U.S. Fish & Wildlife Service

Abundance and Run Timing of Adult Pacific Salmon in Big Creek, Becharof National Wildlife Refuge, 2004

Alaska Fisheries Data Series Number 2005–12

King Salmon Fish and Wildlife Field Office
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Jeffry L. Anderson

Abstract

The King Salmon Fish and Wildlife Field Office operated a weir on Big Creek, Becharof National Wildlife Refuge, in 2004 to estimate Pacific salmon escapement. Salmon are an important Refuge resource, and accurate escapement estimates are needed to conserve these species. In 2004, 11,906 Chinook *Oncorhynchus tshawytscha*, 24,957 chum *O. keta*, 10,451 coho *O. kisutch*, 3,295 pink *O. gorbuscha*, and 189 sockeye *O. nerka* salmon passed the Big Creek weir. Chinook and chum salmon migrated past the weir from late June to early September with peaks during the second week of July for Chinook and mid August for chum salmon. Coho salmon first passed the weir in early August with peaks in late August, early and mid September. Age 1.3 Chinook, 0.3 chum, and 2.1 coho salmon were the dominant age classes. Fewer age 1.1 jack Chinook salmon were observed compared to previous years. The sex ratios of Chinook and chum salmon were approximately 1:1, while the coho salmon run was comprised mostly of males (72%).

Introduction

The Alaska National Interest Lands Conservation Act specifically mandates that fish populations and their habitats be conserved in their natural diversity within the Becharof National Wildlife Refuge (Refuge; USFWS 1994). The conservation of Chinook *Oncorhynchus tshawytscha*, chum *O. keta*, coho *O. kisutch*, pink *O. gorbuscha*, and sockeye *O. nerka* salmon stocks that are exploited in commercial, sport, and subsistence fisheries requires accurate monitoring of escapement. Big Creek, the largest tributary to the Naknek River, provides important spawning habitat for Chinook, chum, and coho salmon. The majority of adult salmon spawning in Big Creek likely occurs within Refuge boundaries. Therefore, it is necessary to determine current levels of escapement to ensure conservation of these Pacific salmon stocks originating from the Refuge. In addition, information on human use and dependence upon Refuge resources is becoming more important as competition and conflict develops between user groups for the same finite resources (USFWS 1994). Monitoring salmon escapement in Big Creek provides managers with stock status data that can be used to manage these fisheries. Management decisions based on this information will benefit commercial, subsistence, and sport users.

Conflicts between Chinook salmon commercial, subsistence, and sport fishermen in the Naknek River drainage have increased in recent years due to an increase in competition for a limited resource. From 1994 to 1998, the average commercial harvest of Chinook salmon was 4,116 (42%), sport harvest averaged 3,710 (38%), and subsistence harvest averaged 2,009 (20%) (Dunaway and Sonnichsen 2001). From 1990 to 2000, the sport harvest of Chinook salmon in the Naknek River averaged 4,028, with a range from 2,927 in 2000 to 5,552 in 1997 (Walker et al. 2003). In an attempt to balance increasing harvest with escapement goals, the Alaska Department of Fish and Game (ADFG) has implemented seasonal commercial and sport fishing closures, as well as harvest and gear restrictions to protect Chinook salmon in the Naknek River drainage. The biological escapement goal for Chinook salmon in the Naknek drainage is 5,000 spawning adults as indexed by aerial surveys (Dunaway and Sonnichsen 2001). This goal is

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based on index counts, and therefore represents a minimum estimate of total escapement. Chinook salmon returning to spawn in Big Creek represent a sizeable portion of the entire Naknek River escapement. From 1990 to 2002, Chinook salmon escapement in Big Creek has averaged 35% of the total escapement into the Naknek River drainage, ranging from 895 to 2,531 (Sands et al. 2003). Numbers of Chinook salmon counted past the Big Creek weir from 2000 to 2003 ranged from 649 to 10,063, although numbers were not complete counts in some years (Whitton 2003; Anderson et al. 2004).

Coho salmon are also an important species targeted by sport fishermen in the Naknek River drainage, with an average sport harvest of 7,020 during 1990 to 2000 (range 3,253 to 10,276; Walker et al. 2003). Currently, the ADFG has not established a biological escapement goal or management objectives, and no monitoring program exists to assess spawning escapement or overall exploitation of coho salmon in the Naknek River drainage (Dunaway and Sonnichsen 2001). Declines seen in some coho salmon runs in the ADFG Southwest Management Area may be due to excessive harvest, but the lack of escapement data prevents managers from verifying this conclusion (Minard et al. 1998). The lack of escapement data has become a major concern, and without this information it is difficult to determine the health of coho salmon stocks and thus determine appropriate escapement and harvest goals. Coho salmon counts past the Big Creek weir from 2000 to 2003 ranged from 806 to 9,600, although counts were not complete in some years (Whitton 2003; Anderson et al. 2004).

The ADFG does not have biological escapement goals or escapement monitoring for chum or pink salmon in the Naknek River drainage. Harvest in the commercial fishery is monitored, however, and 34,481 chum and 24 pink salmon were harvested in the Naknek River commercial fishery in 2003 (Morstad et al. 2004). The average sport harvest of pink salmon in the Naknek River from 1990 to 2000 was 4,897 (range 1,283 to 23,178), and the average chum salmon sport harvest was 374 (range 179 to 607; Walker et al. 2003). Chum salmon passage at the Big Creek weir ranged from 3,240 to 33,943, and pink salmon passage ranged from 15 to 873 during 2000 - 2003 (Whitton 2003; Anderson et al. 2004).

In 2000, the King Salmon Fish and Wildlife Field Office (KSFO) initiated a multi year study on Big Creek to:

1. Enumerate escapement of Chinook, chum, coho, pink, and sockeye salmon in Big Creek from 15 June to 15 October;
2. Describe the run timing of Chinook, chum, coho, pink, and sockeye salmon through the weir;
3. Estimate the weekly age and sex composition of spawning Chinook, chum, and coho salmon in Big Creek, such that simultaneous 90% confidence intervals have a maximum width of 0.20;
4. Estimate the mean length of Chinook, chum, and coho salmon by sex and age; and
5. Characterize current public use on Big Creek and Becharof National Wildlife Refuge lands by conducting a general survey of boaters passing the weir.

Whitton (2003) reports results of the project from 2000 to 2002; Anderson et al. (2004) reports project results from 2003. This report focuses on work accomplished in 2004.

Study Area

Big Creek originates in the mountains south of Brooks Lake in Katmai National Park and flows northwest about 60 km before joining the Naknek River, 6 km east of King Salmon, Alaska (Figure 1). The drainage is comprised of numerous tributaries, small lakes, and ponds and is almost entirely located within Refuge boundaries. Big Creek is a clear water stream that supports five species of Pacific salmon and spawning populations of rainbow trout *O. mykiss*, Dolly Varden *Salvelinus malma*, Arctic grayling *Thymallus arcticus,* and northern pike *Esox lucius*. Round whitefish *Prosopium cylindraceum*, longnose sucker *Catostomus catostomus*, and lamprey *Lampetra* spp. are also present in Big Creek. The weir site is 35 km upriver from the confluence of Big Creek and the Naknek River. This section of the stream is characterized by glides and riffles flowing over sand, gravel, and small cobble substrate. Willow *Salix* spp., birch *Betula* spp., and grasses dominate the riparian zone. Maximum discharge often occurs during spring breakup, but high discharge also occurs during periods of heavy rainfall between late July and October.

Methods

Escapement Monitoring

KSFO has operated a weir on Big Creek since 2000. In 2002, the fixed-picket weir used in 2000 and 2001 was replaced with a nontraditional resistance-board weir. The new weir was modeled after designs reported by Tobin (1994), with modifications so that it was constructed and installed in a V-shaped formation that directs upstream migrant fish to a trap box and video passage chute positioned at the apex of the V. Weir panels were constructed from 4.6-m lengths of polyvinyl chloride (PVC) electrical conduit pickets separated by 38-mm lengths of PVC. Aircraft cable (3 mm in diameter) was used to string the pickets and PVC spacers together, and clamps were attached to the ends of the cables to create 1.2-m wide panels. Six stringers were installed on each panel to provide rigidity. Panels were attached to an 8-mm diameter cable secured to the stream bottom with duckbill anchors. Adjustable resistance boards, constructed of plywood (6 mm thick) and waterproof Styrofoam, were attached to the downstream end of panels to provide flotation. Five weir panels were modified to allow boats to pass the weir. The V-shaped resistance-board weir was operated from 23 June to 29 September 2004 when it was submerged by high water. During the period of operation, the weir was inspected, cleaned, and maintained daily to insure integrity.

To facilitate fish passage and reduce the number of fish handled at the weir, a video monitoring system was incorporated into the weir. The video monitoring system consisted of an Applied Microvideo M250 underwater video camera mounted in a sealed aluminum video box filled with filtered water treated with an algaecide. Images were collected through a clear safety-glass window fixed to the front of the video box. The distance between the camera lens and the glass window provided separation between upstream migrant fish and the lens, as needed to obtain full frame images of large Chinook salmon. The sealed video box design was developed to allow underwater video equipment to operate in the fall when frequent rains often create turbid water conditions. In turbid water, image quality is maintained as the majority of the distance between fish and the lens is within the filtered water contained in the video box. The video box was attached to a fish passage chute that blocked external light from affecting the camera, providing a controlled lighting environment. A baffle was installed in the fish passage chute that forced fish to pass within 25 cm of the camera box glass to further improve performance during turbid water conditions. The fish passage chute was lit from above and below by four, 4-ft long, 12-V DC underwater fluorescent light fixtures and from the side by two35-W, 12-V DC underwater

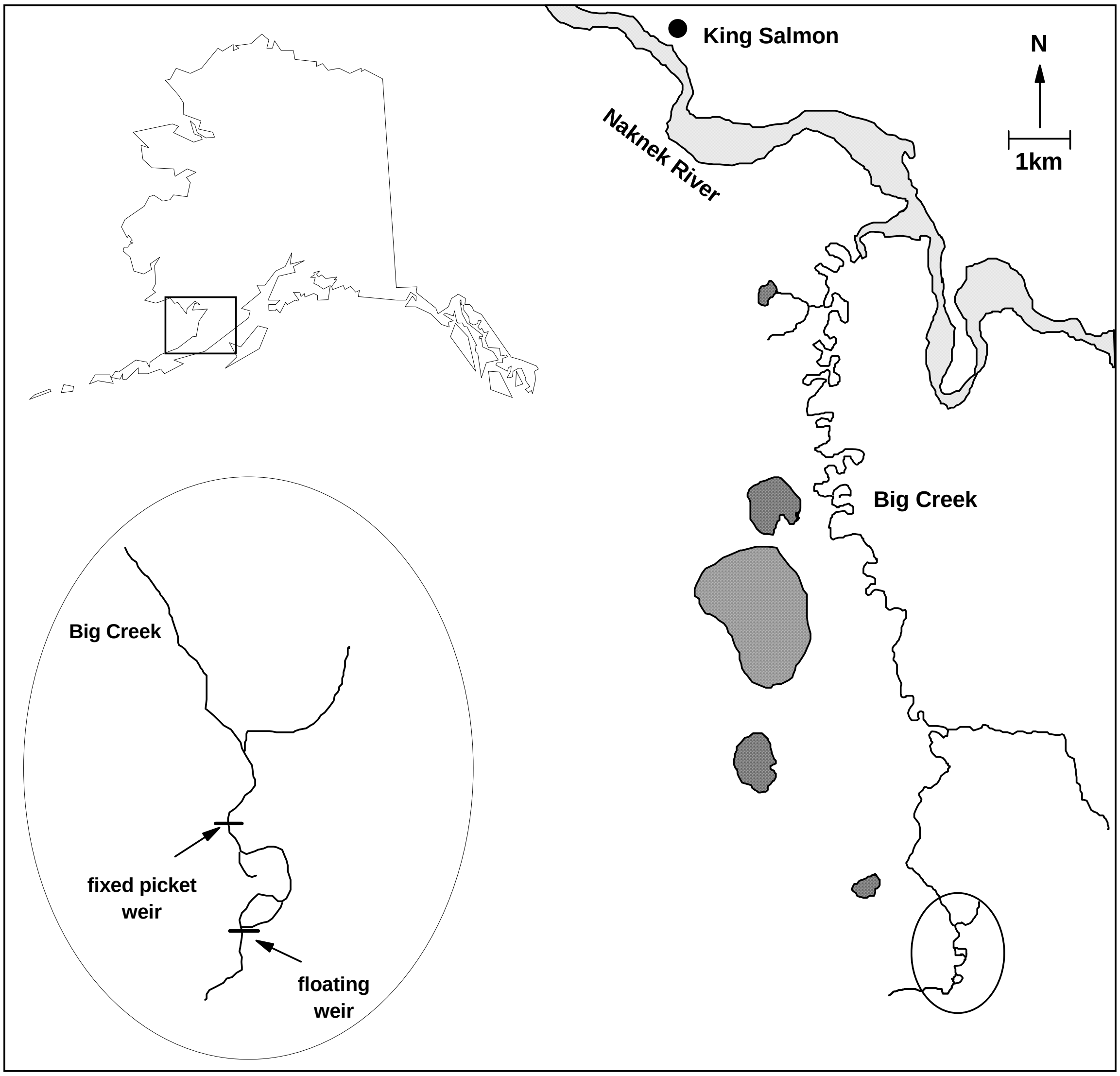

Figure 1. Big Creek study area showing the fixed picket weir site used during 2000 - 2001, and the floating weir site used since September 2001, Becharof National Wildlife Refuge.

halogen lights mounted near the camera. Lights were positioned to minimize backscatter and disperse lighting to eliminate "hot spots" while still providing enough illumination to identify fish. During normal operation, only the halogen lights were used; all lights were used during turbid water conditions.

