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Falls Lake Subsistence Sockeye Salmon Project: 2009 Annual and Final Report

by

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August 2010

Alaska Department of Fish and Game **Divisions of Sport Fish and 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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ADF&G Fishery Data Series was established in 1987 for the publication of Division of Sport Fish technically oriented results for a single project or group of closely related projects, and in 2004 became a joint divisional series with the Division of Commercial Fisheries. Fishery Data Series reports are intended for fishery and other technical professionals and are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

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ABSTRACT

In 2009, we conducted the ninth consecutive year of a project to monitor the subsistence harvest and escapement of sockeye salmon (*Oncorhynchus nerka*) at Falls Lake. Fish were counted and marked as they migrated into a trap at the top of a fish ladder at the outlet of the lake. Scale samples and length measurements were taken at the trap for analysis of age and length compositions. The sampling crew also conducted an on-site harvest survey of the subsistence fishery. The mark-recapture estimate of the sockeye salmon escapement for 2009 was 2,100 fish. The dominant brood year was 2004 (62.4% of the run) with about half the 2004 brood year spending one year in freshwater (age 1.3; 32.7% of the run). The estimated subsistence harvest of 1,350 sockeye salmon (based on interviews of fishermen on the grounds), was about 40% of the terminal run (subsistence harvest plus escapement). Monitoring of the sockeye salmon escapement and subsistence harvest provides the basic data needed to make informed management decisions in the Falls Lake subsistence fishery.

Key words: Sockeye salmon, *Oncorhynchus nerka*, subsistence, Falls Lake, escapement, mark-recapture, age composition, Southeast Alaska.

INTRODUCTION

Falls Lake, located on the east side of Baranof Island, produces small but consistent runs of sockeye salmon (*Oncorhynchus nerka*) that support an active subsistence fishery for the people of Kake (Figure 1). The Tlingit regional group occupying the area, known as the *Keex'kwaan*, traditionally harvested fish from Falls Lake for hundreds of years (Goldschmidt and Haas 1998; Turek et al. 2006). Before European-American contact, this sockeye salmon system was controlled by the leader of a clan or house group, and an extended family group most likely lived seasonally at a fish camp or semi-permanent village near the creek (Betts and Wolfe 1992; Turek et al. 2006). Kake residents kept seasonal fish camps at the Falls Lake outlet at least through the 1940s.

Directed commercial harvest on the Falls Lake sockeye salmon stock occurred between 1913 and 1922, with annual harvests ranging from about 1,000 to 10,000 fish, and averaging about 3,600 fish (Rich and Ball 1933). Directed harvest of this stock was discontinued after the 1920s, but Falls Lake sockeye salmon undoubtedly continued to be caught in mixed stock, primarily purse seine, fisheries in Chatham Strait. The specific contribution of the Falls Lake stock in recent commercial harvests, however, is unknown because individual stocks are not identified in these fisheries.

More recently, subsistence fishermen from Kake are the primary harvesters of the terminal sockeye salmon run. Present-day Kake residents now travel the distance of about 50 km from Kake, across the exposed waters of lower Chatham Strait, to day-fish for sockeye salmon at Falls Lake. Because of the long, exposed crossing and lack of suitable anchorages around Falls Lake, most subsistence fishermen try to travel from Kake during good weather and harvest their season's supply of sockeye salmon in a single day.

Quantitative records of subsistence effort and harvest of sockeye salmon in Falls Creek Bay, starting from 1985, have been obtained from Alaska Department of Fish and Game (ADF&G) subsistence fishing permits. Subsistence fishing participants are required to turn in their permit with catch and area information to ADF&G after the season prior to obtaining a permit for the subsequent year; however, the tendency to under report harvest has been observed at Falls Lake and elsewhere (Riffe et al. 2009, Walker 2009), and these harvest data should be considered minimum estimates of the actual subsistence harvest. In addition, we have collected subsistence harvest data through on-site harvest surveys (2001–2005 and 2008), which, while better than the reported harvest, should also be considered underestimates of total subsistence harvest (Riffe et al. 2009).

Regardless of the subsistence harvest data type (permit or on-site survey), the subsistence harvest rate on the terminal run has been relatively high, often 50% or greater, which has lead to conservative management of the subsistence fishery (Conitz and Cartwright 2005; Conitz 2008; Appendix A1). Sockeye salmon return to the outlet of Falls Lake starting in late June or early July. They often spend several weeks schooled up around the creek mouth before ascending the falls into the lake (from which the lake derives its name), and when weather and tides are favorable for fishing they are especially susceptible to harvest. Most sockeye salmon are unable to ascend the lower falls when the tide is low, and once they are able to enter Falls Creek the upper falls immediately presents another partial barrier to their migration into the lake. A fish pass was constructed in the upper part of the outlet stream in 1986 by the U.S. Forest Service to aid salmon passage. In order to continue to provide fishing opportunities on this heavily harvested stock, managers have used stock assessment information on the timing of harvest and escapement to adjust time and area regulations in the subsistence area.

Escapement counting and other biological studies, including a lake fertilization study, were conducted at Falls Lake through most of the 1980s (summarized in Conitz et al. 2002). The current sockeye salmon stock assessment program was started in 2001 (Conitz et al. 2002; Conitz and Cartwright 2003; Conitz and Cartwright 2005; Conitz and Cartwright 2007; Conitz 2007; Conitz 2008; Riffe et al. 2009). Each season a trap or weir was installed at the top of the fish ladder on the outlet creek to count sockeye salmon and other fish that ascended the falls via the fish ladder. A portion of the sockeye salmon escapement was marked and sampled for age-sex-length data. Other sampling conducted in the past included visual surveys of spawning areas, mark-recapture studies, on-site subsistence harvest surveys, and limnological and juvenile sockeye salmon sampling. In 2009, our ninth straight year of field operations at Falls Lake, we estimated the sockeye salmon subsistence harvest, conducted a mark-recapture study to estimate the spawning escapement of sockeye salmon, and collected scale samples to estimate the age-sex composition of the escapement.

