Fishery Data Series No. 05-51

Estimates of Escapement of Sockeye Salmon Into Speel Lake in 2004

by

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October 2005

Alaska Department of Fish and Game **Division of Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

In 2004, the Douglas Island Pink and Chum Aquaculture Corporation operated a weir to count sockeye salmon entering Speel Lake to spawn, and to mark about 20 percent of the fish counted with an adipose fin clip. Rainfall triggered passage of fish through the weir several times during the season. After the weir was dismantled, ADF&G personnel examined sockeye salmon on 2 trips to the spawning grounds, for a mark-recapture study to validate the weir counts. Because the weir is believed to be size selective for larger fish, the mark-recapture estimates were stratified, into number of fish larger than lengths 430 mm mid-eye to fork, and fish smaller than or equal to 430 mm. For the larger fish, the pooled Petersen estimate was 8,500 sockeye salmon, with a 95% confidence interval of 7,300 to 10,400 fish. The number of sockeye salmon greater than 430 mm in the weir count was 7,460, within the confidence limits of the pooled Petersen estimate. The pooled Petersen estimate of fish 430 mm or smaller was 640 sockeye salmon, with a 95% confidence interval of 400 to 1,400 fish. Petersen estimates calculated from different combinations of marking and recapture events usually yielded similar results for the 2 strata. Another estimate of total escapement was also calculated, using the estimated number of fish larger than 430 mm counted through the weir, divided by the percentage of these larger fish present in the recovery sampling trips. This third method (size-based post stratification) produced a total escapement estimate of 9,200 sockeye salmon, of which 1,700 were less than 430 mm in length, and 7,500 were larger. The weir count was an accurate estimate of the number of fish lengths greater than 430 mm, mid-eye to fork. The predominant age classes were 1.2 for males and 1.3 for females.

Keywords: escapement, mark-recapture, sockeye salmon, Speel Lake, weir

INTRODUCTION

Speel Lake is located south of the Taku River, adjacent to the Speel Arm of Port Snettisham (Figure 1). The ADF&G stream number for the outlet of Speel Lake is 111-33-034. Speel Lake has a surface area of 167.5 hectares (413.9 acres), and supports a small run of sockeye salmon (*Oncorhynchus nerka*). The lake is shallow with a maximum depth of 8.5 meters (28 feet) and a mean depth of 3 meters (10 feet). The shallower parts of the lake have extensive aquatic vegetation. The lake is stained (humic). Scree slopes, on the northeast side of the lake, plunge into the lake and provide the primary spawning habitat for sockeye salmon.

A weir has been used to count sockeye salmon escapements into Speel Lake from 1983 to 1992 and from 1995 to 2004, first by the Alaska Department of Fish and Game (ADF&G), then by the Douglas Island Pink and Chum Aquaculture Corporation (DIPAC). Following an analysis of the historical data, Riffe and Clark (2003) recommended an escapement goal of 4,000 to 13,000 adult spawners for Speel Lake sockeye salmon. The Alaska Board of Fisheries adopted this goal, and the weir is the primary means of monitoring this management objective. By comparing daily amounts of rainfall from the Snettisham power plant with daily Speel Lake weir counts, Riffe and Clark demonstrated that a spike in rainfall would trigger the passage of returning adult sockeye salmon past the weir, especially when little rain had fallen in the previous weeks. Riffe and Clark also concluded that, except for 1983, 1995, and 2002, the weir was dismantled too early in the spawning migration to substantially enumerate it. Because of the influence of rainfall on fish passage, the degree of the past undercounting is unknown for most years prior to 2002. ADF&G encouraged DIPAC to continue weir operations through the third week in September to obtain more reliable estimates of escapement. ADF&G also began conducting a mark-recapture experiment to validate the weir count.

Mark-recapture validation studies are now standard practice on every major ADF&G weir project in Southeast Alaska. For Speel Lake, the mark-recapture study involves placing a visible mark on a proportion of the fish that are counted through the weir, and examining fish on the spawning grounds, noting the mark rate, and estimating the length distribution of spawning fish.

OBJECTIVES

My primary goal with this project was to monitor the sockeye salmon escapement into Speel Lake in 2004. Knowledge of escapement levels and identification of changes in trends over time is necessary for responsive management of the District 111 drift gillnet salmon fishery, and for the management of the cost-recovery fishery. These data were also used to assess the effects of various management decisions on the escapement levels, and to reconstruct the total run of the Speel Lake sockeye salmon stock. Additionally, extending weir operations into September documented the relationship between rainfall and Speel Lake weir counts.

Specific objectives:

1. Estimate the escapement of sockeye salmon into Speel Lake at the weir.
2. Describe the age, length, and sex composition of the sockeye salmon in the escapement at Speel Lake, based on a sample size of 800 fish or more.
3. Estimate the annual sockeye escapement into Speel Lake, using mark-recapture methods and observer counts on the spawning grounds, so that the estimated coefficient of variation is less than 15%.

METHODS

DIPAC operated the Speel Lake weir in 2004, in accordance with a project operational plan developed by ADF&G and reviewed by DIPAC. The Speel Lake weir was operational from July 14 to September 20. The weir was constructed with 8 foot sections of railing, drilled with 1-1/8 inch holes, with a spacing of 2-1/8 inch center-to-center. Each section of railing would hold 43 pickets. Electrical conduit, called ¾ EMT, was used for the pickets. The outside diameter of ¾ EMT is 0.92 inches, or 23.4 mm, and the gap between pickets placed in the railing was 1.2 inches or 3.1 cm. Data collected by weir personnel included number and species of fish counted through the weir, length sex and scales from sampled sockeye salmon, number of sockeye salmon marked, weather, water temperature, and water level. The data were recorded in "*Rite in the Rain*"© notebooks or Opscan© sheets, and summaries were transmitted daily to the Snettisham Hatchery office via VHF radio.

The weir was inspected regularly for holes and gaps; any holes or gaps that fish could swim through were corrected by pounding pickets down further or blocking holes using sandbags. Inspections increased during and after periods of high water.

Migrating salmon were counted through the weir by removing several pickets from an appropriate location on the weir face. Weir personnel would sit above the opening in the weir and tally fish passing through the weir by species during daylight and evening hours. Fish passage by species, as well as other sampling data, was recorded in a "*Rite in the Rain*"© notebook, and then transferred to a daily weir count sheet after the day's tallies had been completed.

MARKING

About 20% of the fish counted through the weir were marked and sampled for sex, scales, and length (mid-eye to fork of tail). Several times during the day, when the rest of the weir was fish-tight, weir personnel would remove pickets from the fish trap. When the trap was full or fish stopped entering the trap, the technicians would replace the pickets, and remove individual fish from the trap by dip net. The technicians then removed the adipose fin from each fish, and sampled for sex, scales and mid-eye to fork-of-tail length (in mm). The four essential elements of this effort were: (1) marking a specific fraction of fish counted through the weir, irrespective of size (i.e., jacks included), (2) measuring the size of each marked fish for future comparisons with the size distribution of the recaptured fish, and (3) collecting a minimum of 800 scale samples from fish from throughout the run. At the end of the season, the scales and associated data were sent to the ADF&G office in Douglas for scanning, data analysis, and archiving.

RECAPTURE

The recapture portion of the study was completed in two trips. The first trip occurred on September 21 and 22. The second recovery trip occurred on October 5 and 6. The recovery crew consisted of 2 ADF&G employees.

On each trip, the crew located fish on or near the spawning grounds, quickly deployed a seine around groups of fish and, sampled each captured fish. The crew sampled as many fish as possible. All fish were to be sampled for sex and length. During the recovery phase, a sub-sample of 100 fish was collected for otolith and brain parasite analysis, using spawned out fish or carcasses when possible.

During the first recovery trip, the weir crew examined all fish for adipose fin clips, and applied a partial dorsal clip to all these fish. If the crew captured a fish with a partial dorsal clip during the first recovery trip, they released it without sampling or counting it.

