U.S. Fish and Wildlife Service

Abundance and Run Timing of Adult Pacific Salmon in the Kwethluk River, Yukon Delta National Wildlife Refuge, Alaska, 2010

Alaska Fisheries Data Series Number 2011-3

Kenai Fish and Wildlife Field Office
Soldotna, Alaska
April 2011

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Steve J. Miller and Ken C. Harper

Abstract

The Kenai Fish and Wildlife Field Office, assisted by the Organized Village of Kwethluk, monitored the escapement of five species of Pacific salmon returning to the Kwethluk River. From June 25 to September 6, 2010, a resistance board weir was utilized to collect abundance, run-timing, age, sex, and length data from returning adult salmon. These data support in-season and post-season management of the commercial and subsistence fisheries that occur on the Yukon Delta National Wildlife Refuge and the Kuskokwim River drainage. The estimated escapement was 19,222 chum salmon *Oncorhynchus keta*, 1,669 Chinook salmon *O. tshawytscha*, 4,187 sockeye salmon *O. nerka*, 565 pink salmon *O. gorbuscha*, and a partial count of 795 coho salmon *O. kisutch*. Peak weekly passage occurred July 11–17 for chum, July 4–10 for Chinook and sockeye, and July 18–24 for pink salmon. Age, sex, and length data were collected for each species except pink salmon. Dominant ages were 0.3 for chum, 1.3 for male and 1.4 for female Chinook, 1.3 for sockeye, and 2.1 for coho salmon. Overall percentages for female salmon were chum 41%, Chinook 44%, sockeye 49%, and coho 29%. Mean lengths varied between male and female salmon for each species. High water at the weir caused by frequent and persistent rain resulted in partial counts and the need to estimate escapements during some periods in August and September. The estimated Chinook salmon escapement during 2010 was the lowest on record and below the escapement goal range of 6,000 to 11,000 for the third consecutive year.

Introduction

The Kwethluk River, a lower Kuskokwim River tributary located on the Yukon Delta National Wildlife Refuge (Refuge), provides important spawning and rearing habitat for chum salmon *Oncorhynchus keta*, Chinook salmon *O. tshawytscha*, sockeye salmon *O. nerka*, pink salmon *O. gorbuscha*, and coho salmon *O. kisutch* (Alt 1977; U.S. Fish and Wildlife Service 1992). Adult salmon returning to the Kwethluk River migrate 130 river kilometers (rkm) through the lower Kuskokwim River and up to an additional 160 rkm in the Kwethluk River before reaching spawning grounds. These salmon pass through one of Alaska's most intensive subsistence fisheries, which is located in the lower Kuskokwim River (U.S. Fish and Wildlife Service 1988; Burkey et al. 2001). In general, half of the total statewide subsistence harvest of Chinook salmon occurs in the Kuskokwim drainage (Alaska Department of Fish and Game 2001, 2002, 2003a, 2003b).

Under guidelines established in the Sustainable Salmon Fisheries Policy 5AAC.39.222, the Alaska Board of Fisheries designated Kuskokwim River chum and Chinook salmon as stocks of yield concern in September 2000 and managed the fishery under those guidelines through 2006 (Bergstrom and Whitmore 2004; Linderman and Bue 2006). This designation was based upon the inability, despite specific management measures, to maintain expected yields or to have a stable surplus above the stock's escapement needs. Beginning in January 2001, the salmon fishery in the Kuskokwim River drainage was managed under the Kuskokwim River Salmon Rebuilding Management Plan (Rebuilding Plan) (5AAC 07.365; Ward et al. 2003; Bergstrom and Whitmore

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2004). During 2007, the designation as stocks of concern was discontinued after chum and Chinook salmon escapements returned to levels above the historical average (Linderman and Rearden 2007).

The Alaska Department of Fish and Game (Department), the U.S. Fish and Wildlife Service (Service), and the Kuskokwim River Salmon Management Working Group (Working Group) work together to achieve the goals of both the Rebuilding Plan and the Federal Subsistence Fishery Management program. In addition to the goals set by the Department, the Service, and the Working Group; the Alaska National Interest Lands Conservation Act (ANILCA) established the Yukon Delta National Wildlife Refuge in Alaska for the general purposes to: "conserve fish and wildlife populations and habitats in their natural diversity" (ANILCA § 303 (7) (B) (*i*)).

The broad geographic distribution of escapement monitoring projects in the Kuskokwim area provides insight for sustainable salmon management. Recent tagging studies conducted on chum, Chinook, sockeye, and coho salmon have all demonstrated differential stock-specific run timing with the general pattern of salmon stocks from upper river tributaries entering the Kuskokwim River earliest, while stocks from lower river tributaries enter progressively later (Kerkvliet and Hamazaki 2003; Kerkvliet et al. 2003, 2004; Stuby 2004, 2005, 2006). The temporal stock-specific run timings overlap and the difference between the mid-point of one stock and another of the same species can be several weeks. Concurrent with this phenomenon is the extensive subsistence fishery that harvests more heavily from early arriving salmon, and commercial fisheries that have historically focused on early, middle, or late segments of the overall salmon run (D. Molyneaux, Alaska Department of Fish and Game, personal communication).

This mixture of different stock-specific run timings and uneven distribution of harvest produce the possibility of significant differential exploitation rates between stocks. This situation mandates that managers develop and maintain a rigorous monitoring program capable of assessing escapement trends within the Kuskokwim River drainage. To manage for sustained yields and conservation of individual salmon stocks, managers need data on escapement, migratory timing, and sex and age composition.

A resistance board weir has been used to monitor salmon escapements on the Kwethluk River from mid to late June through early September during 1992, 2000–2004 and 2006–2010. After the 1992 season, the Organized Village of Kwethluk (OVK) opposed the weir, and it was not operated from 1993 to 1999. Since 2000, OVK and the Service have jointly cooperated in staffing and operating the weir, which remains a high priority for the Department, OVK, and Service. Objectives of the project during 2010 were to: (1) enumerate adult salmon; (2) describe the run timing for chum, Chinook, sockeye, pink, and coho salmon returns; (3) estimate the age, sex, and length composition of adult chum, Chinook, sockeye, and coho salmon populations; and (4) identify and count other fish species passing through the weir. These data support the in-season and post-season management of the Kuskokwim River subsistence and commercial fisheries. This information also assists managers in establishing escapement goals to maintain the sustainability of salmon stocks returning to the Kwethluk River.

The Kwethluk River weir also plays an important role as a platform to collect information and data for additional research projects. Examples include: (1) genetic baseline collections; (2) monitoring of tagged fish in mark-recapture projects; (3) a long term data set for evaluation of management projects, e.g., Bethel test fishery and climate change; and (4) the Salmonid Rivers Observatory

Network (SaRON), a multi-year project focused on pristine Pacific salmon rivers measuring processes and changes to the shifting habitat mosaic of ecosystems (Available: http://www.umt.edu/flbs/Research/SaRON.htm).

Study Area

The Kwethluk River is in the lower Kuskokwim River drainage of Western Alaska (Figure 1). The region has a sub-arctic climate characterized by extremes in temperature, ranging from summer highs near 15˚C to average winter lows near -12˚C (Alt 1977). Average yearly precipitation is approximately 50 cm, with the majority falling between June and October. The rivers in this area generally become ice-free in the slow current sections by early May and freeze up occurs during late November. Break up on the Kwethluk River can occur from early April to late May. The Kwethluk River originates in the Kilbuck Mountains, flows northwest approximately 222 km, and drains an area of about 3,367 km^2. The weir is located in the middle section of the river characterized by braiding and gravel substrates. Below the middle section, the lower 47 km consists of a deeper, muddy-bottomed channel that averages 53 m in width (Alt 1977). Turbid water conditions, the result of active stream cutting on tundra banks, are also characteristic of the lower section and are incompatible with weir operations.

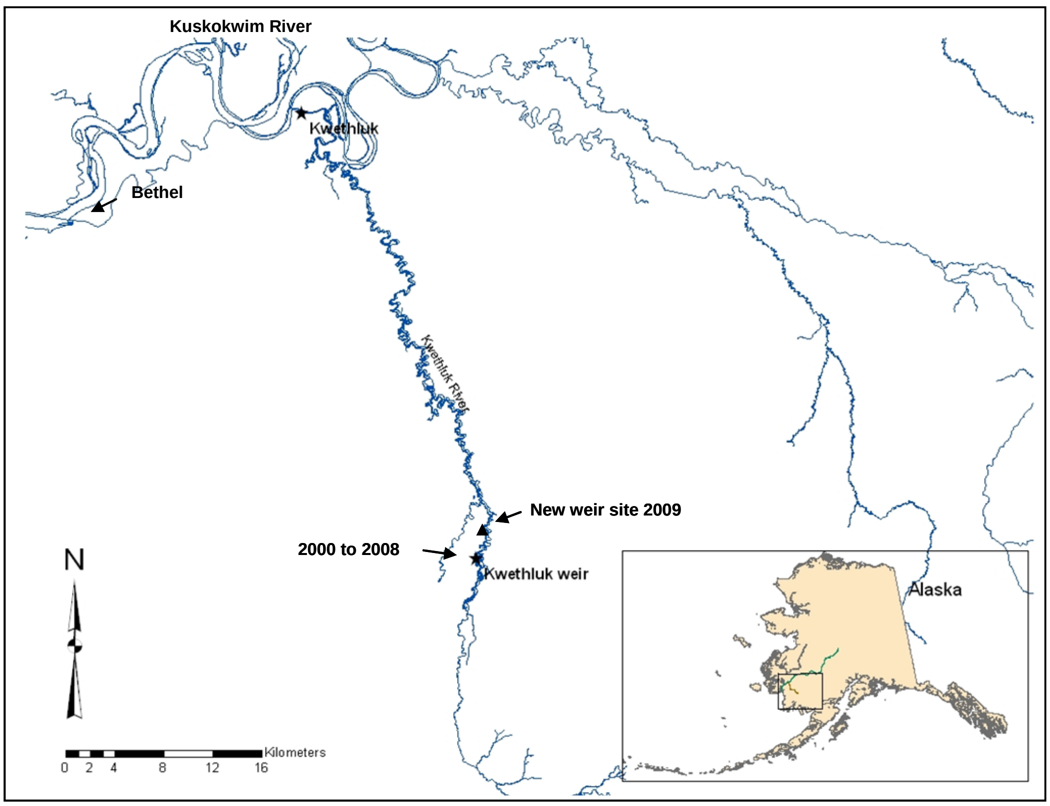

FIGURE 1.—Location of the Kwethluk River weir 2000–2008 and new weir site established in 2009.

Methods

Weir Operations

A resistance board weir (Tobin 1994; Stewart 2002; Harper et al. 2007) spanning 56 m was installed in the Kwethluk River (N 60.51828, W 161.09245, NAD 83) approximately 83.9 rkm upstream from the Kuskokwim River and 42 air-km south of Kwethluk, Alaska (Figure 1). This location is approximately 4.1 rkm downstream from the 2008 weir site described by Miller et al. (2009). The weir was relocated during 2009 due to channel morphology changes and operated 2009–2010 (Figure 1). A staff gauge was installed upstream of the weir site to measure daily water levels and measurements represent average water depth across the river channel at the upstream edge of the weir. Water temperatures were collected daily using a handheld thermometer from June 19 to September 10. Ambient temperature, water temperature, and fish passage counts were relayed daily by radio to the Department in Bethel. Hobo® recording thermometers were also installed at the weir to collect yearly water and ambient temperature data for a separate Service funded project addressing climate change.

One live trap and a counting passage-chute were installed to facilitate sampling and fish passage during varying river stage heights. Counts began at approximately 0600 hours each day and continued through 2300 hours as daylight permitted. Count periods varied with fish passage intensity and were recorded to the nearest 0.25 hours. All fish were enumerated to species as they migrated through the live trap or passage-chute.