OBJECTIVES

1. Estimate the subsistence harvest of sockeye salmon from the fishing area around the mouth of the Falls Lake outlet using an on-site survey, so that the estimated coefficient of variation is less than 15%.
2. Estimate the escapement of sockeye salmon into Falls Lake with a standard, 2-sample mark-recapture study, marking fish at a trap at the top of the fish ladder and sampling for marked fish on the spawning grounds, so that the estimated coefficient of variation is less than 10%.
3. Estimate the age, length, and sex composition of sockeye salmon in the Falls Lake spawning population, with a target sample size of 600 fish, so that the estimated coefficient of variation for the 2 major age classes is 10% or less.

SUBSISTENCE HARVEST MANAGEMENT HISTORY

Harvest of subsistence sockeye salmon at Falls Lake has increased since 1992 as a result of changes to the commercial fishing industry (Turek et al. 2006). Prior to limited entry (in the commercial fishery) Kake residents retained salmon through commercial fisheries rather than through subsistence fisheries. Since limited entry was instituted in the commercial fisheries, there has been a decline in the number of commercial salmon fishing boats operating out of Kake; salmon and halibut permits declined from 103 in 1980 to 67 in 2000 (Turek et al. 2006).

This change in harvest patterns has lead to a series of management changes in the subsistence fishery. In the late 1990s, the department received complaints from members of the public who observed illegal subsistence harvest practices, including harvests well above the 10 fish daily possession limit in place at the time (Dave Gordon, ADF&G fisheries management biologist, *personal communication*). This raised concerns about the sustainability of the fishery, which prompted management action. In the absence of information about the size of the spawning escapement, managers chose to shorten the subsistence fishing season. The idea was to limit harvest on the latter part of the run to ensure some minimum level of escapement into the lake while still providing for subsistence opportunity. ADF&G managers, somewhat arbitrarily, chose to close the subsistence season on July 20, the date when 80% of the harvest had normally occurred, based on the daily harvest figures reported on state subsistence permits for years 1985–1997. The July 20 closure date was implemented during the 1999 and 2000 seasons (Conitz and Cartwright 2005; Appendix A1). Similar actions were taken at several other Sitka Management Area sockeye salmon systems using an 80% harvest criteria to determine a closure date.

Although harvest data were used to set the harvest closure, one concern that this strategy did not address was the need to distribute harvest evenly throughout the run. In years when a weir was operated, over 90% of the total harvest already occurred by the time 50% of the total escapement passed through the weir (Dave Gordon, ADF&G fisheries management biologist, *personal communication*; ADF&G unpublished data). Falls Lake sockeye salmon are highly susceptible to harvest pressure because these fish spend several weeks staging in saltwater at the creek mouth prior to ascending the partial barrier falls or the fish pass (constructed in the upper part of the outlet stream in 1986 by the U.S. Forest Service) into the lake.

Additional changes have been made to the subsistence management of the Falls Lake stock since 2001. In 2002, representatives from the Organized Village of Kake tribal government and ADF&G fishery managers negotiated to close a 300 ft area in front of the fish pass as a way to reduce the efficiency of fishing nets and, ideally, distribute the harvest over a longer period. In addition, the annual possession limit for sockeye salmon was increased from 10 fish to 50 fish in order to reduce the need for repeated trips to and from the fishing grounds across the open water of Chatham Strait (Bill Davidson, ADF&G fisheries management biologist, *personal communication*). The season dates have since been adjusted in an attempt to protect the earlier-returning (late June–early July) portion of the sockeye salmon run. The latest change occurred before the start of the 2009 season. Due to a low escapement in 2008, the annual household limit was lowered from 50 to 25 sockeye salmon and the fishing line was moved farther out into the saltwater away from the falls (Dave Gordon, ADF&G fisheries management biologist, *personal communication*).

STUDY SITE

Falls Lake (lat 56°49.5’N, long 134°42.2’W) is located on the east side of Baranof Island (Figure 1), just south of Red Bluff Bay and within the central Baranof metasediments subsection (Nowacki et al. 2001). It lies in a steep mountain cirque basin at an elevation of about 20 m, and drains a watershed area of about 1,650 ha. The continental ice sheets of the Pleistocene Ice Age never overrode the upper elevations of the steep angular mountains in this area, but abundant precipitation formed smaller alpine glaciers, which carved the landscape and persist today. Frequent landslides, debris torrents, and avalanches sweep down the steep slopes, forming colluvial and alluvial fans around the bases of the mountains (Nowacki et al. 2001).