The underwater video camera was connected to a Sanyo DSR-3000 digital video recorder using a shielded coaxial cable. The digital video recorder processed the video stream using motion detection hardware and software to eliminate blank footage, and digitally recorded footage containing fish (alarms) for later counting and identification. We tested the motion detection by doing live counts for 60 min and noting whether every fish that passed through the field of view triggered an alarm. We then reviewed the recorded alarm footage and compared counts of each species, number of alarms recorded, and time required to review the footage. After the motion detection was verified to be functional, fish counts were made by reviewing motion detection alarm files.

Vertical sliding doors were installed in both the trap box and fish passage chute. When fish were not being collected for biological sampling, the trap box was closed and fish were passed through the video monitoring chute. This allowed fish to pass freely through the weir unless the video chute was closed to capture fish for biological sampling. The gate to the video chute was normally closed from approximately 22:00 hours until 06:30 hours the next morning to conserve power.

Stream discharge (flow; m^3/s) was monitored at a site near the Big Creek weir. The site was selected in an area with uniform water depth and velocity to minimize sampling error. Discharge was measured using the methods of Gordon et al. (1992), and water velocity was measured with a Marsh-McBirney model 201 flow meter. Stage height (ft) was measured twice daily from a staff gauge. A stage-discharge relationship was not established at the Big Creek weir in 2004, as only two discharge measurements were taken.

Water temperature was monitored in 2004 with a Hobo® Temp data logger that recorded temperatures every two hours. The data logger was placed in a secure, well-mixed site near the weir. Water temperature was summarized as daily minimum, mean, and maximum.

Age, Sex, and Length Data

We collected Chinook, chum, and coho salmon age, sex, and length (ASL) data using a temporally stratified sampling design (Cochran 1977), with statistical weeks defining strata. Samples were collected uniformly throughout the week (Sunday through Saturday). To avoid potential bias caused by the selection or capture of individual fish, all target species within the trap were included in the sample even if the sample size goal for a species was exceeded. Although weir passage was stratified into statistical weeks a priori, strata for the analysis of Pacific salmon biological data at the Big Creek weir were modified following the field season to represent actual weir passage (Table 1).

Maximum weekly sample size goals for chum and coho salmon were established such that simultaneous 90% interval estimates of age composition for each week have maximum widths of 0.20 (Bromaghin 1993; Table 2). Sample sizes obtained using these methods were increased to account for the expected number of unreadable scales. The derivation of maximum sample size goals was based on a multinomial sampling model (sampling with replacement or small samples relative to a large population). For some salmon species, the sample size goal was expected to be a substantial fraction of the passage in some weeks. Therefore, during weeks of low passage when the maximum sample size goal could not be practically obtained, about 20% of the weekly escapement was sampled. This was sufficient to describe the age composition and reduce the number of fish handled at the weir. For sample size determination, age categories were defined as the total age (fresh water and ocean age combined) for all species.

To gather Chinook salmon length data, we mounted two 12-V DC underwater lasers (635 nm, 10 mW) with line generating lenses below the video camera to measure fish lengths electronically. Lasers were mounted so they projected parallel vertical lines with 100-mm spacing (Figure 2). An onscreen micrometer, (Video Ruler Version 7 DVD; C-Map Systems, Inc. 2004), was then used to measure lengths from captured still images of fish. Prior to using the onscreen micrometer to measure fish lengths, the system was calibrated to correct for barrel distortion near the edges of the camera's field of view following the procedures of C-Map Systems, Inc. (2004). The onscreen micrometer was calibrated for each captured image by inputting the known 100 mm laser separation distance into the software and then dragging the mouse cursor from one

Table 1. Strata (time periods) used for analysis of Big Creek biological data, 2004.

Stratum	Chinook salmon	Chum salmon	Coho salmon
1	23 Jun - 3 Jul	23 Jun - 3 Jul	27 Jul - 14 Aug.
2	4 - 10 Jul	4 - 10 Jul	15 - 21 Aug.
3	11 - 17 Jul	11 - 17 Jul	22 - 28 Aug
4	18 - 24 Jul	18 - 24 Jul	29 Aug - 4 Sep
5	25 - 31 Jul.	25 - 31 Jul	5 - 11 Sep
6	1 - 7 Aug	1 - 7 Aug	12 - 18 Sep
7	8 Aug - 20 Sep	8 - 14 Aug	19 - 28 Sep
8	--	15 - 21 Aug.	--
9	--	22 - 28 Aug	--
10	--	29 Aug - 26 Sep	--

Table 2. Maximum weekly sample size goals based on the sampling model of Bromaghin (1993) for collecting age, sex, and length data at the Big Creek weir, 2004.

Species	Number of Age Categories	Sample Size	Percent Unreadable	Adjusted Sample Size
Chum salmon	4	121	15	142
Coho salmon	3	109	15	128

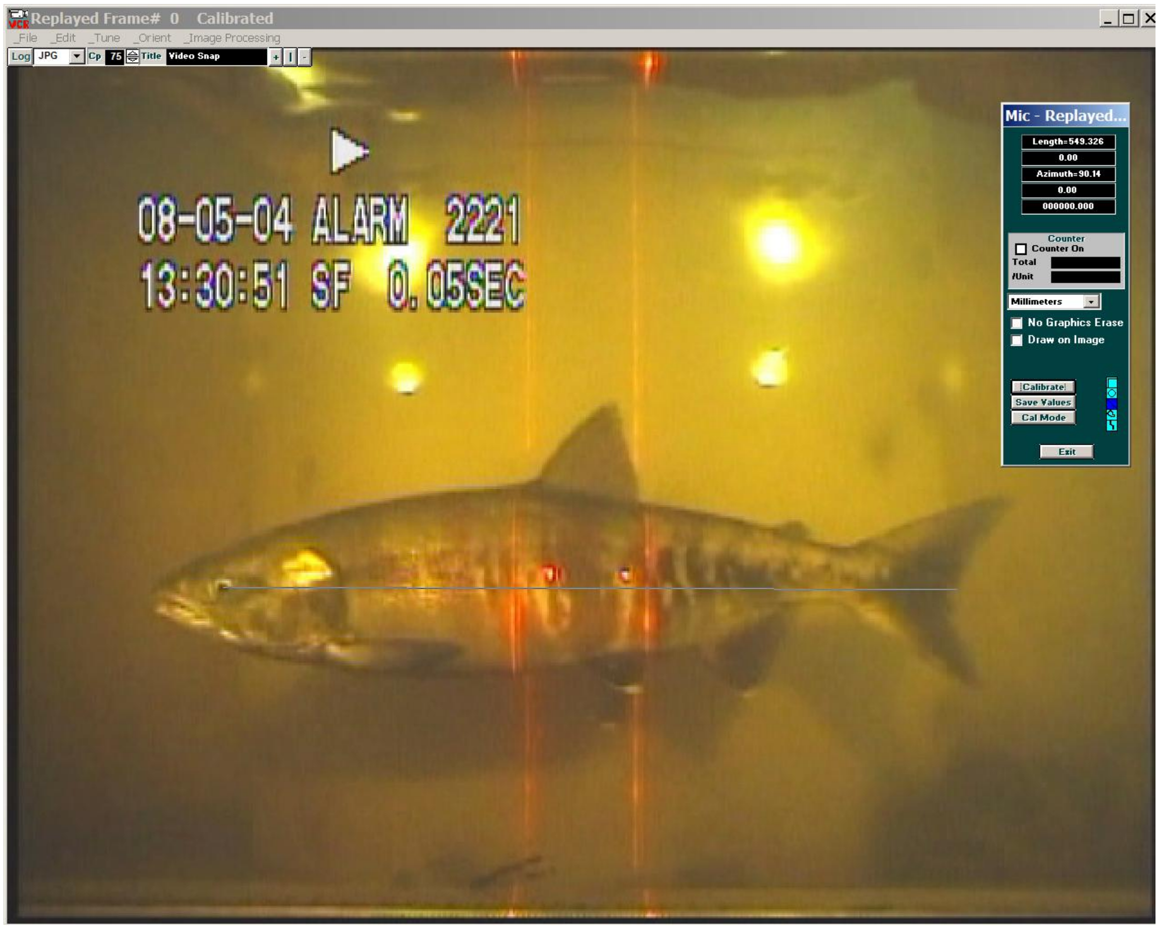

Figure 2. Screen capture of a chum salmon demonstrating use of the Video Ruler 7 DVD onscreen micrometer (C-Map Systems, Inc 2004) used to measure fish lengths electronically in 2004. The vertical red lines are the lasers projected from beneath the camera, and the blue horizontal line is the length measurement.

laser line to the next. Following calibration, the length of the fish was measured by dragging the mouse cursor from the middle of the fish's eye to the fork of its tail. Only fish that presented a fully extended side-on aspect (Figure 2) were measured. The accuracy of the onscreen micrometer was verified by comparing micrometer-measured fish lengths to those measured in the trap box with calipers. Mid-eye-to-fork length for each fish was measured with calipers and recorded; the same fish was then passed through the video chute and measured with the onscreen micrometer. The relationship between caliper-measured and micrometer-measured fish lengths was determined using simple linear regression. The regression equation was then used to standardize onscreen micrometer lengths to caliper lengths for analysis.

In 2004 we used an age-length key (ALK) to describe the age composition of Chinook salmon at the Big Creek weir. The use of the laser measurement system allowed us to sample lengths on a large number of fish without having to physically trap and handle them. Based on modeling of 2003 data with the equations of Quinn and Deriso (1999), the ALK would produce similar accuracy and precision to the current multinomial sampling design (Table 3). The benefit of using the ALK is that we could produce valid age composition estimates with a much smaller sample size. We chose weekly sample size goals of A = 50 Chinook salmon for age and length

Table 3. Comparison of Chinook salmon weekly age compositions developed using an age-length key (ALK) and the current multinomial sampling design at the Big Creek weir using 2003 data (Anderson et al. 2004). The ALK was developed from weekly samples of $A = 25$ fish for age determination. L = number of fish sampled for length measurement; $\hat{\theta}_a$ = proportion of fish of age a; CV = coefficient of variation.

Age-Length Key ($A = 165$)

		Age 1.1			Age 1.2			Age 1.3			Age 1.4		
Stratum	L	$\hat{\theta}_a$	SE	CV	$\hat{\theta}_a$	SE	CV	$\hat{\theta}_a$	SE	CV	$\hat{\theta}_a$	SE	CV
1	97	0.65	0.06	0.10	0.26	0.06	0.23	0.07	0.02	0.33	0.01	0.01	0.53
2	94	0.46	0.06	0.12	0.29	0.05	0.17	0.21	0.04	0.20	0.04	0.02	0.41
3	100	0.33	0.05	0.16	0.30	0.05	0.18	0.29	0.05	0.16	0.08	0.02	0.30
4	45	0.07	0.04	0.48	0.15	0.04	0.27	0.50	0.06	0.13	0.26	0.06	0.22
5	41	0.12	0.05	0.38	0.16	0.04	0.27	0.41	0.07	0.17	0.29	0.07	0.23
6	44	0.35	0.07	0.21	0.24	0.06	0.25	0.25	0.05	0.21	0.14	0.04	0.29

Multinomial Sampling Design

		Age 1.1			Age 1.2			Age 1.3			Age 1.4		
Stratum	n	$\hat{\theta}_a$	SE	CV	$\hat{\theta}_a$	SE	CV	$\hat{\theta}_a$	SE	CV	$\hat{\theta}_a$	SE	CV
1	122	0.63	0.04	0.06	0.26	0.04	0.15	0.08	0.02	0.25	0.02	0.01	0.50
2	122	0.48	0.04	0.08	0.31	0.04	0.13	0.18	0.03	0.17	0.03	0.02	0.67
3	127	0.25	0.04	0.16	0.27	0.04	0.15	0.31	0.04	0.13	0.17	0.03	0.18
4	75	0.05	0.03	0.60	0.16	0.04	0.25	0.57	0.06	0.11	0.21	0.05	0.24
5	68	0.09	0.03	0.33	0.16	0.04	0.25	0.46	0.06	0.13	0.28	0.05	0.18
6	70	0.39	0.06	0.15	0.20	0.05	0.25	0.33	0.05	0.15	0.09	0.03	0.33

samples collected in the trap box, and L = 200 length samples measured with the laser system such that the coefficient of variation for age 1.4 fish (worst case scenario) would be less than 20%. All age and length samples were used to construct the ALK, and the weekly length samples were used to estimate weekly age composition.