During the second recovery trip, the crew examined fish for adipose fin clips and partial dorsal fin clips, then gave the fish an anal fin clip. Length and sex information was taken for all fish examined. The crew collected 100 brain parasite and otolith samples from carcasses and spawned out fish.

DATA ANALYSIS

To determine if rainfall affected passage rates in 2004, I obtained daily rainfall data from Alaska Electric Light and Power for the Snettisham power plant, and made graphical comparisons with the daily weir counts.

The weir sampling (marking) and Speel Lake recovery data for sockeye salmon were analyzed using the statistical program “Stratified Population Analysis System” (SPAS) (Arnason et al. 1996). This program calculates chi-square diagnostic statistics, ML Darroch estimates, Darroch Moment estimates, least-squares estimates, and pooled Petersen estimates.

Conditions for accurate use of the above method for a closed population model are:

1. All adults have an equal probability of being marked; or
2. All adults have an equal probability of being inspected for marks; and
3. There is no recruitment to the population between weir and the spawning grounds upstream; and,
4. There is no trap-induced behavior; and,
5. Fish do not lose their marks and all marks are recognizable.

Experience has shown that probabilities of capture of sockeye and chum salmon change as their annual migration progresses. The multi-dimensional Darroch model adjusts for these temporal changes in probability of capture. Darroch’s method cannot be used to adjust for size-selective capture at the weir or on the spawning grounds. I calculated Kolmogorov–Smirnov tests, to detect possible size–selective sampling, and if necessary, adjust calculations to remove bias. There should be no trap-induced behavior because technicians used different capture gear in the recovery sampling, as compared to the initial marking at the weir. Fish were identified as marked fish by their missing adipose fin or secondary fin clips.

Petersen Estimate and Confidence Interval

The initial marking and recovery samples were tested for mixing, using diagnostic tests within the SPAS program. If the diagnostic tests were not significant ($p \geq 0.05$), I used the Chapman's form of the Petersen mark-recapture estimate for "instantaneous" population estimates (Seber 1982, p. 60). Let M denote the number of fish marked in a random sample of a population of size N. Let C denote the number of fish examined for marks at a later time, and let R denote the number of fish in the second sample with a mark. Then the estimated number of fish in the entire population, N^*, is given by

$$N^* = \frac{(M+1)(C+1)}{(R+1)} - 1 . \tag{1}$$

In this equation, R is a random variable, and which I assume follows a hypergeometric distribution. Moreover, when R is large compared with the size of the second sample, C, we can assume its distribution is approximately normal (a practical check is to ensure R is at least 30 before using the normal approximation). Let $\hat{p}$ be an estimate of p, the proportion of marked fish in the population, such that $\hat{p} = R/C$. Define the confidence bounds for p as ($a_{0.025}$, $a_{0.975}$). Then the 95% confidence interval bounds for the Petersen population estimate, N^*, are found by taking reciprocals of the confidence interval bounds for p, and multiplying by M. That is, the confidence bounds for the Petersen estimate are given by ($M \cdot 1/a_{0.975}$, $M \cdot 1/a_{0.025}$).

Sample size criteria are given in Seber (1982, p. 63). If $\hat{p} \geq 0.1$ and the size of the second sample C is at least the minimum sample size, a 95% confidence interval for p is given by:

$$\hat{p} \pm \left[1.96 \sqrt{\left(1 - \frac{C}{\hat{N}}\right) \cdot \hat{p}(1-\hat{p})/(C-1)} + \frac{1}{2C} \right], \text{ (Seber 1982, eq. 3.4).} \tag{2}$$

Seber's (1982) equation 3.4 may also be used when $\hat{p} < 0.1$ if $R > 50$. In several cases these criteria were not met, and I estimated the confidence interval bounds for p from Table 41 in Pearson and Hartley (1966).

I estimated the variance of the Petersen estimate using eq. 3.2 from Seber (1982), for the purpose of estimating its coefficient of variation.

Estimates of Escapement

First, I developed one set of escapement estimates from the weir count, but divided into two length-based strata, from percentage of fish by length sampled at the weir.

Next, I also calculated another estimate of escapement, which I called the "weir count" estimate. To generate this estimate I first estimated the number of "large fish that are retained by the weir," using some size criterion, so that the weir count of fish in this size category was a reliable measure. Then I estimated the fraction of the total escapement above that size criterion, based on recover samples #1 and #2. Therefore, a reasonable estimate of total escapement is found, by dividing the number of fish above this predetermined size threshold in the weir count by the percentage of fish above that size threshold in the recovery sampling trips.

Then, let W equal the number of fish counted through the weir. Let j equal the threshold size that precludes fish from swimming between the weir pickets. Now let m_j equal the percentage of fish sampled at the weir that were above size j. Because m_j represents the proportion of "large fish" in the weir count, we can estimate the number of large fish in the entire escapement. Let $\hat{W}_j$ equal the estimated number of fish above size j that were counted through the weir, and let's assume this is the number of "large fish" in the entire escapement. Thus, the estimated number of fish above size j that were counted at the weir is given by:

$$\hat{W}_j = W \cdot m_j \,. \tag{3}$$

Let r_j equal the percentage of fish above size j that were examined in the recovery sampling. T hen the estimated total escapement past the weir is given by:

$$\hat{E} = \hat{W}_j / r_j \,. \tag{4}$$

Finally, I developed four different sets of Petersen estimates using (1) initial marking at the weir and combined results in recovery samples #1 and #2, (2) initial marking at the weir and the results from recovery sample #1, (3) initial marking at the weir and the results from recovery sample #2, (4) initial marking from recovery sample #1 and results from recovery sample #2.

In the results section, I will refer to these as *Estimate Numbers 1–6*, respectively.

RESULTS

WEIR OPERATIONS

The Speel Lake weir was operational from July 14 to September 20. The weir crew counted 7,813 sockeye salmon past the weir (Table 1). Of the 7,813 fish, the weir crew marked 1,597 sockeye salmon with an adipose fin clip, and sampled 1,593 sockeye salmon for age sex and length. The 2003 total weir count was near the average for counts between 1996 and 2004 (Figure 2).

The sockeye salmon passed through the weir in distinct pulses, triggered by spikes in rainfall, as fish began to cluster at the mouth of the outlet stream (Table2; Figure 3). In early August, small amounts of amounts of rain triggered large numbers of fish to swim through the weir, and the effect continued for several days thereafter. The high weir counts occurred on August 4, August 11, August 27, and September 3. Changes in water temperature or water level at the weir did not have the effect that rainfall did in triggering fish passage (Figures 4 and 5).

RECAPTURE

On the first recovery trip, 330 sockeye salmon were examined and measured, and 56 had an adipose clip (Table 3). On the second recovery trip, 407 sockeye salmon were examined, and 63 had an adipose clip; 29 of the fish examined had been recovered during the first recovery trip.

DATA ANALYSIS

Estimates of Escapement

Comparisons of the fish lengths recorded during the initial marking at the weir, with those recorded during recovery samples (henceforth referred to as samples #1 and #2) confirmed that small fish were swimming through the weir (Kolmogorov–Smirnov or $K\text{-}S$=0.2046, p<0.001; Appendices 1 and 2, Table 4, Figure 6). I believe that, above a certain length, fish could not swim between the weir pickets, and sampling at the weir was representative of the fish larger than this length on the spawning grounds. I tried to ascertain the threshold length by specifying a length, deleting all samples smaller than or equal to this length from marking and recovery samples, performing a K-S test, then increasing the specified length if the K–S value was significant at α=0.05. Because the sample sizes were large, all K-S tests were significant, and detected minute differences in the initial marking and recovery samples. Therefore, I could not use K–S tests to detect a biologically meaningful threshold size for the marking and the recovery samples.