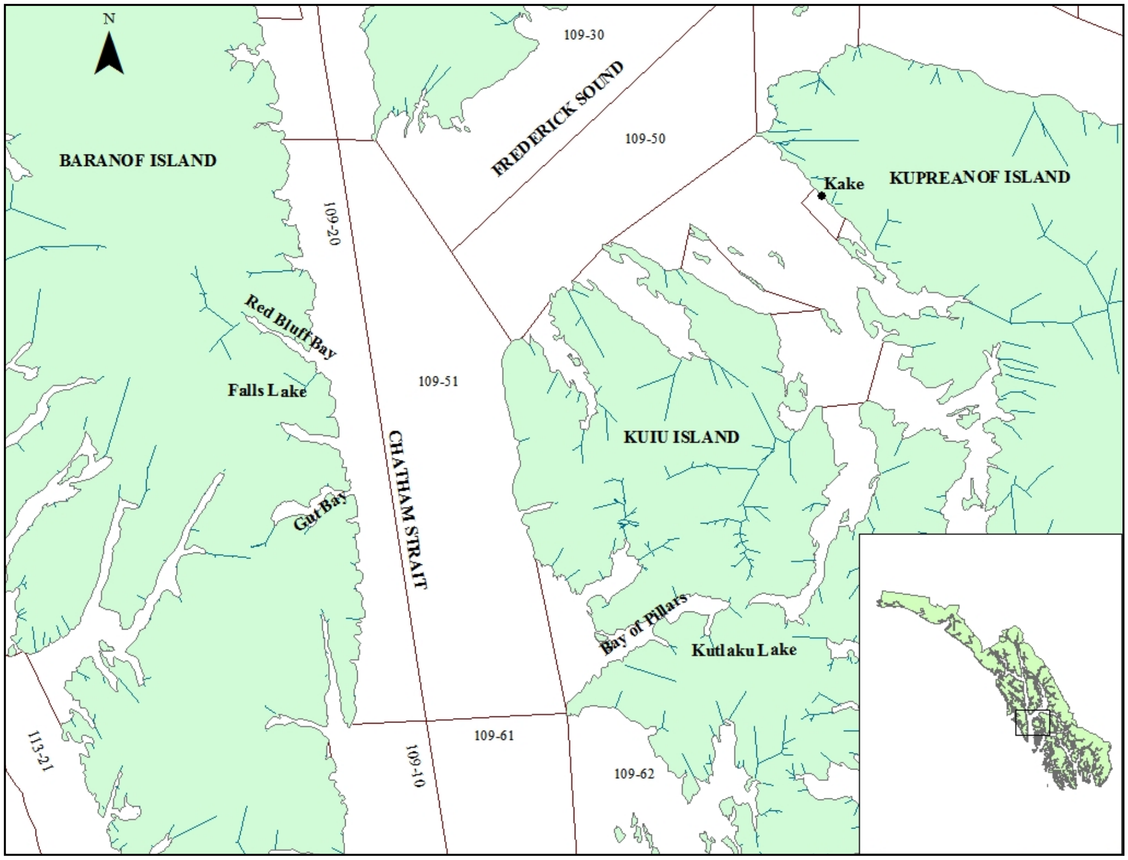

Figure 1.–Map showing the location of Falls Lake on Baranof Island, in relation to the village of Kake, in Southeast Alaska (inset). Commercial fishing districts in waters adjacent to the study site are also shown.

Falls Lake's 2 main inlet streams, originating in hanging glaciers and steep mountain falls, have formed large alluvial fans at their lower ends, which support productive old-growth spruce forest and willow and alder thickets. Both stream channels are dynamic, with rapid changes apparent from flooding, beaver activity, and forest succession. The southwest inlet stream is sometimes cloudy with glacial silt; the west-southwest inlet stream is usually clear. Falls Lake has a surface area of about 95 ha, and an average depth of 32 m. The large main basin in the center of the lake reaches a maximum depth of 75 m; a shallow sill separates the main basin from a smaller basin near the outlet (Figure 2). Falls Lake is organically stained and oligotrophic. Nutrient and chlorophyll levels, measured in the 1980s, were low and levels of dissolved ions and other water chemistry parameters were typical of lakes along the southeast Alaska coast (Conitz et al. 2002).

A very short outlet stream plunges over 2 falls directly into Chatham Strait. A fish pass was constructed in the upper part of the outlet stream in 1986 by the U.S. Forest Service to aid salmon migration. Sockeye and coho (*O. kisutch*) salmon ascend the falls and spawn in the lake or inlet streams. Spawning occurs mainly in the lower reaches and around the mouths of the 2 largest inlet streams, which enter the southwest corner of the lake (Figure 2). Both streams have partial or complete migration barriers a short distance upstream from the lake. Pink salmon (*O. gorbuscha*) spawn in lower section of the outlet stream; a very small number of pink salmon ascend the falls. The lake supports resident and anadromous populations of Dolly Varden char (*Salvelinus malma*), as well as sticklebacks (*Gasterosteus aculeatus*), and a few sculpins (*Cottus cognatus*).

