4	5801	3	2933	7	3084	8	3984	5	3308	4	1321	1	3365	0	4110	1	4313	23	7854
13-Aug			11	5812	0	2933	14	3098	7	3991	3	3311	1	1322	10	3375	1	4111	2	4315	[a]19	7873
14-Aug			2	5814	0	2933	18	3116	1	3992	9	3320	[b]	1322	0	3375	1	4112	3	4318	[a]15	7889
15-Aug			2	5816	0	2933	26	3142	0	3992	2	3322	6	1328	11	3386	0	4112	[a]3	4321	[a]12	7900
16-Aug			3	5819	3	2936	2	3144	12	4004	4	3326	2	1330	8	3394	0	4112	[a]2	4323	[a]8	7908
17-Aug			3	5822	0	2936	4	3148	[b]	4004	7	3333	1	1331	2	3396	3	4115	[a]1	4324	4	7912
18-Aug			3	5825	2	2938	3	3151	[b]	4004	3	3336	2	1333	2	3398	0	4115	1	4325	10	7922
19-Aug			2	5827	2	2940	3	3154	2	4006	0	3336	2	1335	2	3400	1	4116	2	4327	9	7931
20-Aug			1	5828	3	2943	2	3156	[b]	4006	6	3342	3	1338	1	3401	0	4116	2	4329	6	7937
21-Aug			2	5830	3	2946	1	3157	[b]	4006	0	3342	1	1339	0	3401	0	4116	0	4329	8	7945
22-Aug			0	5830	0	2946	4	3161	[b]	4006	1	3343	1	1340	1	3402	5	4121	0	4329	5	7950
23-Aug			1	5831	2	2948	2	3163	[b]	4006	0	3343	0	1340	0	3402	0	4121	0	4329	1	7951
24-Aug			1	5832	0	2948	1	3164	[b]	4006	0	3343	1	1341	1	3403	1	4122	2	4331	3	7954
25-Aug			0	5832	0	2948	4	3168	[b]	4006	0	3343	0	1341	0	3403	0	4122	2	4333	1	7955
26-Aug			0	5832	1	2949	0	3168	[b]	4006	1	3344	2	1343	0	3403	0	4122	1	4334	0	7955
27-Aug			0	5832	0	2949	0	3168	[b]	4006	1	3345	0	1343	0	3403	0	4122	0	4334	1	7956
28-Aug			3	5835	0	2949	1	3169	[b]	4006	0	3345	0	1343	0	3403	0	4122	0	4334	0	7956
29-Aug			1	5836	2	2951	2	3171	0	4006	0	3345	0	1343	0	3403	0	4122	0	4334	0	7956
30-Aug			0	5836	1	2952	3	3174	1	4007	0	3345	0	1343	0	3403	1	4123	0	4334	4	7960
31-Aug			0	5836	2	2954	1	3175	1	4008	0	3345	0	1343	0	3403	0	4123	0	4334	2	7962
1-Sep			1	5837	0	2954	0	3175	0	4008	0	3345	0	1343	0	3403	0	4123	0	4334	2	7964
2-Sep			0	5837	0	2954	0	3175	0	4008	1	3346	1	1344	[b]	3403	[b]	4123	0	4334	0	7964
3-Sep			0	5837	0	2954	4	3179	0	4008	0	3346	0	1344	[b]	3403	[b]	4123	0	4334	0	7964
4-Sep			0	5837	0	2954	0	3179	0	4008	0	3346	0	1344	[b]	3403	0	4123	0	4334	1	7965
5-Sep			1	5838	0	2954	1	3180	0	4008	1	3347	0	1344	[b]	3403	0	4123	0	4334	1	7966
6-Sep			0	5838	1	2955	1	3181	0	4008	0	3347	[b]	1344	[b]	3403	0	4123	0	4334	2	7968
7-Sep			0	5838	0	2955	0	3181	1	4009	0	3347	0	1344	[b]	3403	0	4123	0	4334	0	7968
8-Sep			3	5841	0	2955	2	3183	0	4009	0	3347	0	1344	[b]	3403	0	4123	0	4334	1	7969
9-Sep			0	5841	0	2955	1	3184	1	4010	0	3347	0	1344	[b]	3403	0	4123	1	4335	1	7970
10-Sep			0	5841	0	2955	0	3184	0	4010	0	3347	0	1344	0	3403	0	4123	0	4335	0	7970
11-Sep			0	5841	0	2955	0	3184	1	4011	0	3347	0	1344	0	3403	0	4123	0	4335	2	7972
12-Sep			0	5841	0	2955	2	3186	0	4011			0	1344	0	3403	0	4123	0	4335	0	7972
13-Sep					0	2955	0	3186	0	4011			0	1344	0	3403	0	4123	0	4335	0	7972
14-Sep					0	2955							0	1344	0	3403	0	4123	0	4335	0	7972
15-Sep					0	2955							0	1344	1	3404			1	4336	0	7972
16-Sep					0	2955							0	1344							0	7972
17-Sep					0	2955							0	1344							1	7973
18-Sep													0	1344							0	7973
19-Sep													0	1344							1	7974
20-Sep													0	1344								
21-Sep													0	1344								
22-Sep													0	1344								
23-Sep													0	1344								
Total	7,801		5841		2955		3186		4011		3347		1344		[a]3404		4123		4336		7974	

[a] = estimated escapement count
[b] = no counts, no estimates made

Historical daily Chinook salmon estimates recorded at the East Fork Andreafsky River weir 1994 -2004. Missing daily counts were estimated using an average historical daily proportion of passage (2001) or a linear interpolation of values before and after days with missing data (2003, 2004).

