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Abundance and Run Timing of Pacific Salmon in Gertrude Creek, Becharof National Wildlife Refuge, Alaska, 1997-1999

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Cheryl A. Dion and Nicholas J. Hetrick

Abstract

A bidirectional fish weir was installed and operated near the mouth of Gertrude Creek, Becharof National Wildlife Refuge from 1997 to 1999. Chum salmon *Oncorhynchus keta* were the most abundant species counted through the weir in 1997 (*N*=11,133), 1998 (*N*=11,821) and 1999 (*N*=16,992), followed by Chinook *O. tshawytscha* (*N*=1,335, *N*=1,646, *N*=1,171), pink *O. gorbuscha* (*N*=1,290, *N*=2,492, *N*=1,131), coho *O. kisutch* (*N*=614, *N*=950, *N*=293) and sockeye salmon *O. nerka* (*N*=15, *N*=13, *N*=19). Chum salmon were the first fish to migrate past the weir beginning in June followed by Chinook, sockeye, pink, and coho salmon. Pink and coho salmon were still migrating past the weir when it was removed each fall. The sex composition of chum, Chinook, coho, and pink salmon was dominated by males. Predominate age classes for chum (age 0.3 and 0.4), Chinook (age 1.3), and coho (age 2.1) salmon were similar to other populations in Bristol Bay. Chinook and coho salmon lengths varied considerably between years, whereas chum salmon lengths did not show much annual variation.

Introduction

The U.S. Fish and Wildlife Service conducted a study from 1997 to 1999 to assess salmon populations in Gertrude Creek. This was conducted ancillary to another study which assessed the status of rainbow trout *Oncorhynchus mykiss* in Gertrude Creek and determined the degree of bias in assessing rainbow trout populations using hook and line sampling techniques (Hetrick and Bromaghin, 2006). A bidirectional weir was installed and operated to intercept the up and downstream migration of resident species from ice out in April to late September. Since the weir would also intercept the salmon migration and knowledge of salmon abundance and run timing were lacking in Gertrude Creek, the weir provided an opportunity to gather valuable salmon migration and life history information. Previous population assessment information for Pacific salmon (Russell 1983) and resident fish in Gertrude Creek is limited (Russell 1977 and 1983; Adams 1999). The Alaska Department of Fish and Game performs aerial surveys on the major tributaries of the King Salmon River drainage in early August each year to monitor abundance of Chinook *O. tshawytscha*, coho *O. kisutch*, and chum *O. keta* salmon. These counts are only an index of abundance based on counts of fish sighted, not escapement estimates.

Pacific salmon populations from Gertrude Creek are harvested in the commercial fishery near Egegik. The commercial fishery primarily targets sockeye salmon *O. nerka*, other Pacific salmon species are caught incidentally, yet in some years coho salmon are targeted. From 1990 to 1999, the average annual harvest from the Egegik district was 76,495 chum, 36,592 coho, 2,626 pink *O. gorbuscha*, and 1,033 Chinook salmon (Sands et al. 2002). Based on aerial survey data from the King Salmon and Egegik rivers, about 35% of the Chinook salmon and 39% of the chum salmon spawn in Gertrude Creek (Browning et al. 2002). To maintain healthy populations, stocks that are exploited need to be assessed and monitored to ensure effective management. In addition, Section 302 of the Alaska National Interest Lands Conservation Act (ANILCA)

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mandates that Becharof National Wildlife Refuge be managed to "conserve fish and wildlife populations and habitats in their natural diversity" (USFWS, 1994). To conserve Pacific salmon stocks in Gertrude Creek, managers need escapement and run timing data along with sex and age composition throughout the migratory period. Data generated from this study will be used as a benchmark to compare future monitoring efforts and determine trends in population size and structure. Specific objectives of the project were to (1) estimate the abundance, run timing, length composition, and sex composition of Chinook, sockeye, coho, chum, and pink salmon in Gertrude Creek; and (2) estimate the age compositions of Chinook, coho and chum salmon in Gertrude Creek.

Study Area

Gertrude Creek flows through Becharof National Wildlife Refuge in southwest Alaska (Figure 1). This third-order, clear-water stream is a tributary to the King Salmon River, a glacially-turbid river originating in the Kejulik Mountains in Katmai National Park. Gertrude Creek empties into the King Salmon River about 90 km upstream from its confluence with the Egegik River at Egegik Bay. Gertrude Creek supports resident populations of rainbow trout, Arctic grayling *Thymallus arcticus*, round whitefish *Prosopium cylindraceum*, and Dolly Varden *Salvelinus malma*, as well as populations of Chinook, chum, coho, and pink salmon. Sockeye salmon and northern pike *Esox lucius* are also found in the drainage. The diversity of species in the stream coupled with its close proximity to King Salmon (about 60 km) and accessibility by float or wheel plane, has made Gertrude Creek a popular sport fishery.

Methods

Weir Operations

A bidirectional weir was installed near the mouth of Gertrude Creek in mid April 1997 and 1998 and early May 1999 that captured both upstream and downstream migrant fishes. The weir was constructed from 12 mm diameter electrical metal tubing pickets separated by 19 mm lengths of polyvinyl chloride pipe. Pickets and spacers were strung together with 4 mm diameter steel cable to make 3 m long panels, measuring either 1.0 or 1.5 m high. The bottom ends of panels were pushed into the substrate, and the tops were lowered onto a 9.5 mm diameter cable spanning the channel. Weir panels were angled about 45 degrees in relation to the stream bed to shunt debris to the water surface, thereby maintaining free flow of water through the pickets and to aid in cleaning debris from the weir. The weir was installed diagonally across the channel at about a 45 degree angle to direct upstream and downstream migrant fishes to opposite sides of the stream. A fyke was installed on each side of the weir to guide and subsequently trap fish in upstream and downstream holding pens. Holding pens were positioned as close to the stream banks on opposite sides of the channel as adequate depth and velocity would allow. Depth in the holding pens was greater than 0.5 m to minimize escapement of fish from pens. At a minimum, the entire weir was inspected, cleaned, and maintained daily to insure integrity.

A 0.2 to 1.0 m wide adjustable gate was installed on the weir near the upstream holding pen to expedite upstream passage and minimize the need for trapping and holding salmon. A contrasting substrate was placed on the stream bottom in front of the gate to enhance visibility of fish and to facilitate species identification as they passed through the counting panel. The door of the gate, when open, was positioned to help block downstream movement of resident fishes through the opening in the weir.

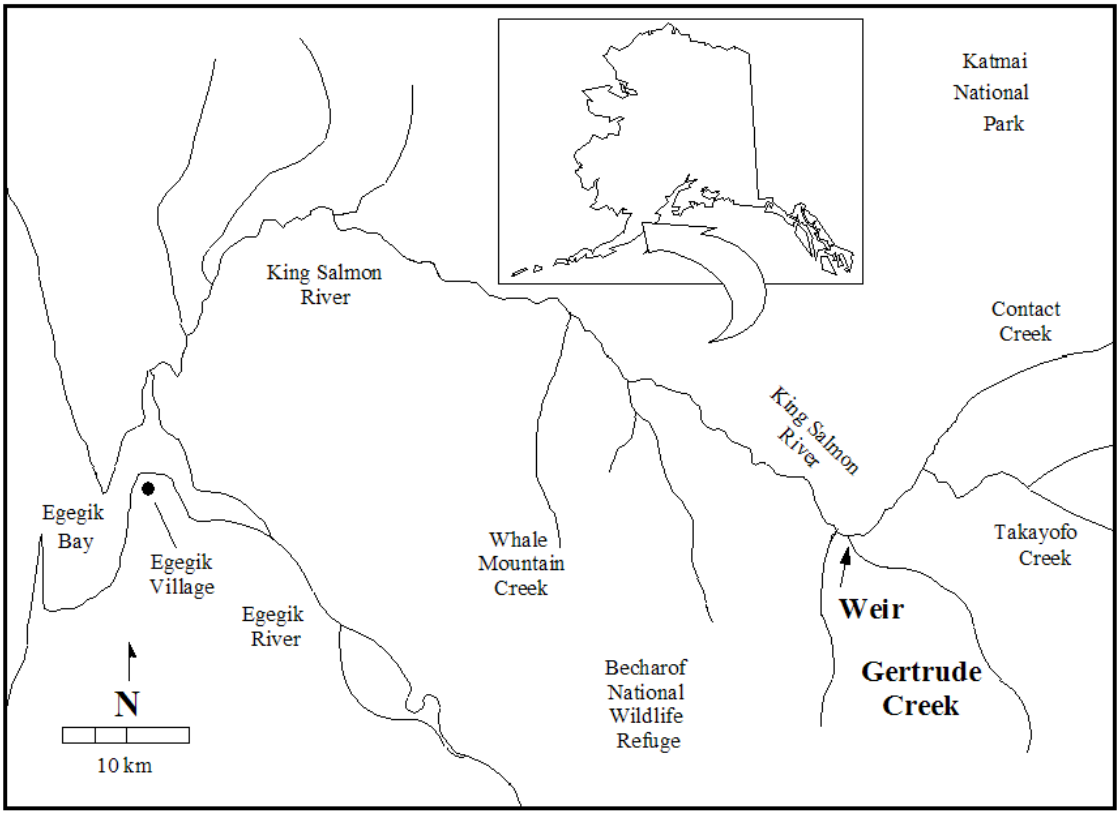

Figure 1. Gertrude Creek weir location, Becharof National Wildlife Refuge, 1997-1999.

Water Temperature

An electronic temperature recorder was installed near the weir to monitor water temperatures in Gertrude Creek. The recorder was programmed to record temperatures (˚C) hourly, which was later summarized to daily maximum, mean, and minimum temperatures.

Biological Data

Length and sex data were collected from all five species of Pacific salmon and age data were collected from Chinook, chum, and coho salmon. Biological data were collected using a temporally stratified sampling design (Cochran 1977), with statistical weeks defining strata. Salmon species were sampled weekly for biological information, and to the extent logistically feasible, samples were collected uniformly throughout the week (Monday through Sunday). When collections occurred, all target species within the pen were sampled, even if the weekly sample size goal for a species was exceeded. This was done to avoid potential bias that may result from selective netting of individual fish from the pen. During weeks of low passage when the maximum sample size goal could not be obtained, about 10-20% of the weekly escapement was sampled. Salmon passing the weir in excess of the weekly sample size goals were not sampled and instead, counted as they passed over the contrasting substrate panel positioned in front of the adjustable gate.