The weir was inspected for holes and cleaned daily except on days with flooding and safety concerns. An observer outfitted with a mask and snorkel checked weir integrity and substrate conditions. Debris was removed from the upstream surface of the weir by raking, or walking across each panel until partially submerged, which allowed the current to wash accumulated debris downstream.

Biological Data

Statistical weeks started on a Sunday and continued through the following Saturday. Target sample sizes were 200 chum, 210 Chinook, 200 sockeye, and 200 coho salmon each week. Biological sampling occurred between Sunday and Thursday of each statistical week in order to obtain a snapshot sample (Geiger et al. 1990). Once the weekly sample was met for a species, then sampling would stop for that species. Sampling would not typically extend past Thursday of each week. Post-season analysis included the combination of weekly strata to ensure adequate sample sizes were obtained.

Age, sex, and length data were collected from each salmon sampled. Salmon were caught using the live trap attached to the passage-chute. A fyke-gate, installed on the entrance of the trap, allowed fish to enter and, at the same time, minimized the number of fish exiting the trap downstream. Sampling typically started when approximately 40 fish were in the trap. To avoid potential bias caused by selection or capture of individual fish, all target species in the trap were included in the sample. Four scales were extracted from Chinook and coho, three from sockeye, and one from chum salmon for age analysis. All scales were taken from the preferred area using methods described by Koo (1962) and Mosher (1968). Sex was determined from external characteristics or visible sex products and length measured to the nearest 5 mm from the mid-eye to the fork of the caudal fin. Female Chinook salmon less than 700 mm in length have been rare in samples collected from the commercial fishery (D. Molyneaux, Alaska Department of Fish and Game, personal communication). Chinook salmon smaller than 700 mm were considered males for this study. Data were recorded and transferred later to Excel spreadsheets. Department staff aged the scales and processed the forms in Anchorage. All sampled fish were released upstream of the weir.

Salmon ages were reported according to the European Method (Koo 1962) where numerals preceding the decimal denote freshwater annuli and numerals following the decimal denote marine annuli. Total years of life at maturity are determined by adding one year to the sum of the two digits on either side of the decimal; i.e. age 1.4 and 2.3 (1.4 = 1 + 4 + 1 = 6, and 2.3 = 2 + 3 + 1 = 6) are both six-year-old fish from the same brood year. The brood year is determined by subtracting fish-age from the current year.

Characteristics of fish passing through the weir were estimated using standard stratified random sample estimators (Cochran 1977). Within a given stratum *m*, the proportion of species *i* passing the weir that are of sex *j* and age *k* (p_{ijkm}) was estimated as

$$\hat{P}_{ijkm} = \frac{n_{ijkm}}{n_{i++m}}$$

where n_{ijkm} denotes the number of fish of species *i*, sex *j*, and age *k* sampled during stratum *m*, and a subscript of "+" represents summation overall possible values of the corresponding variable, e.g., n_{j++m} denotes the total number of fish of species *i* sampled in stratum *m*. The variance was estimated as

$$\hat{v}(\hat{p}_{ijkm}) = \left(1 - \frac{n_{i++m}}{N_{i++m}}\right) \frac{\hat{p}_{ijkm}\left(1 - \hat{p}_{ijkm}\right)}{n_{i++m} - 1}$$

where N_{i++m} denotes the total number of species *i* fish passing the weir in stratum *m*. The estimated number of fish species *i*, sex *j*, age *k* passing the weir in stratum *m* (N_{ijkm}) is

$$\hat{N}_{ijkm} = N_{i++m}\hat{P}_{ijkm}$$

with estimated variance

$$\hat{v}\left(\hat{N}_{ijkm}\right) = N^2_{i++m}\hat{v}\left(\hat{p}_{ijkm}\right)$$

Estimates of proportions for the entire period of weir operation were computed as weighted sums of the stratum estimates, i.e.,

$$\hat{p}_{ijk} = \sum_m \left(\frac{N_{i++m}}{N_{i+++}}\right)\hat{p}_{ijkm}$$

with estimated variance

$$\hat{v}\left(\hat{p}_{ijk}\right) = \sum_m \left(\frac{n_{i++m}}{N_{i+++}}\right)^2 \hat{v}\left(\hat{p}_{ijkm}\right)$$

The total number of fish in a species, sex, and age category passing the weir during the entire period of operation was estimated as

$$\hat{N}_{ijk} = \sum_m \hat{N}_{ijkm}$$

with estimated variance

$$\hat{v}\left(\hat{N}_{ijk}\right) = \sum_m \hat{v}\left(\hat{N}_{ijkm}\right)$$

If the length of the r^{th} fish of species *i*, sex *j*, and age *k* sampled in stratum *m* is denoted x_{ijkmr}, the mean length of all such fish (μ_{ijkm}) was estimated as

$$\hat{\mu}_{ijkm} = \left(\frac{1}{n_{ijkm}}\right)\sum_r x_{ijkmr}$$

with corresponding variance estimator

$$\hat{v}\left(\hat{\mu}_{ijkm}\right) = \left(1 - \frac{n_{ijkm}}{\hat{N}_{ijkm}}\right)\frac{\sum_r \left(x_{ijkmr} - \hat{\mu}_{ijkm}\right)^2}{n_{ijkm}\left(n_{ijkm} - 1\right)}$$

The mean length of all fish of species *i*, sex *j*, and age *k* ($\hat{\mu}_{ijk}$) was estimated as a weighted sum of the stratum means, i.e.,

$$\hat{\mu}_{ikk} = \sum_m \left(\frac{\hat{N}_{ijkm}}{\hat{N}_{ijk}}\right)\hat{\mu}_{ijkm}$$

An approximate estimator of the variance of $\hat{\mu}_{ijk}$ was obtained using the delta method (Seber 1982).

$$\hat{v}\left(\hat{\mu}_{ijk}\right) = \sum_m \left\{ \hat{v}\left(\hat{N}_{ijkm}\right)\left[\frac{\hat{\mu}_{ijkm}}{\sum_x \hat{N}_{ijkx}} - \sum_y \frac{\hat{N}_{ijky}\,\hat{\mu}_{ijky}}{\left(\sum_x \hat{N}_{ijkx}\right)^2}\right]^2 + \left(\frac{\hat{N}_{ijkm}}{\sum_x \hat{N}_{ijkx}}\right)^2 \hat{v}\left(\hat{\mu}_{ijkm}\right) \right\}$$

Estimates of fish passage are calculated when flooding or holes in the weir result in days with partial or zero counts. During years when this occurs, estimates are based on the average daily proportion of passage. An average of the daily proportions for previous years is calculated since daily escapement can vary between years. The sum of the averaged daily proportions, calculated for days with partial or zero counts, is the estimated total proportion of the missed escapement. The total escapement is the sum of the observed counts divided by one minus the proportion missed.

Results

Weir Operations

Water and ice conditions of the Kwethluk River were monitored by biologists and Refuge pilots during March and April. River ice covered approximately 90% of the channel at the weir site on April 26 but disappeared with high flows and warming temperatures over the next week. A helicopter was used to transport gear and 5 crew members to the weir site on May 7. The crew set-up a partial camp, installed weir panels, and returned by helicopter to Bethel May 11. Personnel returned to the weir site on June 22 by boat to complete installation of the weir. The trap was installed on June 24 and the weir was operational from June 25 to September 6. Due to high water at the end of the monitoring period that typically ends on September 10, the weir had to be left in the river. Between September 7and September 26, crew members monitored water conditions and cleaned debris off the weir as needed. On September 26 the level of water had receded enough to start pulling the trap and weir panels. Weir removal was completed on September 27 and crew returned to Bethel on September 28.

Average water depth at the leading edge of the weir during 2010 was 105 cm. From August 1 to September 25, periods of high water completely submerged approximately 45% of the weir. The maximum water depth of 158 cm occurred on September 10 and the minimum water depth of 63 cm occurred on July 17 (Appendix 1). Water temperatures ranged from a high of 12°C on July 16 to a low of 8°C on July 6 and September 3 (Appendix 1).

Biological Data

Chum Salmon —A total of 19,222 chum salmon was estimated to have passed through the weir June 25–September 10 (Appendix 2, Figure 2). The actual count observed (N = 17,934) passed June 25–July 31 and August 4–16. An additional 1,288 chum salmon were estimated to have passed August 1–3 and August 17–September 10. Peak weekly passage (N = 4,464) occurred July 11–17 (Figure 2). Median cumulative passage occurred on July 19 (Appendix 2; Figure 3).

Four ages (0.2, 0.3, 0.4, and 0.5) were identified from chum salmon scale samples. The predominant age was 0.3 for both male (58%) and female (67%) chum salmon (Appendix 3). Females comprised 41% of the chum salmon escapement (Appendix 3; Figure 3). Mean length of males was larger than females for all ages (Appendix 4).

Chinook Salmon —A total of 1,669 Chinook salmon was estimated to have passed through the weir from June 28 to August 26 (Appendix 2; Figure 2). The actual count observed (N = 1,651) passed June 28–July 31 and August 4–16. An additional 54 Chinook salmon were estimated to have passed August 1–3 and August 17–26. Peak weekly passage (N = 441) occurred July 4–10 (Figure 2). Median cumulative passage occurred on July 17 (Appendix 2; Figure 3).

Four ages (1.2, 1.3, 1.4, and 1.5) were identified from Chinook salmon scale samples. The predominant age was 1.3 for males and 1.4 for females (Appendix 5). Ages 2.2, 2.3 and 1.6 were not present during 2010 but present in previous years. Ages 1.2 and 1.3 accounted for 87% of the male and ages 1.3 and 1.4 accounted for 91% of the female Chinook salmon escapement. Females comprised 44% of the Chinook salmon escapement. Sex ratios favored males through mid July, but then shifted to a dominant female component (Appendix 5; Figure 3). Mean length of females was greater than males for ages 1.3 and 1.4 (Appendix 6).