Appendix 2. Daily Chinook salmon counts from the Gisasa River weir for the years 1994–2004.
Data set obtained from Fairbanks Fish and Wildlife Field Office, May 2005

Date	1994		1995		1996		1997		1998		1999		2000		2001		2002		2003		2004	
14-Jun-94				0		0	0	0		0		0		0		0		0		0		0
15-Jun-94				0		0	0	0		0		0		0		0		0		0		0
16-Jun-94				0		0	0	0		0		0		0		0		0		0		0
17-Jun-94				0		0	0	0		0		0		0		0		0		0		0
18-Jun-94				0		0	0	0		0		0		0		0		0		0		0
19-Jun-94				0	0	0	0	0		0		0		0		0		0		0		0
20-Jun-94				0	4	4	0	0		0		0		0		0		0		0		0
21-Jun-94			0	0	9	13	0	0	0	0		0		0		0		0		0		0
22-Jun-94			1	1	6	19	0	0	0	0		0		0		0	0	0		0		0
23-Jun-94			0	1	8	27	0	0	0	0	0	0		0		0	0	0		0		0
24-Jun-94			2	3	32	59	0	0	0	0	0	0		0		0	0	0		0	0	0
25-Jun-94			4	7	63	122	0	0	0	0	0	0		0		0	0	0		0	0	0
26-Jun-94			1	8	69	191	0	0	0	0	0	0		0		0	1	1		0	14	14
27-Jun-94			5	13	16	207	1	1	2	2	0	0		0		0	0	1		0	14	28
28-Jun-94			19	32	[b]46	253	3	4	0	2	1	1	0	0		0	3	4	2	2	6	34
29-Jun-94			23	55	[a]76	329	9	13	1	3	0	1	0	0		0	0	4	8	10	9	43
30-Jun-94			46	101	30	359	2	15	2	5	0	1	0	0		0	4	8	8	18	14	57
1-Jul-94			82	183	57	416	33	48	5	10	0	1	0	0		0	5	13	25	43	14	71
2-Jul-94			46	229	72	488	11	59	[a]13	23	0	1	0	0		0	5	18	32	75	18	89
3-Jul-94			35	264	28	516	6	65	[b]18	41	0	1	0	0		0	9	27	19	94	35	124
4-Jul-94			57	321	35	551	78	143	[b]22	63	0	1	0	0		0	0	27	13	107	10	134
5-Jul-94			39	360	41	592	120	263	[b]26	89	1	2	0	0		0	15	42	7	114	36	170
6-Jul-94			92	452	78	670	64	327	[a]30	119	2	4	13	13		0	41	83	23	137	38	208
7-Jul-94			258	710	234	904	70	397	37	156	1	5	8	21	18	18	134	217	36	173	39	247
8-Jul-94			175	885	51	955	138	535	71	227	5	10	70	91	41	59	103	320	73	246	34	281
9-Jul-94			184	1069	63	1018	310	845	71	298	45	55	40	131	43	102	135	455	186	432	283	564
10-Jul-94			300	1369	81	1099	320	1165	107	405	60	115	21	152	26	128	134	589	222	654	127	691
11-Jul-94			385	1754	70	1169	144	1309	116	521	80	195	28	180	100	228	100	689	109	763	147	838
12-Jul-94	212	212	281	2035	51	1220	424	1733	142	663	19	214	40	220	63	291	259	948	88	851	17	855
13-Jul-94	259	471	468	2503	215	1435	137	1870	163	826	83	297	82	302	63	354	359	1307	120	971	142	997
14-Jul-94	189	660	205	2708	158	1593	38	1908	225	1051	49	346	103	405	117	471	66	1373	26	997	55	1052
15-Jul-94	239	899	104	2812	40	1633	112	2020	102	1153	50	396	345	750	306	777	78	1451	79	1076	265	1317
16-Jul-94	355	1254	211	3023	26	1659	146	2166	155	1308	89	485	223	973	196	973	37	1488	41	1117	40	1357
17-Jul-94	248	1502	126	3149	14	1673	632	2798	115	1423	37	522	59	1032	299	1272	48	1536	94	1211	170	1527
18-Jul-94	219	1721	72	3221	38	1711	92	2890	147	1570	154	676	177	1209	238	1510	23	1559	217	1428	47	1574
19-Jul-94	302	2023	155	3376	54	1765	257	3147	74	1644	30	706	66	1275	258	1768	37	1596	102	1530	11	1585
20-Jul-94	248	2271	62	3438	93	1858	88	3235	62	1706	397	1103	41	1316	388	2156	63	1659	94	1624	19	1604
21-Jul-94	70	2341	87	3525	15	1873	91	3326	50	1756	363	1466	66	1382	254	2410	22	1681	50	1674	18	1622
22-Jul-94	42	2383	79	3604	17	1890	142	3468	75	1831	27	1493	188	1570	74	2484	27	1708	57	1731	20	1642
23-Jul-94	100	2483	68	3672	18	1908	98	3566	54	1885	26	1519	53	1623	44	2528	16	1724	11	1742	28	1670
24-Jul-94	99	2582	87	3759	45	1953	38	3604	90	1975	70	1589	89	1712	25	2553	18	1742	53	1795	20	1690
25-Jul-94	65	2647	42	3801	4	1957	120	3724	[b]82	2057	307	1896	42	1754	36	2589	15	1757	8	1803	15	1705
26-Jul-94	48	2695	21	3822	21	1978	25	3749	[b]74	2131	276	2172	13	1767	37	2626	73	1830	22	1825	13	1718
27-Jul-94	39	2734	45	3867	13	1991	15	3764	[b]66	2197	103	2275	23	1790	14	2640	91	1921	8	1833	12	1730
28-Jul-94	33	2767	35	3902		1991		3764	[b]58	2255	106	2381	18	1808	27	2667	[b]61	1982	9	1842	8	1738
29-Jul-94	32	2799	11	3913		1991		3764	[a]52	2307	68	2449	79	1887	149	2816	[b]31	2013	16	1858	15	1753
30-Jul-94	24	2823	42	3955		1991		3764	33	2340	40	2489	52	1939	20	2836	[a]2	2015	6	1864	13	1766
31-Jul-94	9	2832	29	3984		1991		3764	17	2357	[b]33	2522	27	1966	88	2924	9	2024	3	1867	7	1773
1-Aug-94	21	2853	14	3998		1991		3764	14	2371	[b]26	2548	27	1993	18	2942		2024	13	1880	1	1774
2-Aug-94	12	2865	8	4006		1991		3764	12	2383	[b]19	2567	34	2027	23	2965		2024	0	1880		1774
3-Aug-94	5	2870	17	4023		1991		3764		2383	[a]13	2580	24	2051	9	2974		2024	6	1886		1774
4-Aug-94	2	2872		4023		1991		3764		2383	13	2593	16	2067	28	3002		2024		1886		1774
5-Aug-94	3	2875		4023		1991		3764		2383	15	2608	10	2077	29	3031		2024		1886		1774
6-Aug-94	5	2880		4023		1991		3764		2383	23	2631	3	2080	12	3043		2024		1886		1774
7-Aug-94	6	2886		4023		1991		3764		2383	11	2642	9	2089	4	3047		2024		1886		1774
8-Aug-94	1	2887		4023		1991		3764		2383		2642		2089	5	3052		2024		1886		1774
9-Aug-94	0	2887		4023		1991		3764		2383		2642		2089		3052		2024		1886		1774
10-Aug-94	1	2888		4023		1991		3764		2383		2642		2089		3052		2024		1886		1774
Cumulative	[c]2888		4023		1991		3764		2383		2642		2089		3052		2024		1886		1774	