By comparing the lengths of fish in the weir and the recovery samples, I knew that minimum length (for stratifying the population) was going to be at least 400 mm. However, the K–S test for the 2 recovery samples above 400 mm was also significant ($K\text{–}S$ =0.1083, p =0.0352). I performed the same procedure on the 2 recovery samples, specifying a length above 400 mm, omitting all smaller fish in the samples, calculating a K–S test comparing the recovery samples, and respecifying a higher threshold length if the K–S test was significant. The K–S test for fish above 430 mm in the 2 recovery events was not significant ($K\text{-}S$ =0.076, p=0.33; Figure 7). Because this length was only 10 mm larger than the threshold length, I used for the 2003 escapement calculations, I chose 430 mm as the threshold length for stratifying the Speel Lake sockeye escapement.

Based on the results of the SPAS program, I chose the pooled Petersen estimate, for both larger (>430 mm) and smaller ($\leq$ 430 mm) fish. Data from the initial marking, and both recovery samples were included in the calculation. For the pooled Petersen estimate (Table 5, Estimate Number 3) for larger fish, the estimated number marked was 1,525. The estimated number of larger (non-jack) fish was 8,500, with a 95% confidence interval of 7,300 to 10,400. The coefficient of variation was 8%. For smaller fish or jacks, the pooled Petersen estimate was 640 sockeye salmon, with a 95% confidence interval of 400 to 1,400 fish, and coefficient of variation of 20%. In comparison, the weir count (Table 5, Estimate Number 1) contained about 7,500 larger fish, and about 350 smaller fish. The weir count for larger fish was within the confidence interval of the pooled Petersen estimate for its stratum, while the weir count for smaller fish was not.

I also calculated Petersen estimates for a combination of marking and recapture events (Table 5, Estimate Numbers 4–6). Except for the estimate of larger fish in Estimate Number 6, all estimates were near the corresponding pooled Petersen estimates (Estimate Number 3), and generated similar confidence intervals.

The "weir count" estimate (Estimate Number 2) of escapement is about 9,210 sockeye salmon, or which 1,750 were small fish (jacks) and 7,460 were large fish (Table 5).

The range of Petersen estimates from my various cases led me to conclude that the actual total escapement was between 8,400 and 9,800 sockeye salmon, and was probably about 9,000 fish. I concluded that the weir count was accurate for fish larger than 430mm (lengths mid-eye to fork), and that the "weir count" estimate (Estimate Number 2) was the preferred estimate of total escapement.

Age Composition

Of the 1,597 scale samples taken at the weir, 319 or 20.0% could not be aged. Of the 1,279 samples that were aged, 821 (64.2%) were classified as male and 458 (35.8%) were classified as female (Table 6). The largest age class for males was 1.2, which comprised 76.5% of the aged scales for males. The second most common age class for males was 1.3, which comprised 22.8% of aged male scale samples. For females, the largest age class was 1.3, and comprised 81.5% of the aged scales of females. The second largest age class for females was 1.2, and comprised 16.8% of the aged scales of females. All other age classes comprised less than 2% of the age composition for their respective sexes.

DISCUSSION

Results of the 2004 mark-recapture study at Speel Lake support the hypothesis that the Speel Lake weir allows sockeye small fish or jacks to pass between the pickets uncounted. The estimated weir count for fish larger than 430mm (lengths mid-eye-to-fork) was within the 95% confidence interval of the pooled Petersen estimate. Therefore, the weir appears to have effectively blocked fish larger than 430 mm, and allowed for accurate counting and sampling of these fish. The effective blocking of migration of larger fish is a requirement for the "weir count" estimate, which appears to be an accurate estimate of the total Speel Lake sockeye escapement for 2004.

ADF&G does have a weir configuration that obstructs passage of most sockeye jacks; the railings allow for 52 pickets per 8 foot section (instead of 43 pickets), and the holes are drilled 1-3/4 inches center-to-center (Leon Shaul, ADF&G, *personal communication*). However, this weir configuration requires considerably more daily debris removal, and the hatchery technicians assigned to the weir do not remain there overnight. Use of a more obstructive weir without 24-hour surveillance invites weir washouts.

The number of scale samples taken from male fish was almost twice as large as the number taken from female fish. Possible reasons include weir personnel being unable to sex fish accurately, and that high survival rates for the offspring of brood year 2000 produced a high return of age 1.2 males. The former explanation is unlikely, given the experience of the weir crew. The high percentage of age 1.2 fish may signal a higher than usual adult return to Speel Lake in 2005. However, the low percentage of age 1.2 females weakens the evidence for a large return in 2005.

Because the weir is size selective for larger fish, the age composition from the weir samples is not representative of the escapement as a whole. Scale samples taken on the spawning grounds would likely be more representative, but would also present other obstacles to the analysis. Some fraction of the scale samples taken on the spawning grounds would be impossible to read because of scale resorption. Taking scales on the spawning grounds during the mark-recapture study would entail considerably more effort, and would require sample sizes much larger than 800, to compensate for the scale samples that were too resorbed to use in scale pattern analysis of District 111 catches.

In previous years, temporal rainfall patterns exerted a compelling influence on salmon migration past the Speel lake weir (Riffe and Clark 2003). The 2004 season exhibited the same pattern of rainfall triggering migration past the weir in August and September.

RECOMMENDATIONS

In the future, DIPAC should conduct the Speel Lake weir project in the same manner as in 2004, and ADF&G should continue to conduct mark-recapture estimates to evaluate the weir counts.

ACKNOWLEDGEMENTS

Many people have contributed their time and expertise in assisting the author with this report. Douglas Island Pink and Chum (DIPAC) personnel manned the weirs, marked fish, and collected length data. Eric Prestegard, Rick Foch, and Steve Reid of DIPAC provided the weir data on a timely basis. Mark Olsen and Clyde Andrews examined fish on the spawning grounds, in the recovery portion of the mark-recapture study. Scott Willis of Alaska Electric Light and Power provided rainfall data. Hal Geiger provided guidance and direction.

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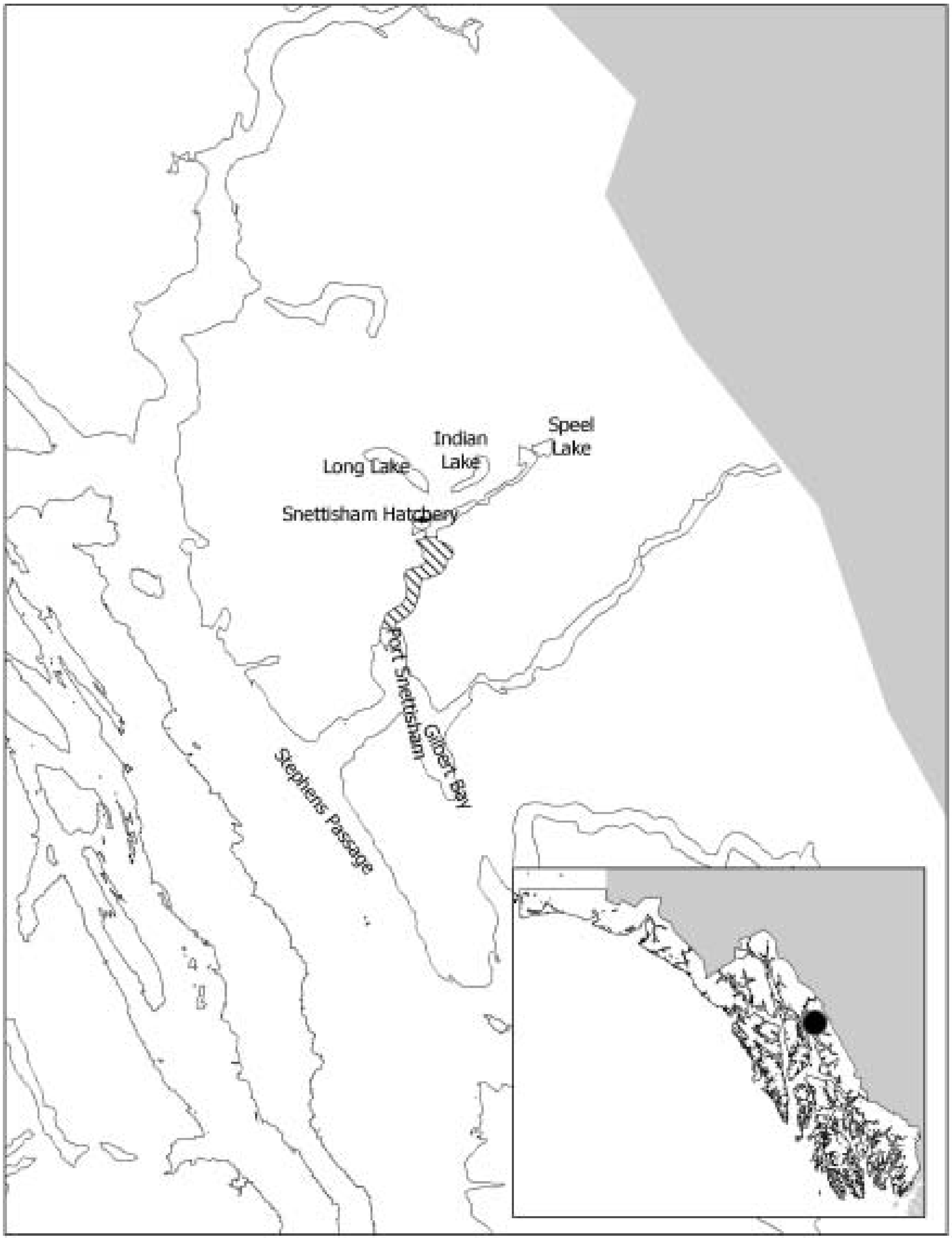

