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Klawock Lake Subsistence Sockeye Salmon Project 2004 Annual Report

by

Jan M. Conitz

Margaret A. Cartwright

and

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December 2006

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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The Division of Sport Fish Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Since 2004, the Division of Commercial Fisheries has also used the Fishery Data Series. Fishery Data Series reports are intended for fishery and other technical professionals. Fishery Data Series reports 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 2004, we estimated 12,400 sockeye salmon escaped fisheries to enter Klawock Lake and potentially breed. We are surprised by the striking stability in this system over the four years we have studied it. In that time we observed three sockeye escapements within 5% of 13,000 fish and one escapement estimate of 21,000 in 2003. Our estimate of subsistence harvest in 2004 (4,500 sockeye salmon) was the lowest value in our four-year series of subsistence harvest estimates for Klawock Inlet. The 2004 estimate contrasts with two estimates of 6,000 fish harvested in 2002 and 2003, and the largest estimate of 6,400 sockeye salmon harvested in 2001. Once again, the subsistence fishery removed fish only from the early part of the sockeye run. When the fishery closed on 31 July in 2004, the sockeye escapement count at the Klawock River weir was 600 fish - less than 5% of the entire escapement into the lake. We used open-population mark-recapture studies to estimate the number of sockeye spawners in each of the three main inlet spawning streams. The sum of spawning population estimates for all three streams totaled 11,000 fish - surprisingly similar to the overall escapement estimate of 12,400. Although this open-population approach was not very precise (CV=23%), and probably similarly inaccurate as an estimate of total escapement, we think that it could be further developed to provide continued monitoring of Klawock sockeye stock at a fraction of the cost of the existing studies. The fact that the sum of the estimates of spawning population size in these three streams was so close to the whole-lake escapement estimate suggests that there were few, if any, lake-spawning sockeye salmon in this system in 2004.

Key words: Sockeye salmon, *Oncorhynchus nerka*, subsistence, Klawock Lake, Klawock, weir, escapement, mark-recapture, age composition, zooplankton

INTRODUCTION

Sockeye salmon (*Oncorhynchus nerka*) returning to the Klawock Lake system (Figure 1) have supported one of the oldest known permanent Tlingit villages on Prince of Wales Island, and continue to support one of the largest subsistence fisheries in the Southeast Alaska. Remains of fishing structures, including a tightly spaced stake wall and interconnected semi-circular traps, were found in the Klawock River estuary and lagoon and dated to 750–800 years ago (Langdon *unpublished*). Langdon (1977) attempted to synthesize several anthropological studies of the oral history of the Tlingit Ganaxadi and Tekwedih clans. In doing so, he reported that the founders of the village of Klawock fled from a conflict in their home village near the mainland, crossed Prince of Wales Island from Kasaan Bay, and discovered Klawock Lake with its exceptional sockeye runs. They established a settlement at the upper end of the Klawock River estuary, which, because of the sockeye salmon resource, became one of the principal villages on Prince of Wales Island. Present-day residents of Klawock continue to depend on sockeye salmon, harvesting about 7,500 fish annually from nearby waters, including the Klawock River estuary (Alaska Department of Fish and Game, Division of Subsistence Community Profile Database 2001).

Klawock Lake sockeye salmon were also targeted by some of the earliest commercial fish processing enterprises in Alaska, with a saltery opening in 1868 and a cannery opening in 1878 (Moser 1899, Roppel 1982). From these early years of commercial fishing through the present, the traditional subsistence fishing economy and the commercial fishing economy have been highly interconnected in Klawock, as in many other villages in Southeast Alaska. The early cannery owners borrowed from Tlingit fishing methods and employed Tlingit people living in Klawock to catch and process the fish (Moser 1899; Langdon 1977). In the 1920s, two local owners opened canneries in Klawock: R. J. Peratrovich in 1922 and C. A. Demmert in 1923. In 1954 the Klawock tribal (IRA) government purchased the Demmert plant and operated it as a village cooperative until 1976, purchasing fish from many small commercial operators from the village (Langdon 1977).