[a] Estimated count, partial day
[b] Estimated count, missing day
[c] Incomplete season

Appendix 3. Mean length[a] of Andreafsky River carcass sample data by year, age, and sex.[b]

		Age									
		1.1		1.2		1.3		1.4		1.5	
Year		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
1980	Mean Length			537.25		689.82	749.45	787.75	819.29		737.00
	Standard Error			12.11		12.38	25.37	38.67	10.99		115.00
	Sample Size			16		28	11	4	7		2
1981	Mean Length			564.27	690.00	736.41	796.31	857.45	872.18		950.00
	Standard Error			7.74		6.49	9.96	7.63	4.33		
	Sample Size			27	1	74	16	48	120		1
1982	Mean Length	379.86		544.80	496.60	697.64	751.00	787.62	823.07	867.50	937.00
	Standard Error	8.92		4.28	16.31	4.30	21.69	16.98	8.35	7.50	25.28
	Sample Size	7		103	10	151	8	13	27	2	4
1983	Mean Length			531.09		712.78	790.00	827.17	840.90		
	Standard Error			8.27		7.15		9.02	6.80		
	Sample Size			32		60	1	36	40		
1984	Mean Length	385.00		558.69		703.04	759.64	828.96	854.31	893.50	907.40
	Standard Error			11.59		4.89	19.73	9.29	8.33	51.50	25.53
	Sample Size	1		42		178	14	58	80	2	5
1985	Mean Length			529.50		715.67	755.00	807.78	854.39	927.50	878.57
	Standard Error			4.04		8.02	20.00	10.81	5.26	7.50	10.13
	Sample Size			152		52	2	57	113	2	14
1988	Mean Length	335.00		563.05		700.14	784.44	840.00	871.76	935.00	928.33
	Standard Error			5.35		7.89	10.10	16.29	6.75	6.12	7.14
	Sample Size	1		80		76	18	25	58	4	44
1989	Mean Length			505.42		732.19	761.18	787.94	844.09	981.67	905.00
	Standard Error			14.11		3.97	14.01	8.75	8.17	57.83	
	Sample Size			12		139	17	34	13	3	1
1990	Mean Length	562.50		587.13	766.67	724.41	838.71	853.84	867.21	845.00	936.43
	Standard Error	12.50		5.45	66.73	9.26	10.67	9.24	8.76		18.12
	Sample Size	2		171	3	103	58	65	177	1	7
1991	Mean Length			519.12		743.21	770.48	841.67	840.89	877.50	909.29
	Standard Error			10.61		3.82	6.51	8.89	5.45	77.50	15.45
	Sample Size			34		209	44	49	79	2	7
1992	Mean Length			571.82		666.46	840.00	835.00	843.75		922.50
	Standard Error			19.67		12.00		19.26	14.75		47.50
	Sample Size			12		24	1	5	8		2
1993	Mean Length	420.00		574.13		711.44	797.50	828.81	834.64	987.50	840.00
	Standard Error			7.44		4.96	16.45	6.63	4.05	57.50	16.51
	Sample Size	1		64		128	10	69	125	2	7
1996	Mean Length			545.00		690.47	802.50	775.00	835.00		
	Standard Error			25.00		9.16	17.50				
	Sample Size			3		32	2	1	1		

[a] All measurements are MEF and reported in millimeters.
[b] Statistics reflect only individuals with complete age, length, and sex information reported in the data set.