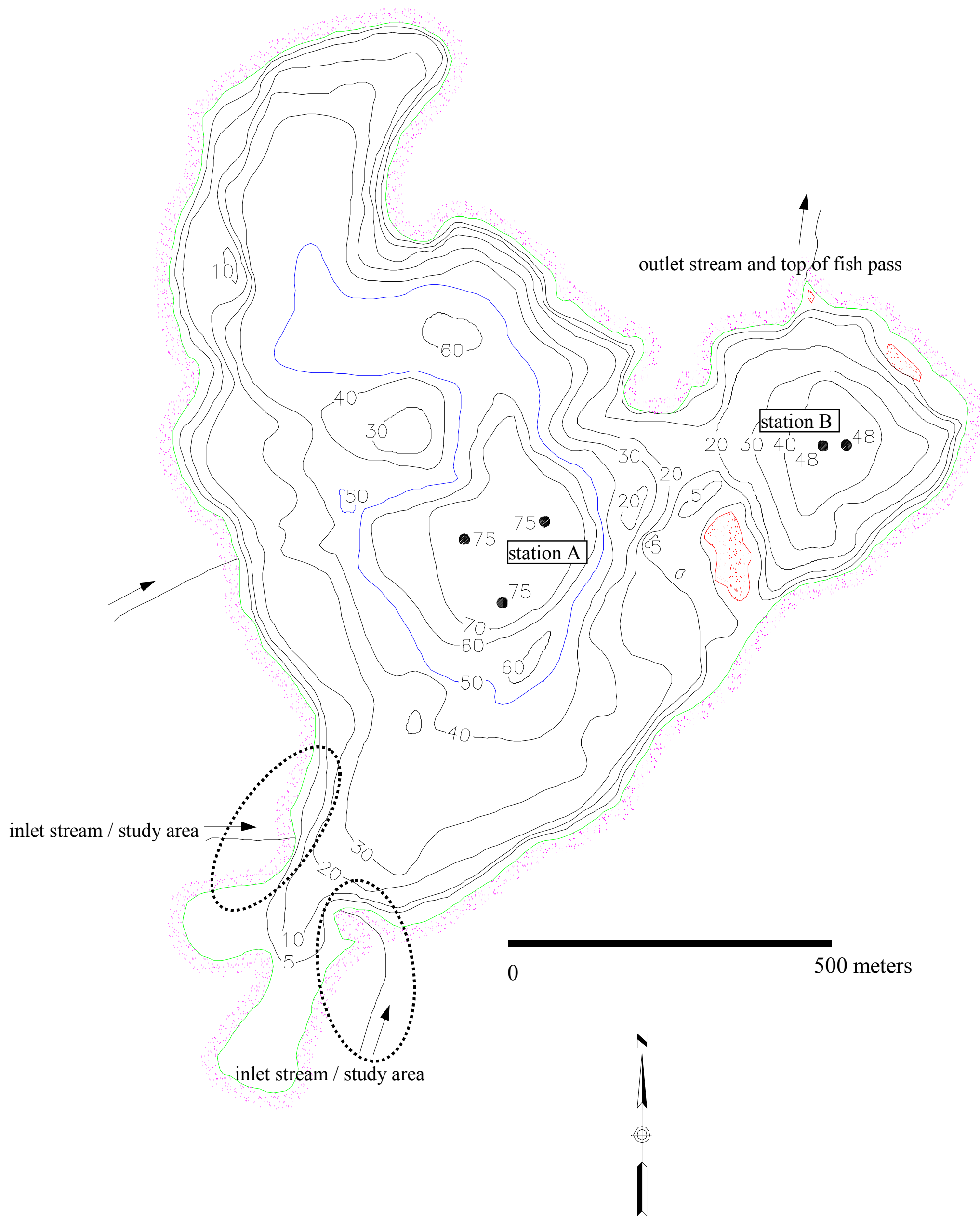

Figure 2.–Bathymetric map of Falls Lake, showing 10 m depth contours, fixed limnology sampling stations A and B (not sampled in 2009), and mark-recapture study areas at the two inlet spawning streams.

METHODS

SUBSISTENCE HARVEST ESTIMATE

In 2009, subsistence fishing at Falls Lake was open from June 1 through July 13, and again from July 23 to August 15. Sport fishing was open the entire season from May through September. Given the low number of participants in the fishery, samplers were able to monitor the fishing area from 0500 to 2300 daily, between July 1 and August 31. Both subsistence and sport fisheries were monitored. Fishery participants were contacted as they entered the area, counted by gear type (subsistence seine, subsistence gillnet, subsistence dipnet, or sport rod), and asked to complete an interview before leaving the area. Data collected during each interview included angler effort (rod or net hours) and harvest by species. If the technician was unable to interview a participant it was recorded as a missed interview if no estimate of harvest was observed.

Equations for estimating harvest, catch, and effort in each harvest survey were those for a one-stage direct expansion (access point, completed-trip interview) survey (Cochran 1977). This design was appropriate because the crew could accurately count all boats in the fishery and interview participants in most boats after they completed fishing. The primary sampling units were boat-parties within days. For each gear group, let h_j denote harvest on boat j, m denote number of boat-parties interviewed, and M denote number of boat-parties counted. The harvest, for a given gear group, was estimated as,

$$\hat{H} = \frac{M}{m}\sum_{j=1}^{m} h_{j}. \tag{1}$$

Letting $\overline{h}$ denote the mean harvest per boat, the variance of the harvest by stratum (gear group) was estimated as,

$$\operatorname{var}(\hat{H}) = (1-\frac{m}{M})M^2 \frac{\sum_{j=1}^{m}(h_j-\overline{h})^2}{m(m-1)}. \tag{2}$$

If all boat-parties within a gear group were interviewed, the one-stage design collapsed into a complete census, and we estimated harvest of each species by simply summing the harvests reported by all the boat-parties. The total harvest estimate of each species for the season was the sum of harvests for all gear groups, and estimated variance of the total harvest estimate was the sum of variances for all gear groups. The coefficient of variation (CV) for each estimate was the square root of the variance divided by the estimate.

SOCKEYE SALMON SPAWNING POPULATION ESTIMATE

Mark-Recapture Study

Fish Trap and Field Operations

Migrating fish that ascended the Falls Lake fish ladder were channeled into a 1.25 m x 1.25 m x 2.5 m box frame trap above the ladder (Conitz et al. 2002). The trap served as a marking platform for the mark-recapture study, as only a portion of the fish that migrated over the falls were funneled into the trap. All fish entering the trap were identified by species, counted, and passed upstream. The trap was operated continuously from June 28 through August 25, 2009.

A stratified 2-sample mark-recapture study was conducted to estimate sockeye salmon escapement into Falls Lake (Seber 1982). Sockeye salmon that passed through trap were marked with an adipose fin clip and a uniquely-numbered, light blue T-bar tag. The adipose clip was considered the primary mark in the event of tag loss. To minimize handling, fish sampled for age, sex, and length were also tagged. The target tagging sample size was 60% of the daily trap count to achieve a marking rate of about 30% of the sockeye salmon escapement, assuming that about half of the run was funneled into the trap. Sockeye salmon that appeared unhealthy were enumerated and released without marks. Following the season, tag numbers applied at the weir were stratified by tagging date into 9 strata of one week each.

Seven recapture events were conducted on the spawning grounds at approximately weekly intervals throughout the spawning period. Fish were sampled in the main spawning areas around the mouths of both inlet streams with a beach seine and in the channels of both inlet streams with dip nets. An operculum punch was applied to all sockeye salmon in these samples to ensure sampling without replacement during that day or in later sampling events. A member of the crew recorded tag numbers of all newly captured and recaptured fish, along with sampling date and location.

The crew conducted visual surveys around the lake prior to each sampling event. The survey encompassed the entire lake and each inlet stream to the upper extent that sockeye salmon have been observed. Two counts were recorded, a total count for the entire lake system, and a count for just those areas where sampling was conducted. The counts served only as an indicator of the number of fish available on the spawning grounds for each sampling event.

Data Analysis

At the end of field operations, we compiled tag data into electronic tables, and used database software to sort tag numbers by sampling event and count sample sizes and numbers of recaptured fish in each sample. Newly captured or recaptured fish were only counted on the first sampling event in which they were encountered. We accounted for tag loss in this study by recording recaptures of sockeye salmon with a clipped adipose fin but no tag. Because all tagged fish were marked with adipose clips, fish with lost tags could still be identified as recaptures and included in the recapture data.