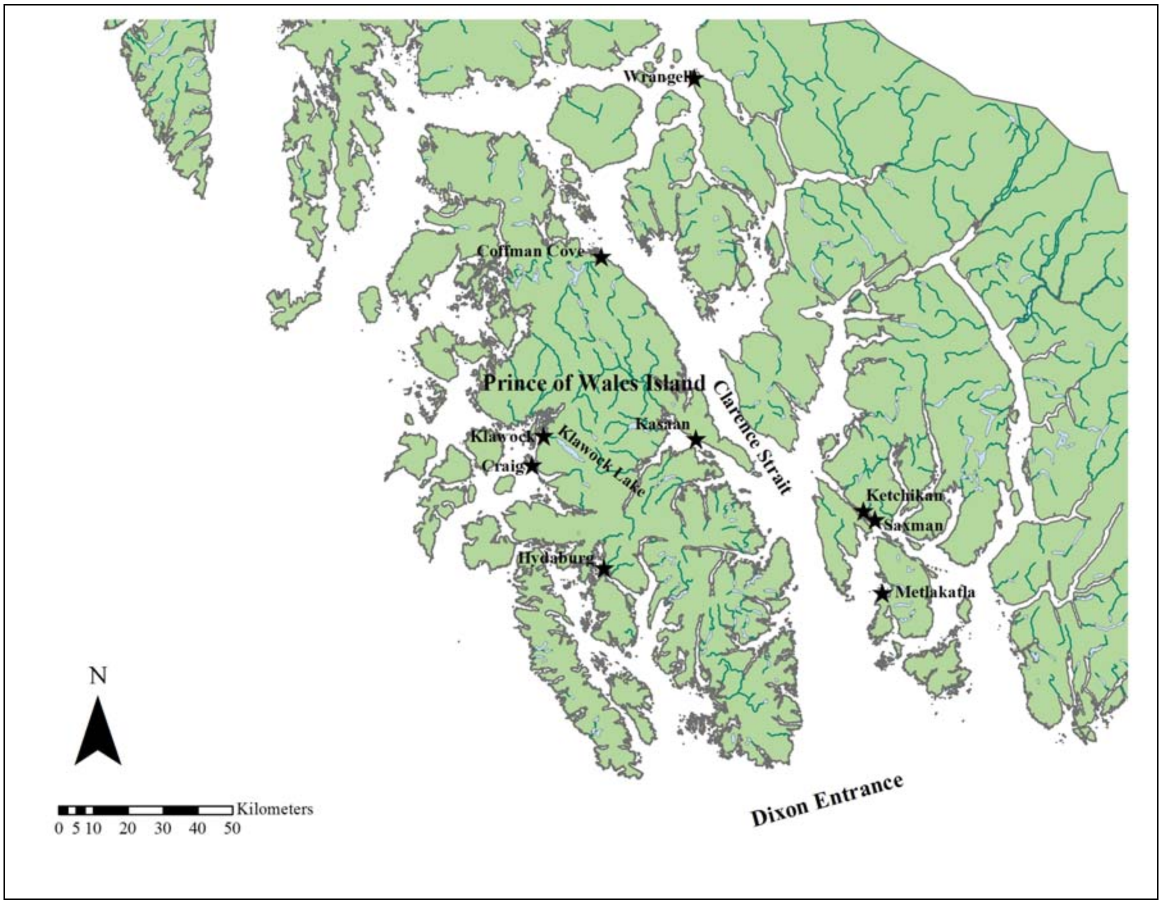

Figure 1.–Geographic location of Klawock Lake, in Southeast Alaska on Prince of Wales Island. The communities of Klawock and Craig, and other towns on and near Prince of Wales Island are shown.

The early commercial fishery in the vicinity of the village of Klawock centered on the Klawock River estuary; thus, most of the early sockeye harvest was attributable to Klawock Lake stocks. Sockeye harvests from Klawock Inlet averaged about 39,000 fish annually between 1886 and 1899 (Moser 1899) and about 35,000 fish annually between 1900 and 1927 (Rich and Ball 1933). From the 1930s through the 1970s, the village of Klawock continued to play a central role in commercial salmon fishing and processing on Prince of Wales Island (Langdon 1977). The commercial sockeye harvest in southern Southeast Alaska, particularly in District 104 (ADF&G unpublished data), increased dramatically since the late 1970s. However, we have no stock-specific sockeye harvest estimates for the commercial fishery, except for some large Canadian stocks and for the Hugh Smith Lake stock (Geiger et al. 2005). A program in which over 200,000 wild and hatchery sockeye juveniles from Klawock Lake were coded-wire tagged during 1988–1998 failed to yield any defendable statistical estimates of interceptions in commercial fisheries, although a few tags were recovered in District 103 and 104 commercial catches (Lewis and Zadina 2001).

Historical weir counts for Klawock Lake from the 1930s ranged from 7,000 to 65,000 and averaged 31,000 sockeye salmon (Lewis and Zadina 2001), considerably higher than the most recent average. At this time we have no way to judge the accuracy of these historical numbers. From 2001 to 2003 sockeye escapement estimates ranged from 12,000 to 21,000 sockeye salmon

(Cartwright et al. 2006). The recent weir counts are within the range of variation of escapements estimates from the 1930s; however the very large escapements of over 50,000, reported for 1932 and 1936, have not been seen in recent years. Furthermore, the median escapement estimate from the 1930s was 27,000 sockeye salmon - approximately twice the median escapement in 2001–2003.