Appendix 4. Mean length[a] of Andreafsky River weir sample data by year, age, and sex.[b]

		Age									
		1.1		1.2		1.3		1.4		1.5	
Year		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
1994	Mean of Length			549.86		713.84	766.52	794.59	832.62		866.05
	Standard Error			9.88		3.71	8.95	7.49	4.75		7.53
	Sample Size			35		199	33	49	103		19
1995	Mean of Length			519.42	493.75	696.14	782.11	797.00	857.42	915.00	868.00
	Standard Error			5.52	9.58	16.78	20.91	10.04	5.03		22.62
	Sample Size			112	8	35	19	45	118	1	5
1996	Mean of Length	437.50	360.00	565.00	548.89	699.72	719.53	754.71	819.66	920.00	917.73
	Standard Error	11.81		14.59	22.23	5.00	8.84	19.85	12.32	40.00	13.66
	Sample Size	4	1	15	9	158	93	17	29	2	11
1997	Mean of Length			577.38	595.00	678.61	711.76	777.76	827.14		
	Standard Error			4.20	9.91	12.05	23.37	11.70	5.17		
	Sample Size			181	34	46	17	29	98		
1998	Mean of Length			532.89	562.00	703.93	772.74	751.94	801.48		861.67
	Standard Error			6.98	25.52	4.45	6.20	18.12	7.18		38.12
	Sample Size			57	5	191	73	18	27		3
1999	Mean of Length	440.00		524.78	551.88	658.45	729.72	738.78	859.13	755.00	860.00
	Standard Error			4.15	13.59	7.40	24.00	11.34	5.84		
	Sample Size	1		115	8	97	18	41	75	1	1
2000	Mean of Length			520.38	516.27	704.63	727.71	783.88	831.92	790.00	
	Standard Error			17.75	12.42	4.84	13.14	8.88	9.01		
	Sample Size			21	11	135	35	48	52	1	
2001	Mean of Length			523.89		689.33	820.50	798.18	866.09	750.00	885.00
	Standard Error			16.34		14.17	16.18	17.40	5.53		30.00
	Sample Size			18		15	8	11	69	1	2
2002	Mean of Length			541.33	540.00	678.95	700.30	760.15	811.51	860.00	864.00
	Standard Error			4.09		4.67	8.89	11.25	8.48		25.81
	Sample Size			132	1	177	33	34	53	1	5
2003	Mean of Length	382.50		533.24	513.53	710.28	730.87	824.06	841.19		860.00
	Standard Error	2.50		5.92	13.61	4.51	6.14	10.66	5.15		21.10
	Sample Size	2		68	17	177	92	32	139		6
2004	Mean of Length			587.92	575.90	696.23	727.50	810.00	841.92		900.00
	Standard Error			3.20	6.20	4.17	10.27	13.01	5.63		15.28
	Sample Size			159	39	158	44	13	91		3

[a] All measurements are MEF and reported in millimeters.
[b] Statistics reflect only individuals with complete age, length, and sex information reported in the data set.

Appendix 5. Mean length[a] of Anvik River carcass sample data by year, age, and sex.[b]

		Age									
		1.1		1.2		1.3		1.4		1.5	
Year		**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
1976	Mean Length			549.00		676.07	755.00	715.00	836.00		
	Standard Error			22.27		13.86	18.44		9.88		
	Sample Size			5		27	6	1	7		
1977	Mean Length			470.00	659.00	697.74	847.60	814.64	836.13	936.00	834.00
	Standard Error			8.00		14.38	18.94	16.88	7.62		24.67
	Sample Size			2	1	27	5	22	53	1	5
1978	Mean Length			596.11		650.80		866.25	876.47		
	Standard Error			8.60		20.74		18.39	8.59		
	Sample Size			9		5		4	32		
1980	Mean Length			580.35		735.33	777.81	870.00	885.18		970.00
	Standard Error			7.00		10.54	8.49		7.78		44.06
	Sample Size			20		21	21	1	17		3
1981	Mean Length			572.06	520.00	752.85	801.11	834.33	865.22		845.00
	Standard Error			12.61		8.01	7.43	13.93	4.21		
	Sample Size			33	1	59	37	15	116		1
1982	Mean Length			561.63	660.00	678.72	792.00	814.17	840.00		
	Standard Error			8.71		7.83	36.52	53.22	8.46		
	Sample Size			46	1	47	5	6	32		
1984	Mean Length			543.62	542.25	701.03	720.40	811.48	854.68		877.83
	Standard Error			10.46	24.58	5.28	11.00	14.08	12.68		21.81
	Sample Size			29	4	107	30	25	74		6
1985	Mean Length			581.67		738.33	775.00	801.67	841.25		
	Standard Error			19.65		16.09	35.00	10.93	19.83		
	Sample Size			3		9	2	3	4		
1988	Mean Length			586.60		715.43	795.00	791.73	859.27	880.00	913.13
	Standard Error			6.38		7.76	9.51	15.81	8.90		22.52
	Sample Size			75		69	23	26	41	1	8
1989	Mean Length	405.00		567.22		736.25	780.50	805.75	830.88		934.29
	Standard Error			35.75		5.79	10.40	9.07	5.21		20.19
	Sample Size	1		10		96	30	40	74		7
1990	Mean Length	336.00		576.91		709.23	770.61	830.31	846.02	900.75	907.00
	Standard Error			3.70		7.88	15.38	7.41	4.72	12.83	9.23
	Sample Size	1		105		86	18	55	119	4	11
1991	Mean Length			555.33		737.72	778.00	813.34	822.84	840.00	886.00
	Standard Error			9.14		3.96	5.64	9.85	5.30		12.00
	Sample Size			39		145	63	38	82	1	10