Samples for biological data were collected using a dip net to remove fish from the holding pen. Fish were sampled at least twice a day or more frequently as the number of fish moving through the weir increased. Salmon were sampled for length (mid-eye to tail fork), identified to sex using secondary sexual characteristics, and had scales collected for age analysis. The number of scales extracted varied per species, one scale was sampled from chum salmon and three scales were sampled from Chinook and coho salmon. Scales were extracted from the preferred area on the left side of adult salmon (Jearld 1983). Scale samples were cleaned and mounted on gummed scale cards. The cards were later pressed and aged. Scales were read by two independent readers and discrepancies were resolved in conference or discarded if they were not resolved. Salmon ages were reported according to the European method (Koo 1962), where the number on the left side of the decimal indicates the number of winters spent in fresh water and the number on the right side indicates the number of winters spent in salt water. Fish that could not be aged were not included in age analyses and fish where sex could not be determined were not included in sex analyses. Salmon that were collected in the downstream trap (n=6) were dropped from all analyses.

Data Analysis

Although sample collection was stratified by statistical week a priori, age data were analyzed post season to calculate age composition estimates for the entire escapement, rather than for individual strata. Weekly passage totals for each salmon species were used to derive weekly sub-sample sizes necessary to estimate age compositions within a specified level of precision (0.05). A common stratum sample size was selected so that the maximum width of a confidence interval for a single age class would not exceed a specified value, assuming the worst case scenario that the age class might comprise 50% of the escapement (Cochran 1977, Bromaghin 1993). Starting with a sample size of 1 from each stratum, the sample size was increased by 1 in each stratum, unless the result would exceed the number of scales available in a particular stratum, until the confidence interval width became less than the specified maximum. A random sample of the identified size was taken from the available scales within each stratum and the selected scales were aged.

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

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

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

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

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, where

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

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

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

Results

Weir Operations

1997— Gertrude Creek was ice-free on 18 April when the weir was installed and first operational. Water remained low and clear throughout the season due to infrequent rain and the weir did not become inoperable until it was removed on 18 September due to high water.

Chum salmon (*N*=11,133) were the most abundant species counted through the weir in 1997 followed by Chinook (*N*=1,335), pink (*N*=1,290), coho (*N*=651), and sockeye salmon (*N*=15) (Appendix D). Chum salmon were counted at the weir from 1 June to 10 September, with a peak of 807 (or 7% of the run) on 30 June (Figure 2; Appendix D). Chinook salmon were counted at the weir from 1 July to 8 September, with a peak of 184 (or 14% of the run) on 20 July (Figure 3; Appendix D). Pink salmon were counted at the weir from 7 July to 17 September, with a peak of 65 (or 5% of the run) on 6 September (Figure 4; Appendix D). Pink salmon were still being counted at the weir before it was removed on 18 September; therefore, counts of pink salmon were incomplete. Coho salmon were counted at the weir from 15 August to 17 September, with a peak of 213 (or 33% of the run) on 8 September (Figure 5; Appendix D). Coho salmon were still being counted at the weir when it was removed on 18 September; therefore, counts of coho salmon were incomplete. Sockeye salmon were counted at the weir from 2 July to 9 September.

1998— Gertrude Creek was again ice-free when the weir began operation on 14 April. Frequent storms during the summer months, typical in southwest Alaska, kept the water level higher in 1998 than in 1997. The weir was down on 4 occasions (9 – 12 and 16 – 18 May, 27 May – 10 June, and 26 – 27 August) due to high flows. The weir was removed on 18 September, following high flows that topped the structure.

Chum salmon (*N*=11,821) were the most abundant species counted through the weir in 1998 followed by Chinook (*N*=1,646), pink (*N*=2,492), coho (*N*=950), and sockeye salmon (*N*=13) (Appendix E). Chum salmon were counted at the weir from 12 June to 6 September, with a peak of 681 (or 6% of the run) on 15 July (Figure 2; Appendix E). Chinook salmon were counted at the weir from 20 June to 13 September, with a peak of 293 (or 18% of the run) on 26 July (Figure 3; Appendix E). Pink salmon were counted at the weir from 9 July to 17 September,

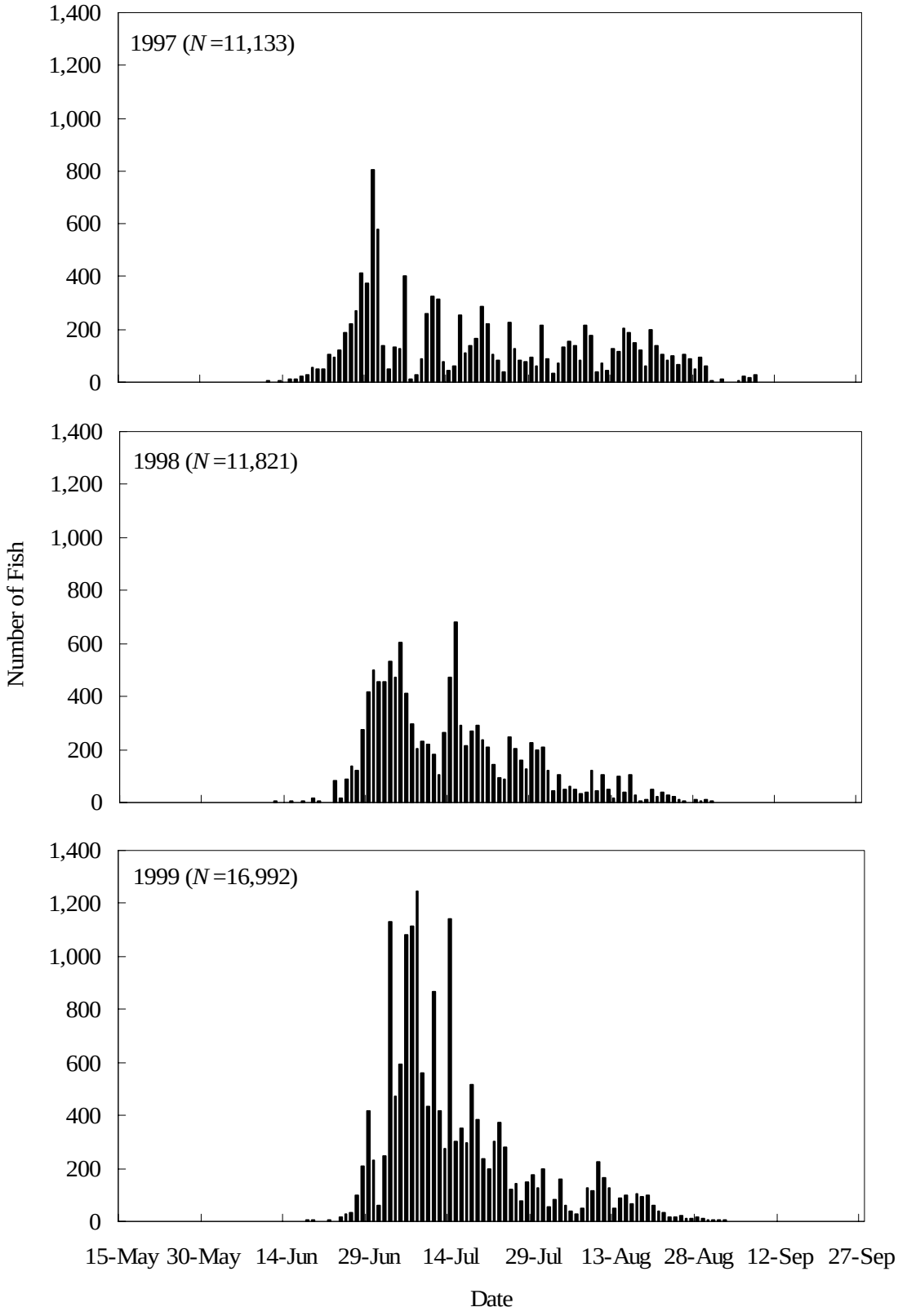

Figure 2. Daily counts of chum salmon at the Gertrude Creek weir, 1997-1999.

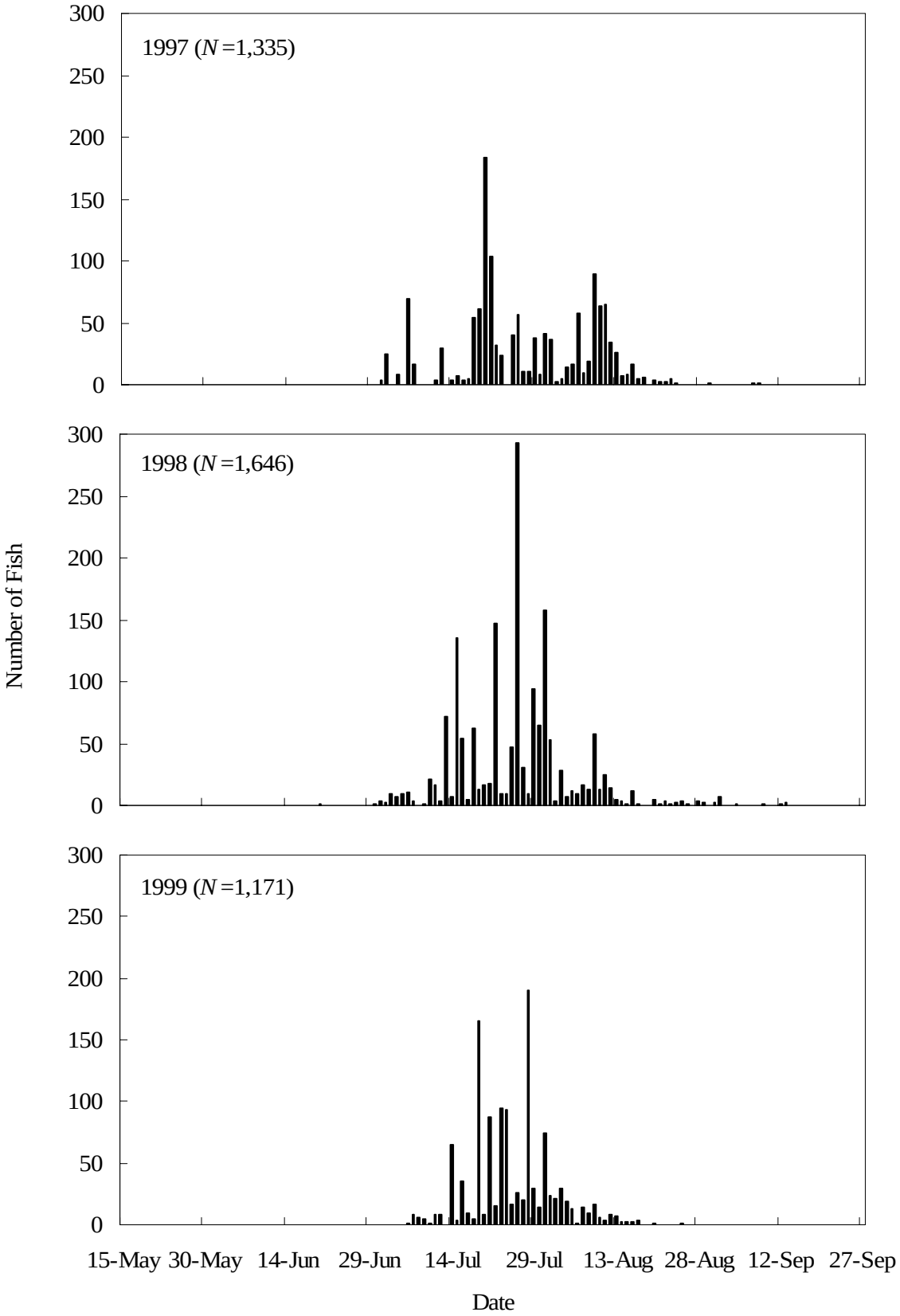

Figure 3. Daily counts of Chinook salmon at the Gertrude Creek weir, 1997-1999.