Weirs were intermittently operated for hatchery broodstock in the 1970s and 1980s. However, record keeping was clearly unreliable during this period. Weir counts appear to have been entered into the records during periods when the weir was not actually even operated. Apparently hatchery personnel mixed actual weir counts with hypothetical values that simply represented personal opinion about likely fish movement (H. J. Geiger, personal observation, and a series of unpublished Fisheries Rehabilitation, Enhancement, and Development (FRED) Division of ADF&G memoranda on Klawock Lake Hatchery record keeping from the early 1980s).

After Alaska statehood, a separate “subsistence fishery” was designated and defined in state law (Alaska Statute 16.05.940[30, 32]) as non-commercial fishing for customary and traditional use, including personal and family consumption and sharing. The Alaska Department of Fish and Game (ADF&G) has tracked trends in subsistence fisheries through a harvest permit system. To participate in subsistence fisheries, the fishers need a permit and are required to return the permit with a record of how many fish were caught. We refer to the sum of the harvest on these reports as the *reported harvest*, to distinguish these harvest estimates from other sources, such as those from the on-site surveys that were operated by our project from 2001 to 2004. Reported harvests from Klawock Inlet increased over the past several decades (Lewis and Zadina 2001; Figure 2). The average reported sockeye harvest between 1969 and 1989 was about 2,100 fish, but for the period from 1990 to 2004 the average reported harvest was nearly 4,000 sockeye salmon (ADF&G Div. of Commercial Fisheries database 2006). Actual sockeye harvests were probably higher than the reported harvests. From 2001 to 2003 we estimated total subsistence sockeye harvests of about 6,000 each year in Klawock Inlet using on-site surveys (Cartwright et al. 2006), but in those years permit holders reported only about 50–70% of this harvest level on their returned permits.

The commercial fisheries have changed over the last two decades as the value of salmon flesh fell in response to a huge increase in the production of farmed salmon. These changes in the commercial fisheries have included a large reduction in small, local fishing fleets. In turn, the loss of the commercial fishing vessels in small coastal villages has meant that subsistence fishing has become more important for many families in providing for household and community needs. We assume that this loss of fishing vessels is the reason for the increase in reported harvest from Klawock Inlet.

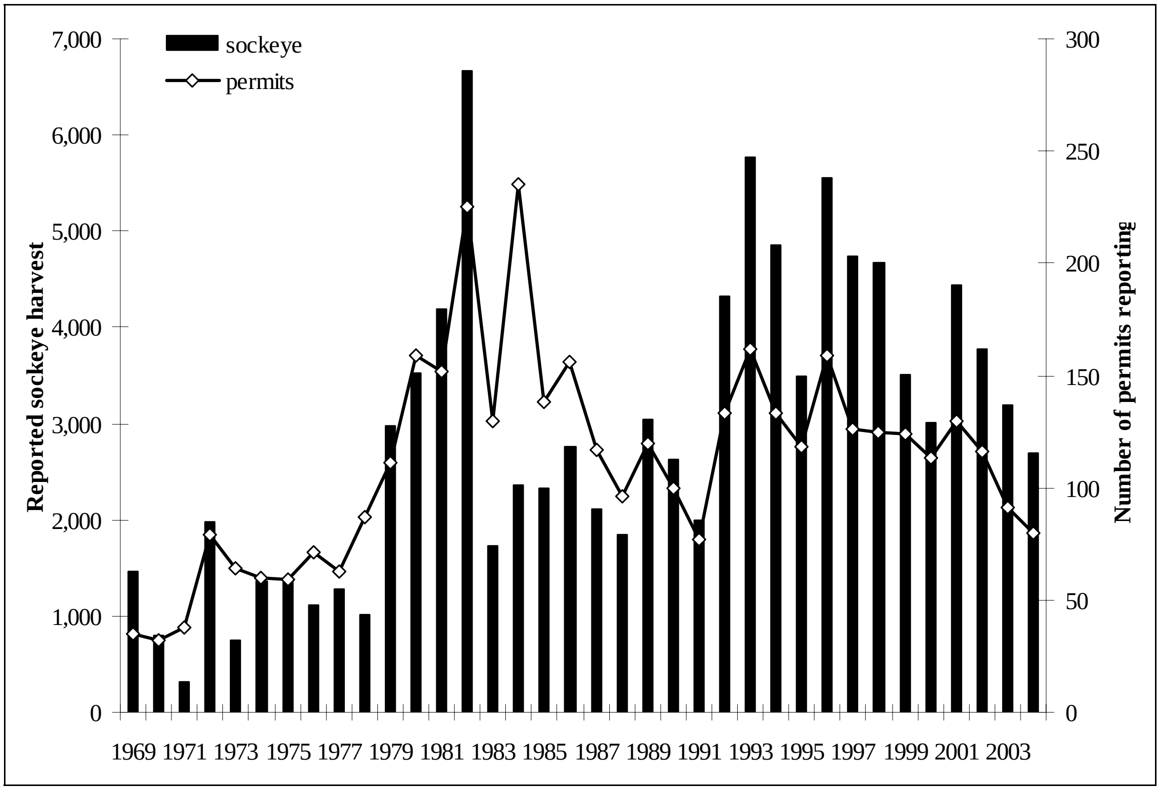

Figure 2.–Reported subsistence sockeye harvest and number of permits fished in Klawock Inlet from 1969 to 2004 (ADF&G Division of Commercial Fisheries database 2006).