The 2-sample Petersen method is a simple model for estimating animal populations based on a first sample, in which all live animals captured are marked, and a second sample at some later time, in which the numbers of marked and unmarked animals are counted (Seber 1982, p. 59; Pollock et al. 1990). Stratified mark-recapture models, which extend the 2-sample Petersen method over 2 or more sampling occasions or events in both the marking (first) and mark-recovery (second) samples, are widely used for estimating salmon populations as they enter their natal streams or spawning areas (Arnason et al. 1996). A fundamental assumption of the Petersen and related mark-recapture models is that capture probabilities for individual animals are equal (Pollock et al. 1990). Briefly stated, the assumptions of equal probability of capture required by the Petersen model are as follows: 1) all fish have an equal probability of capture in the first sample (marking); 2) all fish have an equal probability of capture in the second sample (mark-recovery); and, 3) fish mix completely between the first and second sample. Generally, if one or more of these assumptions is met, the marking and recovery strata can be pooled, thereby providing the most precise estimate. However, if none of the assumptions are met, the pooled estimate can be badly biased (Arnason et al. 1996).

We used the Stratified Population Analysis System (SPAS) software to aid in analyzing and interpreting our mark-recapture results (Arnason et al. 1996; for details, refer to http://www.cs.umanitoba.ca/~popan/). SPAS calculates Darroch and "pooled-Petersen" estimates, and provides goodness-of-fit tests to compare observed and expected capture probabilities in the marking (first) and mark-recovery (second) samples (Arnason et al. 1996). The test of the assumption of complete mixing is incorporated into the test for equal probability of capture in the second sample. We considered a test statistic with p-value ≤ 0.05 as "significant." If neither test statistic—or only one of them—was significant, the fully pooled estimate was accepted. If both test statistics were significant, we looked for a full or partial stratification, following the guidelines and suggestions in Arnason et al. (1996) that would better satisfy the assumptions.

A parametric bootstrap procedure was used to estimate the standard error and construct the 95% confidence interval for a pooled-Petersen escapement estimate. We assumed that the number of marked fish recaptured in the second sample, m_2, follows a hypergeometric probability distribution. Then we used the number of fish marked in the first sample, n_1, the number of fish caught in the second sample, n_2, and the Petersen estimate of escapement, $\hat{N}$, to generate 5,000 simulated recapture numbers based on the hypergeometric probability density function, $f(m_2 | n_1, n_2, \hat{N})$. From the bootstrap values of m_2, we derived 5,000 Petersen escapement estimates, then calculated the standard error of these estimates and used the 0.025 and 0.975 quantiles to form the 95% confidence interval.

Adult Population Age and Size Distribution

About 600 adult sockeye salmon were sampled for length, sex, and scales (for age determination) at the trap. Fish were selected systematically to prevent selection bias, and weekly sampling goals were set throughout the run based on average weekly escapements from previous years (Appendix A2). Length of each fish was measured from mid eye to tail fork, to the nearest millimeter. Sex of the fish was decided by length and shape of the kype or jaw. Three scales were taken from the preferred area of each fish (INPFC 1963), and prepared for analysis as described by Clutter and Whitesel (1956). Scale samples were analyzed at the ADF&G salmon-aging laboratory in Douglas, Alaska. Age classes were designated by the European aging system where freshwater and saltwater years are separated by a period (e.g., 1.3 denotes a fish with one freshwater and 3 ocean years; Koo 1962). Associated standard error was estimated using standard statistical techniques and assuming a binominal distribution (Thompson 1992).

RESULTS

Subsistence Harvest Estimate

In 2009, between June 28 and August 19, sampling technicians counted 23 fishing parties (including both subsistence and sport) in the marine area around the outlet stream of Falls Lake (Table 1). Many of these parties were interviewed about their catches and reported their harvest; however, in 9 cases the technicians had to estimate the harvest. In 4 of those cases, the observed harvest was estimated to be the bag limit of 100 fish, but the actual harvest might have been greater than the bag limit. Conversely, if the technicians observed the fisherman catching no fish they estimated the catch to be zero. The technicians were unable to obtain an estimate from 4 parties. A couple of sport fishermen were observed fishing during the mid season subsistence closure (14 July–22 July). More subsistence fishing effort and larger harvests of sockeye salmon occurred before the mid season subsistence closure, July 14–22, than after.

An estimated 1,346 sockeye (SE=204; CV=15%), 2 coho, 2 chum, and 1 pink salmon were harvested in 2009 (Table 2). About 77% of the sockeye salmon were harvested by beach seines, the most common gear type used. There was no observed sport harvest of sockeye salmon.

Table 1.–Number of subsistence and sport fishing parties with available harvest estimates, missed estimates, and salmon harvest reported in interviews in the Falls Lake area, by week, in 2009.

		Fishing party		Salmon harvest reported in interviews, by species			
Week	**Dates**	**Available estimates**	**No estimate**	**Sockeye**	**Coho**	**Chum**	**Pink**
27–28[a]	28/ Jun-11/Jul	10		560	0	0	0
29	12/Jul-18/Jul	4		373	0	0	0
30	19/Jul-25/Jul	1	3	40	2	0	0
31	26/Jul-1/Aug	3		361	2	2	0
33–34[a]	9/Aug-22/Aug	1	1	0	0	0	0
Total		19	4	1,294	2	2	1

[a] Combined weeks 27–28 and 33–34 for confidentiality.

Table 2.–Estimated subsistence and sport salmon harvest and SE in the Falls Lake area, by gear type, in 2009.

	Fishing party interviews		Estimated harvest by species (SE)			
Gear	**Total**	**Interviewed**	**Sockeye**	**Coho**	**Chum**	**Pink**
Gillnet[a]	5	4	311 (94)	2	2	0
Beach seine [a]	10	10	1,035 (181)	0	0	0
Sport, rod & reel	5	5	0	0	0	1
Unknown gear[b]	3	0	0	0	0	0
Total		19	1,346 (204)	2	2	0

[a] One party used 2 gear types, gillnet and beach seine. Not used in the estimate.
[b] Not used in estimate; unknown gear type.

SOCKEYE SALMON SPAWNING POPULATION ESTIMATE

Between June 28 and August 26, 2009, 818 adult sockeye salmon, 6 sockeye salmon jacks, 47 coho salmon, and 58 pink salmon were passed through the Falls Lake trap (Figure 3). The largest number of sockeye salmon counted through the trap on a single day was 93 fish on July 28. During the study period, the water depth at the gauge site near the top of the falls fluctuated between a low of 0.18 m and a high of 0.85 m. A total of 458 sockeye salmon (56% of all the fish caught in the trap) was marked at the fish trap before they entered Falls Lake.