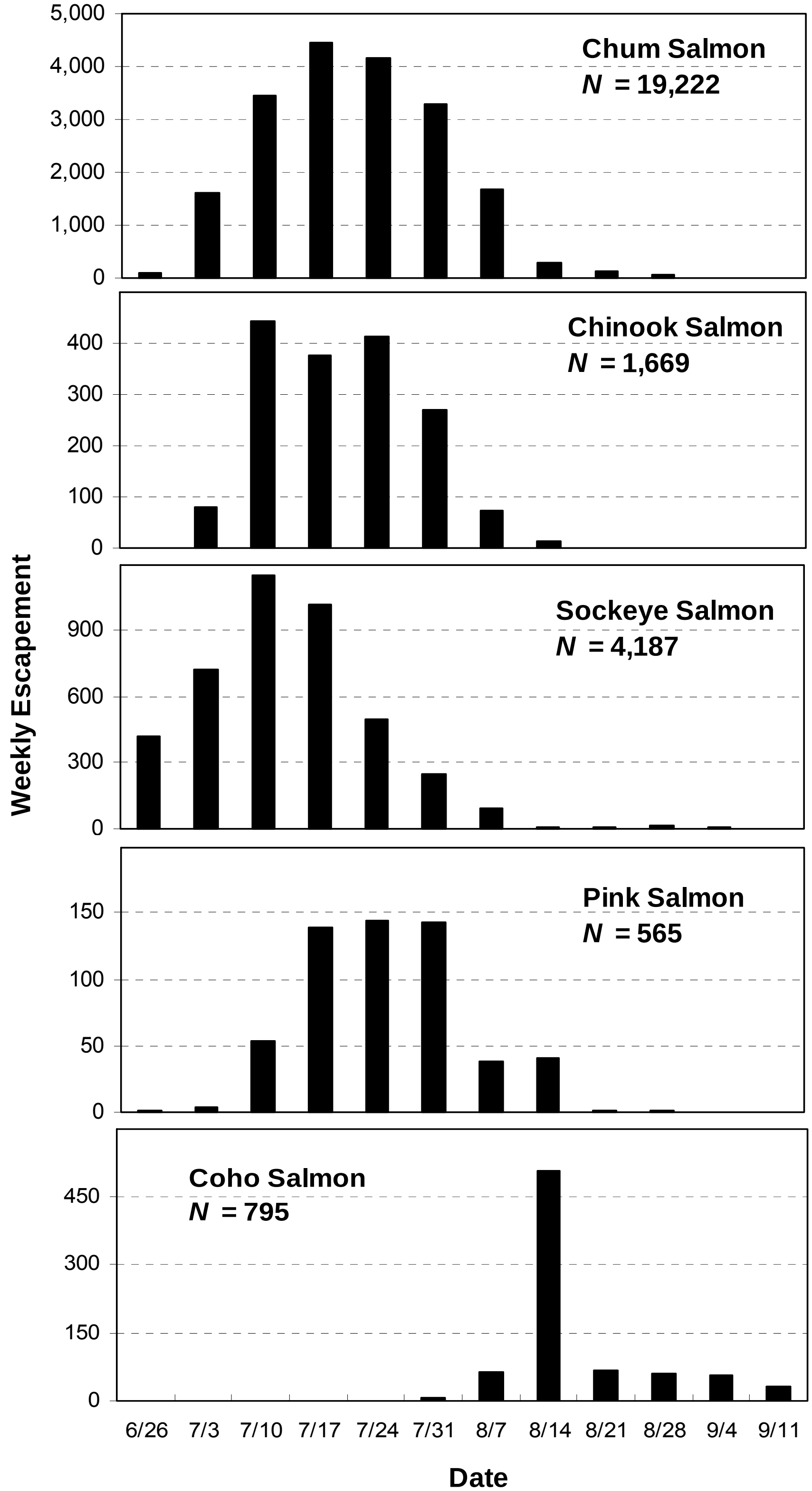

FIGURE 2.—Weekly escapements of chum, Chinook, sockeye, pink and coho salmon passing through the Kwethluk River weir, 2010. Totals include estimates generated for chum, Chinook, and sockeye salmon during periods of incomplete counts. No estimate was generated for coho salmon due to high water and incomplete counts during the majority of the escapement.

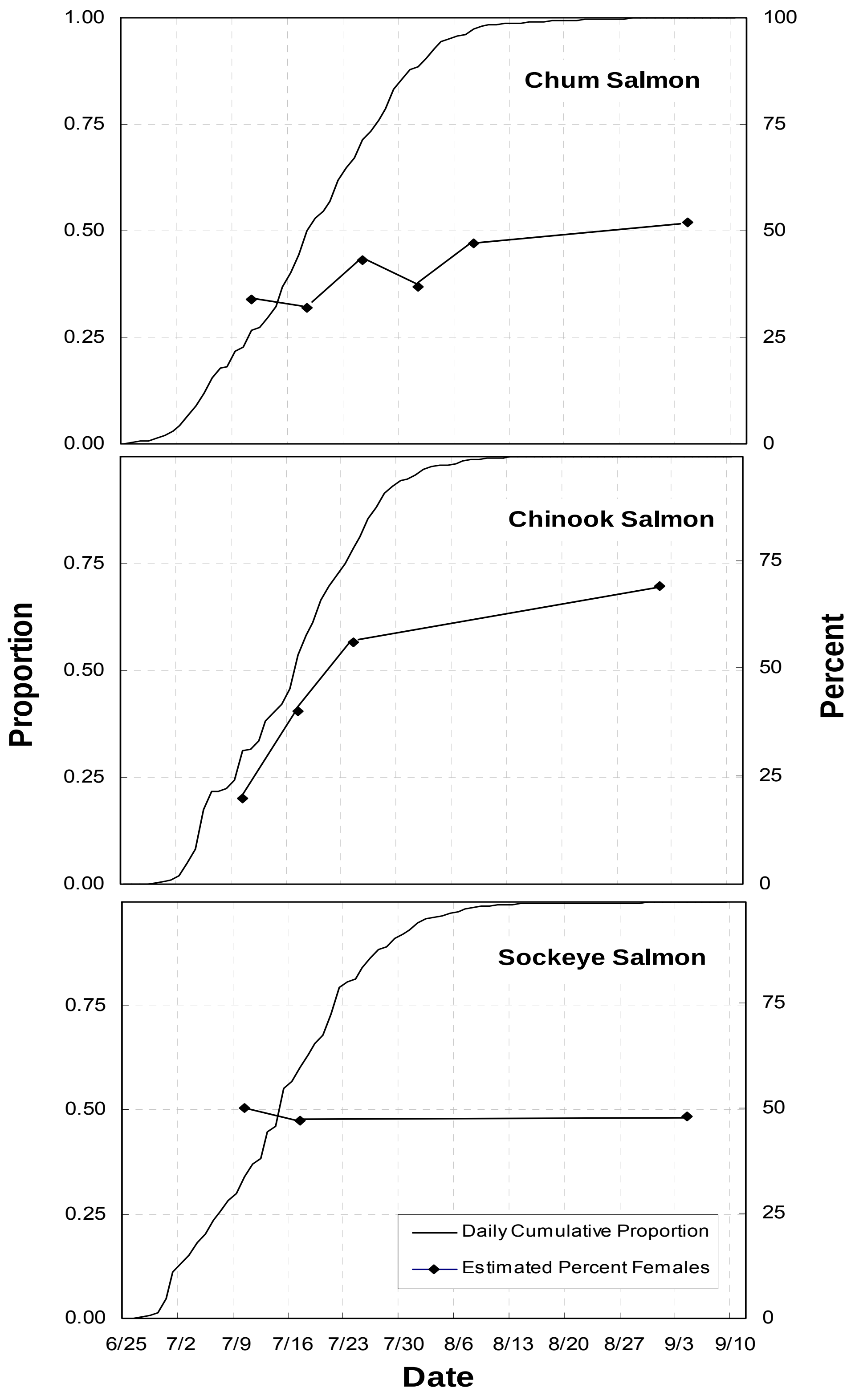

FIGURE 3.—Cumulative proportion of escapement and percent females for chum, Chinook, and sockeye salmon returning to the Kwethluk River during 2010. Percentage of females in returns for each species was estimated by weekly stratum.

Sockeye Salmon —A total of 4,187 sockeye salmon was estimated to have passed through the weir from June 25 to September 4 (Appendix 2; Figure 2). The actual count observed (*N* = 4,100) passed June 25–July 31 and August 4–16. An additional 87 sockeye salmon were estimated to have passed August 1–3 and August 17–September 4. Peak weekly passage (*N* = 1,150) occurred July 4–10 (Figure 2). Median cumulative upstream passage occurred on July 10 (Appendix 2).

Seven ages (0.3, 1.2, 0.4, 1.3, 2.2, 1.4, and 2.3) were identified from sockeye salmon scale samples. The predominant age was 1.3 for both males and females and comprised 77% of the estimated sockeye salmon escapement (Appendix 7). Age-0.2 sockeye were not present during 2010 but present in previous years. Females comprised 49% of the total sockeye salmon escapement. The mean length of males was greater than that of females for all ages (Appendix 8).

Pink Salmon —A total of 565 pink salmon was counted passing through the weir from June 27 to August 27 (Appendix 2; Figure 2). Peak weekly passage of pink salmon (*N* = 144) occurred July 18–24 (Figure 2). Median cumulative upstream passage occurred on July 23 (Appendix 2).

Coho Salmon —A total of 795 coho salmon was counted passing through the weir from July 28 to September 6 (Appendix 2, Figure 2). High waters affected coho salmon counts during 29 days of the season and the estimated escapement total, peak weekly passage and median cumulative passage dates were not calculated in 2010 (Figure 2).

Three ages (1.1, 2.1 and 3.1) were identified from scales of coho salmon (Appendix 9). Age-2.1 was the predominant age for both males (92%) and females (100%). Females comprised 29% of the escapement counted (Figure 3; Appendix 9). Of those counted, the mean length of males was larger than females for age-2.1 (Appendix 10).

Other Species

Resident and other species counted through the weir included 27 Dolly Varden *Salvelinus malma*, six whitefish *Coregonus* spp. and *Prosopium* sp., 13 Arctic grayling *Thymallus arcticus*, one northern pike *Esox lucius* and 19 rainbow trout *O. mykiss.* Although smaller sized fish were able to pass freely through the pickets, fish passed through the counting chute were recorded the entire season.

Discussion

Weir Operations

Aerial surveys of the Kwethluk River are typically flown each season from late March through April to determine if conditions are suitable for weir installation (Roettiger et al. 2004, 2005; Miller et al. 2007, 2008, 2009; Miller and Harper 2010). The river channel at the site must be ice free and water levels low enough for installation of the weir. Weir installation during April usually avoids the annual high water event which normally begins in May, and often continues until August. This strategy of installing the weir prior to these high water events, controlled by air temperature, snow pack, and rainfall, has proven successful over time (Roettiger et al. 2004, 2005; Miller et al. 2007, 2008, 2009; Miller and Harper 2010). During 2010, late ice-free conditions delayed weir installation until May 5. The weir was operational from June 25 to September 6. The 2010 field season was wet and rainy which resulted in high waters that exceeded the design capacity of the weir panels on several occasions. From August 1 to 3 and August 17 to September 10 spikes in high water resulted in incomplete or no counts and passage was estimated for chum, Chinook, and sockeye salmon. Rapidly rising waters dislodged debris included trees and large pieces of tundra.

High water prevented removal of the weir during the normal removal period of September 11–14. From September 11 through September 25 crew members traveled from the village of Kwethluk to the weir site monitoring water conditions and to clean debris off the weir. The weir and camp were dismantled by October 1. The added labor, fuel and other expenses increased the overall cost of 2010 operations.

Biological Data

Chum Salmon —The estimated 2010 escapement of 19,222 chum salmon to the Kwethluk River was within the range of escapements (11,691–54,913) observed during previous years (Figure 4), but lower than the 9-year average (*N* =33,882) (Harper 1998; Harper and Watry 2001; Roettiger et al. 2002, 2003, 2004, 2005; Miller et al. 2007, 2008, 2009; Miller and Harper 2010). The estimate generated for incomplete counts was less than 7% of the total chum salmon escapement. Although the 2010 return fell within the historic range of escapements, it represents the fourth lowest on record. The mean-passage date of July 19 was within the mid range of median dates (Appendices 2 and 11). Females comprised 41% of the return, the same as 2006 which was the lowest observed during previous years (Appendices 3 and 11).

The dominant age for chum salmon during 2010 was age-0.3. This age represented 61% of the escapement and a significant increase from the 20% observed in 2008 but a decrease from 79% during 2009. There was a strong prevalence of age-0.4 fish during 2010 (35%) which was likely the result from a strong showing of age-0.3 in 2009 (Miller and Harper 2010). Van Alen (1999) suggests strong brood years often drive runs in successive years.

Chinook Salmon —The estimated escapement of Chinook salmon in the Kwethluk River during 2010 (*N* = 1,669) was the lowest on record, and below the escapement goal range (*N* = 6,000–11,000) set by the Department (Molyneaux and Brannian 2006; Volk et al. 2009). The escapement estimate for days with incomplete counts was approximately 3% of the total Chinook salmon escapement. This weak return represented only 15% of the 9-year average (*N* = 11,395; Figure 4). Preliminary data shows low returns of Chinook salmon were also observed at other Kuskokwim escapement projects during 2010. This is the third year in a row the estimated escapement of Chinook salmon at the weir was below the escapement goal range (Estensen et al. 2009, Miller and Harper 2010).