Figure 1.– Map of Speel Lake and surroundings, with inset of Southeast Alaska. Striped area denotes the hatchery Special Harvest Area (SHA).

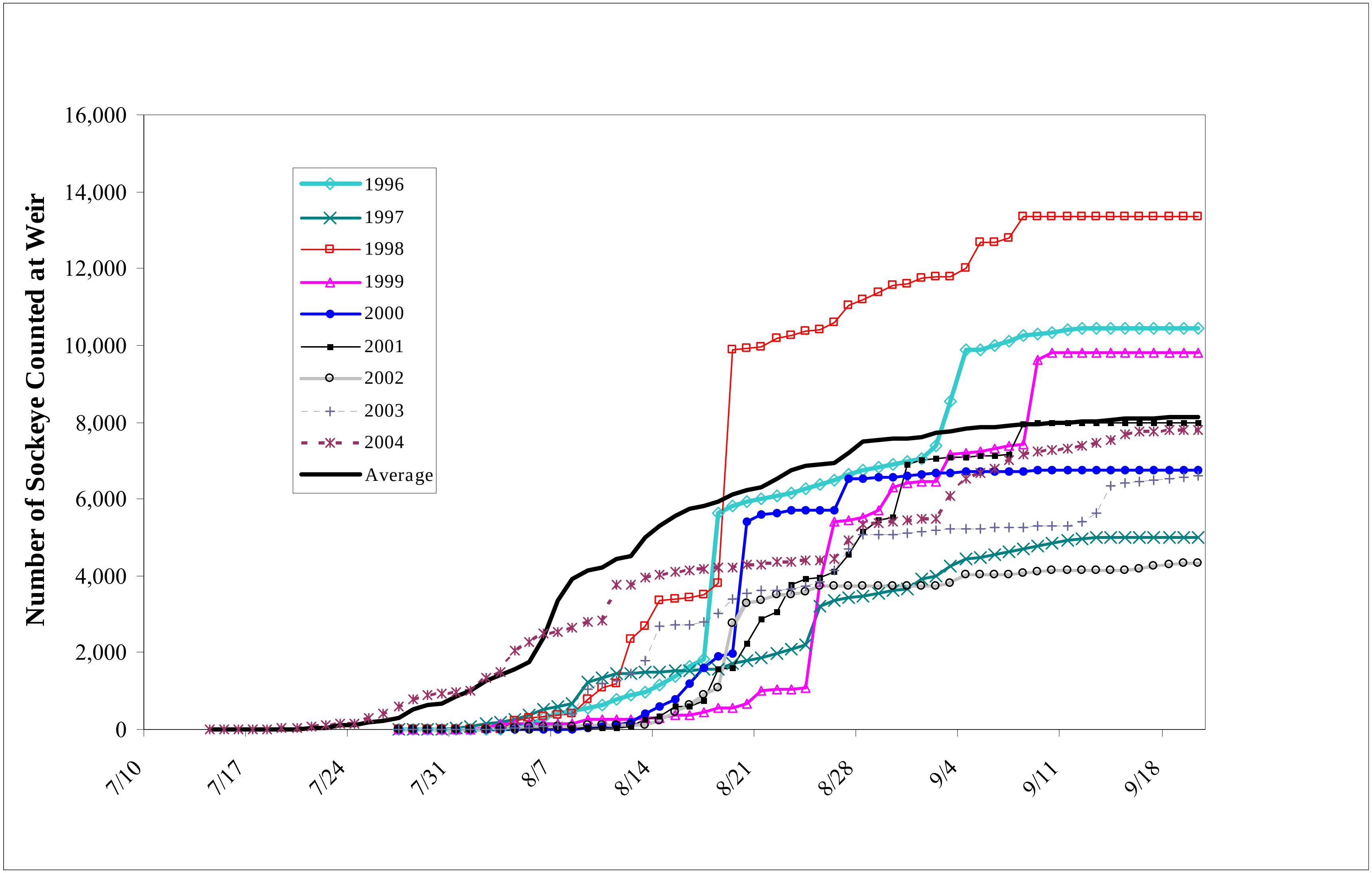

Figure 2.–Annual and average cumulative daily weir counts for Speel Lake sockeye salmon, from 1996 to 2004.