Seven recapture events were conducted on the lake-spawning beds in Falls Lake and on the 2 inlet spawning streams on August 26, September 2, September 10, September 18, September 23, September 30, and October, 6, 2009. A total of 613 sockeye salmon was captured in the study area. Of these captures, 127 fish were weir-tagged recaptures and 8 fish (6%) had shed their T-bar tag. Tag loss was generally quite easy to determine from the presence of the adipose fin clip (primary mark) and the residual tag hole. Since we could not determine which marking strata these fish were from, we assumed 6% of the total number of tagged sockeye salmon that we released had lost their tag. We then adjusted the marking strata accordingly (Table 3).

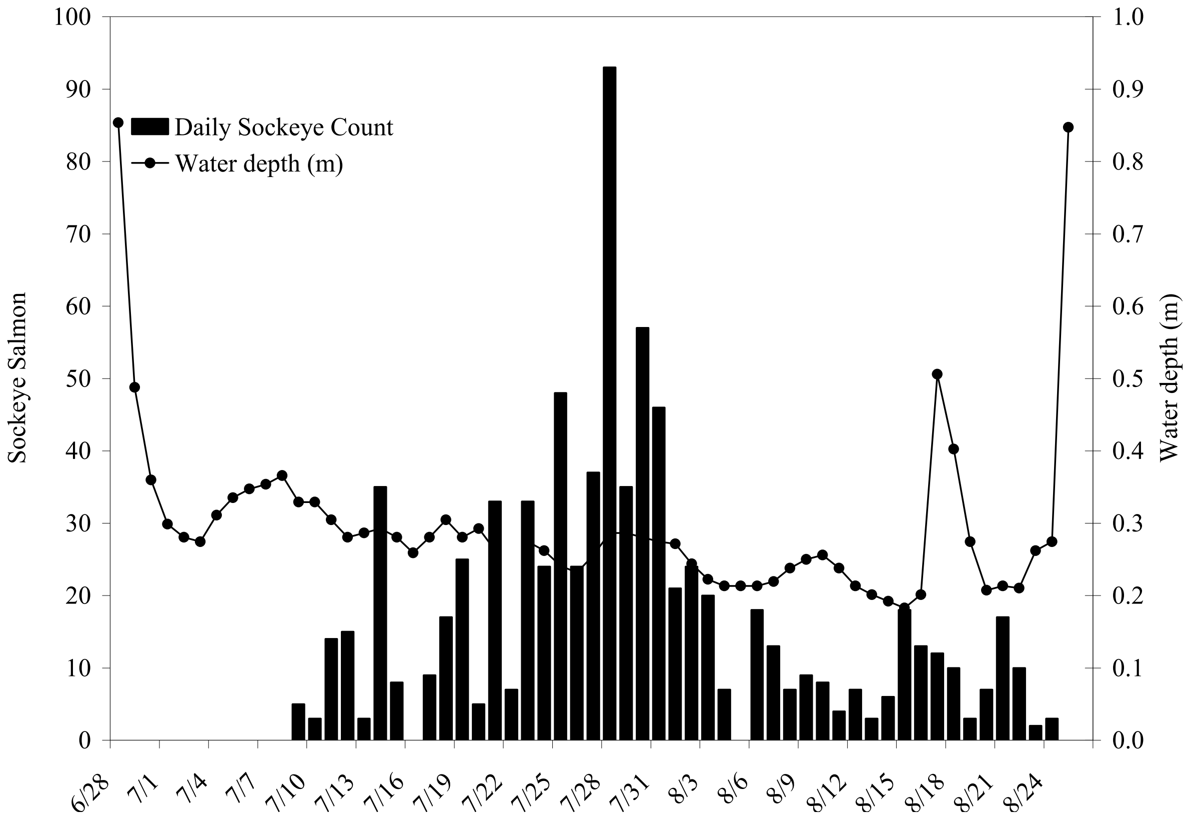

Figure 3.–Daily sockeye salmon escapement counts and water depth at the Falls Lake trap, 2009.

The marked fish were divided into 3 temporal strata (Table 3). Altogether, 29% of marked fish were recovered. The chi-squared test of complete mixing of marked fish between release and recovery strata was significant (reject; χ^2=6.7, *p*-value=0.03, 2 df). The chi-square test of equal probability of capture in the second sample, however, yielded a non-significant result (do not reject; χ^2=8.8, *p*-value=0.12, 5 df); therefore, the pooled-Petersen estimate was used. The estimated escapement of sockeye salmon into Falls Lake was 2,100 fish (95% confidence interval, 1,900–2,200 fish; CV=6.6%). Although the pooled-Petersen estimate was chosen, the Darroch estimate of 2,000 fish was very similar (95% confidence interval, 1,700–2,300 fish; CV=14.6%). Assuming this estimate represents the entire Falls Lake escapement, about 40% of the sockeye salmon used the fish ladder to migrate into the lake (where they were counted in our trap), rather than by directly ascending the falls.

Visual surveys were conducted 8 times, of which 7 were conducted in conjunction with recapture events, August–October (Table 4). The highest number of sockeye salmon spawners counted was 880 on September 1.

Table 3.–Sockeye salmon marked and marked fish recovered by stratum in the mark-recapture study at Falls Lake in 2009.

Marking phase (first sample)				Marks recovered by date (recovery sample no.)						All recoveries	
Marking strata				1	2	3	4	5	6		Percent of all marked
No.	Dates	Fish counted	Fish marked	22-Aug	30-Aug	4-Sep	11-Sep	17-Sep	24-Sep	Total	
1	10 Jul-25 Jul	284	133	8	16	2	1	0	1	28	21%
2	26 Jul-6 Aug	402	221	27	33	5	5	2	0	72	33%
3	7 Aug-24 Aug	132	77	5	7	6	4	3	2	27	35%
Total		818	431	40	56	13	10	5	3	127	29%
Total fish sampled				165	254	49	88	34	23	613	
Percent marked fish in recovery samples				24%	22%	27%	11%	15%	13%	21%	

Table 4.–Visual counts of sockeye salmon spawners in Falls Lake in 2009.