with a peak of 250 (or 10% of the run) on 29 July (Figure 4; Appendix E). Pink salmon were still being counted at the weir before it was removed on 18 September; therefore, counts of pink salmon were incomplete. Coho salmon were counted at the weir from 7 August to 17 September, with a peak of 432 (or 33% of the run) on 17 September (Figure 5; Appendix E). Coho salmon were still being counted at the weir before it was removed on 18 September; therefore, counts of coho salmon were incomplete. Sockeye salmon were counted at the weir from 18 July to 8 September.

1999— When the weir was installed on 6 May 1999, Gertrude Creek was mostly covered with ice starting about 3 km upstream of the weir. Flow remained relatively high throughout the season. The weir was down on 5 occasions (11, 20 – 25, and 30 – 31 May, 2 – 3 and 7 – 11 June) due to ice break-up and high flows. The weir was topped by high flows on 13 September and subsequently removed.

Chum salmon (*N*=16,992) were the most abundant species counted through the weir in 1999 followed by Chinook (*N*=1,171), pink (*N*=1,131), coho (*N*=293), and sockeye salmon (*N*=19) (Appendix F). Chum salmon were counted at the weir from 16 June to 8 September, with a peak of 1,248 (or 7% of the run) on 8 July (Figure 2; Appendix F). Chinook salmon were counted at the weir from 6 July to 20 August, with a peak of 190 (or 16% of the run) on 28 July (Figure 3; Appendix F). Pink salmon were counted at the weir from 17 July to 12 September, with a peak of 131 (or 12% of the run) on 10 August (Figure 4; Appendix F). Pink salmon were still being counted at the weir before it was removed on 13 September; therefore, counts of pink salmon were incomplete. Coho salmon were counted at the weir from 12 August to 12 September, with a peak of 97 (or 33% of the run) on 5 September (Figure 5; Appendix F). Coho salmon were still being counted at the weir before it was removed on 13 September; therefore, counts of coho salmon were incomplete. Sockeye salmon were counted at the weir from 14 July to 9 September.

Water Temperature

Water temperatures increased progressively over time but fluctuated greatly on a daily or weekly basis throughout the study (Figure 6). In 1997, temperatures peaked at the weir on 29 June with a maximum temperature of 19.2˚C. In 1998, water temperatures peaked on 31 July with a maximum temperature of 13.4˚C and in 1999, water temperatures peaked on 30 July with a maximum temperature of 14.1˚C.

Biological Data

1997— Age, sex, and length data were collected from 1,446 chum salmon in 1997 and 494 were sub-sampled for age analysis. Scales from 11 fish (2%) were either illegible or regenerated. Four age classes were identified from scales collected in 1997 (Table 1). The majority of the run consisted of age 0.3 and 0.4 fish, and females comprised 38% of the sample (Table 2). Chum salmon lengths ranged from 486 to 647 mm for females and from 489 to 700 mm for males (Table 3).

Biological data were collected from 452 Chinook salmon in 1997 and 199 scales were sub-sampled for age analysis. Scales from 2 fish (1%) were either illegible or regenerated. Five age classes were identified from scales collected in 1997 (Table 4), with the majority of the run consisting of age 1.3 fish. Females comprised 35% of the sample (Table 2). Chinook salmon lengths ranged from 573 to 924 mm for females and from 319 to 942 mm for males (Table 5).

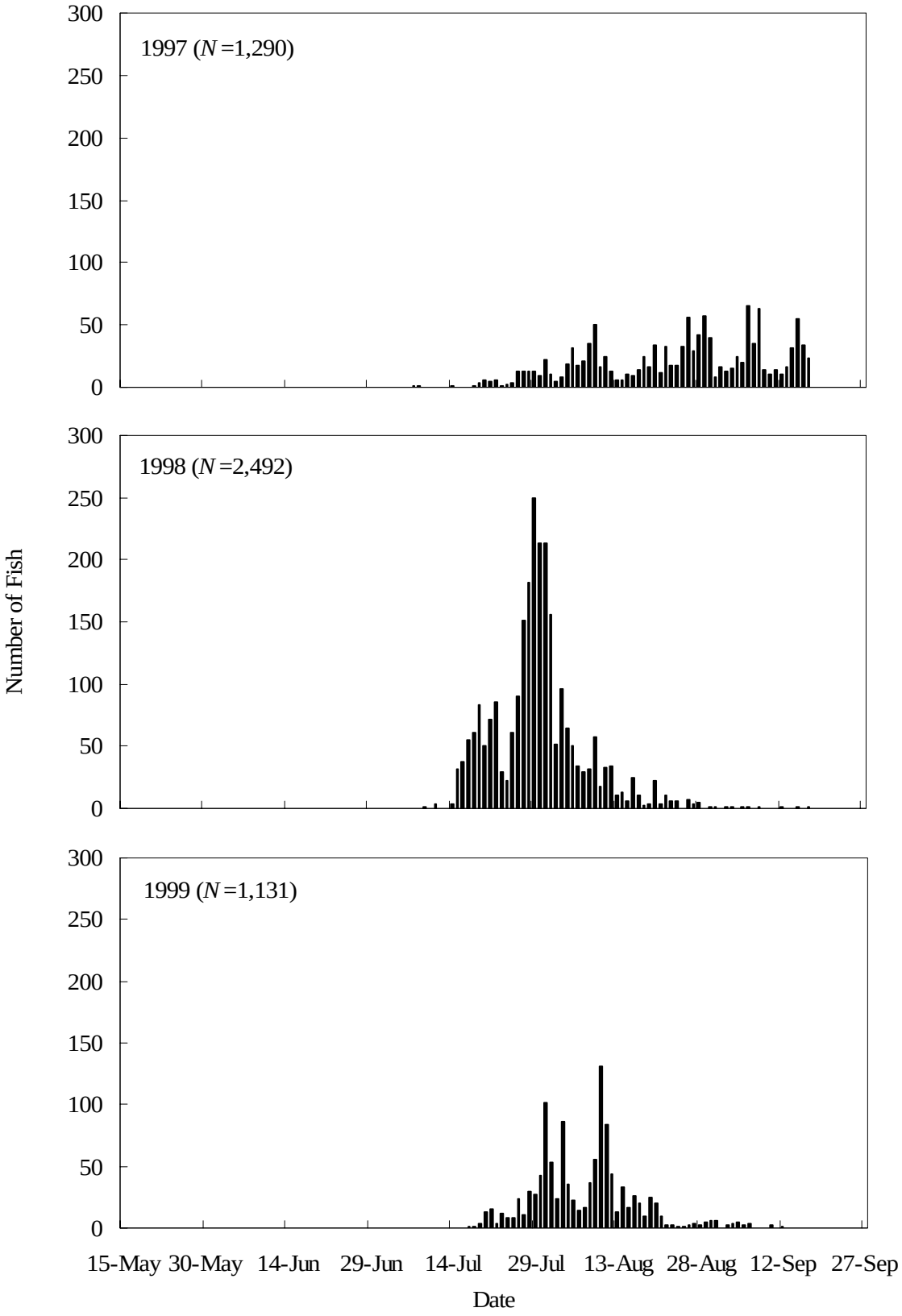

Figure 4. Daily counts of pink salmon at the Gertrude Creek weir, 1997-1999.