Samples for ASL and ALK data were collected using a dip net to remove fish from the trap box at least once daily or more often as the number of fish moving through the weir increased. Adult salmon were measured to the nearest mm (mid-eye-to-fork length) and the sex of the fish was determined from secondary characteristics. Three scales from each Chinook and coho salmon, and one scale from each chum salmon were removed from the preferred area on the left side of the fish (Jearld 1983), cleaned, and mounted on gummed scale cards. Chum and coho salmon scales were pressed and aged following the field season by KSFO personnel. Standards and guidelines of Mosher (1968) were used in aging scales. Chinook salmon scales were pressed and aged following the field season by ADFG personnel. Salmon ages are reported according to the European method described by Jearld (1983) and Mosher (1968), where the number of winters the fish spent in fresh water and in the ocean is separated by a decimal. Fish with scales that could not be aged, or where sex could not be determined from secondary characteristics, were not included in the ASL analysis. Non-target fishes captured in the trap box were identified to species, enumerated, and released above the weir. Fish were not allowed to hold downstream of the weir. If this occurred, the trap box was closed and the video chute was opened to facilitate upstream passage.

Characteristics of Chinook, chum, and coho salmon passing through the weir were estimated using standard stratified random sampling 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 over all possible values of the corresponding variable, e.g., n_{i++m} denotes the total number of fish of species i sampled in stratum m. The variance of $\hat{p}_{ijkm}$ 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 of species i, sex j, age k passing the weir in stratum m ($\hat{N}_{ijkm}$) was

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

with estimated variance

$$\hat{v}(\hat{N}_{ijkm}) = N_{i++m}^{2}\,\hat{v}(\hat{p}_{ijkm}).$$

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

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

and

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

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 fish of species *i*, sex *j*, and age *k* sampled in stratum *m* is denoted x_{ijkm}, the sample mean length of fish of species *i*, sex *j*, and age *k* within stratum *m* was calculated as

$$\bar{x}_{ijkm} = \frac{\sum x_{ijkm}}{n_{ijkm}} ,$$

with corresponding sample variance s^2_{ijkm}

$$s^2_{ijkm} = \left(1 - \frac{n_{ijkm}}{\hat{N}_{ijkm}} \right) \frac{\sum \left(x_{ijkm} - \bar{x}_{ijkm} \right)^2}{n_{ijkm} - 1} .$$

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

$$\hat{\bar{x}}_{ijk} = \sum_m \left(\frac{\hat{N}_{ijkm}}{\hat{N}_{ijk}} \right) \bar{x}_{ijkm} .$$

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

$$\hat{v}\left(\hat{\bar{x}}_{ijk}\right) = \sum_m \left\{ \hat{v}\left(\hat{N}_{ijkm}\right) \left[\frac{x_{ijkm}}{\sum_x \hat{N}_{ijkx}} - \sum_y \frac{\hat{N}_{ijky}}{\left(\sum_x \hat{N}_{ijkx} \right)^2} x_{ijky} \right]^2 + \left(\frac{\hat{N}_{ijkm}}{\sum_x \hat{N}_{ijkx}} \right)^2 s^2_{ijkm} \right\}.$$

Age characteristics of Chinook salmon were also estimated using an ALK following the methods of Quinn and Deriso (1999). Length (mid-eye to fork of tail) was measured from a simple random sample of size L from the total weir passage, C, as the first stage sample. The sample (L) was classified into 50-mm length intervals with frequencies $\{L_l\}$, $l = 1,..., J$. Scales were collected and ages determined on a sample of size A, with A_l taken randomly from L_l using proportional allocation, where the number of fish aged is selected proportional to the length frequencies. Two different methods were used to measure lengths. Most length measurements were taken using the calibrated onscreen micrometer on captured images of Chinook salmon passing through the video chute. Lengths of fish captured in the trap box for the age sub sample were measured with calipers. All length measurements were standardized to caliper length for analysis.

After ages were obtained, age frequencies were classified by length l and age a into an ALK, denoted $\{A_{la}\}$, $l = 1,..., J$; $a = r,..., A$ where r is the youngest age and A is the oldest age. An unbiased estimator of the proportion of fish of length l ($\hat{\alpha}_l$) was estimated as

$$\hat{\alpha}_l = \frac{L_l}{L},$$

and an unbiased estimator of the proportion of fish of length l and age a ($\hat{\theta}_{la}$) was

$$\hat{\theta}_{la} = \frac{A_{la}}{A_l}.$$

An unbiased estimate of the proportion of age a fish ($\hat{\theta}_a$) was estimated as

$$\hat{\theta}_a = \sum_l \hat{\alpha}_l \hat{\theta}_{la},$$

with variance ($\text{var}(\hat{\theta}_a)$) given by

$$\text{var}(\hat{\theta}_a) = \sum_l \frac{\hat{\alpha}_l^2 \hat{\theta}_{la}\left(1 - \hat{\theta}_{la}\right)}{A_l - 1} + \sum_l \frac{\hat{\alpha}_l \left(\hat{\theta}_{la} - \hat{\theta}_a\right)^2}{L}.$$

The estimate of the total number of age a Chinook salmon in the population ($\hat{C}_a$) was estimated as

$$\hat{C}_a = C\hat{\theta}_a$$

with estimated variance

$$\text{var}\left(\hat{C}_a\right) = C^2 \,\text{var}\left(\hat{\theta}_a\right).$$

Public Use Survey

During 2004, boats traveling past the weir were interviewed opportunistically. The following information was obtained for each interview: (1) primary purpose for visit (hunting, fishing, other); (2) secondary purpose (hunting, fishing, other); (3) reason (subsistence, sport, or other);

(4) residence (city, state, or country of residency); (5) guiding status (guided or unguided); (6) target species and the number kept; (7) group size; and (8) time spent on the Refuge (hours or days). Unless boat passage occurred when the crew was present at the weir, boaters were not likely to be interviewed as the weir design allows boats to motor over the weir without stopping.

Public Outreach

A microwave link was installed at the Big Creek weir in 2004 that allowed us to broadcast a live image from the underwater camera back to a receiver site at the U. S. Fish and Wildlife Service Visitor Center in King Salmon. A pan-tilt-zoom camera was also installed on a tripod tower at the weir site that was remotely controlled at the Visitor Center. Visitors could switch between views from the underwater and overhead cameras, and the video signal was displayed on a 32" diagonal flat panel screen mounted on a wall. Video and audio connections were also available, enabling visitors to record video from the system to a personal camcorder. A second microwave receiver was installed at KSFO, but we did not have the ability to switch between camera views; we received the video signal from whichever camera the Visitor Center had selected.

Results

Escapement Monitoring

We counted 11,906 Chinook, 24,957 chum, 10,451 coho, 3,295 pink, and 189 sockeye salmon past the Big Creek weir from 23 June to 29 September 2004 (Figures 3 and 4; Appendix A). Chinook salmon were observed at the weir from 23 June to 20 September, with a peak of 1,770 fish passing the weir on 9 July. Chum salmon passed the weir from 23 June to 26 September, with a peak of 1,732 on 8 August. Coho salmon were counted at the weir from 27 July to 28 September, with a peak of 2,641 on 20 September. Estimates for coho salmon are incomplete, as the weir was inundated with high water and not fish tight for several days in August and September (Table 4); the weir was not fish tight after 20 September, although we were able to operate the video equipment and count fish until 29 September. Pink salmon migration peaked in early August, and sockeye salmon had no defined peak migration past the Big Creek weir in 2004 (Figure 4). Dolly Varden (N = 1,529), rainbow trout (N = 673), round whitefish (N = 179), Arctic grayling (N = 55), northern pike (N = 14), and lamprey (N = 3) were observed passing through the weir in 2004 (Figures 4 and 5; Appendix B). Most Dolly Varden passed the Big Creek weir in early July 2004 (Figure 4).

Tests of the motion detection were conducted on 28 occasions in 2004. The majority of motion detection failures occurred when small resident fish and juvenile salmon failed to trigger alarm events. The motion detection capabilities failed on several occasions during late July and early August when large groups of chum salmon moved through the camera field of view in a continuous stream. During these times, the crew recorded all fish passage manually and reverted to motion detection alarm recording when the chum salmon passage rate slowed.

We were able to compare live counts to motion detection counts on 18 of the 28 occasions when valid start and stop times were recorded for the live and file review counts. Counts of all species were similar with both methods (Table 5). In general, the crew had a tendency to misidentify Chinook salmon jacks, pink salmon, and sockeye salmon during the live counts. It was also difficult to distinguish between rainbow trout and Dolly Varden during live counts when they moved quickly through the field of view or in large groups. The average fish passage rate during the 18 trials was 169 fish/hr (range 5 to 477), and the average number of motion detection alarms recorded was 49 (range 22 to 96).

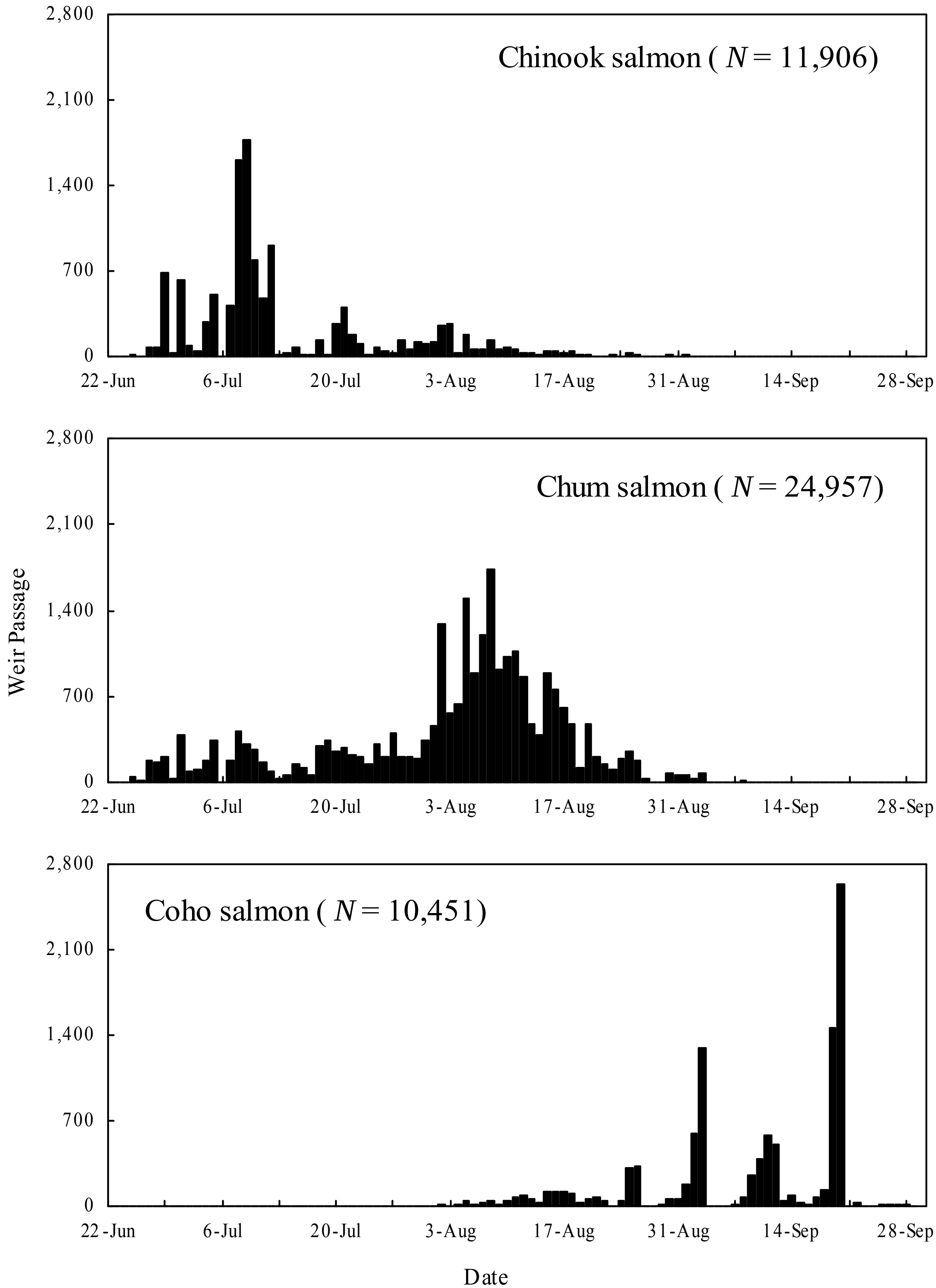

Figure 3. Daily passage of Chinook, chum, and coho salmon at the Big Creek weir, 2004.