Date	Sockeye salmon count
Aug 18	160
Aug 26	498
Sep 1	880
Sep 9	620
Sep 17	475
Sep 22	289
Sep 29	131
Oct 06	38

Adult Population Age and Size Distribution

In 2009, 621 sockeye salmon were sampled for age, sex, and length composition, and 510 were successfully aged. About the same number of males and females were sampled. Brood year 2004 accounted for 62% of the samples, split evenly between fish that spent one year and 2 years in freshwater (ages 1.3 and 2.2; Table 5). In general, the 2009 age composition was consistent with the long-term average (Appendix A3). Adult sockeye salmon that spent 3 years at sea (age-1.3 and age-2.3) were larger on average than their 2 ocean counterparts (age-1.2 and age-2.2) by 40–50 mm (Table 6).

Table 5.–Age composition of adult sockeye salmon escapement in Falls Lake, by sex, in 2009.

	Number and percentage by brood year and age class					
	2006	**2005**	**2004**	**2004**	**2003**	
Sampling stratum	**1.1**	**1.2**	**1.3**	**2.2**	**2.3**	**Total aged**
Male						
Sample size	3	49	112	54	41	259
Proportion	0.6%	9.6%	22.0%	10.6%	8.0%	50.8%
SE	0.3%	1.3%	1.8%	1.4%	1.2%	2.2%
Female						
Sample size	0	70	55	97	29	251
Proportion	0.0%	13.7%	10.8%	19.0%	5.7%	49.2%
SE	0.0%	1.5%	1.4%	1.7%	1.0%	2.2%
All Fish						
Sample size	3	119	167	151	70	510
Proportion	0.6%	23.3%	32.7%	29.6%	13.7%	
SE	0.3%	1.9%	2.1%	2.0%	1.5%	

Table 6.–Mean mideye-to-fork length of adult sockeye salmon in the 2009 Falls Lake escapement.

	Mean length by brood year and age class				
	2006	**2005**	**2004**	**2004**	**2003**
Sampling stratum	**1.1**	**1.2**	**1.3**	**2.2**	**2.3**
Males					
Sample size	3	49	112	54	41
Mean length (mm)	343	513	564	506	560
SE (mm)	17	4	3	3	4
Females					
Sample size	0	70	55	97	29
Mean length (mm)		496	571	505	553
SE (mm)		4	4	3	5
All fish, by age					
Sample size	3	119	167	151	70
Mean length (mm)	343	503	566	505	557
SE (mm)	17	3	2	2	3

DISCUSSION

Our best estimate of sockeye salmon escapement in Falls Lake in 2009 was 2,100 fish, based on the pooled-Petersen mark-recapture estimate. The coefficient of variation of this estimate (CV = 6.6%) easily met the project objectives for precision, likely because we were able to sample more than 600 fish on the spawning grounds and we recovered 29% of the fish that were marked and released at the falls. Unlike some sockeye salmon systems, Falls Lake is a good candidate for a mark-recapture study because much of the spawning habitat and spawning fish are accessible for sampling in both the inlet streams and in the lake. It should also be noted that our 2009 Petersen estimate was very similar to the stratified Darroch estimate that we generated from the same mark-recapture data (2,000 fish; CV = 14.6%).

The estimated escapement in 2009 was at the lower quartile (25th percentile) of sockeye salmon escapement at Falls Lake since the current monitoring project began in 2001. Although the 2009 escapement was somewhat smaller than those observed in some recent years (Table 7), escapements at Falls Lake appear to have been remarkably consistent between the 1980s and since 2001. From 1981 to 1989, a simple weir count was used to estimate escapements, which should be considered minimum estimates since no mark-recapture studies were conducted to back-up the weir counts in those years. The median weir count during that period was 1,870 and ranged from 1,114 to 5,789 sockeye salmon (Conitz et al. 2002). Since 2001, mark-recapture escapement estimates have ranged from 750 to 8,800 sockeye salmon (median 2,600). In addition, the relative magnitude of the run does not appear to have changed greatly compared to the early 1900s. Terminal harvests of sockeye salmon in Falls Creek Bay from 1913 to 1922 ranged from 1,800 to 9,600 (median 3,214) sockeye salmon (Rich and Ball 1933; Appendix A4). The fact that Rich and Ball (1933) concluded there "were no important fisheries on the east shore of Baranof Island south of Kelp Bay" also suggests that Falls Lake has probably supported a relatively small sockeye salmon run since the early 1900s.

The estimated subsistence harvest in 2009 from the on-site surveys was 1,350 sockeye salmon. On-site harvest estimates provide better estimates than those obtained from returned subsistence permits, For example, Walker (2009) reported a household survey estimate of the number of subsistence chum and sockeye salmon harvested in 2001 by Kake residents, the primary users of Falls Lake sockeye salmon, that was 3 times the number reported on returned subsistence permits. The on-site harvest estimates should still be considered minimum estimates of the harvest since samplers have not been able to obtain 100% coverage of the fishery and have sometimes included best-estimates of individual harvests during the census (Riffe et al. 2009).

Although no changes to management of the subsistence fishery are expected for the 2010 season, the information provided by stock assessment projects at Falls Lake allow for better informed management of the sockeye salmon subsistence fishery. Fishery managers would be forced to manage more conservatively through smaller bag limits and shorter seasons without this basic information, whereas accurate escapement and better harvest information will likely provide for the maximum subsistence fishing opportunity over the long term. Because this sockeye salmon run is a valuable and long-standing subsistence resource for the people of Kake, it should continue to be monitored to ensure escapements remain at a sustainable level.

Table 7.–Methods of estimating escapement, estimates of escapement, estimates of on-site harvest, harvest reported from permits, and estimated terminal run (escapement + on-site harvest), of Falls Lake sockeye salmon, 1981–2009. Note: from 1981 to 1989, the weir was located below the falls.