[a] All measurements are MEF and reported in millimeters.
[b] Statistics reflect only individuals with complete age, length, and sex information reported in the data set.

Appendix 5. ***Continued***

		Age									
		1.1		1.2		1.3		1.4		1.5	
Year		**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
1992	Mean Length			561.83		680.45	763.71	820.35	854.25	894.00	887.00
	Standard Error			7.30		5.32	15.81	9.21	4.07	39.00	13.32
	Sample Size			30		112	7	40	120	2	3
1993	Mean Length			582.34		702.50	793.11	820.33	833.22		887.14
	Standard Error			9.38		5.70	9.99	9.52	4.94		25.21
	Sample Size			47		104	27	46	107		7
1994	Mean Length			586.67		722.47	764.69	801.36	846.84	850.00	874.52
	Standard Error			13.63		3.95	6.84	10.60	4.12		8.90
	Sample Size			12		178	32	44	117	1	21
1995	Mean Length			602.21	771.67	744.04	827.27	822.36	847.53	810.75	881.36
	Standard Error			14.22	11.67	10.88	7.13	9.43	3.51	30.34	11.52
	Sample Size			34	3	52	44	55	201	4	11
1996	Mean Length			530.42	695.00	691.57	737.31	765.20	833.42	880.00	902.80
	Standard Error			6.42	20.00	4.86	15.21	11.11	9.43		10.62
	Sample Size			24	2	118	26	25	38	1	25
1997	Mean Length			569.60	405.00	704.63	808.33	835.97	843.21		835.00
	Standard Error			4.72		7.76	18.52	9.29	4.53		
	Sample Size			75	1	81	12	36	98		1
1998	Mean Length	495.00		547.81		724.47	776.66	800.16	813.48		855.00
	Standard Error			8.06		4.43	4.60	10.06	6.77		25.33
	Sample Size	1		48		139	58	32	46		4
1999	Mean Length			564.83		692.80	750.71	790.80	839.14		
	Standard Error			13.02		5.39	17.42	11.04	4.89		
	Sample Size			32		125	21	56	109		
2000	Mean Length			509.50		689.29	735.00	765.95	817.31		
	Standard Error			13.13		6.78	15.00	9.65	6.71		
	Sample Size			10		71	14	39	68		1
2001	Mean Length			546.94	545.00	702.83	778.50	803.78	836.67	870.00	878.93
	Standard Error			5.26		6.68	22.85	7.43	5.50	29.87	13.49
	Sample Size			36	1	90	10	74	102	5	14
2002	Mean Length			563.61		693.93	737.22	804.66	821.59	950.00	878.89
	Standard Error			5.67		5.93	13.97	10.31	6.63		20.78
	Sample Size			61		117	18	44	63	1	9
2003	Mean Length	375.00		534.59	620.00	721.14	744.65	833.33	831.48	875.00	855.91
	Standard Error			5.14		4.18	6.81	8.91	5.47	55.00	23.30
	Sample Size	1		37	1	177	57	50	92	2	11
2004	Mean Length	360.00		611.24		697.65	805.00	846.13	825.75		915.00
	Standard Error			4.17		5.96	10.70	20.25	5.64		43.30
	Sample Size	2		106	1	116	19	16	69		3

Appendix 6. Mean length[a] of Gisasa River weir sample data by year, age, and sex.[b]

		Age									
		1.1		1.2		1.3		1.4		1.5	
Year		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
1995	Mean Length			572.22	570.00	742.43	821.47	806.85	865.47	810.00	895.00
	Standard Error			8.11		9.08	9.55	9.18	4.39		20.74
	Sample Size			54	1	70	34	62	118	1	6
1996	Mean Length	405.00		508.16		688.32	776.11	739.29	839.62	895.00	886.32
	Standard Error	12.58		5.70		3.89	16.63	13.25	11.27	5.00	11.21
	Sample Size	4		61		185	18	21	26	2	22
1997	Mean Length	462.50		551.02	667.50	672.70	760.00	799.17	845.13		990.00
	Standard Error	32.50		3.27	82.50	5.12	26.51	9.03	4.40		
	Sample Size	2		182	2	122	10	60	116		1
1998	Mean Length			514.14	560.00	693.38	704.76	730.13	801.90	807.50	870.00
	Standard Error			6.58		3.91	16.11	13.10	8.32	27.50	11.25
	Sample Size			58	1	195	21	39	29	2	6
1999	Mean Length	417.50		522.79		674.58	785.00	759.16	823.98	762.50	850.00
	Standard Error	7.50		4.81		4.45	24.45	7.16	4.64	112.50	
	Sample Size	2		86		202	10	83	123	2	1
2000	Mean Length			502.50	595.00	699.44	779.63	773.24	825.57	790.00	906.54
	Standard Error			8.59		3.25	5.75	6.49	3.88		11.30
	Sample Size			44	1	288	51	105	159	1	13
2001	Mean Length	335.00		535.34		697.13	827.33	798.11	847.03	795.00	862.86
	Standard Error			6.72		7.20	16.15	8.09	2.87	40.52	11.93
	Sample Size	1		106		108	30	103	269	4	14
2002	Mean Length			528.93		672.86	736.19	753.90	819.11		882.33
	Standard Error			3.16		4.02	10.66	8.36	5.57		11.08
	Sample Size			168		199	21	50	73		15
2003	Mean Length	305.00		521.35		723.26	743.78	803.91	866.94		946.00
	Standard Error			10.09		3.44	7.38	11.71	5.21		36.82
	Sample Size	1		26		242	86	23	89		5
2004	Mean Length	397.50		607.25	613.00	698.15	734.19	796.25	871.74		935.00
	Standard Error	21.46		3.13	10.55	4.85	13.36	28.13	4.67		15.00
	Sample Size	4		203	10	135	31	16	138		2