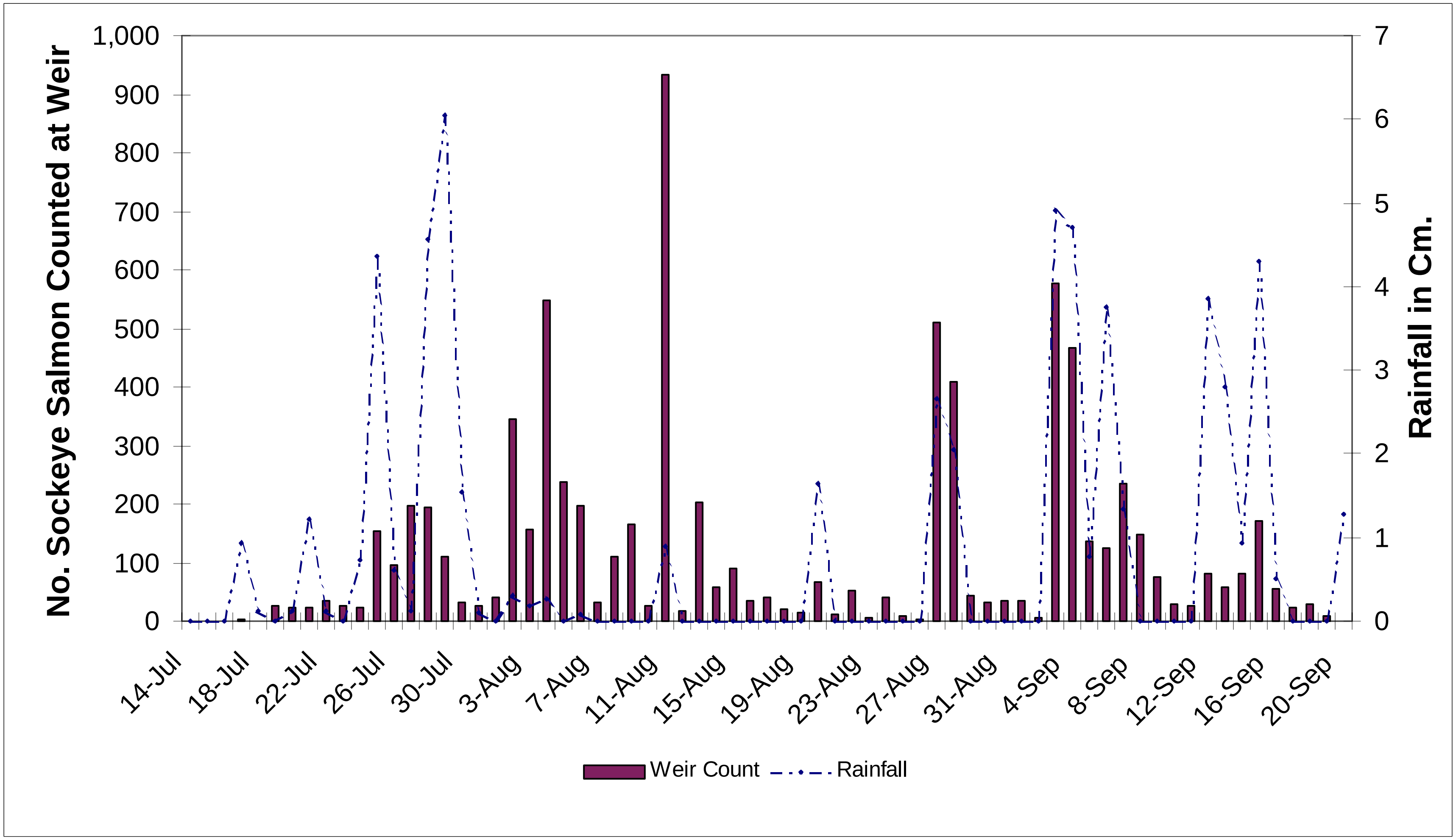

Figure 3.–Number of sockeye salmon per day counted Speel Lake weir, and amount of rainfall per day falling at Snettisham power plant in 2004.

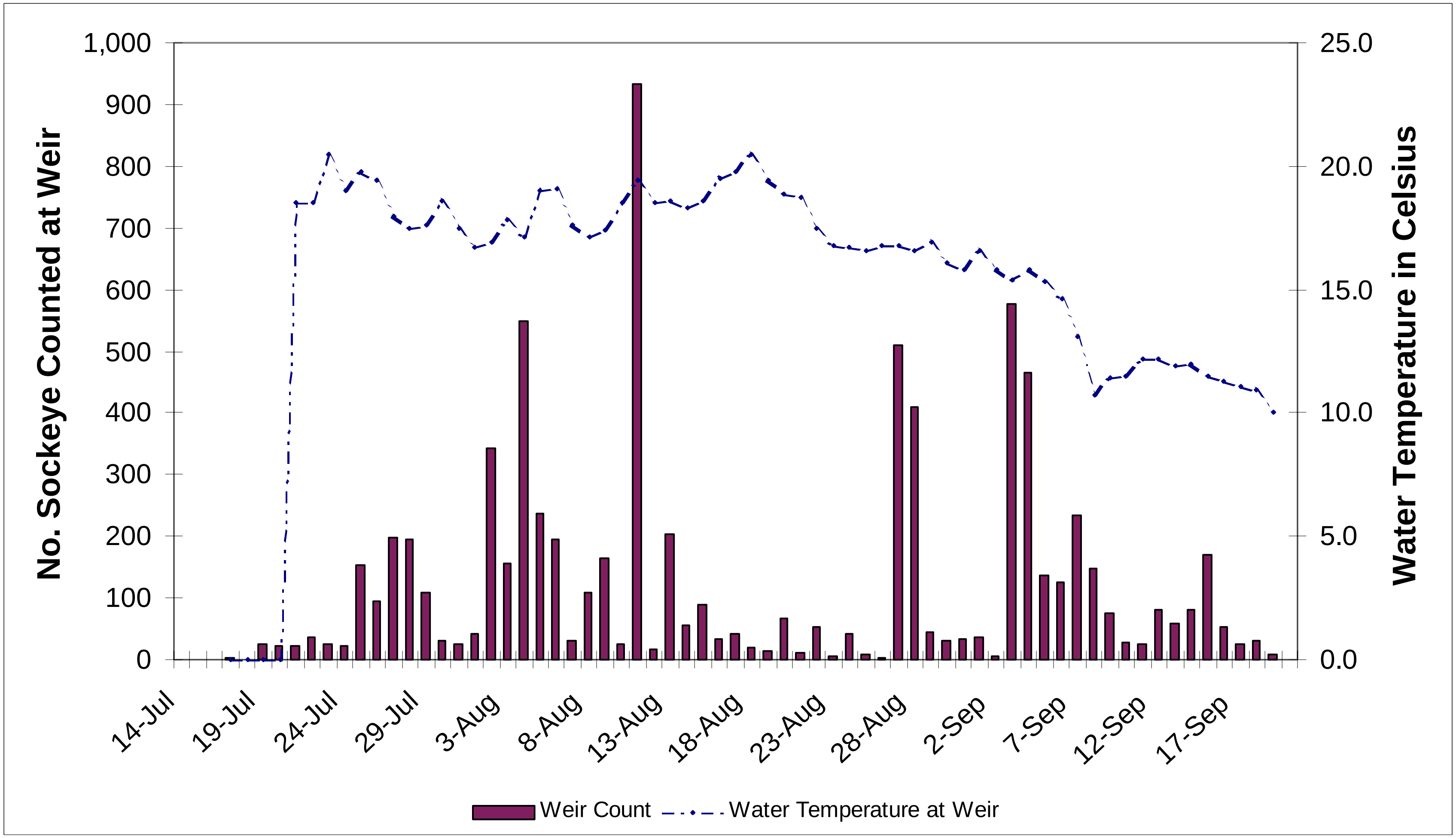

Figure 4.–Number of sockeye salmon counted per day at Speel Lake weir, and water temperature in degrees Celsius at Speel Lake weir in 2004.