The median cumulative passage date for Chinook salmon was July 17, the same as 2008, and nine days later than the earliest median passage date of July 8 observed in 2004 (Appendices 2 and 11). The median passage date for all years is July 12.

The dominant ages of Chinook salmon in 2010 were 1.2, 1.3, and 1.4 representing 18, 44, and 34% of the return, respectively (Appendix 5). This age composition was different from 2009, when these ages represented 14, 24, and 61% of the return (Miller and Harper 2010). The poor showing of ages 1.2 in 2008 and 1.3 fish in 2009 may have translated into weaker returns of age-1.4 fish during 2010. The return of age-1.3 fish in 2010 should translate into a stronger age-1.4 during 2011 (Van Alen 1999; Miller et al. 2008, 2009; Miller and Harper 2010). The small percentage of age-1.2 fish in 2010 may indicate a weak return of age-1.3 fish during 2011. Other factors that can influence the variation in returning adults are ocean conditions and estuarine survival in Chinook salmon smolt. Hillgruber and Zimmerman (2009) state that water temperature, prey availability and abundance, and predation during the early marine life stage of Chinook salmon smolt are factors associated with survival. Petrosky and Schaller (2010) indicate river velocity during smolt migration as a factor associated with Chinook salmon smolt survival as well.

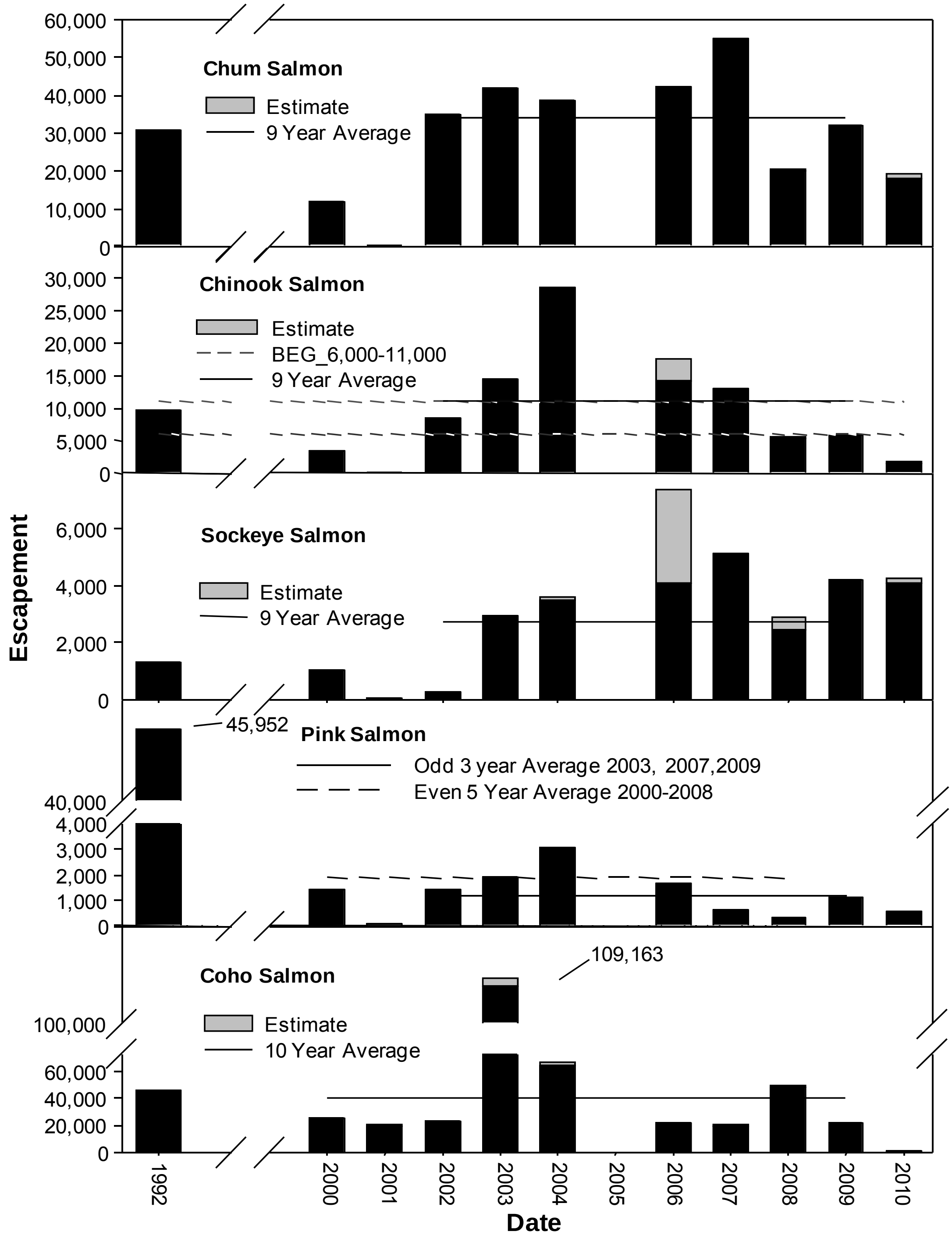

Figure 4.—Estimated salmon escapements through the Kwethluk River weir, 1992, 2000–2004, 2006–2010. Averages include estimates generated for prior years (Miller and Harper 2010). Weir operations during 2001 commenced on August 12 and escapements were not estimated for chum, Chinook, sockeye, and pink salmon. High water in 2010 hindered coho salmon counts and escapement was not estimated. Nine-year averages are reported for Chinook, chum and sockeye salmon and a ten-year average for coho salmon. Pink salmon averages are based on odd (2003, 2007, 2009) and even (2000–2008) years after 2000 when wider picket spacing was used on weir panels. Averages for all species do not include the current year. An escapement goal range has only been established for Chinook salmon.

Female Chinook salmon comprised 44% of the escapement during 2010, which is the second highest observed since 1992 (Appendix 11). However, the estimate for female escapement was only 735, the lowest number on record. The higher percentage of females in the return may be attributed to changes in harvest strategies. Bromaghin (2005) showed a correlation of catch efficiency to mesh size and fish length which would be reflected in both the subsistence and commercial harvests. Observations by Harris and Harper (2010) on the Chinook salmon subsistence harvest in the Native Community of Tuluksak indicate that some subsistence fishers from the area have changed to smaller (≤20.5-cm stretch mesh) nets, which selectively harvest a higher percentage of smaller and the more prevalent males. Smaller mesh nets (≤20.5-cm stretch) have also been required in the commercial fishery and incidental harvests of Chinook salmon during 2008, 2009, and 2010 were 8,797, 6,664 and 2,731 respectively (Estensen et al. 2009; Brazil et al. 2010). Male Chinook salmon comprised 90%, 80%, and 75% respectively of those harvests (D. Molyneaux, Alaska Department of Fish and Game, personal communication).

Low returns to the Kwethluk River and conservation concerns resulted in emergency orders being issued on July 10 by both the Department and the Service. The Department closed the waters to sport fishing for Chinook salmon. The Service action closed the Chinook salmon subsistence fishery in all federal waters of the Tuluksak and Kwethluk rivers starting at 6pm on July 10 and through July 31. Subsistence gill nets larger than 10 cm and the use of rod and reel for subsistence harvest of Chinook salmon were not allowed. It is unknown how effective this action was on increasing escapements but with such low escapements conservation actions were deemed necessary.

Sex identification for small Chinook salmon is often difficult to ascertain. Generally, female Chinook salmon returning to the Kuskokwim River are larger than 700 mm. Extensive sampling by the Department and the examination of carcasses by the Service showed Chinook salmon less than 700 mm in length to be predominately male (D. Molyneaux, Alaska Department of Fish and Game, personal communications, J. Olsen, U.S. Fish and Wildlife Service, unpublished data). Using these lengths and sex data, Chinook salmon less than 700 mm have thus been classified as males unless sex products were visible.

Sockeye Salmon —The estimated escapement of 4,187 sockeye salmon was within the range observed during past years (N = 272–6,732) and well above the 9-year average (Figure 4). The estimate generated for incomplete counts was approximately 2% of the total sockeye salmon escapement. The escapement for 2010 was the fourth highest return and similar to strong returns that occurred during 2006, 2007 and 2009. The high return of sockeye during 2010 may be the result of a strong brood year in 2005 (Van Alen 1999). The median cumulative passage date of July 10 was the same as in 2009 and within the range of July 1–11 (Appendix 11). Female sockeye salmon comprised 49% of the return during 2010, much lower than during 2008 and 2009, but between the 43–65% observed in previous years (Harper 1998; Harper and Watry 2001; Roettiger et al. 2002, 2003, 2004, 2005; Miller et al. 2007, 2008, 2009; Miller and Harper 2010).

The dominant age of sockeye salmon in 2010 was 1.3 and represented 77% of the return. Age-1.3 fish have dominated the age structure and have ranged from a low of 60% during 2009 to a high of 93% during 2000 (Harper 1998; Harper and Watry 2001; Roettiger et al. 2002, 2003, 2004, 2005; Miller et al. 2007, 2008, 2009; Miller and Harper 2010).

Pink Salmon —The number of pink salmon observed during 2010 (N = 565) was well below the odd-year (N = 1,210) and even-year (N = 1,579) average counts since year 2000 when wider picket spacing was implemented on the Kwethluk River weir (Figure 4). The actual count provides only an index of abundance since most pink salmon are small enough to pass between pickets of the weir panels. During 2010, high water conditions may have also allowed for a higher number of pink salmon to pass the weir undetected. The median cumulative passage date was July 23, similar to that observed during even-year 2006 (Appendices 2 and 11). Pink salmon return to spawning grounds in predictable and segregated even and odd-numbered years (Scott and Crossman 1973). Age, sex, and length data were not collected for pink salmon.

Coho Salmon —An estimated escapement of coho salmon for 2010 was not generated (Figure 4). Due to high water and flooding the weir was inoperable for long periods of time starting August 1 until take out during late September. However the collection of 64 samples for age, sex, and length data provided some information. Female coho salmon comprised 29% of the fish sampled. This is the lowest composition observed in years prior (37–57%) and this sex ratio data may not represent the actual spawning escapement based on the limited number of samples (Harper 1998; Harper and Watry 2001; Roettiger et al. 2002, 2003, 2004, 2005; Miller et al. 2007, 2008, 2009; Miller and Harper 2010) (Appendices 9 and 11).

The dominant age of coho salmon sampled in 2010 was 2.1 and represented 95% of the return sampled and the highest to-date. Age-2.1 fish have dominated the age structure across strata and have ranged from 82–93% of the total escapement in previous years (Harper 1998; Harper and Watry 2001; Roettiger et al. 2002, 2003, 2004, 2005; Miller et al. 2007, 2008, 2009; Miller and Harper 2010). Coho salmon typically spend two years in fresh water and spend one year in the marine environment (Groot and Margolis 1991).

Recommendations

The Kwethluk River weir continues to be an important project to monitor Kuskokwim River salmon stocks that originate on the Refuge. This weir and other escapement projects spread throughout the Kuskokwim River drainage provide important information used by Federal and State fishery managers. Annual operation of the weir should continue well into the future to gather a long-term data set and weir operations should continue into September to monitor coho salmon escapements. Early weir installation by mid April is essential, though more costly due to ice and debris damage to panels and increased cost for personnel and helicopter use. We have been able to operate a weir during the majority of salmon escapement for 10 of the last 11 years (2000–2010) even with high spring flows, channel changes, damage to weir components, scouring and variable break up periods. We believe that the river channel is more stable at the new site selected in 2009 and do not anticipate having to move to another site in the years to come.