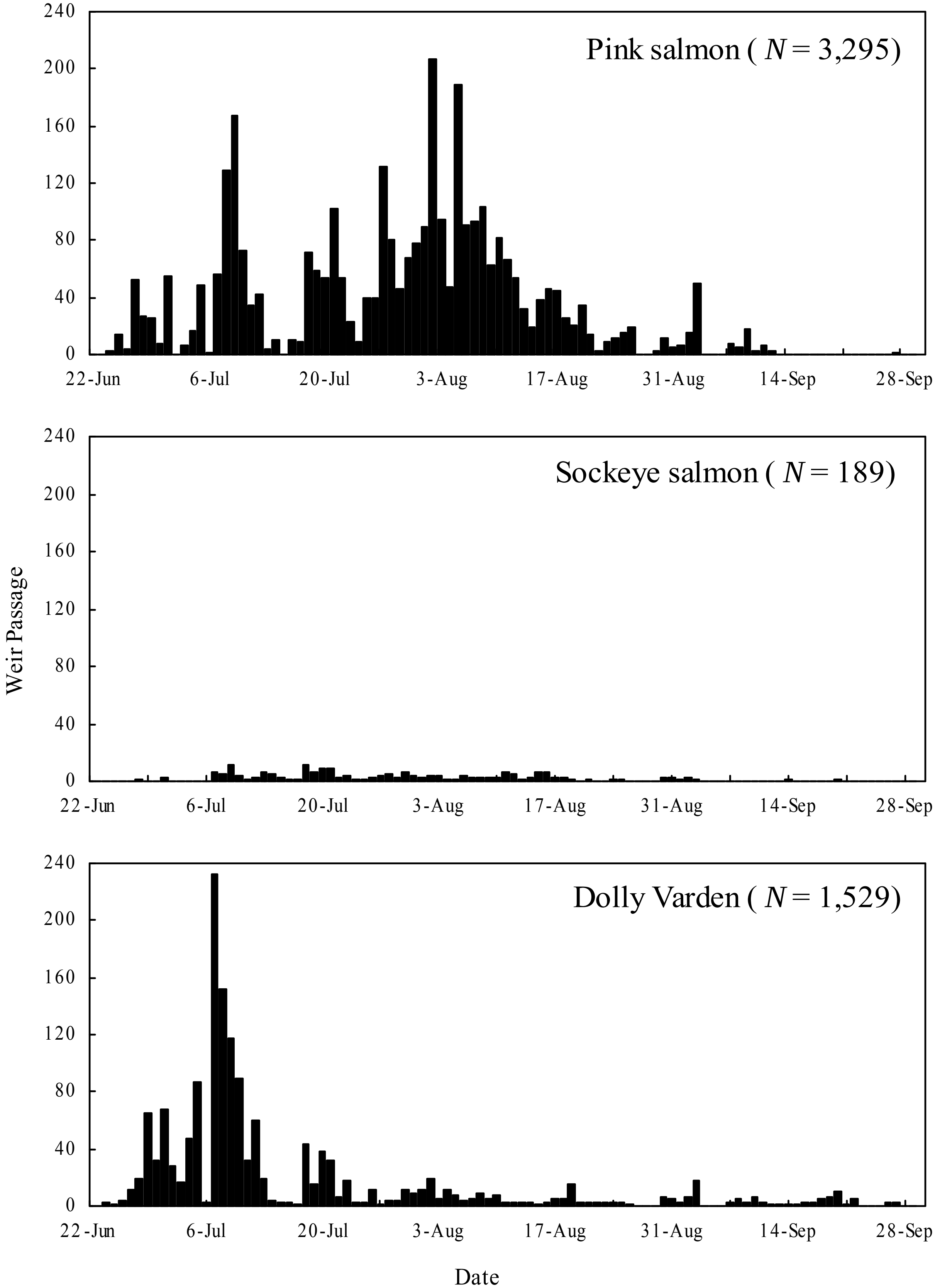

Figure 4. Daily passage of pink salmon, sockeye salmon, and Dolly Varden at the Big Creek weir, 2004.

Table 4. Summary of Big Creek weir failures, 2004.

Date/Time Failed	Date/Time Repaired	Hours Not Fish Tight
25 June, 05:00	26 June, 08:00	27
27 August, 06:00	29 August, 15:00	57
3 September, 15:00	7 September, 12:00	93
20 September, 21:00	--	--

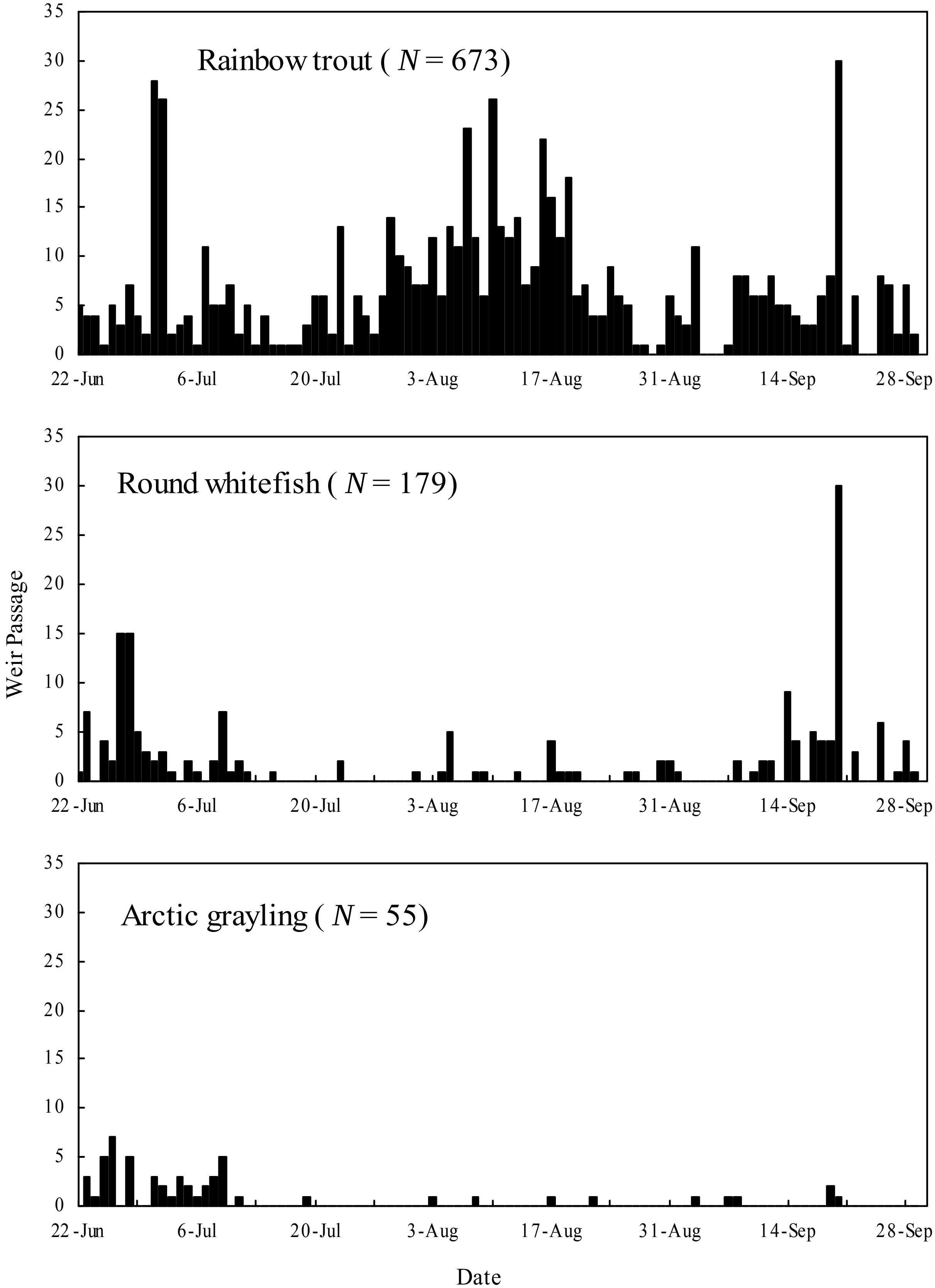

Figure 5. Daily passage of rainbow trout, round whitefish, and Arctic grayling at the Big Creek weir, 2004.

Table 5. Comparison of real time versus file review counts by species for *n* = 18 trials at the Big Creek weir, 2004.

	Count Method	
Species	Real Time	File Review
Chinook salmon	1,366	1,376
Chum salmon	1,629	1,598
Pink salmon	274	281
Sockeye salmon	17	19
Coho salmon	45	43
Dolly Varden	336	336
Rainbow trout	28	31
Arctic grayling	3	3
Round whitefish	1	1
Other	5	3
Total	3,704	3,691

Discharge measured near the Big Creek weir was 11.4 m^3/s (stage height = 1.78 ft) on 4 August and 6.1 m^3/s (stage height = 1.39 ft) on 18 August. Peak stage heights in late June, late August, early September, and after 20 September resulted in weir failures in 2004 (Figure 6, Table 4). A stage-discharge relationship was not established at the Big Creek weir in 2004, as only two discharge measurements were taken.

Water temperatures at the Big Creek weir peaked in early July 2004, with a maximum recorded temperature of 21.7°C on 11 July (Figure 7). Temperatures gradually decreased after mid August until the thermograph was removed on 30 September (Figure 7).

Age, Sex, and Length Data

Age, sex, and length data were collected from 288 Chinook salmon from 25 June to 2 September, 1,181 chum salmon from 25 June to 18 September, and 256 coho salmon from 2 August to 19 September 2004. Scales could not be collected from two Chinook, 51 chum, and one coho salmon. Scale samples were unreadable or regenerated for 15 Chinook (5%), 86 chum (8%), and 43 coho salmon (17%). Sex could not be determined from external characteristics for 13 Chinook, two chum, and two coho salmon.

Five age classes were identified from Chinook salmon scale samples in 2004. Over all strata, age 1.3 fish comprised the majority of the run (54%, Table 6). Ages 1.2 (29%) and 1.4 (12%) Chinook salmon were also abundant, while only 12 age 1.1 and three age 1.5 fish were sampled at the weir in 2004. Over all strata in 2004, 47% of the Chinook salmon sampled were females (Table 7). Sex composition varied by sample period and ranged from 32% females in strata 1

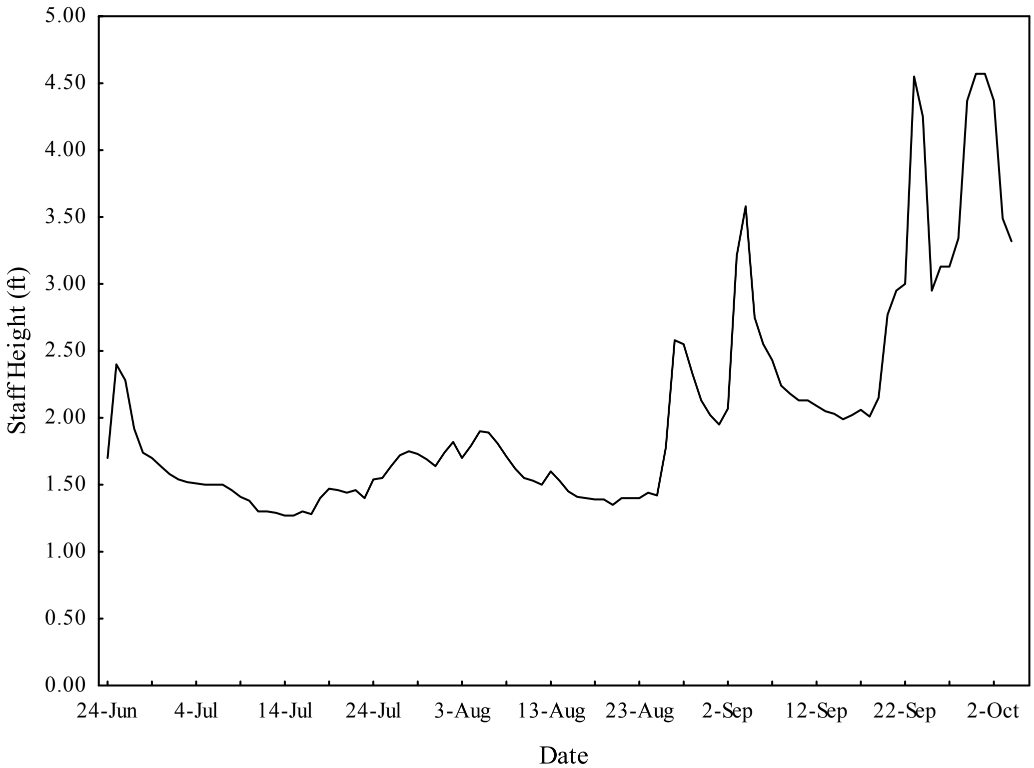

Figure 6. Maximum daily stage height measured at the Big Creek weir, 2004.