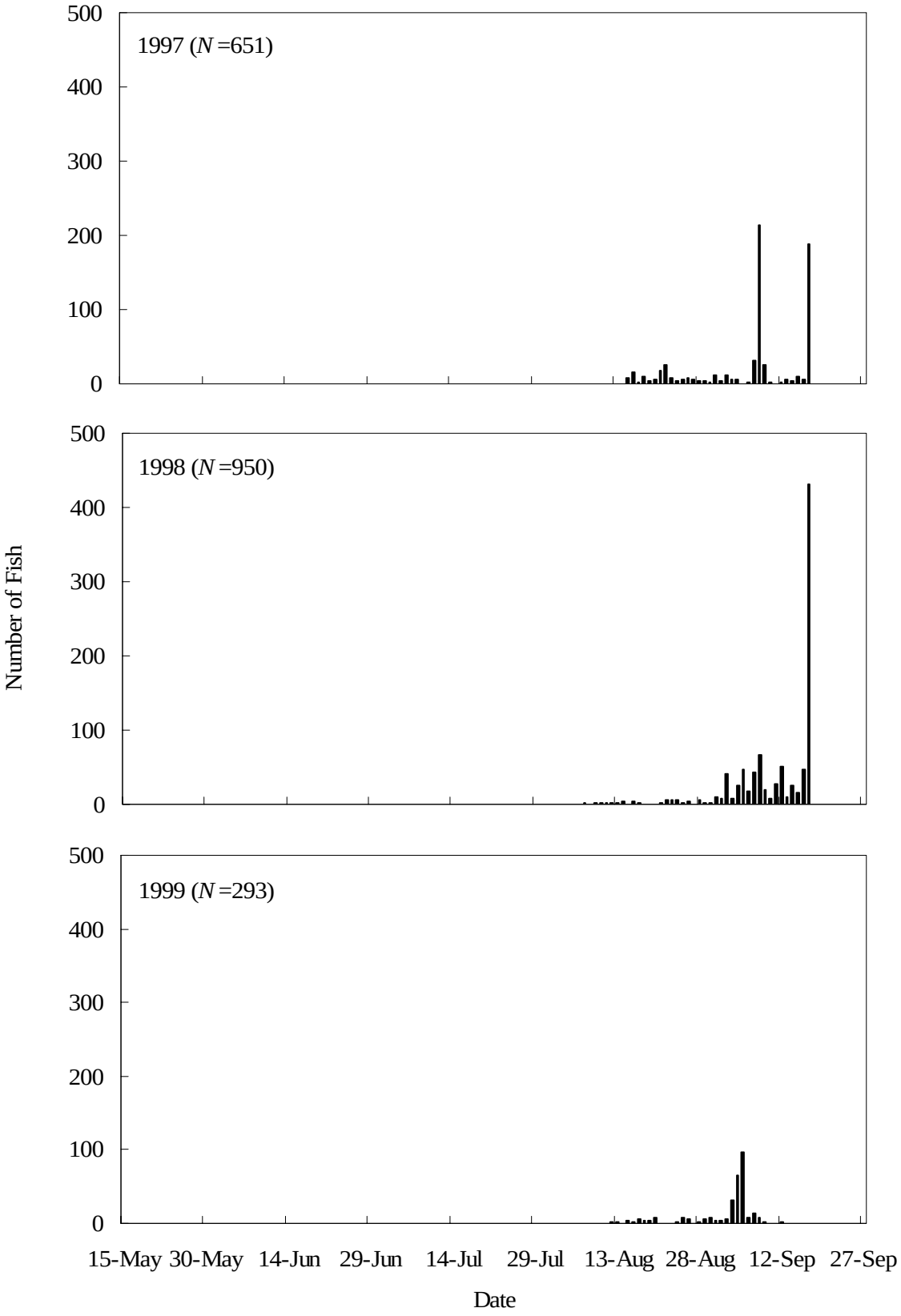

Figure 5. Daily counts of coho salmon at the Gertrude Creek weir, 1997-1999.

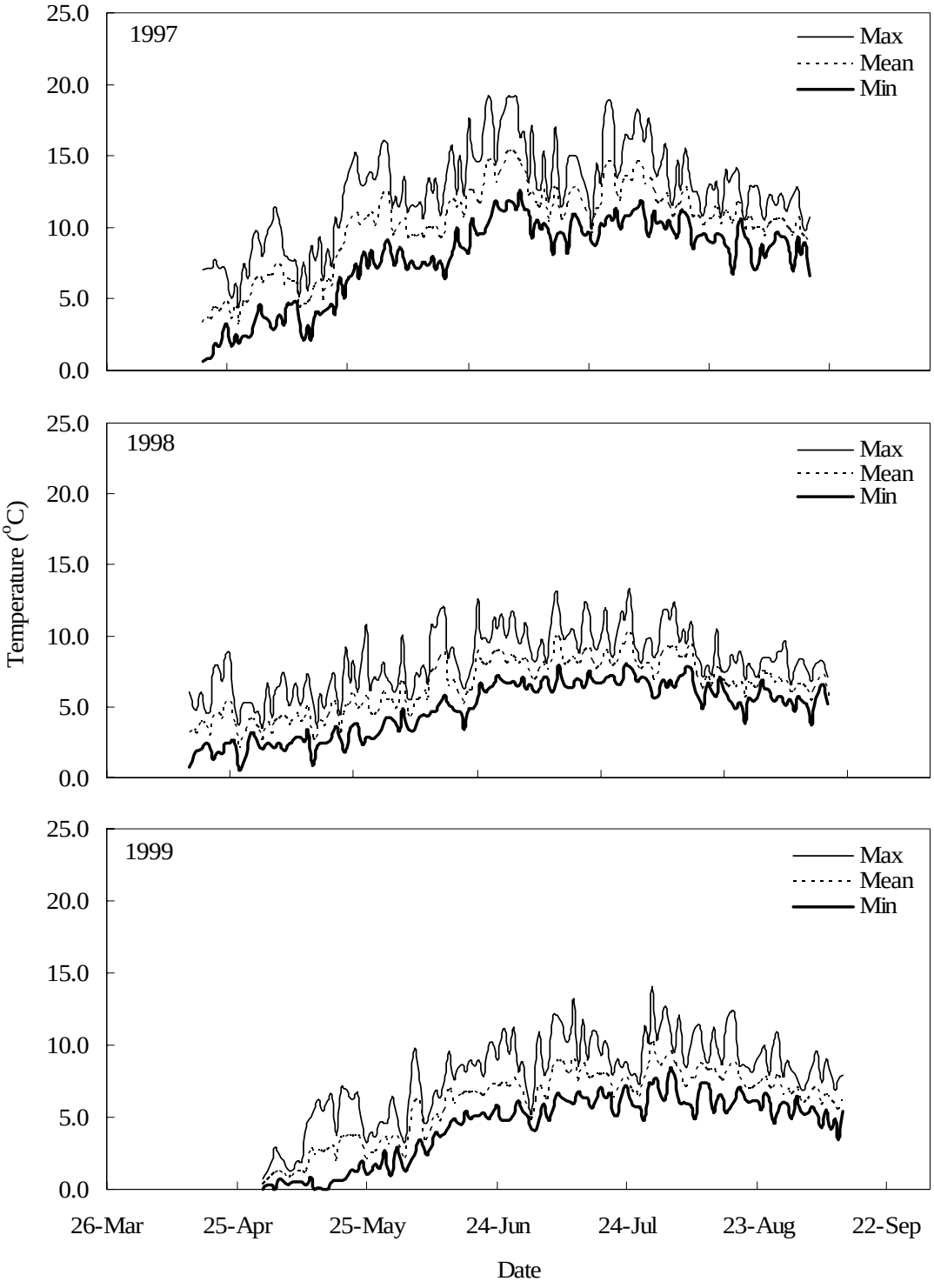

Figure 6. Maximum, mean, and minimum daily water temperatures (˚C) in Gertrude Creek, 1997-1999.

Table 1. Estimated age composition and standard error of chum salmon sampled at the Gertrude Creek weir, 1997-1999.

	Age Class				
	0.1	0.2	0.3	0.4	0.5
			1997		
%	--	2	37	60	1
SE	--	0.5	1.9	1.9	0.5
N	--	12	217	262	3
			1998		
%	--	2	58	34	6
SE	--	0.7	2.4	2.3	1.2
N	--	34	409	221	34
			1999		
%	<1	<1	72	27	1
SE	0.01	0.2	2.3	2.3	0.3
N	1	2	561	164	5

Table 2. Estimated sex composition, sample size, standard error, and escapement of Pacific salmon sampled at the Gertrude Creek weir, 1997.

Species	*N*	Female (%)	Male (%)	SE (%)	Escapement
Chum	1,444	38	62	1.3	11,133
Chinook	431	35	65	2.8	1,335
Coho	227	39	61	5.3	651
Pink	251	34	66	2.9	1,290
Sockeye	6	34	66	20.9	15

Table 3. Mean, standard error, minimum, maximum, and sample size of length (mm) by age class for chum salmon sampled at the Gertrude Creek weir, 1997.

	Age Class			
	0.2	0.3	0.4	0.5
		Female		
Mean	527	560	589	--
SE	8.6	9.4	10.0	--
Min	486	502	503	606
Max	549	625	647	--
N	5	89	111	1
		Male		
Mean	532	585	616	587
SE	21.4	11.3	11.2	--
Min	490	489	536	586
Max	570	660	700	596
N	7	128	151	2
		Total		
Mean	530	575	604	593
SE	15.9	10.9	11.9	--
Min	486	489	503	586
Max	570	660	700	606
N	12	217	262	3

Table 4. Estimated age composition and standard error of Chinook salmon sampled at the Gertrude Creek weir, 1997-1999.

	Age Class					
	1.1	1.2	1.3	1.4	1.5	2.4
			1997			
%	17	21	38	21	3	--
SE	3.1	3.3	3.4	3.2	1.6	--
N	24	44	91	36	4	--
			1998			
%	20	13	38	25	4	--
SE	2.8	2.5	3.7	3.3	1.5	--
N	64	32	76	49	8	--
			1999			
%	12	13	27	38	9	<1
SE	3.2	3.5	3.9	3.1	1.9	0.1
N	21	16	56	100	24	1

Table 5. Mean, standard error, minimum, maximum, and sample size of length (mm) by age class for Chinook salmon sampled at the Gertrude Creek weir, 1997.

	Age Class				
	1.1	1.2	1.3	1.4	1.5
			Female		
Mean	--	679	802	806	807
SE	--	29.0	20.2	26.2	--
Min	586	573	622	700	770
Max	--	762	885	924	834
N	1	9	44	26	4
			Male		
Mean	438	622	737	849	--
SE	28.3	33.9	27.9	36.2	--
Min	319	419	526	763	--
Max	624	800	873	942	--
N	22	31	46	10	--
			Total		
Mean	441	629	768	817	807
SE	27.8	31.4	27.0	28.2	--
Min	319	419	526	700	770
Max	624	800	885	942	834
N	24	44	91	36	4

Biological data were collected from 227 coho salmon in 1997 and 176 scales were sampled for age analysis. Scales from 49 fish (22%) were either illegible or regenerated. Six age classes were identified from scales collected in 1997 (Table 6) and the majority of the run consisted of age 2.1 fish. Females comprised 39% of the sample (Table 2). Coho salmon lengths ranged from 369 to 650 mm for females and from 309 to 674 mm for males (Table 7).

Length and sex data were collected from 251 pink salmon in 1997 and females comprised 34% of the sample (Table 2). The mean length was 440 mm for females and 426 mm for males. Pink salmon lengths ranged from 373 to 538 mm for females and from 328 to 545 mm for males. One pink salmon was captured in the downstream trap.

Length and sex data were collected from 6 sockeye salmon in 1997 and females comprised 34% of the sample (Table 2). Sockeye salmon lengths ranged from 563 to 599 mm for females and from 539 to 629 mm for males.

1998— Age, sex, and length data were collected from 1,451chum salmon in 1998 and 698 scales were sub-sampled for age analysis. Scales from 11 fish (2%) were either illegible or regenerated. Four age classes were identified from scales collected in 1998 (Table 1). The majority of the run consisted of age 0.3 and 0.4 fish, and females comprised 45% of the sample (Table 8). Chum salmon lengths ranged from 470 to 666 mm for females and from 490 to 782 mm for males (Table 9).