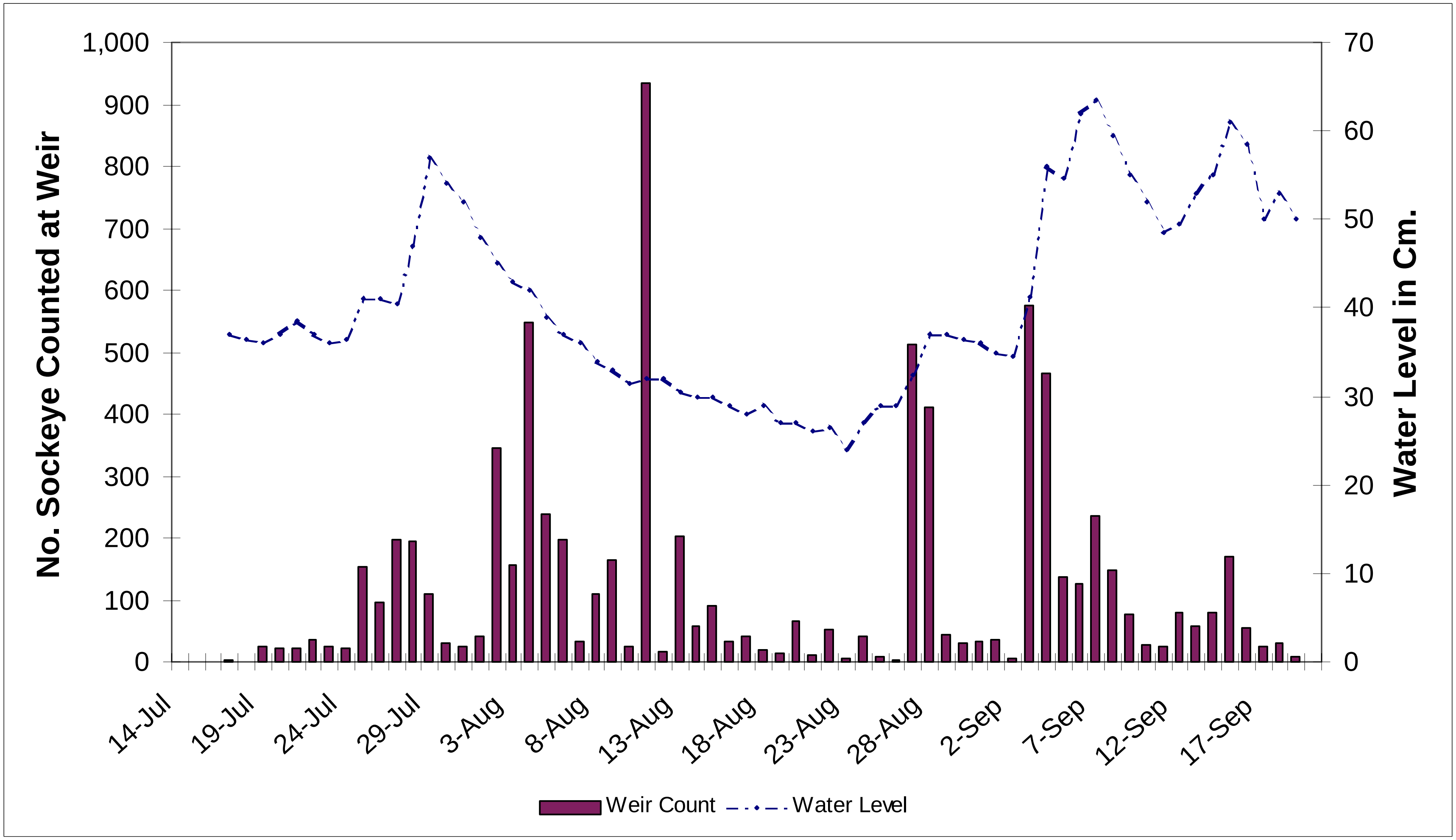

Figure 5.–Number of sockeye salmon counted per day at Speel Lake weir, and water level in centimeters at Speel Lake weir in 2004.

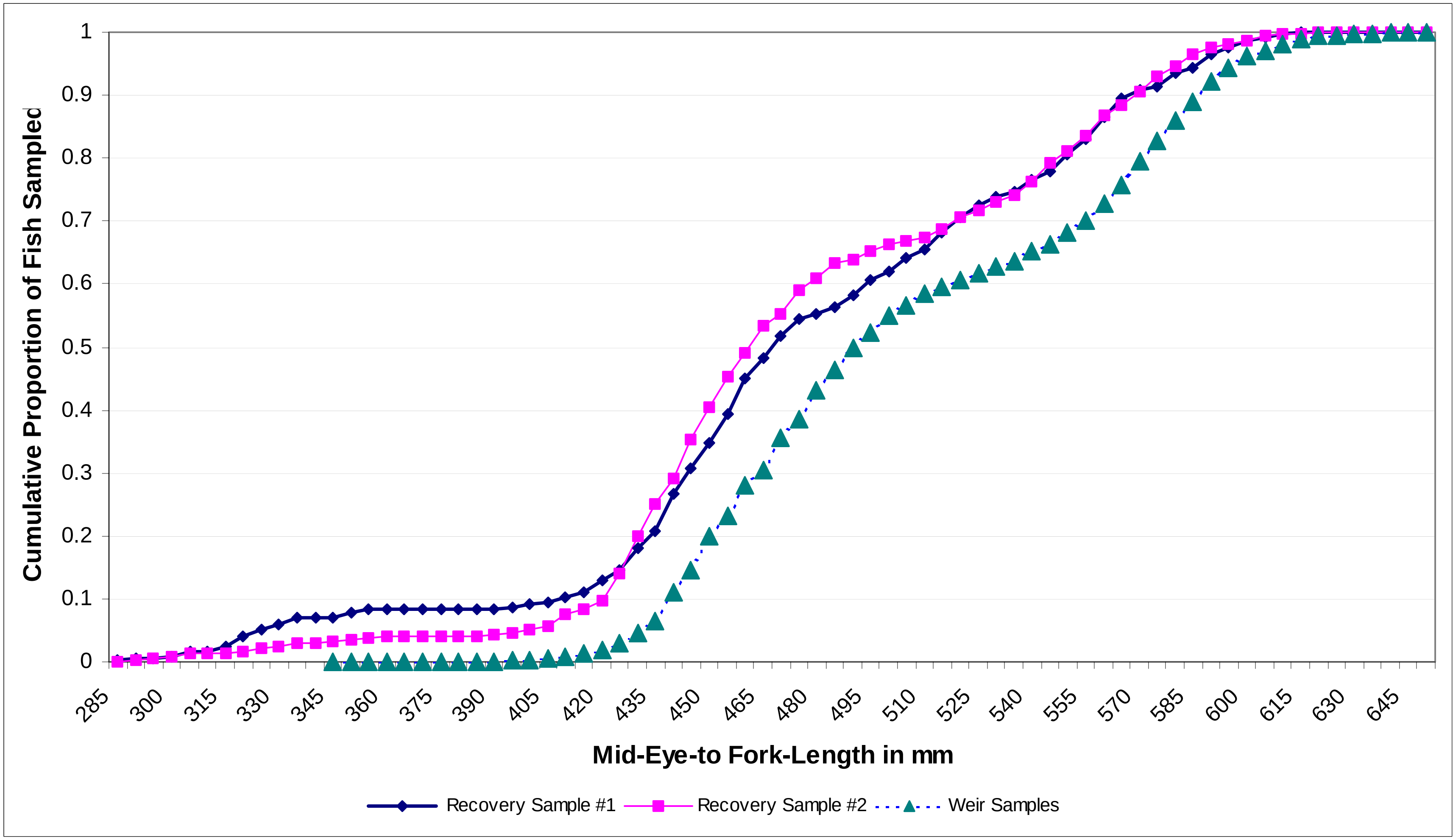

Figure 6.–Cumulative proportion by length of fish sampled at the Speel Lake weir, and in recovery samples #1 and #2.