Starting in the early commercial fishing period, fisheries managers attempted to use hatchery production to compensate for loss of natural production caused by harvesting. Early Federal legislation required canneries to establish hatcheries in salmon systems they exploited, and gave tax breaks based on the number of fry released. Sockeye eggs were collected and fry released into Klawock Lake between 1901 and 1917. These cannery personnel had no understanding of sockeye biology and their efforts ultimately failed (Roppel 1982).

ADF&G's FRED Division built a new hatchery and developed sockeye stocking projects in Klawock Lake beginning in the 1970s. Since 1996 the Prince of Wales Hatchery Association has operated the hatchery that FRED Division built, and the new operators have continued stocking Klawock Lake with sockeye salmon (Lewis and Zadina 2001).

Because of the size and importance of the Klawock Lake fishery resources, we set out to study the size of the sockeye run, document sockeye harvest in the subsistence fishery, and measure lake habitat characteristics related to sockeye production in the Klawock Lake system, starting in 2001. The most important element of this stock assessment program was a weir-based escapement estimate, backed up by mark-recapture-based estimates of the whole-lake sockeye escapement (Lewis and Cartwright 2002; Cartwright and Lewis 2004; Cartwright et al. 2006). In 2001 and 2003, the weir counts were considerably lower than mark-recapture estimates. We interpreted the discrepancy as evidence that fish, at times, passed through the weir uncounted, making the weir counts alone unreliable. The weir was substantially improved in 2004 by reducing the spacing between pickets, increasing the angle on the front of the weir to reduce the water pressure, and installing a boom log upstream of the weir to prevent floating trees from damaging the weir. We modified our 2004 mark-recapture study by using individually numbered tags. These numbered tags allowed us to document the timing of different sockeye spawning groups through the weir. We then also used the tags to obtain independent estimates of spawning populations in each of the major inlet streams: Three-Mile, Half-Mile and Inlet Creeks. In 2004, we continued the on-site surveys of the subsistence fishery in Klawock Inlet, using the same methods we used in 2001–2003 (Cartwright et al. 2006). We also continued to collect information on the age, sex, and length of sockeye spawners in order to reconstruct the number of spawners returning to the lake from each brood year. Finally, we continued to measure lake-habitat characteristics (light levels and temperature) and measured zooplankton biomass and density in 2004, as in 2001–2003, as an aid to understanding relationships between the lake environment and sockeye population size changes.

OBJECTIVES

1. Estimate the subsistence harvest of sockeye salmon from Klawock Lake, so the estimated coefficient of variation was less than 15%.
2. Count the number of salmon through the weir, by species and date, from 1 July to 15 October.
3. Estimate the age, length, and sex composition of the sockeye salmon in the escapement at Klawock Lake, so the estimated coefficient of variation was less than or equal to 5% for the largest two age classes.
4. Estimate the sockeye escapement into Klawock Lake with mark-recapture methods, using the weir as a marking platform and the major spawning grounds as the recapture sites, so the estimated coefficient of variation was less than 10%.
5. Estimate the sockeye spawning populations in Three-Mile, Half-Mile and Inlet Creeks using mark-recapture methods so that the estimated coefficient of variation was less than 15% for the combined estimate.
6. Measure the physical characteristics of the lake and estimate zooplankton species composition and size throughout the season using established ADF&G limnological sampling procedures.
7. Describe the timing of the Three-Mile, Half-Mile and Inlet Creek sockeye spawning populations through the weir.

STUDY SITE

The Klawock River system (ADF&G stream number 103-60-047) is located on the southwestern side of Prince of Wales Island, and enters Klawock Inlet at the site of the village of Klawock (lat 55^{o} 32.97'N, long 133^{o} 02.60'W). Klawock Lake, at 9.1 m elevation, has a surface area of 11.9 km^2, a mean depth of 17.7 m, a maximum depth of 49.0 m (Figure 3), and a volume of 209 x 10^6 m^3. The lake empties into Klawock Inlet via the Klawock River (2.85 km). This dimictic lake is organically stained with a mean euphotic zone depth (EZD) of 4.2 m, based on limnological data collected in 1986–1988 and 2001 (Lewis and Cartwright 2002).