Biological data were collected from 385 Chinook salmon in 1998 and 229 scales were sub-sampled for age analysis. Scales from 36 fish (14%) were either illegible or regenerated. Five age classes were identified from scales collected in 1998 (Table 4). The majority of the run consisted of age 1.3 and 1.4 fish and females comprised 40% of the sample (Table 8). Chinook salmon lengths ranged from 391 to 898 mm for females and from 329 to 916 mm for males (Table 10).

Biological were collected from 379 coho salmon in 1998 and 203 coho salmon scales were sub-sampled for age analysis. Scales from 12 fish (6%) were either illegible or regenerated. Four age classes were identified from scales collected in 1998 (Table 6). The majority of the run consisted of age 2.1 fish, and females comprised 39% of the sample (Table 8). Coho salmon lengths ranged from 431 to 670 mm for females and from 426 to 678 mm for males (Table 11).

Length and sex data were collected from 503 pink salmon in 1998 and females comprised 49% of the total sample (Table 8). The mean length was 414 mm for females and 409 mm for males. Pink salmon lengths ranged from 343 to 549 mm for females and from 310 to 549 mm for males. Four pink salmon were captured in the downstream trap.

Length and sex data were collected from 12 sockeye salmon in 1998 and females comprised 17% of the total sample (Table 8). Sockeye salmon lengths ranged from 395 to 499 mm for females and from 323 to 432 mm for males. One sockeye salmon was captured in the downstream trap.

1999— Age, sex, and length data were collected from 1,243 chum salmon in 1999 and 732 scales were sub-sampled for age analysis. Scales from 23 fish (3%) were either illegible or regenerated. Four age classes were identified from scales collected in 1999 (Table 1). The majority of the run consisted of age 0.3 and 0.4 fish, and females comprised 45% of the sample (Table 12). Chum salmon lengths ranged from 470 to 674 mm for females and from 519 to 687 mm for males (Table 13).

Table 6. Estimated age composition and standard error of coho salmon sampled at the Gertrude Creek weir, 1997-1999.

	Age Class					
	1.1	1.2	2.0	2.1	2.2	3.1
			1997			
%	20	3	--	71	5	<1
SE	5.1	0.8	--	5.3	1.8	--
N	28	8	--	127	12	1
			1998			
%	25	3	1	68	2	--
SE	3.4	1.6	0.5	3.7	1.0	--
N	52	5	1	139	6	--
			1999			
%	11	1	--	81	1	4
SE	5.1	0.3	--	6.0	0.4	3.7
N	10	3	--	59	3	2

Table 7. Mean, standard error, minimum, maximum, and sample size of length (mm) by age class for coho salmon sampled at the Gertrude Creek weir, 1997.

	Age Class				
	1.1	1.2	2.1	2.2	3.1
			Female		
Mean	470	530	575	621	--
SE	54.0	46.4	32.8	9.1	--
Min	369	447	428	604	419
Max	611	616	650	635	--
N	10	4	56	6	1
			Male		
Mean	462	496	574	640	--
SE	64.2	6.6	34.3	2.0	--
Min	309	460	391	566	--
Max	592	520	674	663	--
N	18	4	71	6	--
			Total		
Mean	463	513	575	633	--
SE	58.1	30.4	31.9	5.2	--
Min	309	447	391	566	419
Max	611	616	674	663	--
N	28	8	127	12	1

Table 8. Estimated sex composition, sample size, standard error, and escapement of Pacific salmon sampled at the Gertrude Creek weir, 1998.

Species	*N*	Female (%)	Male (%)	SE (%)	Escapement
Chum	1,447	45	55	1.6	11,821
Chinook	378	40	60	2.6	1,646
Coho	363	39	61	2.6	950
Pink	499	49	51	2.4	2,492
Sockeye	9	17	83	4.3	13

Table 9. Mean, standard error, minimum, maximum, and sample size of length (mm) by age class for chum salmon sampled at the Gertrude Creek weir, 1998.

	Age Class			
	0.2	0.3	0.4	0.5
		Female		
Mean	553	562	581	599
SE	22.1	11.3	8.9	20.3
Min	504	470	508	562
Max	600	661	627	666
N	15	192	95	12
		Male		
Mean	538	586	608	614
SE	5.3	9.7	14.7	23.3
Min	490	510	531	546
Max	618	650	782	694
N	19	216	124	22
		Total		
Mean	545	575	595	609
SE	11.5	11.2	13.9	22.2
Min	490	470	508	546
Max	618	661	782	694
N	34	409	221	34

Table 10. Mean, standard error, minimum, maximum, and sample size of length (mm) by age class for Chinook salmon sampled at the Gertrude Creek weir, 1998.

	Age Class				
	1.1	1.2	1.3	1.4	1.5
			Female		
Mean	483	--	739	800	843
SE	50.7	--	23.8	19.1	46.6
Min	391	640	557	595	781
Max	549	--	854	898	882
N	4	1	33	34	4
			Male		
Mean	441	596	728	761	898
SE	40.1	37.0	37.8	31.8	9.1
Min	329	453	529	713	876
Max	586	732	859	873	916
N	59	29	41	15	4
			Total		
Mean	443	598	732	787	870
SE	39.4	36.3	31.8	21.3	38.3
Min	329	453	529	595	781
Max	586	732	859	898	916
N	64	32	76	49	8

Table 11. Mean, standard error, minimum, maximum, and sample size of length (mm) by age class for coho salmon sampled at the Gertrude Creek weir, 1998.

	Age Class				
	1.1	1.2	2.0	2.1	2.2
			Female		
Mean	593	539	--	591	575
SE	15.6	77.9	--	22.0	27.9
Min	527	473	--	431	537
Max	670	600	--	652	601
N	19	3	--	54	3
			Male		
Mean	538	508	--	564	533
SE	44.8	--	--	30.4	5.8
Min	426	468	--	444	517
Max	668	641	--	678	563
N	29	2	--	82	3
			Total		
Mean	557	527	--	575	546
SE	38.1	62.1	--	28.8	11.6
Min	425	468	351	431	517
Max	670	641	--	678	601
N	52	5	1	139	6

Table 12. Estimated sex composition, sample size, standard error, and escapement of Pacific salmon sampled at the Gertrude Creek weir, 1999.

Species	*N*	Female (%)	Male (%)	SE (%)	Escapement
Chum	1,238	45	55	1.7	16,992
Chinook	246	52	48	4.2	1,171
Coho	92	32	68	6.4	293
Pink	392	52	48	2.2	1,131
Sockeye	11	39	61	17.3	19

Table 13. Mean, standard error, minimum, maximum, and sample size of length (mm) by age class for chum salmon sampled at the Gertrude Creek weir, 1999.

	Age Class				
	0.1	0.2	0.3	0.4	0.5
			Female		
Mean	--	--	577	588	--
SE	--	--	13.2	11.9	--
Min	--	603	470	523	566
Max	--	--	674	639	--
N	--	1	262	65	1
			Male		
Mean	--	--	598	614	618
SE	--	--	10.9	12.5	--
Min	589	561	519	551	601
Max	--	--	687	670	637
N	1	1	296	98	4
			Total		
Mean	--	600	589	604	605
SE	--	--	12.6	13.2	25.3
Min	589	561	470	523	566
Max	--	603	687	670	637
N	1	2	561	164	5

Biological data were collected from 247 Chinook salmon in 1999 and 218 scales were sub-sampled for age analysis. Scales from 29 fish (12%) were either illegible or regenerated. Six age classes were identified from scales collected in 1999 (Table 4). The majority of the run consisted of age 1.3, and 1.4 fish, and females comprised 52% of the sample (Table 12). Chinook salmon lengths ranged from 520 to 910 mm for females and from 300 to 895 mm for males (Table 14).

Biological data were collected from 92 coho salmon in 1999 and 77 scales were sub-sampled for age analysis. Scales from 14 fish (15%) were either illegible or regenerated. Five age classes were identified from scales collected in 1999 (Table 6) and the majority of the run consisted of age 2.1 fish. Females comprised 32% of the sample (Table 12). Coho salmon lengths ranged from 450 to 617 mm for females and from 375 to 651 mm for males (Table 15).

Length and sex data were collected from 392 pink salmon in 1999 and females comprised 52% of the sample (Table 12). The mean length was 407 mm for females and 403 mm for males. Pink salmon lengths ranged from 326 to 477 mm for females and from 323 to 615 mm for males.

Length and sex data were collected from 11 sockeye salmon in 1999 and females comprised 39% of the sample (Table 12). Sockeye salmon lengths ranged from 469 to 544 mm for females and from 397 to 595 mm for males.

Discussion

The Gertrude Creek weir was operated over a 3-year period from 1997 to 1999. Pacific salmon runs in Gertrude Creek began in June and continued through September. Chum salmon were the most abundant species and the first salmon observed at the weir. Chum salmon numbers were the lowest in 1997 and the peak run timing for that year was earlier. Peak run timing for Chinook salmon was also earlier in 1997 than the following years. However, peak run timing for pink salmon was later in 1997 and peak run timing for coho salmon was similar in 1997 and 1999, yet almost two weeks later in 1998. Pink and coho salmon passed through the weir the day before counting ceased in every year of operation. Therefore, it is likely that part of the late run was missed and escapement of these species was underestimated. We are hesitant to make generalizations about the run strength or timing of coho salmon in Gertrude Creek, because run timing has been shown to last through the month of September for other systems in Bristol Bay (Edwards and Larson 2004; Anderson 2005). Pink salmon exhibited an even year run strength, similar to other Alaska Peninsula stocks (Heard 1991). In May and June of 1998 and 1999, high flows or ice break-up occurred, making the weir inoperable. However, these events occurred prior to salmon being observed at the weir and it is unlikely that any salmon were missed during these periods. On 26 and 27 August 1998, the weir was partially down, which may have attributed to the lower salmon counts on these dates.

The salmon run timing varied each year. The earlier peaks in run timing in 1997 may be due to lower water flows and consequently warmer water temperatures. Average daily water temperatures and maximum temperatures were warmer in 1997 than in 1998 and 1999. National Weather Service records for King Salmon in 1997 indicate that record highs were recorded on 7 days between May and August. Maximum water temperatures in 1997 were the warmest recorded (5.1 – 5.8˚C above) during the years of operation and temperatures peaked approximately one month earlier than in 1998 and 1999 (Figure 6). This may have prompted fish to migrate earlier in 1997 than the following years. Frequent storms during the summer months, typical in southwest Alaska, kept water levels higher in 1998 than in 1997 and the late

Table 14. Mean, standard error, minimum, maximum, and sample size of length (mm) by age class for Chinook salmon sampled at the Gertrude Creek weir, 1999.