Acknowledgements

Special appreciation is extended to the crew that staffed the weir: Raymond (Axle) Addis (crew leader) and Steve Schlutz, from Kenai Fish and Wildlife Field Office (KFWFO); John Fisher, Josephine Guy, Timothy Michael, and Kurtis Sergie from the Organized Village of Kwethluk (OVK); Yukon Delta National Wildlife Refuge staff; Frank Harris and Darryl Sipary of the KFWFO for their knowledge of the process; and the assistance of Amy Brodersen, and Doug Molyneaux of the Alaska Department of Fish and Game, Division of Commercial Fisheries, Arctic Yukon Kuskokwim Region, for scale pattern analysis.

Funds for the Kwethluk River weir project (OSM-FRMP 10-306) and for the analysis of Kuskokwim River scale samples (OSM-10-303) were provided through the U.S. Fish and Wildlife

Service, Office of Subsistence Management Fisheries Resource Monitoring Program. As a partner, OVK hired local residents to staff the weir, provided administrative support, purchased supplies, and performed equipment maintenance.

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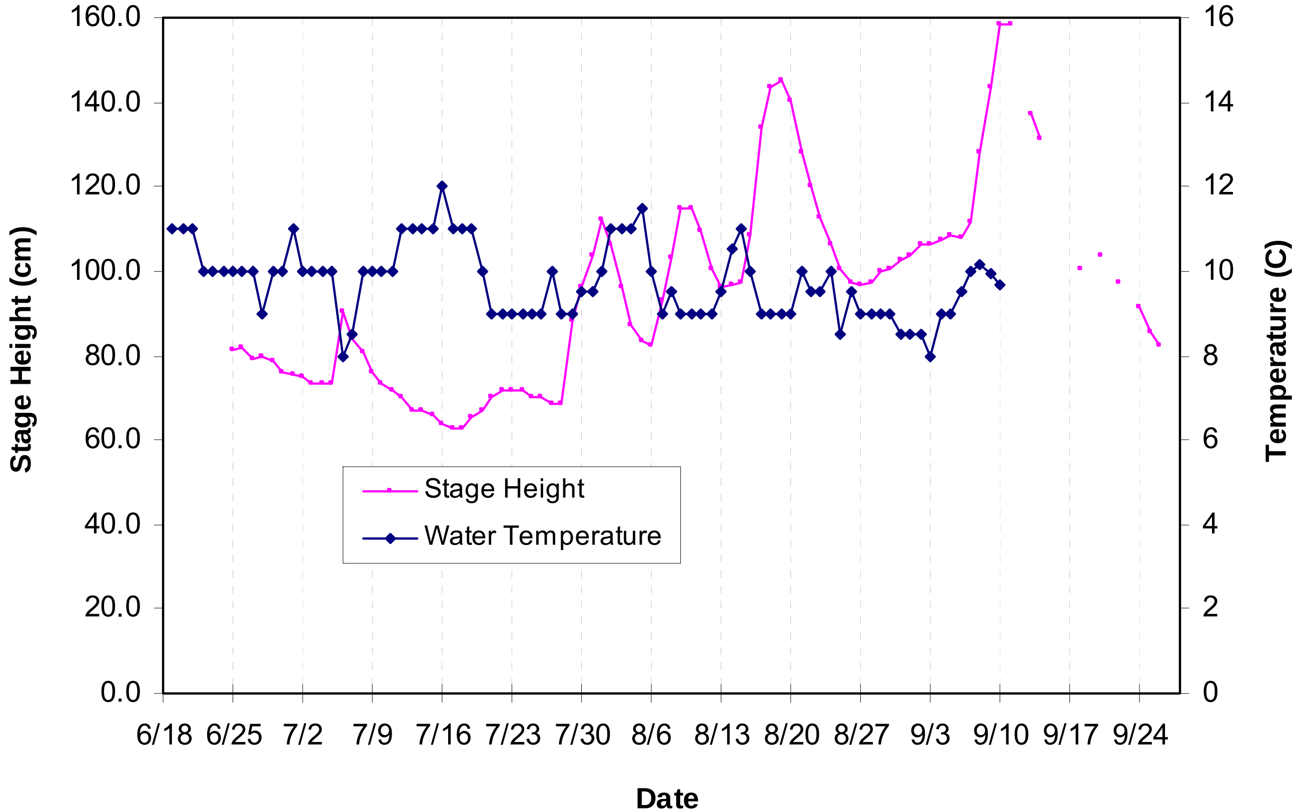

APPENDIX 1.—Water stage heights and daily water temperatures taken at the Kwethluk River weir, Alaska, 2010.

APPENDIX 2.—Daily counts, cumulative counts, and cumulative proportions of chum, Chinook, sockeye, pink, and coho salmon passing through the Kwethluk River weir, Alaska, 2010. Boxed areas represent the second and third quartile and median passage date. Shaded areas represent high water events when partial or no counts were recorded and passage estimates were generated for chum, Chinook, and sockeye salmon. No estimates were generated for coho salmon due to the percent of passage missed.

	Chum Salmon			Chinook Salmon			Sockeye Salmon			Pink Salmon			Coho Salmon		
	Daily	Cumulative		Daily	Cumulative		Daily	Cumulative		Daily	Cumulative		Daily	Cumulative	
Date	Count	Count	Proportion	Count	Count	Proportion	Count	Count	Proportion	Count	Count	Proportion	Count	Count	Proportion
06/25	47	47	0.000	0	0	0.000	146	146	0.035	0	0	0.000	0	0	0.000
06/26	37	84	0.002	0	0	0.000	273	419	0.100	0	0	0.000	0	0	0.000
06/27	27	111	0.004	0	0	0.000	92	511	0.122	1	1	0.002	0	0	0.000
06/28	130	241	0.006	1	1	0.001	89	600	0.143	0	1	0.002	0	0	0.000
06/29	115	356	0.013	2	3	0.002	115	715	0.171	0	1	0.002	0	0	0.000
06/30	215	571	0.019	5	8	0.005	95	810	0.193	0	1	0.002	0	0	0.000
07/01	269	840	0.030	10	18	0.011	132	942	0.225	0	1	0.002	0	0	0.000
07/02	419	1,259	0.044	14	32	0.019	97	1,039	0.248	2	3	0.005	0	0	0.000
07/03	430	1,689	0.065	49	81	0.049	102	1,141	0.273	2	5	0.009	0	0	0.000
07/04	575	2,264	0.088	54	135	0.081	80	1,221	0.292	0	5	0.009	0	0	0.000
07/05	673	2,937	0.118	157	292	0.175	169	1,390	0.332	5	10	0.018	0	0	0.000
07/06	466	3,403	0.153	68	360	0.216	127	1,517	0.362	18	28	0.050	0	0	0.000
07/07	73	3,476	0.177	1	361	0.216	62	1,579	0.377	2	30	0.053	0	0	0.000
07/08	696	4,172	0.181	11	372	0.223	273	1,852	0.442	1	31	0.055	0	0	0.000
07/09	157	4,329	0.217	33	405	0.243	48	1,900	0.454	2	33	0.058	0	0	0.000
07/10	800	5,129	0.225	117	522	0.313	391	2,291	0.547	0	33	0.058	0	0	0.000
07/11	133	5,262	0.267	4	526	0.315	75	2,366	0.565	25	58	0.103	0	0	0.000
07/12	391	5,653	0.274	31	557	0.334	138	2,504	0.598	6	64	0.113	0	0	0.000
07/13	542	6,195	0.294	81	638	0.382	123	2,627	0.627	3	67	0.119	0	0	0.000
07/14	912	7,107	0.322	30	668	0.400	116	2,743	0.655	0	67	0.119	0	0	0.000
07/15	603	7,710	0.370	31	699	0.419	91	2,834	0.677	11	78	0.138	0	0	0.000
07/16	831	8,541	0.401	64	763	0.457	215	3,049	0.728	23	101	0.179	0	0	0.000
07/17	1,052	9,593	0.444	134	897	0.537	264	3,313	0.791	45	146	0.258	0	0	0.000
07/18	612	10,205	0.499	73	970	0.581	56	3,369	0.805	51	197	0.349	0	0	0.000
07/19	272	10,477	0.531	51	1,021	0.612	30	3,399	0.812	6	203	0.359	0	0	0.000
07/20	468	10,945	0.545	86	1,107	0.663	112	3,511	0.839	17	220	0.389	0	0	0.000
07/21	911	11,856	0.569	59	1,166	0.698	94	3,605	0.861	13	233	0.412	0	0	0.000
07/22	612	12,468	0.616	41	1,207	0.723	85	3,690	0.881	25	258	0.457	0	0	0.000
07/23	429	12,897	0.648	42	1,249	0.748	36	3,726	0.890	38	296	0.524	0	0	0.000
07/24	842	13,739	0.671	59	1,308	0.784	84	3,810	0.910	16	312	0.552	0	0	0.000
07/25	386	14,125	0.714	46	1,354	0.811	42	3,852	0.920	29	341	0.604	0	0	0.000
07/26	460	14,585	0.734	74	1,428	0.855	51	3,903	0.932	4	345	0.611	0	0	0.000
07/27	529	15,114	0.758	44	1,472	0.882	61	3,964	0.947	35	380	0.673	0	0	0.000
07/28	881	15,995	0.786	50	1,522	0.912	42	4,006	0.957	46	426	0.754	3	3	0.004
07/29	458	16,453	0.832	30	1,552	0.930	23	4,029	0.962	36	462	0.818	0	3	0.004
07/30	443	16,896	0.855	20	1,572	0.942	13	4,042	0.965	11	473	0.837	4	7	0.009
07/31	127	17,023	0.879	6	1,578	0.945	20	4,062	0.970	9	482	0.853	1	8	0.010

APPENDIX 2.—(Page 2 of 2)