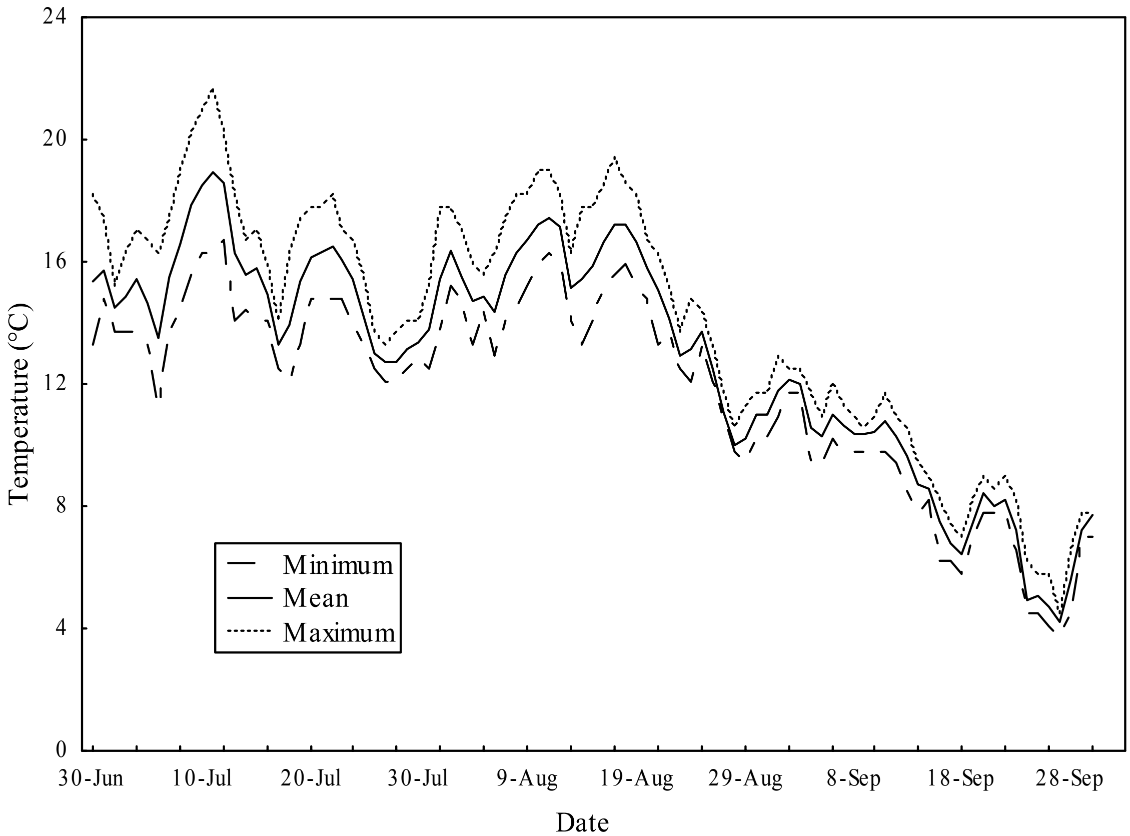

Figure 7. Daily minimum, mean, and maximum water temperatures near the Big Creek weir, 2004.

Table 6. Estimated age composition (%) of Chinook salmon by stratum in Big Creek, 2004.

	Age				
	1.1	1.2	1.3	1.4	1.5
			Stratum 1		
%	4	38	40	15	4
SE (%)	2.6	6.6	6.7	4.9	2.6
n	2	20	21	8	2
			Stratum 2		
%	4	19	69	9	--
SE (%)	2.6	5.3	6.3	4.0	--
n	2	10	37	5	--
			Stratum 3		
%	--	55	33	10	2
SE (%)	--	7.7	7.3	4.5	2.3
n	--	23	14	4	1
			Stratum 4		
%	--	36	39	25	--
SE (%)	--	8.0	8.1	7.2	--
n	--	13	14	9	--
			Stratum 5		
%	--	13	62	24	--
SE (%)	--	4.9	7.0	6.2	--
n	--	6	28	11	--
			Stratum 6		
%	6	31	56	6	--
SE (%)	6.2	11.9	12.7	6.2	--
n	1	5	9	1	--
			Stratum 7		
%	28	36	32	4	--
SE (%)	9.0	9.6	9.4	3.9	--
n	7	9	8	1	--
			Total		
%	4	29	54	12	1
SE (%)	1.4	3.1	3.5	2.2	0.5
n	12	86	131	39	3

Table 7. Estimated sex composition, sample size, and escapement of Chinook salmon by stratum in Big Creek, 2004.

Stratum	*n*	Sex: Female (%)	Sex: Male (%)	SE (%)	Escapement
1	53	32	68	6.4	1,661
2	53	47	53	6.9	5,360
3	47	62	38	7.1	1,542
4	37	46	54	8.2	1,100
5	50	32	68	6.4	562
6	15	53	47	13.2	975
7	20	55	45	11.3	706
Total	275	47	53	3.7	11,906

and 5 to 62% females in stratum 3. Lengths of Chinook salmon sampled in 2003 ranged from 428 to 935 mm for females, and from 391 to 998 mm for males (Table 8, Figure 8). In general, the more winters a fish spent in the ocean, the larger its size.

We were not able to calibrate the camera and laser system and measure lengths of Chinook salmon electronically until 20 July. Therefore, it was not possible to use an age-length key to generate an unbiased estimate of Chinook salmon age composition for the season as 75% of the run had already passed the weir by that time (Appendix A). However, we were able to verify that the laser measurement system was practical, and an ALK would be suitable to describe Chinook salmon age composition. Once the camera and laser system were calibrated, we measured 78 fish with calipers in the trap box and 64 of the 78 fish with the onscreen micrometer. A simple linear regression model fit the data well ($r^2 = 0.98$, $P < 0.00001$; Figure 9). From 27 July to 18 August, we captured footage of 685 Chinook salmon passing through the video chute out of a total weir passage of 1,979 (Appendix A). We were able to measure lengths of 598 Chinook salmon with the onscreen micrometer; 87 fish (13%) could not be measured either because the mid-eye to fork length measurement exceeded the camera's field of view or the fish did not present a side-on aspect to the camera. Most of the Chinook salmon passage we were able to record was from 30 July to 5 August ($n = 582$). We constructed an ALK using the age data collected from Chinook salmon sampled in the trap box ($A_l = 271$), and length data collected using the onscreen micrometer (standardized to caliper lengths) and measured with calipers in the trap box ($L_l = 869$; Table 9). Overall estimates of age composition and precision were similar to those obtained with the multinomial sampling design (Table 10). The ALK is biased, however, because the length samples were mainly collected over a 7-d period, and are not representative of the entire run. More large fish were sampled with the lasers during that 7-d period compared to the lengths of fish collected for the age sub-sample throughout the run (Figures 10 and 11), and we did not achieve our goal of proportional allocation for the length sample. The ALK was not used to estimate weekly age composition.

Table 8. Mean length (mm), SE, range, and sample size by sex and age taken from Chinook salmon at the Big Creek weir, 2004.

	Age				
	1.1	1.2	1.3	1.4	1.5
			Female		
Mean	533	608	780	859	882
SE	--	23.5	43.8	28.4	--
Minimum	428	531	562	726	876
Maximum	584	698	894	935	889
n	2	29	56	26	2
			Male		
Mean	--	618	741	876	--
SE	--	20.9	51.8	42.3	--
Minimum	391	500	551	756	941
Maximum	--	882	960	998	--
n	1	54	75	13	1
			Total		
Mean	426	603	758	863	901
SE	18.4	27.8	48.7	27.4	23.7
Minimum	391	500	551	726	876
Maximum	584	882	960	998	941
n	12	86	131	39	3

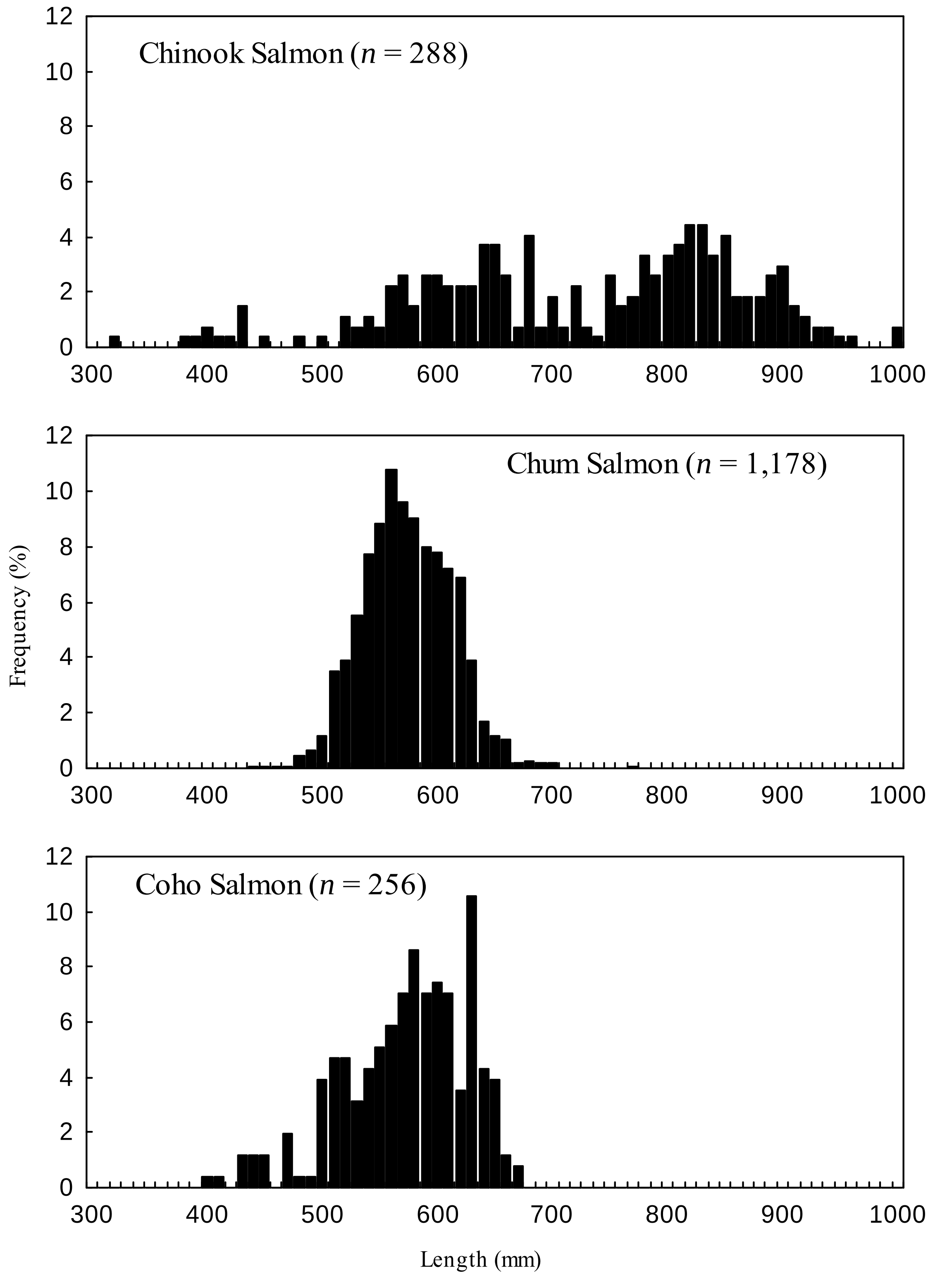

Figure 8. Length-frequency distributions for Chinook, chum, and coho salmon sampled at the Big Creek weir, 2004.

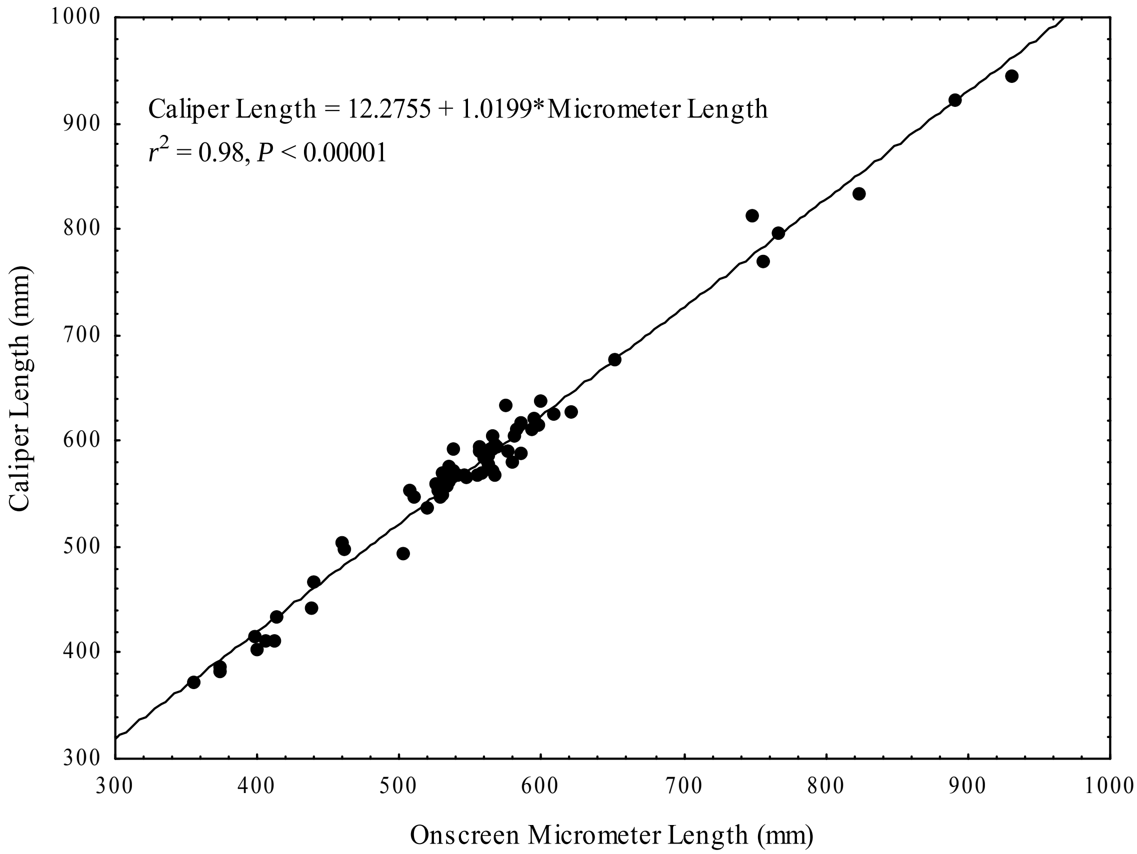

Figure 9. Relationship between mid-eye to fork lengths measured with calipers and the onscreen micrometer. Solid circles are observed measurements and the solid line is the predicted value.