[a] All measurements are MEF and reported in millimeters.
[b] Statistics reflect only individuals with complete age, length, and sex information reported in the data set.

Appendix 7. Mean length[a] of Chena River carcass sample data by year, age, and sex.[b]

		Age									
		1.1		1.2		1.3		1.4		1.5	
Year		**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
1975	Mean Length			590.00		713.57	755.56		881.82	960.00	950.00
	Standard Error			6.10		18.89	29.11		17.93		40.00
	Sample Size			13		14	9		11	1	2
1981	Mean Length	340.00		470.00		625.77	763.33	785.93	788.29		
	Standard Error					10.57	8.82	13.14	5.70		
	Sample Size	1		1		22	3	29	49		
1982	Mean Length			548.63	595.00	690.67	712.61	803.86	847.18	936.50	930.00
	Standard Error			6.33	10.00	10.79	15.23	24.48	6.34	121.50	
	Sample Size			60	2	33	18	21	50	2	1
1984	Mean Length			509.54		695.20	746.43	867.69	863.30	950.00	909.44
	Standard Error			7.34		4.33	12.71	16.92	7.42	21.49	6.95
	Sample Size			54		176	40	27	119	9	37
1985	Mean Length			556.64		691.09	716.67	835.76	873.27	942.50	927.17
	Standard Error			8.55		6.97	15.52	9.43	3.51	40.54	8.22
	Sample Size			61		96	10	75	223	4	31
1988	Mean Length	521.67		557.45		710.85	800.00	815.39	849.19	983.33	919.70
	Standard Error	14.24		6.76		6.13	13.13	10.13	3.29	18.33	4.87
	Sample Size	3		49		65	17	51	166	15	100
1989	Mean Length	540.00		547.27	760.00	778.20	780.29	888.29	884.59	970.00	925.86
	Standard Error			23.01		11.95	9.90	15.21	5.29		9.30
	Sample Size	1		11	1	50	35	35	122	1	29
1990	Mean Length			567.57	876.50	724.82	810.23	863.89	864.74		900.08
	Standard Error			4.75	45.50	11.48	17.45	13.24	3.71		14.23
	Sample Size			93	2	60	26	47	140		12
1991	Mean Length			531.96		745.24	776.38	834.02	860.82	970.36	939.50
	Standard Error			7.00		4.24	7.31	11.91	6.27	13.90	13.18
	Sample Size			28		148	40	41	55	14	11
1992	Mean Length	377.78		531.41		688.90	810.33	867.24	865.71		995.00
	Standard Error	9.76		4.23		5.83	14.94	11.20	3.26		
	Sample Size	9		187		59	15	29	156		1
1993	Mean Length	495.00		591.36		698.04	833.75	787.76	845.91	680.00	945.00
	Standard Error			13.94		8.29	36.81	20.94	10.00		
	Sample Size	1		55		69	8	30	22	1	1
1994	Mean Length			578.67		718.15	777.38	819.77	863.54	1045.00	899.50
	Standard Error			16.41		4.48	10.93	8.74	3.33	40.00	13.87
	Sample Size			15		181	42	82	178	2	10

[a] All measurements are MEF and reported in millimeters.
[b] Statistics reflect only individuals with complete age, length, and sex information reported in the data set.

Appendix 7. *Continued*.