	Chum Salmon			Chinook Salmon			Sockeye Salmon			Pink Salmon			Coho Salmon		
	Daily	Cumulative		Daily	Cumulative		Daily	Cumulative		Daily	Cumulative		Daily	Cumulative	
Date	Count	Count	Proportion	Count	Count	Proportion	Count	Count	Proportion	Count	Count	Proportion	Count	Count	Proportion
08/01	390	17,413	0.886	18	1,596	0.956	22	4,084	0.975	2	484	0.857	0	8	0.010
08/02	434	17,847	0.906	21	1,617	0.969	27	4,111	0.982	0	484	0.857	0	8	0.010
08/03	273	18,120	0.928	13	1,630	0.976	18	4,129	0.986	0	484	0.857	0	8	0.010
08/04	150	18,270	0.943	3	1,633	0.978	9	4,138	0.988	0	484	0.857	14	22	0.028
08/05	110	18,380	0.950	3	1,636	0.980	8	4,146	0.990	7	491	0.869	14	36	0.045
08/06	102	18,482	0.956	7	1,643	0.984	4	4,150	0.991	13	504	0.892	15	51	0.064
08/07	227	18,709	0.961	9	1,652	0.989	5	4,155	0.992	11	515	0.912	22	73	0.092
08/08	118	18,827	0.973	6	1,658	0.993	3	4,158	0.993	7	522	0.924	53	126	0.158
08/09	67	18,894	0.979	2	1,660	0.994	3	4,161	0.994	4	526	0.931	47	173	0.218
08/10	31	18,925	0.983	1	1,661	0.995	1	4,162	0.994	6	532	0.942	31	204	0.257
08/11	17	18,942	0.985	1	1,662	0.995	0	4,162	0.994	4	536	0.949	22	226	0.284
08/12	22	18,964	0.985	3	1,665	0.997	0	4,162	0.994	7	543	0.961	66	292	0.367
08/13	19	18,983	0.987	1	1,666	0.998	1	4,163	0.994	6	549	0.972	53	345	0.434
08/14	32	19,015	0.988	0	1,666	0.998	0	4,163	0.994	6	555	0.982	234	579	0.728
08/15	11	19,026	0.989	1	1,667	0.998	4	4,167	0.995	8	563	0.996	43	622	0.782
08/16	5	19,031	0.990	0	1,667	0.998	0	4,167	0.995	0	563	0.996	24	646	0.813
08/17	35	19,066	0.990	0	1,667	0.998	0	4,167	0.995	1	564	0.998	0	646	0.813
08/18	26	19,092	0.992	0	1,667	0.998	0	4,167	0.995	0	564	0.998	0	646	0.813
08/19	21	19,113	0.993	0	1,667	0.998	0	4,167	0.995	0	564	0.998	0	646	0.813
08/20	19	19,132	0.994	0	1,667	0.998	0	4,167	0.995	0	564	0.998	0	646	0.813
08/21	16	19,148	0.995	0	1,667	0.999	3	4,170	0.996	0	564	0.998	0	646	0.813
08/22	14	19,162	0.996	1	1,668	0.999	1	4,171	0.996	0	564	0.998	0	646	0.813
08/23	10	19,172	0.997	0	1,668	0.999	3	4,174	0.997	0	564	0.998	0	646	0.813
08/24	5	19,177	0.997	0	1,668	0.999	1	4,175	0.997	0	564	0.998	0	646	0.813
08/25	8	19,185	0.998	0	1,668	0.999	2	4,177	0.998	0	564	0.998	0	646	0.813
08/26	5	19,190	0.998	1	1,669	1.000	2	4,179	0.998	0	564	0.998	16	662	0.833
08/27	5	19,195	0.998	0	1,669	1.000	1	4,180	0.998	1	565	1.000	26	688	0.865
08/28	5	19,200	0.999	0	1,669	1.000	2	4,182	0.999	0	565	1.000	18	706	0.888
08/29	4	19,204	0.999	0	1,669	1.000	1	4,183	0.999	0	565	1.000	9	715	0.899
08/30	3	19,207	0.999	0	1,669	1.000	1	4,184	0.999	0	565	1.000	13	728	0.916
08/31	2	19,209	0.999	0	1,669	1.000	1	4,185	0.999	0	565	1.000	7	735	0.925
09/01	3	19,212	0.999	0	1,669	1.000	1	4,186	0.999	0	565	1.000	7	742	0.933
09/02	1	19,213	0.999	0	1,669	1.000	0	4,186	1.000	0	565	1.000	3	745	0.937
09/03	1	19,214	0.999	0	1,669	1.000	0	4,186	1.000	0	565	1.000	9	754	0.948
09/04	1	19,215	1.000	0	1,669	1.000	1	4,187	1.000	0	565	1.000	8	762	0.958
09/05	2	19,217	1.000	0	1,669	1.000	0	4,187	1.000	0	565	1.000	15	777	0.977
09/06	1	19,218	1.000	0	1,669	1.000	0	4,187	1.000	0	565	1.000	18	795	1.000
09/07	1	19,219	1.000	0	1,669	1.000	0	4,187	1.000	0	565	1.000	0	795	1.000
09/08	1	19,220	1.000	0	1,669	1.000	0	4,187	1.000	0	565	1.000	0	795	1.000
09/09	1	19,221	1.000	0	1,669	1.000	0	4,187	1.000	0	565	1.000	0	795	1.000
09/10	1	19,222	1.000	0	1,669	1.000	0	4,187	1.000	0	565	1.000	0	795	1.000

APPENDIX 3.—Estimated age and sex composition of weekly chum salmon escapements through the Kwethluk River weir, Alaska, 2010.

		Brood Year and Age Group				
		2007	2006	2005	2004	
		0.2	0.3	0.4	0.5	Total
Strata 1 – 2:	06/25 – 07/03					
Sampling Dates:	06/28 – 07/03					
Male:	Number in Sample:	0	35	45	1	81
	Estimated % of Escapement:	0.0	28.5	36.6	0.8	65.9
	Estimated Escapement:	0	481	618	14	1,112
	Standard Error:	0.0	66.4	70.9	13.2	
Female:	Number in Sample:	0	15	25	2	42
	Estimated % of Escapement:	0.0	12.2	20.3	1.6	34.1
	Estimated Escapement:	0	206	343	27	577
	Standard Error:	0.0	48.2	59.3	18.6	
Total:	Number in Sample:	0	50	70	3	123
	Estimated % of Escapement:	0.0	40.7	56.9	2.4	100.0
	Estimated Escapement:	0	687	961	41	1,689
	Standard Error:	0.0	72.3	72.9	22.7	
Stratum 3:	07/04 – 07/10					
Sampling Date:	07/04 – 07/08					
Male:	Number in Sample:	0	73	54	2	129
	Estimated % of Escapement:	0.0	38.6	28.6	1.1	68.3
	Estimated Escapement:	0	1,329	983	36	2,348
	Standard Error:	0.0	118.8	110.2	25.0	
Female:	Number in Sample:	0	32	27	1	60
	Estimated % of Escapement:	0.0	16.9	14.3	0.5	31.7
	Estimated Escapement:	0	582	491	18	1,092
	Standard Error:	0.0	91.5	85.3	17.7	
Total:	Number in Sample:	0	105	81	3	189
	Estimated % of Escapement:	0.0	55.6	42.9	1.6	100.0
	Estimated Escapement:	0	1,911	1,474	55	3,440
	Standard Error:	0.0	121.2	120.7	30.5	
Stratum 4:	07/11 – 07/17					
Sampling Dates:	07/11 – 07/12					
Male:	Number in Sample:	3	44	47	2	96
	Estimated % of Escapement:	1.8	26.2	28.0	1.2	57.1
	Estimated Escapement:	80	1,169	1,249	53	2,551
	Standard Error:	44.9	149.0	152.1	36.8	
Female:	Number in Sample:	1	46	25	0	72
	Estimated % of Escapement:	0.6	27.4	14.9	0.0	42.9
	Estimated Escapement:	27	1,222	664	0	1,913
	Standard Error:	26.1	151.1	120.6	0.0	
Total:	Number in Sample:	4	90	72	2	168
	Estimated % of Escapement:	2.4	53.6	42.9	1.2	100.0
	Estimated Escapement:	106	2,391	1,913	53	4,464
	Standard Error:	51.7	169.0	167.7	36.8	

APPENDIX 3.—(PAGE 2 OF 3)

		Brood Year and Age Group				
		2007	2006	2005	2004	
		0.2	0.3	0.4	0.5	Total
Stratum 5:	07/18 – 07/24					
Sampling Dates:	07/18					
Male:	Number in Sample:	1	80	39	1	121
	Estimated % of Escapement:	0.5	41.7	20.3	0.5	63.0
	Estimated Escapement:	22	1,728	842	22	2,613
	Standard Error:	21.1	144.4	117.9	21.1	
Female:	Number in Sample:	4	49	18	0	71
	Estimated % of Escapement:	2.1	25.5	9.4	0.0	37.0
	Estimated Escapement:	86	1,058	389	0	1,533
	Standard Error:	41.8	127.7	85.4	0.0	
Total:	Number in Sample:	5	129	57	1	192
	Estimated % of Escapement:	2.6	67.2	29.7	0.5	100.0
	Estimated Escapement:	108	2,786	1,231	22	4,146
	Standard Error:	46.7	137.6	133.9	21.1	
Stratum 6:	07/25 – 07/31					
Sampling Dates:	07/25 – 07/26					
Male:	Number in Sample:	5	59	28	0	92
	Estimated % of Escapement:	2.9	34.1	16.2	0.0	53.2
	Estimated Escapement:	95	1,120	532	0	1,746
	Standard Error:	40.8	115.5	89.8	0.0	
Female:	Number in Sample:	1	65	15	0	81
	Estimated % of Escapement:	0.6	37.6	8.7	0.0	46.8
	Estimated Escapement:	19	1,234	285	0	1,538
	Standard Error:	18.5	118.0	68.6	0.0	
Total:	Number in Sample:	6	124	43	0	173
	Estimated % of Escapement:	3.5	71.7	24.9	0.0	100.0
	Estimated Escapement:	114	2,354	816	0	3,284
	Standard Error:	44.6	109.8	105.3	0.0	
Strata 7 – 12:	08/01 – 09/10					
Sampling Dates:	08/04 – 08/05, 08/15, 08/29					
Male:	Number in Sample:	2	22	5	0	29
	Estimated % of Escapement:	3.1	34.4	7.8	0.0	45.3
	Estimated Escapement:	69	756	172	0	996
	Standard Error:	47.5	129.7	73.3	0.0	
Female:	Number in Sample:	3	27	5	0	35
	Estimated % of Escapement:	4.7	42.2	7.8	0.0	54.7
	Estimated Escapement:	103	928	172	0	1,203
	Standard Error:	57.7	134.8	73.3	0.0	
Total:	Number in Sample:	5	49	10	0	64
	Estimated % of Escapement:	7.8	76.6	15.6	0.0	100.0
	Estimated Escapement:	172	1,684	344	0	2,199[a]
	Standard Error:	73.3	115.6	99.1	0.0	

APPENDIX 3.—(Page 3 of 3)

		Brood Year and Age Group				
		2007	2006	2005	2004	
		0.2	0.3	0.4	0.5	Total
Strata 1 – 12:	06/25 – 09/10					
Sampling Dates:	06/28 – 08/29					
Male:	Number in Sample:	11	313	218	6	548
	% Males in Age Group:	2.3	57.9	38.7	1.1	100.0
	Estimated % of Escapement:	1.4	34.2	22.9	0.6	59.1
	Estimated Escapement:	265	6,582	4,395	125	11,367
	Standard Error:	79.9	302.9	260.1	50.9	
	Estimated Design Effects:	1.201	1.048	0.988	1.035	1.055
Female:	Number in Sample:	9	234	115	3	361
	% Females in Age Group:	3.0	66.6	29.8	0.6	100.0
	Estimated % of Escapement:	1.2	27.2	12.2	0.2	40.9
	Estimated Escapement:	235	5,230	2,344	46	7,855
	Standard Error:	78.1	286.3	206.6	25.7	
	Estimated Design Effects:	1.288	1.062	1.027	0.731	1.055
Total:	Number in Sample:	20	547	333	9	909
	Estimated % of Escapement:	2.6	61.5	35.1	0.9	100.0
	Estimated Escapement:	500	11,812	6,739	171	19,222[a]
	Standard Error:	110.5	304.7	294.7	56.9	

[a] **Estimates included in total.**

APPENDIX 4.—Estimated length (mm) at age composition of weekly chum salmon escapements through the Kwethluk River weir, Alaska, 2010.