Year	Method of escapement estimation	Estimated escapement	On-site harvest estimate	Harvest reported on permits	Estimated terminal run
1981	Weir	1,278	—		—
1982	Weir	1,687	—		—
1983	Weir	1,656	—		—
1984	Weir	3,622	—		—
1985	Weir	2,612	—	17	—
1986[a]	—	—	—	30	—
1987	Weir	5,789	—	30	—
1988	Weir	1,114	—	338	—
1989	Weir	2,055	—	350	—
—	—	—	—	—	—
2001	Weir [b]	2,600	1,900	1,290	4,500
2002	Mark-recapture [c]	1,100	2,600	1,795	3,700
2003	Trap/mark-recapture	5,700	2,700	2,434	8,400
2004	Trap/mark-recapture	3,300	2,900	2,164	6,200
2005	Trap/mark-recapture	3,400	900[d]	1,134	4,300[d]
2006	Mark-recapture	8,800	—	1,507	10,307 [e]
2007	Mark-recapture	2,600	—	820	3,420 [e]
2008	Trap/mark-recapture	750	1,700	1,031	2,350
2009	Trap/mark-recapture	2,100	1,350	610	3,400

[a] Year in which the Falls Lake fish ladder was installed.
[b] Estimate from weir count, did mark-recapture back up.
[c] Estimate derived from mark-recapture; weir count 774.
[d] Actual number likely greater, due to violation of assumptions for on-site survey in 2005.
[e] Actual number likely greater because reported harvest is usually underrepresented.

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APPENDIX A

Appendix A1.–Timeline of ADF&G management actions for the subsistence fishery of Falls Lake sockeye salmon, 1985–2009.

Year	**Season Change**	**Limit Change**	**Area Closure**	**Reason**
1985–1998	June 1–Aug 15	10 possession/no annual limit	No mouth Closure	
1999	June 1–July 20	No change	No mouth Closure	Made change due to management concerns
2001	June 1–Aug 15	No change	No mouth Closure	Made this change due to start of assessment project
2002	June 1–July 31	50 possession/annual	50 yd closure of mouth	
2003	Jun 1–Jul 6/Jul 14–Jul 20	No Change	No Change	
2005	June 1–July 13/July 23–Aug 15	No Change	No Change	
2009	No Changes	25 possession/annual	Moved closure markers farther off mouth	Made change due to management concerns

Emergency Orders

Year	News Release	Date	Action	Reason
2002	1-S-46-02	July, 24	Closure	Low escapement / High effort and catch
2004	1-S-53-04	Aug, 20	Reopened after season closure date	Adequate escapement

Appendix A2.–Approximate weekly sampling schedule (length, sex, and scales) for sockeye salmon at the Falls Lake trap in 2009.

Statistical Week	**Dates**	**Number of fish to sample**
29	July 12–18	60
30	July 19–25	100
31	July 26–Aug 1	200
32	Aug 2–8	140
33	Aug 9–15	60
34	Aug 16–22	40
35	Aug 23–29	20
Total		620

Appendix A3.–Age composition (proportion) of sockeye salmon in the Falls Lake escapement, 1982–2009.

Year	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.2	3.2	3.3	Age 1.-	Age 2.-	Age 3.-
1982	0.00	0.33	0.20	0.00	0.00	0.30	0.17	0.00	0.00	0.00	0.00	0.53	0.47	0.00
1983	0.00	0.20	0.51	0.00	0.00	0.23	0.06	0.00	0.00	0.01	0.00	0.70	0.29	0.01
1984	0.00	0.06	0.18	0.00	0.00	0.09	0.61	0.00	0.00	0.00	0.06	0.24	0.70	0.06
1985	0.00	0.02	0.19	0.00	0.00	0.23	0.44	0.01	0.00	0.08	0.04	0.21	0.67	0.12
-														
-														
1988	0.00	0.47	0.42	0.00	0.00	0.04	0.06	0.00	0.00	0.00	0.00	0.89	0.11	0.00
1989	0.00	0.02	0.72	0.00	0.00	0.20	0.06	0.00	0.00	0.00	0.00	0.74	0.26	0.00
-														
2001	0.00	0.06	0.89	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.96	0.04	0.00
2002	0.00	0.46	0.11	0.00	0.01	0.23	0.20	0.00	0.00	0.00	0.00	0.57	0.43	0.00
2003	0.01	0.22	0.35	0.00	0.00	0.37	0.05	0.00	0.00	0.00	0.00	0.58	0.42	0.00
2004	0.00	0.38	0.42	0.00	0.00	0.14	0.07	0.00	0.00	0.00	0.00	0.79	0.21	0.00
2005	0.00	0.28	0.17	0.00	0.00	0.22	0.34	0.00	0.00	0.00	0.00	0.45	0.55	0.00
2006	0.00	0.27	0.12	0.00	0.00	0.54	0.07	0.00	0.00	0.00	0.00	0.39	0.61	0.00
2007	0.01	0.19	0.47	0.00	0.00	0.02	0.31	0.00	0.00	0.00	0.00	0.67	0.33	0.00
2008	0.00	0.41	0.15	0.01	0.00	0.38	0.05	0.00	0.00	0.00	0.00	0.57	0.43	0.00
2009	0.01	0.23	0.33	0.00	0.00	0.30	0.14	0.00	0.00	0.00	0.00	0.57	0.43	0.00
Average, all years	0.00	0.24	0.35	0.00	0.00	0.22	0.18	0.00	0.00	0.01	0.01	0.59	0.40	0.01
SE	0.01	0.10	0.12	0.01	0.01	0.10	0.11	0.01	0.01	0.04	0.04	0.16	0.16	0.00
Average, 1982–1989	0.00	0.18	0.37	0.00	0.00	0.18	0.23	0.00	0.00	0.01	0.02	0.55	0.42	0.03
SE	0.00	0.18	0.19	0.02	0.01	0.13	0.20	0.02	0.02	0.07	0.07	0.22	0.20	0.09
Average, 2001–2009	0.00	0.28	0.33	0.00	0.00	0.24	0.14	0.00	0.00	0.00	0.00	0.55	0.42	0.03
SE	0.02	0.12	0.17	0.02	0.01	0.14	0.11	0.01	0.00	0.00	0.00	0.23	0.22	0.09

Appendix A4.–Historical fishery information

Year	Sockeye Salmon
1913	1,279
1914	2,479
1915	3,586
1919	9,615
1920	3,717
1921	1,810
1922	3,214

Source: Data obtained from Rich and Ball (1933).