		Age									
		1.1		1.2		1.3		1.4		1.5	
Year		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
1995	Mean Length			598.71		762.32	827.65	891.55	875.25	982.50	920.87
	Standard Error			12.57		8.74	7.88	6.72	2.12	27.12	12.50
	Sample Size			35		97	68	132	429	4	23
1996	Mean Length	402.73		560.48	630.00	737.04	788.83	899.49	880.67	939.63	909.53
	Standard Error	15.16		14.10		4.39	9.69	13.39	5.53	16.01	4.09
	Sample Size	11		31	1	181	47	39	82	27	96
1997	Mean Length	475.00		579.48	765.00	753.91	856.88	849.34	888.52	965.00	900.83
	Standard Error	25.00		2.79	140.00	8.87	13.13	10.80	2.91		15.41
	Sample Size	2		259	2	78	16	83	254	1	6
1998	Mean Length			523.50		716.57	765.60	794.17	824.58	918.33	917.50
	Standard Error			11.90		4.66	5.92	48.98	7.35	80.07	13.50
	Sample Size			10		115	50	6	36	3	8
1999	Mean Length			592.14	540.00	718.70	798.10	815.32	825.05		
	Standard Error			26.59		19.76	19.91	15.27	5.91		
	Sample Size	3		24	1	53	27	51	157		2
2000	Mean Length			497.33		692.56	762.50	751.24	824.69	876.67	890.50
	Standard Error			6.33		8.98	27.12	35.03	9.42	46.93	15.61
	Sample Size			30		43	10	21	32	3	10
2001	Mean Length										
	Standard Error										
	Sample Size		3	45	5	135	40	103	164	6	20
2002	Mean Length		480.00	553.16		718.77	807.22	826.52	851.07	1020.00	907.78
	Standard Error			2.97		5.16	15.41	7.35	4.69	50.00	8.82
	Sample Size		1	187		158	18	89	107	2	9
2003	Mean Length			555.28	500.00	747.80	803.22	864.59	872.48	927.00	933.00
	Standard Error			12.40		5.64	8.07	9.80	4.88	33.22	7.38
	Sample Size			18	1	127	45	49	105	10	15
2004	Mean Length			619.79		725.55	806.00	848.63	870.54		916.00
	Standard Error			12.73		14.42	11.83	20.84	4.19		26.00
	Sample Size			14		20	8	19	94		3

Appendix 8. Mean length[a] of Salcha River carcass sample data by year, age, and sex.[b]

		Age									
		1.1		1.2		1.3		1.4		1.5	
Year		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
1970	Mean Length			581.89	565.00	742.84	810.26	950.83	881.11	999.29	946.67
	Standard Error			5.06		10.84	10.01	13.69	9.28	15.02	12.02
	Sample Size			82	1	51	19	6	18	7	3
1972	Mean Length			543.86		741.00	739.17	948.35	896.75	1056.25	973.33
	Standard Error			9.96		15.91	24.71	7.40	6.56	4.73	14.30
	Sample Size			22		16	6	88	151	4	6
1973	Mean Length			687.80		749.31	812.00	930.82	901.87	995.00	958.94
	Standard Error			17.63		17.86	50.62	39.06	15.47	21.96	13.64
	Sample Size			10		29	3	11	15	8	17
1975	Mean Length	360.00		574.57		712.28	783.88	874.75	867.42	1028.00	941.17
	Standard Error			8.21		12.39	8.04	17.07	6.66	19.85	15.38
	Sample Size	1		51		43	26	24	48	5	6
1976	Mean Length			567.76		717.16	779.38	925.00	892.83	1040.00	948.33
	Standard Error			10.67		10.44	14.05	29.62	8.36		14.24
	Sample Size			21		51	13	14	46	1	3
1978	Mean Length	390.00		610.56	850.00	767.22	861.86	904.86	896.86		
	Standard Error			34.98	18.93	42.96	15.65	32.98	14.36		
	Sample Size	1		9	3	9	7	22	28		
1979	Mean Length	375.00		615.86	755.00	775.28	851.31	921.11	938.27		
	Standard Error			7.07	155.00	10.47	7.12	17.26	6.81		
	Sample Size	1		72	2	53	42	27	49		
1981	Mean Length			486.42		644.68	680.40	795.74	794.83		852.50
	Standard Error			9.77		6.06	12.02	5.96	2.81		27.50
	Sample Size			31		122	20	118	197		2
1982	Mean Length	377.67		561.55		700.29	715.15	868.98	856.30	980.50	944.67
	Standard Error	14.88		4.42		4.20	14.46	10.33	4.02	25.36	10.85
	Sample Size	3		119		142	13	62	149	10	27
1984	Mean Length			524.67		693.17	781.18	878.17	867.76	944.09	903.52
	Standard Error			6.84		4.19	21.53	11.04	4.58	22.41	8.64
	Sample Size			46		181	18	60	150	11	46
1985	Mean Length			528.33		686.07	699.29	823.85	857.18	982.22	888.44
	Standard Error			7.29		6.63	22.35	8.09	3.33	17.70	13.90
	Sample Size			62		79	7	109	219	9	17
1988	Mean Length	395.00		592.25	790.00	740.95	813.75	864.70	874.22	985.21	948.72
	Standard Error	15.00		7.05		6.83	26.32	10.25	4.28	15.97	8.00
	Sample Size	2		71	1	74	8	67	110	24	39

[a] All measurements are MEF and reported in millimeters.
[b] Statistics reflect only individuals with complete age, length, and sex information reported in the data set.