	Age Class					
	1.1	1.2	1.3	1.4	1.5	2.4
			Female			
Mean	--	669	737	778	820	--
SE	--	40.9	41.5	26.9	19.1	--
Min	--	521	520	647	781	910
Max	--	735	868	902	856	--
N	--	7	30	56	17	1
			Male			
Mean	405	592	679	748	810	--
SE	49.4	26.1	42.8	39.8	56.8	--
Min	300	355	507	608	658	--
Max	567	680	807	866	895	--
N	20	9	26	44	7	--
			Total			
Mean	400	627	704	765	819	--
SE	38.6	33.3	46.4	32.4	19.6	--
Min	300	355	507	608	658	910
Max	567	735	868	902	895	--
N	21	16	56	100	24	1

Table 15. Mean, standard error, minimum, maximum, and sample size of length (mm) by age class for coho salmon sampled at the Gertrude Creek weir, 1999.

	Age Class				
	1.1	1.2	2.1	2.2	3.1
			Female		
Mean	563	--	550	--	--
SE	6.5	--	39.8	--	--
Min	539	466	450	601	561
Max	577	--	617	--	--
N	3	1	20	1	1
			Male		
Mean	534	465	518	616	--
SE	22.2	31.0	47.3	17.4	--
Min	428	419	375	588	479
Max	604	511	651	644	--
N	7	2	39	2	1
			Total		
Mean	537	465	528	610	551
SE	19.5	21.0	44.5	10.6	--
Min	428	419	375	588	479
Max	604	511	651	644	561
N	10	3	59	3	2

ice breakup in 1999 probably contributed to the lower water temperatures observed compared to other years.

Data analysis revealed that a portion of the 1997 coho salmon data (i.e. strata 5) contained discrepancies. On three occasions the data recorded indicated that the number of coho salmon sampled exceeded the daily passage (Appendix D). If a fish was sampled it was released above the weir. Therefore, the minimum escapement equaled the number of fish sampled during those three occasions. The cause of the error is not known. Either the escapement number was written incorrectly or it was not entered correctly into the computer. However, we have no way to verify which error occurred because the data sheets are missing. To include the biological data from these fish for analysis, the standard errors for strata five were all set to zero (J. F. Bromaghin, USFWS, personal communication). Therefore, the standard errors for coho salmon in 1997 are underestimated.

The age composition of the three species of Pacific salmon sampled in Gertrude Creek was similar to other populations in Bristol Bay (Price and Larson 1999, Whitton 2003, Edwards and Larson 2004). Chinook salmon age composition was similar in 1997 and 1998, with age 1.3 fish dominating the run, although there was a greater proportion of age 1.1 fish (jacks) in 1998. In 1999, age composition differed from previous years, with age 1.4 dominating the run and a larger proportion of age 1.5 fish observed in the run. Chum salmon age composition was similar between years. For all years, the run was comprised primarily of age 0.3 and 0.4 fish. The proportion of age 0.4 fish was greater in 1997, although age 0.3 fish were dominant in 1998 and 1999. Coho salmon age composition was similar for all years with age 2.1 dominating the run, similar to previous age composition reported for Gertrude Creek (Russell 1996).

Sub-sample size requirements for Chinook and coho salmon age analysis were not met in all years because of illegible or regenerated scales. Chum salmon sub-sample size requirements were only slightly less than the goal each year. The lack of achieving sample size goals most likely did not affect the age and sex compositions. Standard errors would be smaller with a larger sample size but the estimates would probably be similar (Bromaghin 1993). For the worst case (coho salmon from 1997 with 22% unreadable scales), the confidence interval was only 0.009 greater than if the full sample size had been achieved.

Gertrude Creek appears to support strong and relatively consistent runs of Pacific salmon. Sockeye salmon numbers were low throughout the study; this is mostly likely due to the lack of lake access for juvenile rearing (Burgner 1991). Pacific salmon in Gertrude Creek should be monitored and assessed again in ten years to ensure the health of the populations. Gertrude Creek would provide an opportunity for remote monitoring using underwater video technology and a microwave link to send the video signal to the King Salmon Field Office.

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Appendix A. Strata (time periods) used for analysis of Gertrude Creek Pacific salmon biological data, 1997.

Stratum	Chinook	Chum	Coho	Pink	Sockeye
1	30-Jun - 6-Jul	19-May - 22-Jun	4-17 Aug	30-Jun – 27-Jul	23-Jun – 27 Jul
2	7-13 Jul	23-29 Jun	18-24 Aug	28-Jul – 3 Aug	28-Jul – 24 Aug
3	14-20 Jul	30-Jun - 6-Jul	25-31 Aug	4-10 Aug	25-Aug - 17 Sep
4	21-27 Jul	7-13 Jul	1-7 Sep	11-17 Aug	
5	28-Jul - 3-Aug	14-20 Jul	8-14 Sep	18-24 Aug	
6	4-10 Aug	21-27 Jul	15-17 Sep	25-Aug – 31 Aug	
7	11-Aug - 17-Sep	28-Jul - 3-Aug		1-Sep - 17 Sep	
8		4-10 Aug			
9		11-17 Aug			
10		18-24 Aug			
11		25-Aug - 17-Sep			

Appendix B. Strata (time periods) used for analysis of Gertrude Creek Pacific salmon biological data, 1998.

Stratum	Chinook	Chum	Coho	Pink	Sockeye
1	15-Jun - 12-Jul	8-21 Jun	27-Jul - 16-Aug	29-Jun - 19-Jul	6-26 Jul
2	13-19 Jul	22-28 Jun	17-23 Aug	20-26 Jul	27- Jul - 10- Aug
3	20-26 Jul	29-Jun - 5-Jul	24-30 Aug	27-Jul -2-Aug	17-23 Aug
4	27-Jul - 2-Aug	6-12 Jul	31-Aug - 6-Sep	3-9 Aug	24-30 Aug
5	3-9 Aug	13-19 Jul	7-13 Sep	10-16 Aug	31-Aug - 17-Sep
6	10-Aug - 17-Sep	20-26 Jul	14-17 Sep	17-23 Aug	
7		27-Jul - 2-Aug		24-Aug - 17-Sep	
8		3-9 Aug			
9		10-16 Aug			
10		17-23 Aug			
11		24-Aug - 17-Sep			

Appendix C. Strata (time periods) used for analysis of Gertrude Creek Pacific salmon biological data, 1999.

Stratum	Chinook	Chum	Coho	Pink	Sockeye
1	28-Jun - 18-Jul	7-27 Jun	9-22 Aug	5-25 Jul	5-Jul - 8 Aug
2	19-25 Jul	28-Jun - 4-Jul	23-29 Aug	26-Jul - 1-Aug	9-15 Aug
3	26-Jul - 1-Aug	5-11 Jul	30-Aug - 5-Sep	2-8 Aug	16-22 Aug
4	2-8 Aug	12-18 Jul	6-12 Sep	9-15 Aug	23-29 Aug
5	9-Aug - 12-Sep	19-25 Jul		16-22 Aug	30-Aug - 12-Sep
6		26-Jul - 1-Aug		23-29 Aug	
7		2-8 Aug		30-Aug - 12-Sep	
8		9-15 Aug			
9		16-22 Aug			
10		23-Aug - 12-Sep			

Appendix D. Summary of Pacific salmon passage at the Gertrude Creek weir, 1997.

	Chinook		Chum		Coho		Pink		Sockeye	
Date	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum
1-Jun	0	0	1	1	0	0	0	0	0	0
2-Jun	0	0	0	1	0	0	0	0	0	0
3-Jun	0	0	1	2	0	0	0	0	0	0
4-Jun	0	0	0	2	0	0	0	0	0	0
5-Jun	0	0	0	2	0	0	0	0	0	0
6-Jun	0	0	0	2	0	0	0	0	0	0
7-Jun	0	0	0	2	0	0	0	0	0	0
8-Jun	0	0	0	2	0	0	0	0	0	0
9-Jun	0	0	0	2	0	0	0	0	0	0
10-Jun	0	0	2	4	0	0	0	0	0	0
11-Jun	0	0	5	9	0	0	0	0	0	0
12-Jun	0	0	0	9	0	0	0	0	0	0
13-Jun	0	0	6	15	0	0	0	0	0	0
14-Jun	0	0	0	15	0	0	0	0	0	0
15-Jun	0	0	12	27	0	0	0	0	0	0
16-Jun	0	0	12	39	0	0	0	0	0	0
17-Jun	0	0	20	59	0	0	0	0	0	0
18-Jun	0	0	26	85	0	0	0	0	0	0
19-Jun	0	0	55	140	0	0	0	0	0	0
20-Jun	0	0	51	191	0	0	0	0	0	0
21-Jun	0	0	49	240	0	0	0	0	0	0
22-Jun	0	0	105	345	0	0	0	0	0	0
23-Jun	0	0	93	438	0	0	0	0	0	0
24-Jun	0	0	123	561	0	0	0	0	0	0
25-Jun	0	0	185	746	0	0	0	0	0	0
26-Jun	0	0	219	965	0	0	0	0	0	0
27-Jun	0	0	269	1,234	0	0	0	0	0	0
28-Jun	0	0	416	1,650	0	0	0	0	0	0
29-Jun	0	0	374	2,024	0	0	0	0	0	0
30-Jun	0	0	807	2,831	0	0	0	0	0	0
1-Jul	3	3	578	3,409	0	0	0	0	0	0
2-Jul	25	28	139	3,548	0	0	0	0	1	1
3-Jul	0	28	50	3,598	0	0	0	0	0	1
4-Jul	8	36	130	3,728	0	0	0	0	0	1
5-Jul	0	36	129	3,857	0	0	0	0	0	1
6-Jul	69	105	400	4,257	0	0	0	0	1	2
7-Jul	17	122	10	4,267	0	0	1	1	0	2
8-Jul	0	122	26	4,293	0	0	1	2	0	2
9-Jul	0	122	90	4,383	0	0	0	2	0	2
10-Jul	0	122	260	4,643	0	0	0	2	0	2
11-Jul	3	125	327	4,970	0	0	0	2	0	2
12-Jul	30	155	313	5,283	0	0	0	2	0	2
13-Jul	0	155	78	5,361	0	0	0	2	0	2

Appendix D. Continued.