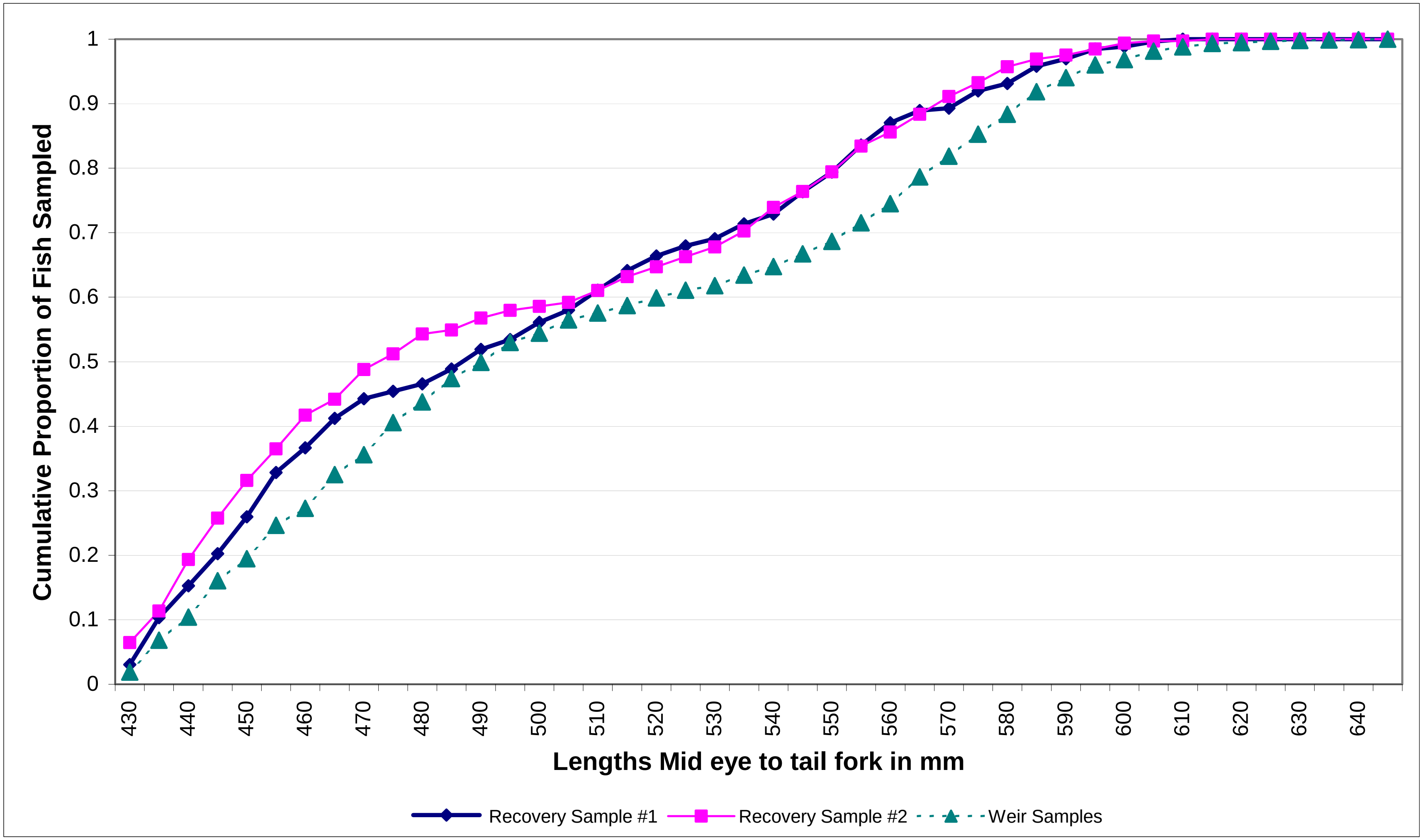

Figure 7.– Cumulative proportion by length of fish larger than 430 mm (lengths mid-eye to fork) that were sampled at the Speel Lake weir, and in recovery samples #1 and #2.

Table 1.–Daily number of sockeye salmon counted marked and sampled, water temperature, and water level, at Speel Lake weir, in 2004.

Date	No. Sockeye Counted	No. Sockeye Marked and Sampled for Scales	Water Temp. in Celsius	Water Level in Cm.
7/14	0	0	–	–
7/15	0	0	–	–
7/16	0	0	–	–
7/17	2	0	–	37
7/18	0	0	–	–
7/19	25	5	–	36
7/20	23	0	–	–
7/21	22	10	18.5	38.5
7/22	35	7	18.5	37.0
7/23	25	5	20.5	36.0
7/24	23	5	19.0	36.5
7/25	154	31	19.8	41.0
7/26	96	19	19.4	41.0
7/27	198	40	18.0	40.5
7/28	194	39	17.5	47.0
7/29	110	24	17.6	57.0
7/30	31	6	18.6	54.0
7/31	25	5	17.5	52.0
8/1	42	9	16.7	48.0
8/2	344	68	16.9	45.0
8/3	157	32	17.8	43.0
8/4	548	108	17.1	42.0
8/5	238	48	19.0	39.0
8/6	196	38	19.1	37.0
8/7	32	7	17.6	36.0
8/8	110	24	17.1	34.0
8/9	164	32	17.4	33.0
8/10	26	5	18.5	31.5
8/11	933	187	19.4	32.0
8/12	16	3	18.5	32.0
8/13	203	41	18.6	30.5
8/14	57	12	18.3	30.0
8/15	90	18	18.6	30.0
8/16	34	7	19.5	29.0
8/17	42	9	19.8	28.0
8/18	20	4	20.5	29.0
8/19	14	3	19.4	27.0
8/20	67	14	18.9	27.0
8/21	11	2	18.7	26.0
8/22	53	11	17.5	26.5
8/23	5	1	16.8	24.0
8/24	42	9	16.7	27.0
8/25	9	2	16.6	29.0
8/26	4	1	16.8	29.0
8/27	511	103	16.8	32.5
8/28	410	82	16.6	37.0
8/29	44	9	16.9	37.0
8/30	31	7	16.1	36.5
8/31	34	7	15.8	36.0
Totals	5,450	1,099		

-continued-

Table 1.–Page 2 of 2.

Date	No. Sockeye Counted	No. Sockeye Marked and Sampled for Scales	Water Temp. in Celsius	Water Level in Cm.
9/1	35	7	16.6	35.0
9/2	6	2	15.8	34.5
9/3	576	115	15.4	41.2
9/4	466	94	15.8	56.0
9/5	136	28	15.3	54.7
9/6	125	25	14.6	62.0
9/7	235	47	13.1	63.5
9/8	149	30	10.7	59.5
9/9	76	15	11.4	55.0
9/10	28	6	11.5	52.0
9/11	26	6	12.2	48.5
9/12	80	16	12.2	49.5
9/13	58	12	11.9	53.0
9/14	80	16	12.0	55.0
9/15	170	38	11.5	61.0
9/16	54	15	11.3	58.5
9/17	24	10	11.1	50.0
9/18	30	10	10.9	53.0
9/19	9	6	10.0	50.0
9/20	0	0	–	–
Grand Total	7,813	1,597		

Table 2.–Daily high and low temperatures, and rainfall, at Snettisham power plant in 2004.

Date	Temp. in ºC		Daily Rain in cm	Date	Temp. in ºC		Daily Rain in cm
	High	Low			High	Low	
7/14	23	14	0				
7/15	24	14	0	**8/18**	23	16	0
7/16	28	14	0	**8/19**	23	14	0
7/17	24	13	0.94	**8/20**	16	13	1.65
7/18	20	13	0.13	**8/21**	14	12	0
7/19	19	13	0	**8/22**	28	16	0
7/20	22	12	0.13	**8/23**	24	11	0
7/21	21	13	1.22	**8/24**	22	11	0
7/22	21	16	0.13	**8/25**	20	10	0
7/23	23	14	0	**8/26**	20	12	0
7/24	24	14	0.74	**8/27**	16	11	2.67
7/25	17	12	4.37	**8/28**	18	11	2.06
7/26	16	12	0.61	**8/29**	16	11	0
7/27	17	13	0.13	**8/30**	14	10	0
7/28	17	15	4.57	**8/31**	16	11	0
7/29	16	13	6.05	**9/1**	19	8	0
7/30	12	12	1.55	**9/2**	19	11	0
7/31	17	12	0.10	**9/3**	19	13	4.90
8/1	17	11	0	**9/4**	13	10	4.70
8/2	11	11	0.30	**9/5**	12	10	0.76
8/3	21	11	0.18	**9/6**	13	9	3.76
8/4	17	11	0.25	**9/7**	13	6	1.35
8/5	20	11	0	**9/8**	16	7	0
8/6	20	13	0.08	**9/9**	17	6	0
8/7	20	12	0	**9/10**	17	3	0
8/8	19	14	0	**9/11**	9	8	0
8/9	22	13	0	**9/12**	9	8	3.86
8/10	24	14	0	**9/13**	9	9	2.79
8/11	28	16	0.89	**9/14**	9	8	0.94
8/12	21	11	0	**9/15**	7	6	4.29
8/13	21	12	0	**9/16**	7	5	0.51
8/14	22	13	0	**9/17**	6	6	0
8/15	23	16	0	**9/18**	13	6	0
8/16	32	17	0	**9/19**	14	2	0
8/17	31	16	0	**9/20**	8	7	1.27

Table 3.–Summary of information obtained during recovery phase of the 2004 Speel Lake sockeye salmon mark-recapture study, stratified by size.

Variables	Recovery Event #1	Recovery Event #2
Dates	**Sept. 21–22**	**Oct. 5–6**
Sockeye larger than 430 mm		
No. examined	262	326
No. marked at weir	52	52
Percent marked at weir	19.8%	17.0%
No. previously recovered	not applicable	21
No. previously recovered adipose clip	not applicable	3
No. given new marks	250	211
Sockeye smaller than or equal to 430 mm		
No. examined	58	81
No. marked at weir	4	11
Percent marked at weir	6.9%	13.6%
No. previously recovered	not applicable	8
No. previously recovered with adipose clip	not applicable	2
No. given new marks	51	53

Table 4.–Comparison of number and percent of sockeye salmon sampled, by size strata, at the Speel Lake weir, and during recovery sampling trips 1 and 2 of the Speel Lake mark-recapture study during 2004.