Appendix 8. ***Continued***

		Age									
		1.1		1.2		1.3		1.4		1.5	
Year		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
1989	Mean Length	370.00		515.56		792.61	847.22	925.71	884.60		961.58
	Standard Error			15.19		13.76	7.79	17.57	4.99		8.49
	Sample Size	1		9		46	18	28	100		19
1990	Mean Length			612.54	602.50	731.20	782.67	926.70	904.58	978.33	923.64
	Standard Error			13.77	2.50	10.17	20.64	10.42	8.88	19.69	10.90
	Sample Size			69	2	71	15	50	133	6	22
1991	Mean Length	355.00		528.81		745.40	795.43	858.28	865.67	994.55	945.53
	Standard Error			9.28		5.93	4.91	11.36	4.16	14.13	11.96
	Sample Size	1		42		158	70	59	153	11	19
1992	Mean Length	385.63		547.33		698.26	818.42	906.43	875.96	992.50	903.33
	Standard Error	8.58		3.54		4.92	15.07	9.34	2.91	37.50	13.33
	Sample Size	8		199		165	19	47	198	2	4
1993	Mean Length	502.50		559.60	660.00	710.87	781.07	844.58	857.93		917.50
	Standard Error	34.97		6.41		5.81	11.97	14.17	4.91		27.80
	Sample Size	4		126	1	149	28	48	92		4
1994	Mean Length	396.67		572.50	608.75	733.77	750.93	855.10	865.36	942.50	910.59
	Standard Error	24.55		12.83	38.91	5.99	10.14	6.88	3.72	38.79	13.51
	Sample Size	3		10	4	162	43	106	168	8	17
1995	Mean Length			548.04	778.33	740.89	810.38	844.73	860.23	925.60	931.11
	Standard Error			7.91	115.77	9.91	9.37	8.38	3.04	45.86	21.34
	Sample Size			71	3	70	42	93	249	5	9
1996	Mean Length	380.45		543.54	570.00	739.03	749.67	889.32	876.44	983.06	927.17
	Standard Error	7.67		12.03		6.96	9.08	13.13	5.96	13.00	4.71
	Sample Size	11		24	1	113	45	37	80	18	83
1997	Mean Length			590.43	858.33	723.64	860.00	876.02	880.19	915.00	832.50
	Standard Error			12.65	6.01	20.55	22.08	12.98	5.07		22.50
	Sample Size			23	3	22	4	44	81	1	2
1998	Mean Length	423.33		502.50		698.23	736.25	786.82	782.09	930.00	862.50
	Standard Error	16.91		30.16		7.23	10.81	24.80	11.21		27.50
	Sample Size	3		6		65	24	11	11	1	2
1999	Mean Length			539.29		700.96	825.68	789.49	859.34		885.00
	Standard Error			11.25		10.46	12.07	12.81	4.06		
	Sample Size			28		52	22	59	145		1
2000	Mean Length			520.71	565.00	689.23	728.57	806.67	811.43		950.00
	Standard Error			15.98	5.00	14.38	18.57	27.28	14.05		50.00
	Sample Size			7	2	13	7	3	7		2

Appendix 8. ***Continued***

		Age									
		1.1		1.2		1.3		1.4		1.5	
Year		**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
2001	Mean Length	330.00		536.00		715.88	723.57	844.17	840.38		866.67
	Standard Error			10.01		12.26	15.36	10.81	6.79		18.56
	Sample Size	1		20		51	14	48	52		6
2002	Mean Length			544.31		706.14	748.75	871.97	864.93	978.21	910.28
	Standard Error			4.06		11.41	29.04	14.32	5.74	16.85	11.78
	Sample Size			102		35	4	33	76	14	18
2003	Mean Length	450.00		538.18		752.31	790.00	841.43	882.33	925.00	885.56
	Standard Error			23.62		8.94	17.84	18.31	8.77	55.00	24.67
	Sample Size	1		11		52	12	21	43	2	9
2004	Mean Length			595.24		734.67	842.00	883.88	882.48		935.00
	Standard Error			30.30		10.46	12.00	9.86	3.55		65.00
	Sample Size			21		15	5	49	137		2

Appendix 9. Mean length[a] of Big Salmon River carcass sample data by year, age, and sex.[b]

		Age							
		1.2		1.3		1.4		1.5	
Year		Male	Female	Male	Female	Male	Female	Male	Female
1980	Mean Length	545.00		751.06	794.95	905.33	879.45		936.00
	Standard Error			21.25	17.59	22.67	4.60		
	Sample Size	1		20	25	20	56		1
1981	Mean Length	605.43	770.00	752.06	813.59	916.83	892.26	1008.00	955.67
	Standard Error	25.92	107.00	9.70	28.43	7.46	3.56		14.67
	Sample Size	7	2	66	41	71	317	1	6
1982	Mean Length			700.87	790.00	874.20	858.36	998.75	944.67
	Standard Error			17.27	85.00	22.19	6.13	34.96	8.69
	Sample Size			23	2	25	72	4	30
1983	Mean Length	545.00		721.94	820	880.13	870.74	1020	940.33
	Standard Error			13.29	13.99	14.37	4.10	17.75	8.81
	Sample Size	1		22	4	31	118	7	29
1984	Mean Length			696.89	770.00	878.57	852.80	941.67	897.46
	Standard Error			15.60	50.62	17.48	5.11	40.45	8.32
	Sample Size			29	4	23	66	3	24
1985	Mean Length	512.57		659.68		773.66	848.22	964.76	943.57
	Standard Error	30.80		5.56		4.64	5.30	8.82	9.38
	Sample Size	8		96		243	92	40	22
1988	Mean Length	535.00		722.86		855.50	874.14	950.83	925.50
	Standard Error	10.00		14.35		27.61	8.12	21.81	5.89
	Sample Size	2		7		10	29	6	40
1989	Mean Length	505		714.40	813.33	846.90	859.67	943.67	914.00
	Standard Error	45.00		9.39	16.41	13.64	6.65	16.93	8.12
	Sample Size	2		25	3	42	47	15	30
1990	Mean Length	573.92		678.81	765.56	858.54	839.87	917.50	911.07
	Standard Error	10.46		15.38	17.88	18.65	8.69	47.50	12.99
	Sample Size	14		23	10	24	44	2	14

[a] All measurements are MEF and reported in millimeters.
[b] Statistics reflect only individuals with complete age, length, and sex information reported in the data set.