		Brood Year and Age Group			
		2007	2006	2005	2004
		0.2	0.3	0.4	0.5
Strata 1 – 2:	06/25 – 07/03				
Sampling Dates:	06/28 – 07/03				
Male:	Mean Length		566	591	635
	Std. Error		6	4	
	Range		460 – 620	530 – 660	–
	Sample Size	0	35	45	1
Female:	Mean Length		553	551	563
	Std. Error		7	5	13
	Range		500 – 610	500 – 600	550 – 575
	Sample Size	0	15	25	2
Stratum 3:	07/04 – 07/10				
Sampling Date:	07/04 – 07/08				
Male:	Mean Length		587	602	606
	Std. Error		4	5	23
	Range		500 – 735	495 – 685	585 – 630
	Sample Size	0	73	54	2
Female:	Mean Length		550	565	570
	Std. Error		5	5	
	Range		465 – 605	510 – 625	–
	Sample Size	0	32	27	1
Stratum 4:	07/11 – 07/17				
Sampling Dates:	07/11 – 07/12				
Male:	Mean Length	532	569	590	633
	Std. Error	6	5	6	13
	Range	520 – 540	505 – 635	490 – 665	620 – 645
	Sample Size	3	44	47	2
Female:	Mean Length	590	549	559	
	Std. Error		5	3	
	Range	–	505 – 760	525 – 585	
	Sample Size	1	46	25	0
Stratum 5:	07/18 – 07/24				
Sampling Dates:	07/18				
Male:	Mean Length	525	582	597	610
	Std. Error		4	6	
	Range	–	525 – 690	525 – 665	–
	Sample Size	1	80	39	1
Female:	Mean Length	535	545	545	
	Std. Error	9	4	6	
	Range	520 – 560	445 – 605	505 – 600	
	Sample Size	4	49	18	0

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		Brood Year and Age Group			
		2007	2006	2005	2004
		0.2	0.3	0.4	0.5
Stratum 6:	07/25 – 07/31				
Sampling Dates:	07/25 – 07/26				
Male:	Mean Length	560	590	593	
	Std. Error	19	4	7	
	Range	530 – 635	530 – 665	540 – 680	
	Sample Size	5	59	28	0
Female:	Mean Length	530	538	541	
	Std. Error		4	7	
	Range	–	460 – 630	500 – 595	
	Sample Size	1	65	15	0
Strata 7 – 12:	08/01 – 09/10				
Sampling Dates:	08/04 – 08/05, 08/15, 08/29				
Male:	Mean Length	548	571	589	
	Std. Error	3	6	15	
	Range	545 – 550	515 – 625	535 – 615	
	Sample Size	2	22	5	0
Female:	Mean Length	520	524	523	
	Std. Error	18	4	8	
	Range	485 – 540	480 – 565	500 – 545	
	Sample Size	3	27	5	0
Strata 1 – 12:	06/25 – 09/10				
Sampling Dates:	06/28 – 08/29				
Male:	Mean Length	547	580	595	621
	Std. Error	9	2	2	9
	Range	520 – 635	460 – 735	490 – 685	585 – 645
	Sample Size	11	313	218	6
Female:	Mean Length	536	544	553	565
	Std. Error	9	2	2	8
	Range	485 – 590	445 – 760	500 – 625	550 – 575
	Sample Size	9	234	115	3

APPENDIX 5.—Estimated age and sex composition of weekly Chinook salmon escapements through the Kwethluk River weir, Alaska, 2010.

		Brood Year and Age Group							
		2006	2005		2004		2003	2002	
		1.2	1.3	2.2	1.4	2.3	1.5	1.6	Total
Strata 2 – 3:	06/28 – 07/10								
Sampling Dates:	06/28, 07/01 – 07/04, 07/06– 07/10								
Male:	Number in Sample:	19	27	0	6	0	0	0	52
	Estimated % of Escapement:	29.2	41.5	0.0	9.2	0.0	0.0	0.0	80.0
	Estimated Escapement:	153	217	0	48	0	0	0	418
	Standard Error:	27.8	30.1	0.0	17.7	0.0	0.0	0.0	
Female:	Number in Sample:	0	7	0	4	0	2	0	13
	Estimated % of Escapement:	0.0	10.8	0.0	6.2	0.0	3.1	0.0	20.0
	Estimated Escapement:	0	56	0	32	0	16	0	104
	Standard Error:	0.0	18.9	0.0	14.7	0.0	10.5	0.0	
Total:	Number in Sample:	19	34	0	10	0	2	0	65
	Estimated % of Escapement:	29.2	52.3	0.0	15.4	0.0	3.1	0.0	100.0
	Estimated Escapement:	153	273	0	80	0	16	0	522
	Standard Error:	27.8	30.5	0.0	22.0	0.0	10.5	0.0	
Stratum 4:	07/11 – 07/17								
Sampling Dates:	07/11 – 07/17								
Male:	Number in Sample:	15	26	0	8	0	0	0	49
	Estimated % of Escapement:	18.3	31.7	0.0	9.8	0.0	0.0	0.0	59.8
	Estimated Escapement:	69	119	0	37	0	0	0	224
	Standard Error:	14.2	17.1	0.0	10.9	0.0	0.0	0.0	
Female:	Number in Sample:	0	9	0	22	0	2	0	33
	Estimated % of Escapement:	0.0	11.0	0.0	26.8	0.0	2.4	0.0	40.2
	Estimated Escapement:	0	41	0	101	0	9	0	151
	Standard Error:	0.0	11.5	0.0	16.3	0.0	5.7	0.0	
Total:	Number in Sample:	15	35	0	30	0	2	0	82
	Estimated % of Escapement:	18.3	42.7	0.0	36.6	0.0	2.4	0.0	100.0
	Estimated Escapement:	69	160	0	137	0	9	0	375
	Standard Error:	14.2	18.2	0.0	17.7	0.0	5.7	0.0	

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		Brood Year and Age Group							
		2006	2005		2004		2003	2002	
		1.2	1.3	2.2	1.4	2.3	1.5	1.6	Total
Stratum 5:	07/18 – 07/24								
Sampling Dates:	07/18 – 07/24								
Male:	Number in Sample:	9	37	0	5	0	0	0	51
	Estimated % of Escapement:	7.8	32.2	0.0	4.3	0.0	0.0	0.0	44.3
	Estimated Escapement:	32	132	0	18	0	0	0	182
	Standard Error:	8.8	15.3	0.0	6.7	0.0	0.0	0.0	
Female:	Number in Sample:	0	15	0	43	0	6	0	64
	Estimated % of Escapement:	0.0	13.0	0.0	37.4	0.0	5.2	0.0	55.7
	Estimated Escapement:	0	54	0	154	0	21	0	229
	Standard Error:	0.0	11.0	0.0	15.8	0.0	7.3	0.0	
Total:	Number in Sample:	9	52	0	48	0	6	0	115
	Estimated % of Escapement:	7.8	45.2	0.0	41.7	0.0	5.2	0.0	100.0
	Estimated Escapement:	32	186	0	172	0	21	0	411
	Standard Error:	8.8	16.3	0.0	16.1	0.0	7.3	0.0	
Strata 6 – 10:	07/25 – 08/26								
Sampling Dates:	07/25 – 07/28, 07/30								
Male:	Number in Sample:	8	10	0	4	0	0	0	22
	Estimated % of Escapement:	11.1	13.9	0.0	5.6	0.0	0.0	0.0	30.6
	Estimated Escapement:	40	50	0	20	0	0	0	110
	Standard Error:	12.0	13.3	0.0	8.8	0.0	0.0	0.0	
Female:	Number in Sample:	0	13	0	33	0	4	0	50
	Estimated % of Escapement:	0.0	18.1	0.0	45.8	0.0	5.6	0.0	69.4
	Estimated Escapement:	0	65	0	165	0	20	0	251
	Standard Error:	0.0	14.7	0.0	19.1	0.0	8.8	0.0	
Total:	Number in Sample:	8	23	0	37	0	4	0	72
	Estimated % of Escapement:	11.1	31.9	0.0	51.4	0.0	5.6	0.0	100.0
	Estimated Escapement:	40	115	0	186	0	20	0	361[a]
	Standard Error:	12.0	17.9	0.0	19.2	0.0	8.8	0.0	

APPENDIX 5.—(Page 3 of 3)

		Brood Year and Age Group							
		2006	2005		2004		2003	2002	
		1.2	1.3	2.2	1.4	2.3	1.5	1.6	Total
Strata 2 – 10:	06/28 – 08/26								
Sampling Dates:	06/28 – 07/30								
Male:	Number in Sample:	51	100	0	23	0	0	0	174
	% Males in Age Group:	31.4	55.5	0.0	13.1	0.0	0.0	0.0	100.0
	Estimated % of Escapement:	17.6	31.0	0.0	7.4	0.0	0.0	0.0	56.0
	Estimated Escapement:	293	518	0	123	0	0	0	934
	Standard Error:	34.6	40.1	0.0	23.5	0.0	0.0	0.0	
	Estimated Design Effects:	1.178	1.091	0.000	1.172	0.000	0.000	0.000	0.899
Female:	Number in Sample:	0	44	0	102	0	14	0	160
	% Females in Age Group:	0.0	29.4	0.0	61.5	0.0	9.1	0.0	100.0
	Estimated % of Escapement:	0.0	13.0	0.0	27.1	0.0	4.0	0.0	44.0
	Estimated Escapement:	0	216	0	452	0	67	0	735
	Standard Error:	0.0	28.8	0.0	33.1	0.0	16.5	0.0	
	Estimated Design Effects:	0.000	1.080	0.000	0.841	0.000	1.053	0.000	0.899
Total:	Number in Sample:	51	144	0	125	0	14	0	334
	Estimated % of Escapement:	17.6	44.0	0.0	34.4	0.0	4.0	0.0	100.0
	Estimated Escapement:	293	734	0	575	0	67	0	1,669[a]
	Standard Error:	34.6	43.0	0.0	37.8	0.0	16.5	0.0	

[a] **Estimates included in total.**

APPENDIX 6.—Estimated length (mm) at age composition of weekly Chinook salmon escapements through the Kwethluk River weir, Alaska, 2010.

		Brood Year and Age Group						
		2006	2005		2004		2003	2002
		1.2	1.3	2.2	1.4	2.3	1.5	1.6
Strata 2 – 3:	06/28 – 07/10							
Sampling Dates:	06/28, 07/01 – 07/04, 07/06– 07/10							
Male:	Mean Length	549	652		686			
	Std. Error	18	14		21			
	Range	440 – 735	525 – 805		620 – 765			
	Sample Size	19	27	0	6	0	0	0
Female:	Mean Length		789		865		900	
	Std. Error		20		17		–	
	Range		725 – 865		815 – 890		900 – 900	
	Sample Size	0	7	0	4	0	2	0
Stratum 4:	07/11 – 07/17							
Sampling Dates:	07/11 – 07/17							
Male:	Mean Length	559	732		806			
	Std. Error	10	10		18			
	Range	510 – 645	640 – 845		710 – 895			
	Sample Size	15	26	0	8	0	0	0
Female:	Mean Length		812		846		923	
	Std. Error		11		10		8	
	Range		735 – 850		730 – 915		915 – 930	
	Sample Size	0	9	0	22	0	2	0
Stratum 5:	07/18 – 07/24							
Sampling Dates:	07/18 – 07/24							
Male:	Mean Length	567	761		841			
	Std. Error	25	13		21			
	Range	450 – 690	585 – 890		765 – 885			
	Sample Size	9	37	0	5	0	0	0
Female:	Mean Length		798		834		873	
	Std. Error		8		7		15	
	Range		735 – 840		715 – 915		830 – 915	
	Sample Size	0	15	0	43	0	6	0

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		Brood Year and Age Group						
		2006	2005		2004		2003	2002
		1.2	1.3	2.2	1.4	2.3	1.5	1.6
Strata 6 – 10:	07/25 – 08/26							
Sampling Dates:	07/25 – 07/28, 07/30							
Male:	Mean Length	563	775		795			
	Std. Error	21	18		8			
	Range	495 – 675	695 – 870		775 – 815			
	Sample Size	8	10	0	4	0	0	0
Female:	Mean Length		832		874		841	
	Std. Error		9		8		24	
	Range		775 – 900		815 – 1070		770 – 875	
	Sample Size	0	13	0	33	0	4	0
Strata 2 – 10:	06/28 – 08/26							
Sampling Dates:	06/28 – 07/30							
Male:	Mean Length	557	726	0	780			
	Std. Error	9	7		7			
	Range	440 – 735	525 – 890		620 – 895			
	Sample Size	51	100	0	23	0	0	0
Female:	Mean Length		809		851		875	
	Std. Error		3		4		12	
	Range		725 – 900		715 – 1070		770 – 930	
	Sample Size	0	44	0	102	0	14	0

APPENDIX 7.—Estimated age and sex composition of weekly sockeye salmon escapements through the Kwethluk River weir, Alaska, 2010.