Klawock Lake has two main basins. Basin A, the location of sample stations A and C, is the larger and shallower of the two basins, with a maximum depth of 30 m. Basin B, the location of sample stations B and D, has a maximum depth of 49 m (Figure 3). Three major tributaries to Klawock Lake, Hatchery Creek, Half-Mile Creek, and Three-Mile Creek, flow into basin A and drain a total area of 76.1 km^2. Inlet Creek, at the head of the lake, flows into basin B, draining a total area of 37.6 km^2. The Prince of Wales hatchery and the weir are located on the Klawock River approximately 300 m below the lake.

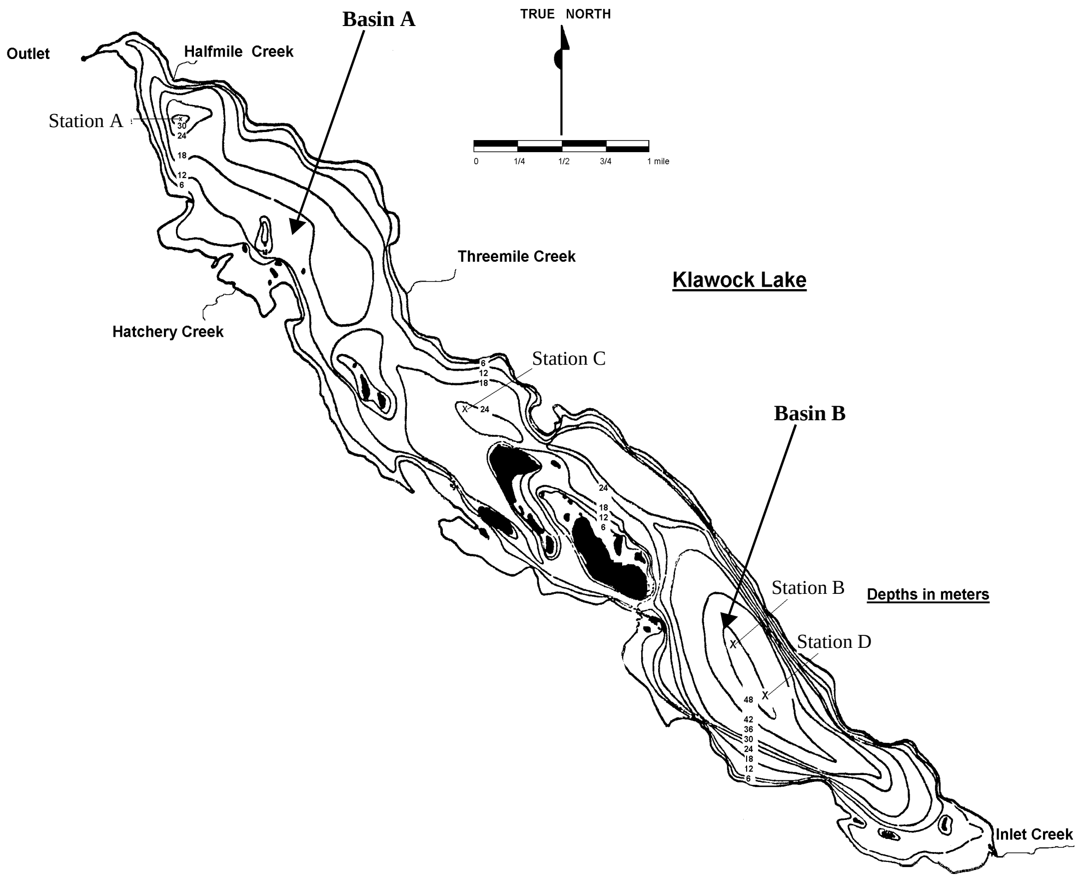

Figure 3.–Bathymetric map of Klawock Lake, Southeast Alaska with limnological sampling stations and inlet stream references.

In addition to sockeye salmon, native fish species include coho (*O. kisutch*), pink (*O. gorbusha*), and chum (*O. keta*) salmon, steelhead (*O. mykiss*) and cutthroat trout (*O. clarki*), Dolly Varden char (*Salvelinus malma*), threespine stickleback (*Gasterosteus aculeatus*), and cottids (*Cottus* sp.). Mysid shrimp (*Neomysis mercedis*) are also present in the lake.

METHODS

SUBSISTENCE HARVEST ESTIMATE

The subsistence fishery, by regulation, was open from 7 July through 31 July on Monday at 0800 through Friday at 1700 each week. We randomly selected three days out of each five-day week to observe and interview fishers (Table 1). We divided each sampling day, from 0600 to 2200 hours, into two shifts, 0600–1400 hours and 1400–2200 hours, with reduced hours on Monday and Friday.