Variable	Weir Samples	Recovery Sample #1	Recovery Sample #2
No. sockeye examined and measured	1,593	320	407
No. greater than 430 mm	1,521	262	326
No. less than or equal to 430 mm.	72	58	81
Percent greater than 430 mm	95.5%	81.9%	80.1%
Percent less than or equal to 430 mm.	4.5%	18.1%	19.9%

Table 5.–Comparison of weir counts and mark-recapture estimates for sockeye salmon larger or smaller than 430 mm (mid-eye to tail fork) escaping into Speel Lake in 2004.

Source of estimate	Estimated No. Sockeye > 430	Estimated No. Sockeye ≤ 430
1.) Weir count * (percent fish in designated length stratum of weir samples)		
Estimate	7,460	353
2.) (Estimated number larger fish in weir count)/(Percent larger fish in recovery sampling)		
"Weir Count" estimate[a]	7,460	1,750
3.) Mark-Recapture Study, Initial Marking at Weir, Recovery (at) Samples #1 (Sept. 21–22) and #2 (Oct. 5–6)		
Mark-–Recapture estimate	8,500	640
95% Confidence Interval for Mark-Recapture estimate	7,300–10,400	400–1,400
Number caught	567	139
Number caught having a weir mark	101	15
Percent of samples marked at weir	18%	11%
95% Confidence Interval for percent marked	15%–21%	5%–17%
4.) Mark-Recapture Study, Initial Marking at Weir, Recovery (at) Sample #1 (Sept.21–22)		
Mark-–Recapture estimate	7,600	860
95% Confidence Interval for Mark-Recapture estimate	6,200–10,000	400–3,600
Number caught	262	58
Number caught having a weir mark	52	4
Percent of samples marked at weir	20%	7%
95% Confidence Interval for percent marked	15%–25%	2%–17%
5.) Mark-Recapture Study, Initial Marking at Weir, Recovery (at) Sample #2 (Oct.5–6)		
Mark-–Recapture estimate	9,300	500
95% Confidence Interval for Mark-Recapture estimate	7,500–12,900	400–1,000
Number caught	305	81
Number caught having a weir mark	49	11
Percent of samples marked at weir	16%	14%
95% Confidence bound for percent marked	12%–20%	7%–17%
6.) Mark-Recapture Study, Marking at Recovery Sample #1 (Sept 21–22), Recapture at Recovery Sample #2 (Oct. 5–6)		
Mark-–Recapture estimate	3,700	470
95% Confidence Interval for Mark-Recapture estimate	2,700–8,300	300–1,900
Number caught	326	81
Number marked during recovery sample #1	21	8
Percent of samples marked during recovery sample #1	6%	10%
95% Confidence bound for percent marked	4%–9%	5%–19%

[a] Result of calculation was an estimated total escapement of 9,200 sockeye salmon.

Table 6.– Number and percent by age and sex of sockeye salmon sampled at Speel Lake weir, 2004.

Brood Year	Age	Males		Females		Total	
		Number	Percent	Number	Percent	Number	Percent
2001	0.2	1	0.1%	1	0.2%	1	0.1%
2000	0.3	1	0.1%	4	0.9%	5	0.4%
	1.2	628	76.5%	77	16.8%	705	55.2%
	2.1	1	0.1%	0	–	1	0.1%
1999	1.3	187	22.8%	373	81.5%	560	43.8%
	2.2	3	0.4%	0	–	3	0.2%
1998	1.4	0	–	2	0.4%	2	0.2%
	2.3	0	–	1	0.2%	1	0.1%
	Total	821	100.0%	458	100.0%	1,278	100.0%

APPENDIX

Appendix 1.–Number of fish sampled by length during the initial sampling at the weir, and the first recovery sampling trip in the 2004 Speel Lake sockeye salmon mark-recapture study. The first recovery sampling recaptures are fish marked at the weir that were caught during the first recovery sampling trip.

Length	Marking at Weir	1st Recovery Sampling	1st Recovery Sampling Recaptures	Length	Marking at Weir	1st Recovery Sampling	1st Recovery Sampling Recaptures
285	–	1	–	**470**	79	12	3
290	–	1	–	**475**	47	8	1
295	–	–	–	**480**	76	3	–
300	–	1	–	**485**	49	3	–
305	–	2	–	**490**	55	6	1
310	–	–	–	**495**	38	8	3
315	–	3	–	**500**	47	4	1
320	–	5	–	**505**	22	7	1
325	–	3	–	**510**	31	5	1
330	–	3	–	**515**	16	8	2
335	–	3	–	**520**	18	8	2
340	–	–	–	**525**	18	6	–
345	1	–	–	**530**	18	4	1
350	–	3	–	**535**	11	3	–
355	–	2	–	**540**	25	6	1
360	–	–	–	**545**	20	4	1
365	–	–	–	**550**	30	9	2
370	–	–	–	**555**	29	8	1
375	–	–	–	**560**	44	11	2
380	–	–	–	**565**	45	9	2
385	–	–	–	**570**	63	5	–
390		–	–	**575**	49	1	–
395	2	1	–	**580**	52	7	2
400	1	1	–	**585**	47	3	–
405	4	1	–	**590**	53	7	2
410	4	3	–	**595**	33	3	–
415	8	2	–	**600**	30	4	1
420	10	6	–	**605**	13	1	–
425	16	6	3	**610**	20	2	–
430	26	11	1	**615**	10	1	1
435	29	8	2	**620**	8	–	–
440	75	19	5	**625**	2	–	–
445	54	13	3	**630**	3	–	–
450	86	13	3	**635**	2	–	–
455	52	15	5	**640**	1	–	–
460	79	18	1	**645**	1	–	–
465	40	10	2	**650**	1	–	–

Appendix 2.–Number of fish sampled by length during the initial sampling at the weir, and the second recovery sampling trip in the 2004 Speel Lake sockeye salmon mark-recapture study. The second recovery sampling recaptures are fish marked at the weir that were caught during the second recovery sampling trip.

Length	Marking at Weir	2nd Recovery Sampling	2nd Recovery Sampling Recaptures	Length	Marking at Weir	2nd Recovery Sampling	2nd Recovery Sampling Recaptures
285	–	–	–	**470**	79	8	1
290	–	1	–	**475**	47	15	3
295	–	1	–	**480**	76	8	–
300	–	1	–	**485**	49	10	1
305	–	2	–	**490**	55	2	1
310	–	–	–	**495**	38	6	1
315	–	–	–	**500**	47	4	–
320	–	2	–	**505**	22	2	–
325	–	2	–	**510**	31	2	2
330	–	1	–	**515**	16	6	1
335	–	2	–	**520**	18	7	–
340	–	–	–	**525**	18	5	–
345	1	1	–	**530**	18	5	1
350	–	1	–	**535**	11	5	1
355	–	1	–	**540**	25	8	1
360	–	1	–	**545**	20	12	–
365	–	1	–	**550**	30	8	1
370	–	–	–	**555**	29	10	3
375	–	–	–	**560**	44	13	1
380	–	–	–	**565**	45	7	3
385	–	–	–	**570**	63	9	2
390	–	1	–	**575**	49	9	1
395	2	1	–	**580**	52	7	2
400	1	2	–	**585**	47	8	1
405	4	2	–	**590**	53	4	1
410	4	8	1	**595**	33	2	1
415	8	3	1	**600**	30	3	1
420	10	6	2	**605**	13	3	
425	16	17	3	**610**	20	1	1
430	26	24	4	**615**	10	–	–
435	29	21	2	**620**	8	1	–
440	75	16	2	**625**	2	–	–
445	54	26	5	**630**	3	–	–
450	86	21	3	**635**	2	–	–
455	52	19	7	**640**	1	–	–
460	79	16	1	**645**	1	–	–
465	40	17	1	**650**	1	–	–