	Chinook		Chum		Coho		Pink		Sockeye	
Date	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum
14-Jul	4	159	46	5,407	0	0	1	3	0	2
15-Jul	7	166	60	5,467	0	0	0	3	0	2
16-Jul	3	169	251	5,718	0	0	0	3	0	2
17-Jul	5	174	108	5,826	0	0	0	3	0	2
18-Jul	54	228	139	5,965	0	0	1	4	0	2
19-Jul	61	289	165	6,130	0	0	3	7	0	2
20-Jul	184	473	286	6,416	0	0	6	13	0	2
21-Jul	104	577	223	6,639	0	0	5	18	1	3
22-Jul	32	609	102	6,741	0	0	6	24	2	5
23-Jul	24	633	81	6,822	0	0	1	25	1	6
24-Jul	0	633	37	6,859	0	0	2	27	1	7
25-Jul	40	673	227	7,086	0	0	4	31	0	7
26-Jul	56	729	127	7,213	0	0	13	44	0	7
27-Jul	11	740	84	7,297	0	0	13	57	0	7
28-Jul	11	751	77	7,374	0	0	13	70	0	7
29-Jul	38	789	94	7,468	0	0	13	83	0	7
30-Jul	8	797	62	7,530	0	0	9	92	0	7
31-Jul	41	838	215	7,745	0	0	22	114	0	7
1-Aug	37	875	88	7,833	0	0	11	125	0	7
2-Aug	2	877	33	7,866	0	0	5	130	0	7
3-Aug	5	882	69	7,935	0	0	8	138	0	7
4-Aug	14	896	130	8,065	0	0	19	157	0	7
5-Aug	16	912	153	8,218	0	0	31	188	0	7
6-Aug	58	970	138	8,356	0	0	17	205	0	7
7-Aug	9	979	84	8,440	0	0	21	226	0	7
8-Aug	19	998	217	8,657	0	0	35	261	0	7
9-Aug	90	1,088	177	8,834	0	0	50	311	0	7
10-Aug	64	1,152	39	8,873	0	0	16	327	0	7
11-Aug	65	1,217	69	8,942	0	0	25	352	0	7
12-Aug	34	1,251	46	8,988	0	0	13	365	0	7
13-Aug	26	1,277	129	9,117	0	0	6	371	0	7
14-Aug	7	1,284	116	9,233	0	0	6	377	0	7
15-Aug	8	1,292	206	9,439	7	7	10	387	0	7
16-Aug	16	1,308	188	9,627	16	23	9	396	0	7
17-Aug	5	1,313	149	9,776	1	24	14	410	0	7
18-Aug	6	1,319	122	9,898	10	34	25	435	0	7
19-Aug	0	1,319	61	9,959	3	37	16	451	0	7
20-Aug	3	1,322	201	10,160	5	42	34	485	0	7
21-Aug	2	1,324	138	10,298	18	60	12	497	2	9
22-Aug	2	1,326	105	10,403	25	85	33	530	1	10
23-Aug	5	1,331	85	10,488	8	93	18	548	2	12
24-Aug	1	1,332	99	10,587	4	97	18	566	0	12
25-Aug	0	1,332	65	10,652	5	102	33	599	0	12

Appendix D. Continued.

	Chinook		Chum		Coho		Pink		Sockeye	
Date	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum
26-Aug	0	1,332	102	10,754	8	110	56	655	0	12
27-Aug	0	1,332	90	10,844	5	115	29	684	0	12
28-Aug	0	1,332	50	10,894	4	119	42	726	0	12
29-Aug	0	1,332	94	10,988	4	123	57	783	0	12
30-Aug	1	1,333	58	11,046	2	125	40	823	0	12
31-Aug	0	1,333	8	11,054	12	137	8	831	0	12
1-Sep	0	1,333	0	11,054	3[a]	137	16	847	0	12
2-Sep	0	1,333	9	11,063	12	149	13	860	0	12
3-Sep	0	1,333	0	11,063	6	155	15	875	0	12
4-Sep	0	1,333	0	11,063	6	161	25	900	0	12
5-Sep	0	1,333	4	11,067	0	161	20	920	0	12
6-Sep	0	1,333	22	11,089	2[a]	161	65	985	1	13
7-Sep	1	1,334	14	11,103	32[a]	161	35	1,020	0	13
8-Sep	1	1,335	29	11,132	213	374	63	1,083	1	14
9-Sep	0	1,335	0	11,132	25	399	14	1,097	1	15
10-Sep	0	1,335	1	11,133	1	400	10	1,107	0	15
11-Sep	0	1,335	0	11,133	0	400	14	1,121	0	15
12-Sep	0	1,335	0	11,133	2	402	10	1,131	0	15
13-Sep	0	1,335	0	11,133	6	408	16	1,147	0	15
14-Sep	0	1,335	0	11,133	4	412	31	1,178	0	15
15-Sep	0	1,335	0	11,133	9	421	55	1,233	0	15
16-Sep	0	1,335	0	11,133	5	426	34	1,267	0	15
17-Sep	0	1,335	0	11,133	188	651	23	1,290	0	15

[a] Escapement estimates for these days are minimum counts.

Appendix E. Summary of Pacific salmon passage at the Gertrude Creek weir, 1998.

	Chinook		Chum		Coho		Pink		Sockeye	
Date	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum
1-Jun	0	0	0	0	0	0	0	0	0	0
2-Jun	0	0	0	0	0	0	0	0	0	0
3-Jun	0	0	0	0	0	0	0	0	0	0
4-Jun	0	0	0	0	0	0	0	0	0	0
5-Jun	0	0	0	0	0	0	0	0	0	0
6-Jun	0	0	0	0	0	0	0	0	0	0
7-Jun	0	0	0	0	0	0	0	0	0	0
8-Jun	0	0	0	0	0	0	0	0	0	0
9-Jun	0	0	0	0	0	0	0	0	0	0
10-Jun	0	0	0	0	0	0	0	0	0	0
11-Jun	0	0	0	0	0	0	0	0	0	0
12-Jun	0	0	3	3	0	0	0	0	0	0
13-Jun	0	0	1	4	0	0	0	0	0	0
14-Jun	0	0	2	6	0	0	0	0	0	0
15-Jun	0	0	6	12	0	0	0	0	0	0
16-Jun	0	0	0	12	0	0	0	0	0	0
17-Jun	0	0	5	17	0	0	0	0	0	0
18-Jun	0	0	2	19	0	0	0	0	0	0
19-Jun	0	0	19	38	0	0	0	0	0	0
20-Jun	1	1	7	45	0	0	0	0	0	0
21-Jun	0	1	0	45	0	0	0	0	0	0
22-Jun	0	1	1	46	0	0	0	0	0	0
23-Jun	0	1	80	126	0	0	0	0	0	0
24-Jun	0	1	15	141	0	0	0	0	0	0
25-Jun	0	1	90	231	0	0	0	0	0	0
26-Jun	0	1	136	367	0	0	0	0	0	0
27-Jun	0	1	121	488	0	0	0	0	0	0
28-Jun	0	1	272	760	0	0	0	0	0	0
29-Jun	0	1	416	1,176	0	0	0	0	0	0
30-Jun	1	2	500	1,676	0	0	0	0	0	0
1-Jul	3	5	455	2,131	0	0	0	0	0	0
2-Jul	2	7	454	2,585	0	0	0	0	0	0
3-Jul	9	16	535	3,120	0	0	0	0	0	0
4-Jul	7	23	473	3,593	0	0	0	0	0	0
5-Jul	10	33	602	4,195	0	0	0	0	0	0
6-Jul	11	44	412	4,607	0	0	0	0	0	0
7-Jul	3	47	296	4,903	0	0	0	0	0	0
8-Jul	0	47	204	5,107	0	0	0	0	0	0
9-Jul	1	48	233	5,340	0	0	1	1	0	0
10-Jul	21	69	218	5,558	0	0	0	1	0	0
11-Jul	16	85	183	5,741	0	0	3	4	0	0
12-Jul	4	89	106	5,847	0	0	0	4	0	0
13-Jul	72	161	265	6,112	0	0	0	4	0	0

Appendix E. Continued.

	Chinook		Chum		Coho		Pink		Sockeye	
Date	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum
14-Jul	7	168	473	6,585	0	0	3	7	0	0
15-Jul	135	303	681	7,266	0	0	32	39	0	0
16-Jul	54	357	289	7,555	0	0	38	77	0	0
17-Jul	5	362	216	7,771	0	0	55	132	0	0
18-Jul	62	424	267	8,038	0	0	61	193	1	1
19-Jul	13	437	293	8,331	0	0	83	276	0	1
20-Jul	17	454	235	8,566	0	0	50	326	2	3
21-Jul	18	472	211	8,777	0	0	71	397	0	3
22-Jul	147	619	144	8,921	0	0	86	483	0	3
23-Jul	10	629	95	9,016	0	0	29	512	0	3
24-Jul	9	638	88	9,104	0	0	22	534	0	3
25-Jul	47	685	246	9,350	0	0	61	595	0	3
26-Jul	293	978	202	9,552	0	0	90	685	2	5
27-Jul	31	1,009	159	9,711	0	0	151	836	0	5
28-Jul	9	1,018	126	9,837	0	0	182	1,018	0	5
29-Jul	94	1,112	223	10,060	0	0	250	1,268	0	5
30-Jul	65	1,177	199	10,259	0	0	213	1,481	0	5
31-Jul	158	1,335	210	10,469	0	0	213	1,694	0	5
1-Aug	53	1,388	120	10,589	0	0	156	1,850	0	5
2-Aug	4	1,392	46	10,635	0	0	52	1,902	0	5
3-Aug	28	1,420	104	10,739	0	0	96	1,998	0	5
4-Aug	7	1,427	48	10,787	0	0	64	2,062	0	5
5-Aug	12	1,439	62	10,849	0	0	50	2,112	0	5
6-Aug	9	1,448	49	10,898	0	0	34	2,146	0	5
7-Aug	16	1,464	35	10,933	1	1	29	2,175	1	6
8-Aug	13	1,477	40	10,973	0	1	32	2,207	0	6
9-Aug	58	1,535	120	11,093	1	2	58	2,265	0	6
10-Aug	13	1,548	46	11,139	2	4	17	2,282	0	6
11-Aug	25	1,573	105	11,244	1	5	33	2,315	0	6
12-Aug	14	1,587	52	11,296	2	7	34	2,349	0	6
13-Aug	5	1,592	19	11,315	1	8	11	2,360	0	6
14-Aug	3	1,595	99	11,414	3	11	13	2,373	0	6
15-Aug	1	1,596	37	11,451	0	11	6	2,379	0	6
16-Aug	12	1,608	105	11,556	3	14	25	2,404	0	6
17-Aug	1	1,609	27	11,583	2	16	10	2,414	0	6
18-Aug	0	1,609	7	11,590	0	16	2	2,416	0	6
19-Aug	0	1,609	13	11,603	0	16	4	2,420	0	6
20-Aug	5	1,614	48	11,651	0	16	22	2,442	0	6
21-Aug	1	1,615	22	11,673	1	17	3	2,445	0	6
22-Aug	4	1,619	38	11,711	6	23	10	2,455	0	6
23-Aug	1	1,620	30	11,741	5	28	6	2,461	1	7
24-Aug	2	1,622	20	11,761	6	34	6	2,467	2	9
25-Aug	3	1,625	13	11,774	2	36	0	2,467	1	10

Appendix E. Continued.