Table 1.–Sampling dates selected randomly in each of the four weeks of the Klawock Inlet subsistence fishery in 2004.

Week	Sample Dates
1	7, 8, 9 July
2	13, 15, 16 July
3	19, 20, 21 July
4	26, 29, 30 July

All subsistence fishers used small, hand-pulled seine nets and usually used two boats to deploy a single net. A set was defined as a single net deployment and retrieval. A *boat-party* referred to all the people on one or two boats fishing the same net. The samplers used binoculars and a motorized skiff to monitor the fishery, positioning themselves on the shore or in the skiff where they could see all boat-parties fishing in Klawock Inlet. As a net was being pulled up, the sampler approached the participants to verbally interview them, or the sampler observed the set and recorded the pertinent information. In addition to direct verbal interviews, samplers and fishers used hand signals to communicate the size of the catch. Hand signals or simply visual observation were often used to indicate that zero fish were caught in a set. If the technician received information from hand signals or visual observation, he usually did not obtain a verbal interview. Verbal interviews were usually used when larger numbers of fish were caught in a set. At the conclusion of the interview, the sampler recorded the date, type of interview (hand, verbal, or visual), number of salmon caught by species, time of day, gear, town of residence, and any comments. The sampler assigned a number to each interview. Names of fishers were not recorded to guard the confidentiality of the fishers. Samplers attempted to interview all boat-parties after each set. However, in cases where samplers were unable to interview a boat-party after a set, the sampler recorded this set as a "missed interview."

We viewed the statistical population to be a collection of "net sets." Sets were organized into a day within a week. The sampling was constructed as a two-stage sampling plan, with a day within a week selected at random (first stage) and then a set within a day (second stage) selected if need be (Bernard et al. 1998; Thompson 1992). If a set was recorded as a "missed interview," the average harvest for that day was assigned to that set (second stage). The average harvest per day, within a week, was expanded to estimate the harvest for the two days not sampled each week (first stage). If harvest data were collected for all sets on the days sampled within a week (i.e. no missed interviews), that week's estimate only required expansion of the average daily harvests to the full week (five fishing days).

We let h_{ijk} denote the harvest for set i on day j in week k, and m_{jk} denote the number of completed interviews on day j, in week k (i.e. the total number of sets for which interviews were obtained). Also, M_{jk} denoted the total number of net sets counted on day j in week k (i.e. the total number of sets observed, including any missed interviews), and d_k denoted the total number of days sampled out of D_k fishing days in week k. For all weeks, d_k was 3. For the first week, D_1 was 3, and for weeks 2–4, D_k was 5. For a given species, the harvest for week k was estimated as,

$$\hat{H}_k = \frac{D_k}{d_k} \sum_{j=1}^{d_k} \frac{M_{jk}}{m_{jk}} \sum_{i=1}^{m_{jk}} h_{ijk} \ ,$$

and the total harvest for the season was estimated as the sum of weekly harvests,

$$\hat{H} = \sum_{k=1}^{4} \hat{H}_k \ .$$

To estimate the variance of $\hat{H}$, we let $\bar{h}_{jk}$ denote the mean harvest per set, on day *j* in week *k*, and $\bar{h}_k$ denote the mean harvest for the week. We then estimated the variance for the estimated harvest in week *k* as,

$$\text{var}(\hat{H}_k) = \frac{D_k}{d_k} \sum_{j=1}^{d_k} M_{jk}^{\ 2} \left(1 - \frac{m_{jk}}{M_{jk}}\right) \frac{\sum_{i=1}^{m_{jk}} (h_{ijk} - \bar{h}_{jk})^2}{m_{jk}(m_{jk} - 1)} + D_k^{\ 2}(1 - \frac{d_k}{D_k}) \frac{\sum_{j=1}^{d_k} (\bar{h}_{jk} - \bar{h}_k)^2}{d_k(d_k - 1)}$$

(Thompson 1992, p. 129).

The overall variance for the season was estimated by summing the four weekly variance estimates, $\text{var}(\hat{H}) = \sum_{k=1}^{4} \text{var}(\hat{H}_k)$. Finally, this overall variance was used to calculate the standard error of the estimate.

SOCKEYE ESCAPEMENT ESTIMATES

Weir Counts and Mark-Recapture Estimate

Project crew, in cooperation with Prince of Wales Hatchery staff, operated the Klawock River weir from 1 July to 15 October 2004. The weir was rebuilt in 2004 in response to problems with flooding and undetected passage of fish through the weir. As mentioned earlier, improvements included reducing the spacing between the pickets, increasing the angle of the face of the weir to reduce the water pressure on the weir, and installing a boom log upstream from the weir to stop large floating trees from hitting the weir. The weir was located adjacent to the hatchery and spanned the 50 m stream width, about 100 m below the lake. Fish migrating upstream were diverted at the weir into the hatchery's raceway and sampling platform, where they were identified by species, counted, and passed upstream.