Table 9. Age-length key developed from sampling at the Big Creek weir, 2004.

	Age						
Length (mm)	1.1	1.2	1.3	1.4	1.5	A_l	L_l
≤ 400	5	0	0	0	0	5	6
401 - 450	6	1	0	0	0	7	17
451 - 500	0	2	0	0	0	2	5
501 - 550	0	10	0	0	0	10	21
551 - 600	1	22	8	0	0	31	49
601 - 650	0	27	11	0	0	38	86
651 - 700	0	17	10	0	0	27	82
701 - 750	0	6	11	1	0	18	66
751 - 800	0	0	29	5	0	34	162
801 - 850	0	0	43	11	0	54	212
851 - 900	0	1	17	10	2	30	130
901 - 950	0	0	1	10	1	12	27
951 - 1000	0	0	1	2	0	3	6
Total	12	86	131	39	3	271	869

Table 10. Comparison of Chinook salmon age compositions and associated statistics based on multinomial and age-length key (ALK) sampling designs for Chinook salmon at the Big Creek weir, 2004. CV = coefficient of variation.

	Age				
	1.1	1.2	1.3	1.4	1.5
			Multinomial Sampling Design		
%	4	29	54	12	1
SE (%)	1.4	3.1	3.5	2.2	0.5
CV (%)	35.0	10.7	6.5	18.3	50.0
			ALK		
%	3	23	57	16	1
SE (%)	0.6	1.9	2.9	2.4	0.7
CV (%)	23.2	8.4	5.1	14.6	59.3

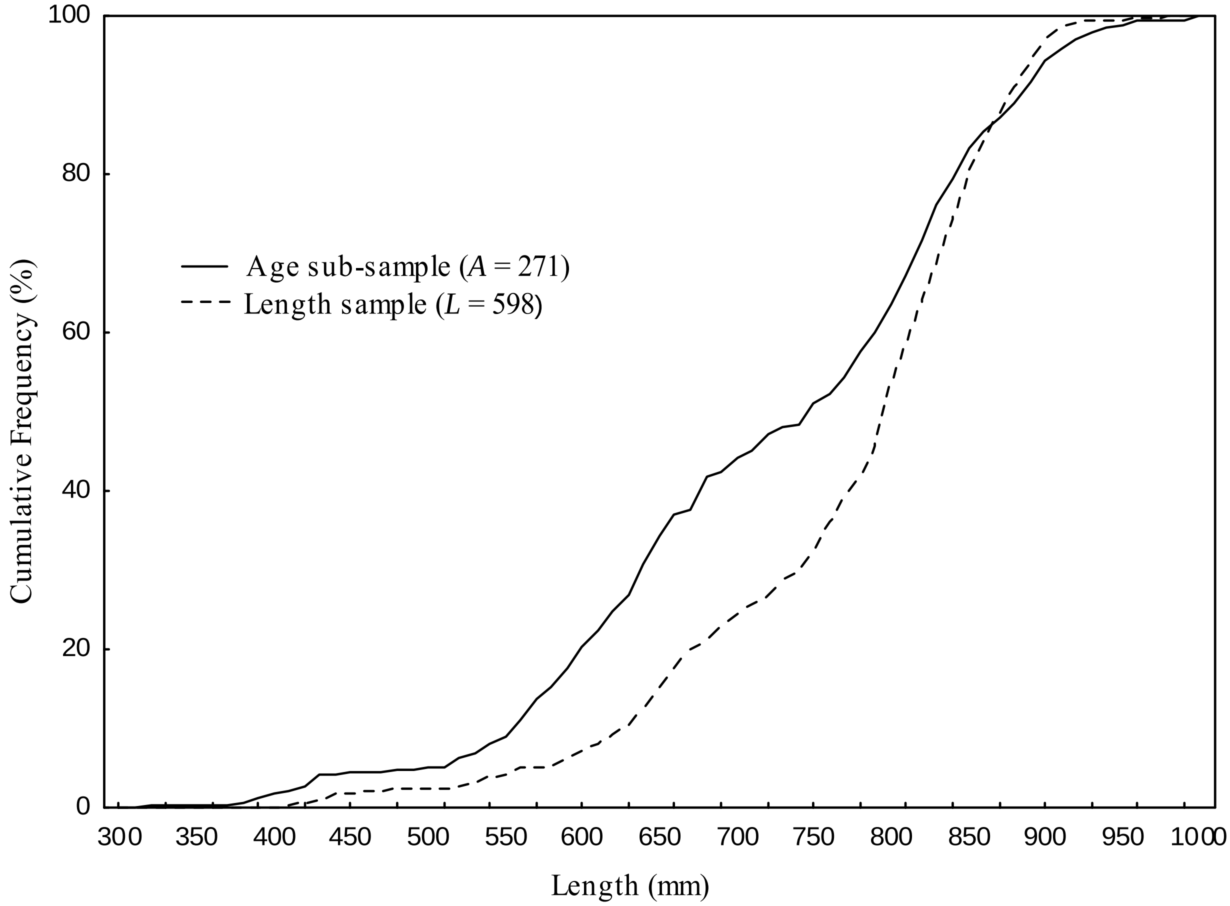

Figure 10. Cumulative length-frequency distributions for Chinook salmon sampled for length (*L*) with the onscreen micrometer and sub-sampled for age (*A*) with calipers at the Big Creek weir, 2004.

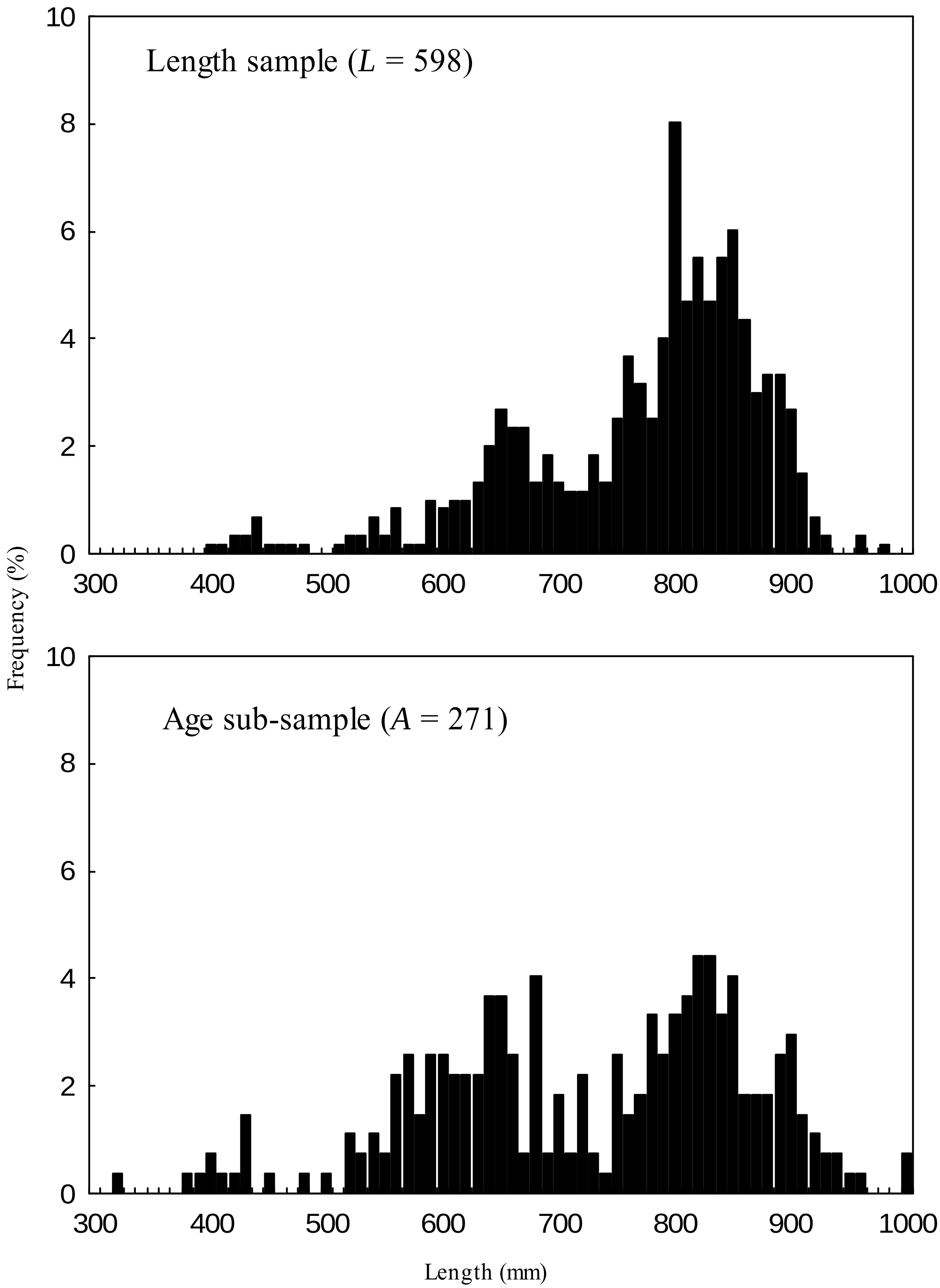

Figure 11. Length-frequency distributions for Chinook salmon sampled for length (*L*) with the onscreen micrometer (top) and sub-sampled for age (*A*) with calipers (bottom) at the Big Creek weir, 2004.

Four age classes of chum salmon were identified from scale samples in 2004. Age 0.3 fish were the predominant age class sampled in most strata and over all strata (52%; Table 11); age composition varied by sample period in 2004. The sex ratio for chum salmon also varied over sample periods in 2003 and ranged from 30% females in stratum 3 to 69% females in stratum 10 (Table 12). Over all strata in 2004, 52% of the chum salmon sampled at the weir were females. Lengths of chum salmon sampled in 2003 ranged from 456 to 681 mm for females, and from 483 to 768 mm for males (Table 13, Figure 8).

Five age classes of coho salmon were identified from scale samples in 2004. Age 2.1 fish made up the majority of the run in each stratum (except stratum 7) and over all strata (55%, Table 14). One age 1.2, one age 2.2, and five age 3.1 coho salmon were sampled at the Big Creek weir in 2004. The sex ratio for coho salmon also varied over sample periods in 2004, and ranged from 9% females in stratum 5 to 47% females in stratum 2 (Table 15). Over all strata in 2004, only 28% of the coho salmon sampled at the weir were females. Lengths of coho salmon sampled in 2004 ranged from 395 to 633 mm for females, and from 425 to 667 mm for males (Table 16, Figure 8).

Public Use Survey

Fifteen groups using the Refuge were surveyed at the Big Creek weir in 2004. Most were hunting and most were from the local area (Table 17). The number of groups interviewed is not representative of total Refuge use during the summer and fall of 2004, as many boats passed the weir without stopping and were not interviewed.

Discussion

Numbers of fish of all species observed at the Big Creek weir in 2004 were similar to 2003, and greater than in any previous year from 2000 to 2002 except for chum salmon (Table 18). Although some counts may represent larger escapements of certain species than in previous years (e.g., Chinook, chum, and coho salmon), much of the observed increase in numbers for non-salmon species since 2002 is due to picket spacing and the operation of the video monitoring equipment at the weir. In 2000 and 2001, fish passing through the weir were identified to species and enumerated by an observer looking down into the water column, so water clarity and surface turbulence were factors in accurate observations. In addition, when large numbers of fish were passing through the weir, identification and enumeration focused on Pacific salmon species. Picket spacing in 2000 and 2001 also allowed smaller fish to pass through the weir undetected (Whitton 2003). Picket spacing of the Big Creek weir (38 mm) allows smaller fish (< 300 mm) to pass through without being enumerated, and the size at which fish can no longer pass between the pickets varies by species. In 2003, rainbow trout and Dolly Varden less than 350 mm were not captured in the trap box, although round whitefish, sockeye salmon, and Artic grayling less than this size were captured (Anderson et al. 2004). Picket spacing was adequate to prevent adult Pacific salmon from passing through the weir undetected.