	Chinook		Chum		Coho		Pink		Sockeye	
Date	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum
26-Aug	1	1,626	5	11,779	3	39	7	2,474	0	10
27-Aug	0	1,626	1	11,780	0	39	3	2,477	0	10
28-Aug	4	1,630	10	11,790	5	44	5	2,482	1	11
29-Aug	2	1,632	4	11,794	2	46	0	2,482	0	11
30-Aug	0	1,632	13	11,807	2	48	1	2,483	1	12
31-Aug	2	1,634	5	11,812	9	57	1	2,484	0	12
1-Sep	7	1,641	2	11,814	7	64	0	2,484	0	12
2-Sep	0	1,641	2	11,816	42	106	1	2,485	0	12
3-Sep	0	1,641	1	11,817	8	114	1	2,486	0	12
4-Sep	1	1,642	1	11,818	25	139	0	2,486	0	12
5-Sep	0	1,642	0	11,818	47	186	1	2,487	0	12
6-Sep	0	1,642	2	11,820	17	203	1	2,488	0	12
7-Sep	0	1,642	0	11,820	43	246	0	2,488	0	12
8-Sep	0	1,642	0	11,820	67	313	1	2,489	1	13
9-Sep	1	1,643	0	11,820	20	333	0	2,489	0	13
10-Sep	0	1,643	0	11,820	8	341	0	2,489	0	13
11-Sep	0	1,643	0	11,820	28	369	0	2,489	0	13
12-Sep	1	1,644	0	11,820	51	420	1	2,490	0	13
13-Sep	2	1,646	0	11,820	9	429	0	2,490	0	13
14-Sep	0	1,646	1	11,821	26	455	0	2,490	0	13
15-Sep	0	1,646	0	11,821	16	471	1	2,491	0	13
16-Sep	0	1,646	0	11,821	47	518	0	2,491	0	13
17-Sep	0	1,646	0	11,821	432	950	1	2,492	0	13

Appendix F. Summary of Pacific salmon passage at the Gertrude Creek weir, 1999.

	Chinook		Chum		Coho		Pink		Sockeye	
Date	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum
1-Jun	0	0	0	0	0	0	0	0	0	0
2-Jun	0	0	0	0	0	0	0	0	0	0
3-Jun	0	0	0	0	0	0	0	0	0	0
4-Jun	0	0	0	0	0	0	0	0	0	0
5-Jun	0	0	0	0	0	0	0	0	0	0
6-Jun	0	0	0	0	0	0	0	0	0	0
7-Jun	0	0	0	0	0	0	0	0	0	0
8-Jun	0	0	0	0	0	0	0	0	0	0
9-Jun	0	0	0	0	0	0	0	0	0	0
10-Jun	0	0	0	0	0	0	0	0	0	0
11-Jun	0	0	0	0	0	0	0	0	0	0
12-Jun	0	0	0	0	0	0	0	0	0	0
13-Jun	0	0	0	0	0	0	0	0	0	0
14-Jun	0	0	0	0	0	0	0	0	0	0
15-Jun	0	0	0	0	0	0	0	0	0	0
16-Jun	0	0	1	1	0	0	0	0	0	0
17-Jun	0	0	1	2	0	0	0	0	0	0
18-Jun	0	0	4	6	0	0	0	0	0	0
19-Jun	0	0	4	10	0	0	0	0	0	0
20-Jun	0	0	0	10	0	0	0	0	0	0
21-Jun	0	0	0	10	0	0	0	0	0	0
22-Jun	0	0	5	15	0	0	0	0	0	0
23-Jun	0	0	0	15	0	0	0	0	0	0
24-Jun	0	0	16	31	0	0	0	0	0	0
25-Jun	0	0	25	56	0	0	0	0	0	0
26-Jun	0	0	31	87	0	0	0	0	0	0
27-Jun	0	0	100	187	0	0	0	0	0	0
28-Jun	0	0	207	394	0	0	0	0	0	0
29-Jun	0	0	419	813	0	0	0	0	0	0
30-Jun	0	0	228	1,041	0	0	0	0	0	0
1-Jul	0	0	62	1,103	0	0	0	0	0	0
2-Jul	0	0	246	1,349	0	0	0	0	0	0
3-Jul	0	0	1,130	2,479	0	0	0	0	0	0
4-Jul	0	0	472	2,951	0	0	0	0	0	0
5-Jul	0	0	595	3,546	0	0	0	0	0	0
6-Jul	1	1	1,080	4,626	0	0	0	0	0	0
7-Jul	8	9	1,116	5,742	0	0	0	0	0	0
8-Jul	6	15	1,248	6,990	0	0	0	0	0	0
9-Jul	5	20	560	7,550	0	0	0	0	0	0
10-Jul	1	21	433	7,983	0	0	0	0	0	0
11-Jul	8	29	867	8,850	0	0	0	0	0	0
12-Jul	8	37	420	9,270	0	0	0	0	0	0
13-Jul	0	37	276	9,546	0	0	0	0	0	0

Appendix F. Continued.

	Chinook		Chum		Coho		Pink		Sockeye	
Date	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum
14-Jul	65	102	1,140	10,686	0	0	0	0	1	1
15-Jul	4	106	300	10,986	0	0	0	0	0	1
16-Jul	35	141	353	11,339	0	0	0	0	0	1
17-Jul	9	150	297	11,636	0	0	1	1	0	1
18-Jul	5	155	516	12,152	0	0	1	2	0	1
19-Jul	165	320	385	12,537	0	0	3	5	0	1
20-Jul	8	328	235	12,772	0	0	13	18	0	1
21-Jul	87	415	196	12,968	0	0	15	33	0	1
22-Jul	15	430	303	13,271	0	0	4	37	0	1
23-Jul	94	524	372	13,643	0	0	12	49	0	1
24-Jul	93	617	281	13,924	0	0	8	57	0	1
25-Jul	17	634	121	14,045	0	0	8	65	0	1
26-Jul	26	660	145	14,190	0	0	24	89	1	2
27-Jul	20	680	78	14,268	0	0	11	100	0	2
28-Jul	190	870	148	14,416	0	0	30	130	0	2
29-Jul	30	900	174	14,590	0	0	27	157	0	2
30-Jul	14	914	129	14,719	0	0	43	200	0	2
31-Jul	75	989	200	14,919	0	0	102	302	1	3
1-Aug	24	1,013	54	14,973	0	0	53	355	2	5
2-Aug	21	1,034	84	15,057	0	0	24	379	0	5
3-Aug	29	1,063	159	15,216	0	0	86	465	0	5
4-Aug	19	1,082	59	15,275	0	0	35	500	0	5
5-Aug	13	1,095	36	15,311	0	0	23	523	1	6
6-Aug	1	1,096	28	15,339	0	0	14	537	0	6
7-Aug	14	1,110	52	15,391	0	0	17	554	1	7
8-Aug	9	1,119	124	15,515	0	0	37	591	0	7
9-Aug	16	1,135	114	15,629	0	0	56	647	0	7
10-Aug	6	1,141	223	15,852	0	0	131	778	1	8
11-Aug	4	1,145	164	16,016	0	0	84	862	0	8
12-Aug	8	1,153	125	16,141	1	1	44	906	0	8
13-Aug	7	1,160	47	16,188	1	2	13	919	0	8
14-Aug	2	1,162	86	16,274	0	2	33	952	0	8
15-Aug	2	1,164	98	16,372	3	5	17	969	0	8
16-Aug	2	1,166	68	16,440	1	6	26	995	0	8
17-Aug	3	1,169	104	16,544	5	11	20	1,015	0	8
18-Aug	0	1,169	94	16,638	4	15	10	1,025	0	8
19-Aug	0	1,169	97	16,735	4	19	25	1,050	0	8
20-Aug	1	1,170	61	16,796	7	26	20	1,070	1	9
21-Aug	0	1,170	36	16,832	0	26	10	1,080	0	9
22-Aug	0	1,170	32	16,864	0	26	2	1,082	0	9
23-Aug	0	1,170	15	16,879	0	26	2	1,084	1	10
24-Aug	0	1,170	19	16,898	2	28	1	1,085	0	10
25-Aug	1	1,171	23	16,921	8	36	1	1,086	1	11

Appendix F. Continued.

	Chinook		Chum		Coho		Pink		Sockeye	
Date	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum
26-Aug	0	1,171	11	16,932	5	41	2	1,088	1	12
27-Aug	0	1,171	11	16,943	0	41	4	1,092	2	14
28-Aug	0	1,171	17	16,960	2	43	2	1,094	0	14
29-Aug	0	1,171	11	16,971	5	48	5	1,099	1	15
30-Aug	0	1,171	6	16,977	7	55	6	1,105	0	15
31-Aug	0	1,171	4	16,981	4	59	6	1,111	2	17
1-Sep	0	1,171	5	16,986	4	63	0	1,111	1	18
2-Sep	0	1,171	4	16,990	5	68	2	1,113	0	18
3-Sep	0	1,171	1	16,991	31	99	4	1,117	0	18
4-Sep	0	1,171	0	16,991	66	165	5	1,122	0	18
5-Sep	0	1,171	0	16,991	97	262	2	1,124	0	18
6-Sep	0	1,171	0	16,991	8	270	4	1,128	0	18
7-Sep	0	1,171	0	16,991	14	284	0	1,128	0	18
8-Sep	0	1,171	1	16,992	7	291	0	1,128	0	18
9-Sep	0	1,171	0	16,992	1	292	0	1,128	1	19
10-Sep	0	1,171	0	16,992	0	292	2	1,130	0	19
11-Sep	0	1,171	0	16,992	0	292	0	1,130	0	19
12-Sep	0	1,171	0	16,992	1	293	1	1,131	0	19