To test the integrity of the weir and provide an independent estimate of sockeye escapement into Klawock Lake, we also estimated escapement using a stratified, closed-population mark-recapture study (Arnason et al. 1996). Twenty percent of the sockeye salmon passed through the weir were marked with an adipose fin clip and a uniquely-numbered t-bar tag. All jack sockeye salmon, defined for Klawock sockeye salmon as male fish under 440 mm, were marked and tagged, and noted as jacks on the data form. The adipose clip was designated as the primary mark, indicating presence of a tag, which allowed the crew to monitor for tag loss. Following the season, tag numbers applied at the weir were stratified by tagging date into 12 strata of one week each.

Recapture sampling was conducted on the spawning grounds at intervals approximately one week apart, throughout the spawning season. At least six sampling occasions were attempted in each major spawning stream (Three-Mile Creek, Inlet Creek, and Half-Mile Creek). Fish were sampled with small beach seines as they schooled at the mouth of the stream, and with dip nets in the channel of each stream. All unmarked fish in these samples were tagged and given an opercular punch to identify the sampling event in which the fish was caught. Tag numbers were recorded for all fish caught in the sample, whether newly tagged or tagged in a previous event. Fish in these samples were only counted on the first recapture occasion in which they were encountered.

The two-sample Petersen method is a simplistic model for estimating total escapement based on the total number of fish marked as they move into the stream or lake system (first sample), the total number of fish subsequently sampled for marks (second sample), and the number of marks recovered in the second sample (Seber 1982, p.59; Pollock et al. 1990). Stratified mark-recapture models extend the two-sample Petersen method over two or more sampling events in both the marking (first) and mark-recovery (second) samples. Stratified models are widely used for estimating escapement of salmonids as they migrate into their spawning streams (Arnason et al. 1996). Spawning migrations may last for a month or more, during which time there can be substantial variation in biological parameters such as mortality rates. 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 three assumptions of equal probability of capture required by the Petersen model are: 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 as an 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 two goodness-of-fit tests to compare observed and expected capture probabilities in the marking (first) and mark-recovery (second) samples (Arnason et al. 1996). This program also provides associated standard errors of the estimates. 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."

We looked at sample sizes and capture probabilities in each marking and mark-recovery stratum, and considered any natural events such as flooding or failures of our technicians to follow the sampling design. We then checked the Darroch estimate for possible problems, such as a failure of the SPAS program to converge to a solution, or estimates much larger or smaller than the pooled Petersen estimate. Followed the guidelines and suggestions in Arnason et al. (1996) we searched for a pooling scheme that led to the fewest number of strata with non-significant test statistics and an absence of other diagnostic problems.

Spawning Grounds Mark-Recapture Study

The Jolly-Seber model for open populations (Pollock et al. 1990), with an adjustment for spawning salmon populations (Schwarz et al. 1993), was used to estimate the number of sockeye salmon in each of the three main spawning tributaries of Klawock Lake (Three-Mile, Inlet, and Half-Mile Creeks; Figure 3). The field crew sampled sockeye spawners at the stream mouths using a beach seine, and along the channel of each stream with dip nets. Sampling began as soon as sockeye salmon moved into the spawning areas and continued at approximately weekly intervals until the number of available spawners declined and it was apparent that few or no new fish were entering the spawning areas. All unmarked fish in these samples were tagged and also marked with an opercular punch to identify the sampling event in which it was caught. A crew member recorded tag numbers of all newly captured and recaptured fish, along with sampling date and location. Fish that had already been tagged at the weir were treated as if they were tagged on the first sampling event in which they were encountered on the spawning grounds. We constructed an individual capture history for each fish, denoting a sampling event in which the fish was captured with a “1” and a sampling event in which the fish was not captured with a “0” (Pollock et al. 1990).

The Prince of Wales Hatchery crew collected sockeye salmon for broodstock on several occasions at Three-Mile Creek in 2004. Tag numbers of fish removed for broodstock were recorded. In constructing individual capture histories, we used a “2” to indicate the sampling event at which a fish was removed for broodstock; these fish were included in the mark-recapture analysis as fish that were sampled but not released.

Data Analysis

The Jolly-Seber model extends the Schnabel method (Seber 1982, p. 130) to open populations. Population size is estimated at the time of each sample, and the number of new animals entering the population is estimated between sampling events, for s sampling events. In using this model we must assume:

1. Every fish present in the population at time of the i^{th} sampling event (i=1, 2, …, s) has the same probability of capture (p_i).
2. Every fish (marked and unmarked) present in the population immediately after the i^{th} sampling event has the same probability of survival (ϕ_i) until the $(i+1)^{th}$ sampling event (i = 1, 2,…, s-1).
3. Marks are not lost or overlooked.
4. Sampling time is negligible.