		Brood Year and Age Group								
		2007	2006		2005			2004		
		0.2	0.3	1.2	0.4	1.3	2.2	1.4	2.3	Total
Strata 1 – 3:	06/25 – 07/10									
Sampling Dates:	06/28 – 07/04, 07/06 – 07/10									
Male:	Number in Sample:	0	4	14	0	93	0	3	4	118
	Estimated % of Escapement:	0.0	1.7	5.9	0.0	39.2	0.0	1.3	1.7	49.8
	Estimated Escapement:	0	39	135	0	899	0	29	39	1,141
	Standard Error:	0.0	18.2	33.3	0.0	68.9	0.0	15.8	18.2	
Female	Number in Sample:	0	6.00	0.00	0	104	1	2.00	6.00	119
	Estimated % of Escapement:	0.0	2.5	0.0	0.0	43.9	0.4	0.8	2.5	50.2
	Estimated Escapement:	0	58	0	0	1,005	10	19	58	1,150
	Standard Error:	0.0	22.2	0.0	0.0	70.1	9.2	12.9	22.2	
Total:	Number in Sample:	0	10.00	14.00	0	197	1	5.00	10.00	237
	Estimated % of Escapement:	0.0	4.2	5.9	0.0	83.1	0.4	2.1	4.2	100.0
	Estimated Escapement:	0	97	135	0	1,904	10	48	97	2,291
	Standard Error:	0.0	28.4	33.3	0.0	52.9	9.2	20.3	28.4	
Stratum 4:	07/11 – 07/17									
Sampling Dates:	07/11 – 07/13									
Male:	Number in Sample:	0	2	14	0	63	0	0	2	81
	Estimated % of Escapement:	0.0	1.3	9.1	0.0	40.9	0.0	0.0	1.3	52.6
	Estimated Escapement:	0	13	93	0	418	0	0	13	538
	Standard Error:	0.0	8.6	21.9	0.0	37.4	0.0	0.0	8.6	
Female	Number in Sample:	0	2	9	0	60	0	1	1.00	73
	Estimated % of Escapement:	0.0	1.3	5.8	0.0	39.0	0.0	0.6	0.6	47.4
	Estimated Escapement:	0	13	60	0	398	0	7	7	484
	Standard Error:	0.0	8.6	17.9	0.0	37.1	0.0	6.1	6.1	
Total:	Number in Sample:	0	4	23	0	123	0	1	3.00	154
	Estimated % of Escapement:	0.0	2.6	14.9	0.0	79.9	0.0	0.6	1.9	100.0
	Estimated Escapement:	0	27	153	0	816	0	7	20	1,022
	Standard Error:	0.0	12.1	27.1	0.0	30.5	0.0	6.1	10.5	

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		Brood Year and Age Group								
		2007	2006		2005			2004		
		0.2	0.3	1.2	0.4	1.3	2.2	1.4	2.3	Total
Strata 5 – 11:	07/18 – 09/04									
Sampling Dates:	07/18 – 07/29, 08/24									
Male:	Number in Sample:	0	2	28	2	20	0	0	0	52
	Estimated % of Escapement:	0.0	2.0	28.0	2.0	20.0	0.0	0.0	0.0	52.0
	Estimated Escapement:	0	17	245	17	175	0	0	0	454
	Standard Error:	0.0	11.6	37.1	11.6	33.1	0.0	0.0	0.0	
Female	Number in Sample:	0	2	10	0	36	1	0	0	48
	Estimated % of Escapement:	0.0	2.0	10.0	0.0	36.0	0.4	0.0	0.0	48.0
	Estimated Escapement:	0	17	87	0	315	10	0	0	420
	Standard Error:	0.0	11.6	24.8	0.0	39.7	9.2	0.0	0.0	
Total:	Number in Sample:	0	4	38	2	56	1	0	0	100
	Estimated % of Escapement:	0.0	4.0	38.0	2.0	56.0	0.4	0.0	0.0	100.0
	Estimated Escapement:	0	35	332	17	489	10	0	0	874[a]
	Standard Error:	0.0	16.2	40.1	11.6	41.0	9.2	0.0	0.0	
Strata 1 – 11:	06/25 – 09/04									
Sampling Dates:	06/28 – 08/04									
Male:	Number in Sample:	0	8	56	2	176	0	3	6	251
	% Males in Age Group	0.0	3.3	22.2	0.8	70.0	0.0	1.4	2.4	100.0
	Estimated % of Escapement:	0.0	1.7	11.3	0.4	35.6	0.0	0.7	1.2	50.9
	Estimated Escapement:	0	69	473	17	1,492	0	29	52	2,133
	Standard Error:	0.0	23.2	54.5	11.6	85.1	0.0	15.8	20.1	
	Estimated Design Effects:	0.000	1.042	0.936	1.017	0.998	0.000	1.130	1.042	1.028
Female	Number in Sample:	0	10	19	0	200	1	3	7	240
	% Female in Age Group	0.0	4.3	7.2	0.0	83.6	0.5	1.3	3.1	100.0
	Estimated % of Escapement:	0.0	2.1	3.5	0.0	41.0	0.2	0.6	1.5	49.1
	Estimated Escapement:	0	89	147	0	1,718	10	26	65	2,054
	Standard Error:	0.0	26.5	30.6	0.0	88.7	9.2	14.3	23.0	
	Estimated Design Effects:	0.000	1.061	0.882	0.000	1.026	1.134	1.044	1.090	1.028
Total:	Number in Sample:	0	18	75	2	376	1	6	13	491
	Estimated % of Escapement:	0.0	3.8	14.8	0.4	76.7	0.2	1.3	2.8	100.0
	Estimated Escapement:	0	158	620	17	3,210	10	55	117	4,187[a]
	Standard Error:	0.0	34.9	58.8	11.6	73.6	9.2	21.2	30.3	

[a] **Estimate included in total.**

APPENDIX 8.—Estimated length (mm) at age composition of weekly sockeye salmon escapements through the Kwethluk River weir, Alaska, 2010.

		Brood Year and Age Group							
		2007	2006		2005			2004	
		0.2	0.3	1.2	0.4	1.3	2.2	1.4	2.3
Strata 1 – 3:	06/25 – 07/10								
Sampling Dates:	06/28 – 07/04, 07/06 – 07/10								
Male:	Mean Length		589	570		577		620	576
	Std. Error		22	11		2		18	7
	Range		530 – 635	455 – 605		480 – 635		695 – 655	560 – 595
	Sample Size	0	4	14	0	93	0	3	4
Female:	Mean Length		538			530	470	553	529
	Std. Error		5			2		8	7
	Range		520 – 555			450 – 575	–	545 – 560	500 – 545
	Sample Size	0	6	0	0	104	1	2	6
Stratum 4:	07/11 – 07/17								
Sampling Dates:	07/11 – 07/13								
Male:	Mean Length		573	579		577			563
	Std. Error		8	3		3			8
	Range		565 – 580	545 – 595		520 – 635			555 – 570
	Sample Size	0	2	14	0	63	0	0	2
Female:	Mean Length		515	524		534		555	545
	Std. Error		15	9		3			
	Range		500 – 530	480 – 565		420 – 640		–	–
	Sample Size	0	2	9	0	60	0	1	1

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		Brood Year and Age Group							
		2007	2006		2005			2004	
		0.2	0.3	1.2	0.4	1.3	2.2	1.4	2.3
Strata 5 – 11:	07/18 – 09/04								
Sampling Dates:	07/18 – 07/29, 08/24								
Male:	Mean Length		605	586	603	587		603	
	Std. Error		20	4	3	6		28	
	Range		585 – 625	550 – 635	600 – 605	525 – 640		575 – 630	
	Sample Size	0	2	28	2	20	0	2	0
Female:	Mean Length		545	547		529	470	570	
	Std. Error		10	8		3			
	Range		535 – 555	515 – 585		490 – 565	–	–	
	Sample Size	0	2	10	0	36	1	1	0
Strata 1 – 11:	06/25 – 09/04								
Sampling Dates:	06/28 – 08/04								
Male:	Mean Length		589	580	603	578		613	572
	Std. Error		12	4	3	2		14	6
	Range		530 – 635	455 – 635	600 – 605	480 – 640		675 – 655	555 – 595
	Sample Size	0	8	56	2	176	0	5	6
Female:	Mean Length		535	536		531	470	558	531
	Std. Error		5	6		2		5	6
	Range		500 – 555	480 – 585		420 – 640	–	545 – 570	500 – 545
	Sample Size	0	10	19	0	200	1	4	7

APPENDIX 9.—Estimated age and sex composition of weekly coho salmon escapements through the Kwethluk River weir, Alaska, 2010.

		Brood Year and Age Group			
		2007	2006	2005	
		1.1	2.1	3.1	Total
Strata 6 – 12:	7/28 – 09/06				
Sampling Dates:	08/04, 08/15, 08/29, 09/02 – 09/04				
Male:	Number in Sample:	2	36	1	39
	Estimated % of Escapement:	3.6	65.5	1.8	70.9
	Estimated Escapement:	29	520	14	564
	Standard Error:	19.5	49.6	13.9	
	Estimated Design Effects:	1.000	1.000	1.000	1.000
Female:	Number in Sample:	0	16	0	16
	Estimated % of Escapement:	0.0	29.1	0.0	29.1
	Estimated Escapement:	0	231	0	231
	Standard Error:	0.0	47.4	0.0	
	Estimated Design Effects:	0.000	1.000	0.000	1.000
Total:	Number in Sample:	2	52	1	55
	Estimated % of Escapement:	3.6	94.5	1.8	100.0
	Estimated Escapement:	29	752	14	795
	Standard Error:	19.5	23.7	13.9	

APPENDIX 10.—Estimated length (mm) at age composition of weekly coho salmon escapements through the Kwethluk River weir, Alaska, 2010.

		Brood Year and Age Group		
		2007	2006	2005
		1.1	2.1	3.1
Strata 6 – 12:	7/28 – 09/06			
Sampling Dates:	08/04, 08/15, 08/29, 09/02 – 09/04			
Male:	Mean Length	528	589	620
	Std. Error	18	7	
	Range	510 – 545	580 – 695	–
	Sample Size	2	8	1
Female:	Mean Length		554	
	Std. Error		12	
	Range		445 – 635	
	Sample Size	0	16	0

APPENDIX 11.—Median cumulative passage dates and percent female for chum, Chinook, sockeye, pink, and coho salmon at the Kwethluk River weir during 1992, 2000–2004, 2006–2009 (Harper 1998; Harper and Watry 2001; Roettiger et al. 2002, 2003, 2004, 2005; Miller et al. 2007, 2008, 2009; Miller and Harper 2010).

	Chum		Chinook		Sockeye		Pink		Coho	
Year	Date	Percent Female	Date	Percent Female	Date	Percent Female	Date	Percent Female	Date	Percent Female
1992	07/18[a]	54	07/09[a]	25	07/05	60	08/13	–	08/26	43
2000	07/16[a]	50	07/13[a]	21	07/01[a]	49	08/04	–	08/21[a]	45
2001	–	–	–	–	–	–	–	–	08/25	51
2002	07/17[a]	47	07/10[a]	22	07/11[a]	60	07/25	–	08/28	45
2003	07/22	44	07/11	19	07/07	55	08/01	–	08/29	51
2004	07/14[a]	43	07/08[a]	17	07/01[1a]	48	08/06	–	08/29	43
2006	07/15	41	07/12	40	07/10	43	07/22	–	08/19[a]	37
2007	07/21	45	07/13	26	07/09	49	07/26	–	08/21	38
2008	07/22[a]	42	07/17[a]	39	07/09[a]	65	08/04	–	08/24	57
2009	07/22	48	07/12	51	07/10	65	07/27	–	08/29	51
2010	07/19[a]	41	07/17[a]	44	07/10[a]	49	07/23	–	08/22[b]	29

[a] Median cumulative passage dates were calculated using estimates for days missed.
[b] Percent calculated on early portion of the escapement and partial count.