We did not achieve our sample size goal for lengths to estimate the age composition of Chinook salmon using an ALK. Technical difficulties in setting up and calibrating the camera and laser system prevented us from measuring fish lengths electronically until after 20 July. The length samples we did collect after 20 July were not representative of the entire run (Figures 10 and 11), so we were unable to produce weekly age composition estimates. However, the ALK we did produce shows that this method has promise for future years (Table 10). We believe the weekly

Table 11. Estimated age composition (%) of chum salmon by stratum in Big Creek, 2004.

	Age			
	0.2	0.3	0.4	0.5
		Stratum 1		
%	7	43	46	4
SE (%)	4.9	9.4	9.5	3.5
n	2	12	13	1
		Stratum 2		
%	25	55	20	1
SE (%)	3.8	4.4	3.5	0.8
n	30	67	24	1
		Stratum 3		
%	26	50	24	--
SE (%)	5.1	5.8	4.9	--
n	18	34	16	--
		Stratum 4		
%	27	58	15	--
SE (%)	3.5	3.8	2.8	--
n	41	88	23	--
		Stratum 5		
%	23	55	22	--
SE (%)	3.6	4.2	3.5	--
n	30	72	28	--
		Stratum 6		
%	31	50	18	1
SE (%)	3.9	4.2	3.3	0.7
n	43	69	25	1
		Stratum 7		
%	39	57	4	--
SE (%)	4.2	4.3	1.7	--
n	52	75	5	--
		Stratum 8		
%	41	50	8	1
SE (%)	4.4	4.4	2.4	0.8
n	51	61	10	1
		Stratum 9		
%	49	42	9	--
SE (%)	5.5	5.5	3.2	--
n	37	32	7	--
		Stratum 10		
%	57	32	11	--
SE (%)	5.1	4.8	3.2	--
n	43	24	8	--
		Total		
%	33	52	14	1
SE (%)	1.7	1.8	1.2	0.3
n	347	534	159	4

Table 12. Estimated sex composition, sample size, and escapement of chum salmon by stratum in Big Creek, 2004.

		Sex			
Stratum	*n*	Female (%)	Male (%)	SE (%)	Escapement
1	34	56	44	8.5	1,221
2	145	43	57	3.9	1,695
3	79	30	70	4.9	668
4	168	39	61	3.6	1,744
5	143	37	63	3.9	1,875
6	149	48	52	4.1	6,539
7	141	60	40	4.1	6,445
8	142	60	40	4.0	3,521
9	95	61	39	4.8	902
10	83	69	31	4.5	347
Total	1,179	52	48	1.7	24,957

Table 13. Mean length (mm), SE, range, and sample size by sex and age taken from chum salmon at the Big Creek weir, 2004.

	Age			
	0.2	0.3	0.4	0.5
		Female		
Mean	534	560	571	--
SE	10.4	10.8	12.2	--
Minimum	456	472	479	575
Maximum	612	681	634	--
n	186	272	71	1
		Male		
Mean	561	589	607	626
SE	12.5	10.9	15.6	--
Minimum	483	520	510	579
Maximum	630	692	768	646
n	161	261	88	3
		Total		
Mean	547	573	590	615
SE	12.1	12.7	14.2	--
Minimum	456	437	479	575
Maximum	630	692	768	646
n	347	534	159	4

Table 14. Estimated age composition (%) of coho salmon by stratum in Big Creek, 2004.

	Age				
	1.1	1.2	2.1	2.2	3.1
			Stratum 1		
%	43	--	57	--	--
SE (%)	13.5	--	13.5	--	--
n	6	--	8	--	--
			Stratum 2		
%	31	--	63	6	--
SE (%)	11.8	--	12.3	6.2	--
n	5	--	10	1	--
			Stratum 3		
%	12	--	76	--	12
SE (%)	8.0	--	10.5	--	8.0
n	2	--	13	--	2
			Stratum 4		
%	28	--	68	--	4
SE (%)	6.2	--	6.4	--	2.6
n	15	--	36	--	2
			Stratum 5		
%	48	--	52	--	--
SE (%)	9.3	--	9.3	--	--
n	14	--	15	--	--
			Stratum 6		
%	38	2	58	--	2
SE (%)	6.9	2.0	7.0	--	2.0
n	18	1	28	--	1
			Stratum 7		
%	57	--	43	--	--
SE (%)	8.5	--	8.5	--	--
n	20	--	15	--	--
			Total		
%	43	< 1	55	< 1	2
SE (%)	4.0	0.2	4.1	0.4	0.8
n	80	1	125	1	5

Table 15. Estimated sex composition, sample size, and escapement of coho salmon by stratum in Big Creek, 2004.

		Sex			
Stratum	*n*	Female (%)	Male (%)	SE (%)	Escapement
1	19	37	63	11.1	487
2	17	47	53	12.3	631
3	21	19	81	8.7	714
4	59	14	86	4.4	2,198
5	32	9	91	5.2	1,325
6	60	22	78	5.2	901
7	46	41	59	7.3	4,195
Total	254	28	72	3.4	10,451

Table 16. Mean length (mm), SE, range, and sample size by sex and age taken from coho salmon at the Big Creek weir, 2004.

	Age				
	1.1	1.2	2.1	2.2	3.1
			Female		
Mean	544	--	579	--	--
SE	36.4	--	22.5	--	--
Minimum	395	--	443	545	570
Maximum	618	--	633	--	--
n	23	--	24	1	1
			Male		
Mean	558	--	586	--	625
SE	27.1	--	22.8	--	15.3
Minimum	425	552	434	--	603
Maximum	660	--	667	--	646
n	57	1	99	--	4
			Total		
Mean	553	--	582	--	619
SE	29.0	--	23.3	--	13.8
Minimum	395	552	409	545	570
Maximum	660	--	667	--	646
n	80	1	125	1	5

Table 17. Summary of public use information collected at the Big Creek weir, 2004.

Category	Number of Groups
Primary Purpose	
Hunting	12
Fishing	3
Secondary Purpose	
Hunting	--
Fishing	2
Other	--
Hunting Target Species	
Moose	5
Bear	--
Small game	3
Reason for Visit	
Subsistence	3
Sport	3
Guide Status	
Guided	1
Not guided	5
Residence	
King Salmon/Naknek	12
Other	1

Table 18. Numbers of fish observed at the Big Creek weir, 2000 to 2004. Data for 2000 to 2002 are from Whitton (2003); data for 2003 are from Anderson et al. (2004).

Species	2004	2003	2002	2001	2000
Chinook salmon	11,906	10,063	4,791	649[a]	1,298
Chum salmon	24,957	33,943	28,812	11,981[a]	3,241
Coho salmon	10,451[a]	9,600	806[a]	4,523	969[a]
Sockeye salmon	189	119	45	38	57
Pink salmon	3,295	873	31	15	80
Dolly Varden	1,529	4,901	347	21[b]	24
Rainbow trout	673	549	24	11[b]	2
Arctic grayling	55	83	3	1[b]	2
Round whitefish	179	210	16	--	4
Northern pike	14	52	1	--	2
Longnose sucker	--	--	--	--	1

[a] Incomplete count due to weir failures.
[b] Numbers observed in trap box.

goal of L = 200 length measurements is achievable, as we were able to measure nearly 600 fish over a 7-d period near the end of the run in 2004. We feel confident from this year's results and modeling of the 2003 data that if enough length samples can be gathered electronically, the ALK will prove to be a viable method to describe the age composition of Chinook salmon. By limiting the required number of fish we need to physically handle to obtain biological data, we can limit potential handling effects on migrating Pacific salmon. One fundamental assumption for this ALK application is that the length at age relationship does not change over the course of the migration, i.e., the length of an age 1.3 Chinook salmon is the same in June as it is in August. We did not collect enough data to test this assumption in 2004.

Chinook salmon age composition in 2004 was similar to that observed in 2000, where age 1.3 fish were the predominant age class (Table 19). The precision (SE) of weekly age and sex estimates for Chinook salmon (Tables 6 and 7) was low compared to previous years due to the smaller weekly sample size goal in 2004 (n = 50) versus goals in previous years (n > 135). The reduced sample size did not allow us to meet the objective for maximum widths of confidence intervals of 0.20 for most ages in most weeks; we did not meet the weekly objective for sex composition precision in any week. However, the age and sex estimates for the entire run were precise. In contrast to 2003, few age 1.1 Chinook salmon (jacks) were observed at the weir, and the sex ratio was nearly 1:1.

Table 19. Chinook salmon sex and composition (%, standard errors in parentheses) sampled at the Big Creek weir, 2000 to 2004. Data for 2000 to 2002 are from Whitton (2003); data for 2003 are from Anderson et al. (2004).

		Age				
Year	Female	1.1	1.2	1.3	1.4	1.5
2000	61 (2.6)	4 (1.1)	34 (2.8)	50 (3.0)	12 (1.8)	< 1
2001	50 (3.7)	2 (1.0)	7 (2.3)	33 (4.0)	56 (4.2)	< 2
2002	34 (2.5)	18 (2.3)	37 (2.9)	22 (2.4)	22 (2.4)	< 2
2003	27 (2.0)	35 (2.0)	25 (2.0)	28 (2.0)	11 (1.0)	< 1
2004	47 (3.7)	4 (1.4)	29 (3.1)	54 (3.5)	12 (2.2)	< 2

In 2004, the age composition of chum salmon sampled at the Big Creek weir was similar to other even-numbered years in that age 0.3 chum salmon did not dominate the sample (Table 20). A larger proportion of age 0.2 chum salmon was observed than in any other year, and fewer age 0.4 fish were observed than in any other even-numbered year. The proportion of female chum salmon in 2004 was similar to 2003, and higher than most previous years (Table 20).

Age 2.1 coho salmon made up the majority of the run in 2004, but were not as dominant as in previous years; a larger proportion of age 1.1 coho salmon was observed than in any other year (Table 21). Improved freshwater rearing conditions in 2002 may have allowed more age 1 coho salmon to reach smolt size than in previous years. The proportion of female coho salmon sampled was the lowest recorded over the course of the project, although similar to the 2000 return (Table 21).

Peak run timing for Chinook salmon in 2004 (early July, Figure 3) was similar to that in 2003 (Anderson et al. 2004) and 2002, but earlier than the peak in 2000 and 2001 (late July, Whitton 2003). Peak run timing of chum salmon in 2004 (early August, Figure 3) was similar to 2003 (Anderson et al. 2004) and 2000, but later than the peak in 2001 and 2002 (early to mid July, Whitton 2003). Peak run timing for coho salmon in 2004 (mid September, Figure 3) was earlier than the observed peak in 2003 (late September; Anderson et al. 2004) and 2001 (Whitton 2003), the only other years the weir was in operation after early September. However, observed coho salmon migration timing in 2004 is not representative of the entire run due to weir failures (Table 4). The escapement estimate for coho salmon in 2004 is also a minimum estimate, as it is likely that numerous fish passed above the weir without being counted during weir failures in August and September.

Table 20. Chum salmon sex and age composition (%, standard errors in parentheses) sampled at the Big Creek weir, 2000 to 2004. Data for 2000 to 2002 are from Whitton (2003); data from 2003 are from Anderson et al. (2004).

		Age				
Year	Female	0.1	0.2	0.3	0.4	0.5
2000	32 (1.7)	--	22 (1.5)	38 (2.0)	38 (1.9)	< 2
2001	27 (1.3)	--	2 (0.5)	93 (0.8)	5 (3.1)	< 1
2002	43 (1.8)	--	10 (1.0)	28 (2.0)	62 (6.5)	< 1
2003	54 (2.0)	< 1	3 (0.6)	91 (0.9)	6 (0.6)	< 2
2004	52 (1.7)	--	33 (1.7)	52 (1.8)	14 (1.2)	< 2

Table 21. Coho salmon sex and age composition (%, standard errors in parentheses) sampled at the Big Creek weir, 2000 to 2004. Data for 2000 to 2002 are from Whitton (2003); data for 2003 are from Anderson et al. (2004).

		Age[a]		
Year	Female	1.1	2.1	3.1
2000	30 (2.6)	9 (1.8)	87 (2.1)	3 (1.1)
2001	50 (1.9)	11 (1.3)	86 (1.4)	2 (0.6)
2002	47 (3.7)	24 (3.6)	72 (3.8)	4 (1.7)
2003	46 (3.0)	16 (2.0)	74 (2.0)	9 (1.0)
2004	28 (3.4)	43 (4.0)	55 (4.1)	2 (0.8)

[a] Table does not include ages 1.2, 2.2, or 4.1 which were less than 1% of the sample in any given year.

The use of underwater video monitoring at the Big Creek weir has produced several benefits. Since 2002, recording the images of fish passing through the video chute allowed the crew to pause the images when necessary to accurately identify and enumerate all species passing through the video chute. Reviewing video files captured with the motion detection requires considerably less time than doing live counts, which could result in reduced labor costs to operate the weir. Although the motion detection capabilities failed due to high passage rates of chum salmon on several occasions, counts were not affected as the crew was able manually record fish passage. The video equipment remains functional during high water events when it is not safe or practical to do a live count. For example, the peak coho salmon count in 2004 (2,641 on 20 September; Appendix A) was captured by the video equipment when water levels and velocities prevented the crew from accessing the trap box to do a live count. Although the weir might not be fish tight during these high water events, the data captured by the video equipment would otherwise not be available. The video equipment has also allowed us to obtain more comprehensive counts of resident fish species than in previous years (Table 18). Small rainbow trout, Dolly Varden, and round whitefish that used to swim between the weir pickets or escape from the trap box without being counted are now swimming through the video chute where we can count and identify them. Finally, the use of underwater video technology has removed much of the variability associated with observation conditions. The video chute provides a controlled lighting environment, and the system design allows it to function well in turbid water conditions.

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Appendix A. Summary of Pacific salmon daily passage at the Big Creek weir, 2004. Chinook salmon less than 508 mm were classified as jacks.

	Chinook			Chum		Coho		Pink	Sockeye
Date	Count	Jacks	Cum	Count	Cum	Count	Cum	Count	Count
22-Jun	0	0	0	0	0	0	0	0	0
23-Jun	4	0	4	1	1	0	0	0	0
24-Jun	5	0	9	6	7	0	0	3	0
25-Jun	6	3	18	48	55	0	0	14	0
26-Jun	0	1	19	15	70	0	0	4	0
27-Jun	77	3	99	171	241	0	0	52	0
28-Jun	56	15	170	164	405	0	0	27	1
29-Jun	620	71	861	213	618	0	0	26	0
30-Jun	27	8	896	29	647	0	0	8	0
1-Jul	607	23	1,526	382	1,029	0	0	55	2
2-Jul	85	4	1,615	91	1,120	0	0	0	0
3-Jul	43	3	1,661	101	1,221	0	0	7	0
4-Jul	265	12	1,938	185	1,406	0	0	17	0
5-Jul	487	16	2,441	339	1,745	0	0	49	0
6-Jul	2	0	2,443	3	1,748	0	0	1	0
7-Jul	402	11	2,856	173	1,921	0	0	56	6
8-Jul	1,577	28	4,461	417	2,338	0	0	129	5
9-Jul	1,728	42	6,231	308	2,646	0	0	167	12
10-Jul	770	20	7,021	270	2,916	0	0	73	4
11-Jul	469	6	7,496	162	3,078	0	0	34	1
12-Jul	902	6	8,404	85	3,163	0	0	42	3
13-Jul	19	2	8,425	32	3,195	0	0	4	7
14-Jul	25	1	8,451	64	3,259	0	0	10	5
15-Jul	70	5	8,526	150	3,409	0	0	0	2
16-Jul	20	0	8,546	113	3,522	0	0	10	1
17-Jul	17	0	8,563	62	3,584	0	0	9	1
18-Jul	135	2	8,700	300	3,884	0	0	71	11
19-Jul	14	1	8,715	335	4,219	0	0	59	6
20-Jul	258	5	8,978	257	4,476	0	0	54	9
21-Jul	394	3	9,375	279	4,755	0	0	102	9
22-Jul	170	2	9,547	227	4,982	0	0	53	2
23-Jul	99	0	9,646	202	5,184	0	0	23	4
24-Jul	17	0	9,663	144	5,328	0	0	9	1
25-Jul	74	1	9,738	305	5,633	0	0	40	1
26-Jul	38	0	9,776	203	5,836	0	0	40	3
27-Jul	23	1	9,800	404	6,240	1	1	131	4
28-Jul	132	4	9,936	210	6,450	0	1	80	5
29-Jul	61	0	9,997	209	6,659	0	1	46	2
30-Jul	114	4	10,115	196	6,855	0	1	68	6
31-Jul	109	1	10,225	348	7,203	0	1	78	4
1-Aug	126	1	10,352	466	7,669	1	2	89	3
2-Aug	249	4	10,605	1,292	8,961	8	10	207	4
3-Aug	262	6	10,873	561	9,522	5	15	94	4
4-Aug	31	2	10,906	640	10,162	17	32	47	1
5-Aug	178	2	11,086	1,491	11,653	40	72	189	1
6-Aug	50	6	11,142	888	12,541	17	89	91	4
7-Aug	52	6	11,200	1,201	13,742	27	116	93	3
8-Aug	125	7	11,332	1,732	15,474	48	164	103	2
9-Aug	52	3	11,387	924	16,398	22	186	62	2
10-Aug	66	7	11,460	1,016	17,414	45	231	82	2
11-Aug	65	2	11,527	1,064	18,478	80	311	66	6
12-Aug	25	2	11,554	855	19,333	88	399	54	5
13-Aug	20	4	11,578	470	19,803	53	452	32	1
14-Aug	9	0	11,587	384	20,187	35	487	19	2
15-Aug	44	2	11,633	890	21,077	124	611	39	6
16-Aug	46	2	11,681	757	21,834	118	729	46	7

Appendix A. continued.

	Chinook			Chum		Coho		Pink	Sockeye
Date	Count	Jacks	Cum	Count	Cum	Count	Cum	Count	Count
17-Aug	27	1	11,709	612	22,446	124	853	45	2
18-Aug	33	13	11,755	470	22,916	106	959	26	2
19-Aug	13	6	11,774	117	23,033	27	986	21	1
20-Aug	12	3	11,789	470	23,503	60	1,046	35	0
21-Aug	2	4	11,795	205	23,708	72	1,118	14	1
22-Aug	2	1	11,798	148	23,856	38	1,156	3	0
23-Aug	11	3	11,812	101	23,957	0	1,156	9	0
24-Aug	2	5	11,819	198	24,155	41	1,197	12	1
25-Aug	12	11	11,842	252	24,407	307	1,504	15	1
26-Aug	4	5	11,851	179	24,586	325	1,829	19	0
27-Aug	0	2	11,853	24	24,610	3	1,832	0	0
28-Aug	0	0	11,853	0	24,610	0	1,832	0	0
29-Aug	5	0	11,858	7	24,617	8	1,840	2	0
30-Aug	7	3	11,868	80	24,697	61	1,901	11	3
31-Aug	2	4	11,874	61	24,758	57	1,958	5	2
1-Sep	7	5	11,886	54	24,812	184	2,142	6	1
2-Sep	6	0	11,892	34	24,846	594	2,736	15	2
3-Sep	4	0	11,896	69	24,915	1,294	4,030	50	1
4-Sep	0	0	11,896	0	24,915	0	4,030	0	0
5-Sep	0	0	11,896	0	24,915	0	4,030	0	0
6-Sep	0	0	11,896	0	24,915	1	4,031	0	0
7-Sep	0	0	11,896	5	24,920	19	4,050	8	0
8-Sep	0	1	11,897	9	24,929	78	4,128	5	0
9-Sep	1	0	11,898	4	24,933	251	4,379	18	0
10-Sep	1	0	11,899	4	24,937	389	4,768	3	0
11-Sep	0	1	11,900	6	24,943	587	5,355	6	0
12-Sep	0	0	11,900	2	24,945	510	5,865	2	0
13-Sep	0	1	11,901	0	24,945	44	5,909	0	0
14-Sep	0	0	11,901	2	24,947	86	5,995	0	1
15-Sep	0	0	11,901	2	24,949	27	6,022	0	0
16-Sep	1	0	11,902	0	24,949	13	6,035	0	0
17-Sep	0	0	11,902	1	24,950	81	6,116	0	0
18-Sep	3	0	11,905	2	24,952	140	6,256	0	0
19-Sep	0	0	11,905	3	24,955	1,459	7,715	0	0
20-Sep	1	0	11,906	0	24,955	2,641	10,356	0	1
21-Sep	0	0	11,906	0	24,955	1	10,357	0	0
22-Sep	0	0	11,906	0	24,955	29	10,386	0	0
23-Sep	0	0	11,906	0	24,955	0	10,386	0	0
24-Sep	0	0	11,906	0	24,955	0	10,386	0	0
25-Sep	0	0	11,906	1	24,956	12	10,398	0	0
26-Sep	0	0	11,906	1	24,957	20	10,418	0	0
27-Sep	0	0	11,906	0	24,957	13	10,431	1	0
28-Sep	0	0	11,906	0	24,957	20	10,451	0	0
29-Sep	0	0	11,906	0	24,957	0	10,451	0	0
Total:	**11,477**	**429**	**11,906**		**24,957**		**10,451**	**3,295**	**189**

Appendix B. Summary of Dolly Varden (DV), rainbow trout (RT), round whitefish (WF), Arctic grayling (AG), and northern pike (NP) passage at the Big Creek weir, 2004.

Date	DV	RT	WF	AG	NP
22-Jun	0	5	1	0	0
23-Jun	0	4	7	3	0
24-Jun	2	4	0	1	0
25-Jun	1	1	4	5	0
26-Jun	4	5	2	7	0
27-Jun	11	3	15	0	0
28-Jun	19	7	15	5	2
29-Jun	65	4	5	0	0
30-Jun	32	2	3	0	0
1-Jul	68	28	2	3	0
2-Jul	28	26	3	2	0
3-Jul	17	2	1	1	0
4-Jul	47	3	0	3	0
5-Jul	87	4	2	2	0
6-Jul	2	1	1	1	0
7-Jul	232	11	0	2	0
8-Jul	152	5	2	3	0
9-Jul	117	5	7	5	0
10-Jul	89	7	1	0	0
11-Jul	32	2	2	1	0
12-Jul	60	5	1	0	0
13-Jul	19	1	0	0	0
14-Jul	4	4	0	0	0
15-Jul	2	1	1	0	0
16-Jul	2	1	0	0	1
17-Jul	1	1	0	0	1
18-Jul	43	1	0	0	0
19-Jul	15	3	0	1	0
20-Jul	38	6	0	0	0
21-Jul	32	6	0	0	0
22-Jul	7	2	0	0	1
23-Jul	18	13	2	0	0
24-Jul	2	1	0	0	0
25-Jul	2	6	0	0	0
26-Jul	11	4	0	0	0
27-Jul	1	2	0	0	0
28-Jul	4	6	0	0	0
29-Jul	4	14	0	0	0
30-Jul	11	10	0	0	0
31-Jul	9	9	0	0	0
1-Aug	11	7	1	0	0
2-Aug	19	7	0	0	0
3-Aug	5	12	0	1	0
4-Aug	11	6	1	0	0
5-Aug	8	13	5	0	0
6-Aug	4	11	0	0	0
7-Aug	5	23	0	0	0
8-Aug	9	12	1	1	0
9-Aug	5	6	1	0	0
10-Aug	8	26	0	0	0
11-Aug	3	13	0	0	0
12-Aug	3	12	0	0	0
13-Aug	2	14	1	0	0
14-Aug	2	7	0	0	0
15-Aug	1	9	0	0	0
16-Aug	3	22	0	0	0
17-Aug	5	16	4	1	2

Appendix B. continued.

Date	DV	RT	WF	AG	NP
18-Aug	5	12	1	0	1
19-Aug	15	18	1	0	0
20-Aug	3	6	1	0	0
21-Aug	2	7	0	0	0
22-Aug	2	4	0	1	0
23-Aug	3	4	0	0	0
24-Aug	3	9	0	0	0
25-Aug	2	6	0	0	1
26-Aug	1	5	1	0	0
27-Aug	0	1	1	0	0
28-Aug	0	1	0	0	0
29-Aug	0	0	0	0	0
30-Aug	6	1	2	0	0
31-Aug	5	6	2	0	1
1-Sep	2	4	1	0	0
2-Sep	7	3	0	0	0
3-Sep	18	11	0	1	0
4-Sep	0	0	0	0	0
5-Sep	0	0	0	0	0
6-Sep	0	0	0	0	0
7-Sep	2	1	0	1	1
8-Sep	5	8	2	1	1
9-Sep	3	8	0	0	0
10-Sep	6	6	1	0	0
11-Sep	3	6	2	0	0
12-Sep	1	8	2	0	0
13-Sep	1	5	0	0	0
14-Sep	1	5	9	0	0
15-Sep	1	4	4	0	0
16-Sep	3	3	0	0	0
17-Sep	2	3	5	0	0
18-Sep	5	6	4	0	0
19-Sep	7	8	4	2	0
20-Sep	10	30	30	1	1
21-Sep	1	1	0	0	0
22-Sep	5	6	3	0	0
23-Sep	0	0	0	0	0
24-Sep	0	0	0	0	0
25-Sep	0	8	6	0	1
26-Sep	2	7	0	0	0
27-Sep	3	2	1	0	0
28-Sep	0	7	4	0	0
29-Sep	0	2	1	0	0
Total:	**1,529**	**673**	**179**	**55**	**14**