We designated the following parameters:

N = size of “super-population,” or escapement;

M_i = number of marked fish in the population at time of the i^{th} sampling event (i=1, 2, …, s; $M_1 = 0$);

N_i = total number of fish in the population at time of the i^{th} sampling event (i=1, 2, …, s; $N_1=B_0$);

B_i= total number of new fish entering the population before the first event and between the i^{th} event and $(i+1)^{th}$ event, and still in the population at time of the $(i+1)^{th}$ event (i=1, …, s-1);

B_0 = the number of fish that entered the population before the first event and are still alive at the time of the first event; and

ϕ_i = survival probability for all fish between the i^{th} event and $(i+1)^{th}$ event (i=1, 2, …, s-1).

We also designated the following statistics:

m_i = number of marked fish captured in the i^{th} event (i=1, 2, …, s);

u_i = number of unmarked fish captured in the i^{th} event (i=1, 2, …, s);

$n_i = m_i + u_i$, total number of fish captured in the i^{th} event (i=1, 2, …, s);

R_i = number of the n_i fish that are released after the i^{th} event (i=1, 2, …, s-1; this may not be all of n_i fish due to losses on capture);

r_i = number of R_i fish released at i and captured again (i=1, 2, …, s-1); and

z_i = number of fish captured before i, not captured at i, and captured again later (i=1,2, …, s-1).

Seber (1982:page 204) recommended the following unbiased estimators:

$$\hat{M}_i = m_i + \frac{(R_i + 1)z_i}{r_i + 1};$$

$$\hat{N}_i = \frac{(n_i + 1)\hat{M}_i}{m_i + 1};$$

$$\hat{\phi}_i = \frac{\hat{M}_{i+1}}{\hat{M}_i - m_i + R_i};$$

$$\hat{B}_i = \hat{N}_{i+1} - \hat{\phi}_i(\hat{N}_i - n_i + R_i).$$

Seber also recommended that m_i and r_i should be greater than 10 for satisfactory performance of these bias-adjusted estimators.

We assumed the interval between the last (s^{th}) sampling event, and the next-to-last ((s-1)th) sampling event was so short that the number of fish entering the population during this interval was negligible. Furthermore, we assumed that sampling extended to a time when immigration had ended, and the number of fish entering the population was negligible. In the Jolly-Seber model, the total population is usually estimated as the sum of $\hat{B}_i$, the estimated numbers of fish that entered the population between sampling events. However, $\hat{B}_i$ are estimates of the number of fish that entered the population after sampling event i and were alive at sampling event i+1. These estimates exclude those fish in the escapement that entered after sampling event i but died before sampling event i+1. Consequently, the sum of the Jolly-Seber estimates of B_i would underestimate the spawning recruitment, except when all fish are known to survive from their entry to the next sampling event. To account for those fish that entered the system after sampling event i, but died before sampling event i+1, we adjusted $\hat{B}_i$ before summing (Schwarz et al. 1993). Let B_i^* denote the total number of new fish entering the population between sampling events (including those that died before the next sampling event). When recruitment and mortality are assumed to occur uniformly between sampling events, the maximum likelihood estimator for B_i^* is,

$$\hat{B}_i^* = \hat{B}_i \frac{\log(\hat{\phi}_i)}{\hat{\phi}_i - 1}.$$

$\hat{B}_0$, $\hat{B}_1$, and $\hat{B}_{s-1}$ are confounded parameters and cannot be estimated without further assumptions (Schwarz et al. 1993). However, we assumed recruitment had virtually ended before the last sampling event, so we set $\hat{B}_{s-1}$ to zero. The number of fish alive in the population at the second sampling event, N_2, was estimated as,

$$\hat{N}_2 = \hat{B}_0\phi_1 + \hat{B}_1.$$

So a reasonable estimate (Schwarz et al. 1993) of the number of fish that entered the system before the first sampling event and between the first and second sampling events, including those that entered the system and died before and between these sampling events, is,

$$\hat{N}_2 \frac{\log(\hat{\phi}_1)}{\hat{\phi}_1 - 1}.$$

We then estimated the super-population, or total escapement, as

$$\hat{N} = \hat{N}_2 \frac{\log(\hat{\phi}_1)}{\hat{\phi}_1 - 1} + \sum_{i=2}^{k-1} \hat{B}_i^* .$$

We used a non-parametric bootstrap technique to estimate variance and form a confidence interval for *N*. A computer program to produce these estimates, written in S-Plus (Insightful Corp. 2001), is available from X. Zhang, ADF&G Division of Commercial Fisheries (Xinxian_Zhang@fishgame.state.ak.us). The procedure works by resampling the observed experimental data to create a series of "pseudo-experiments," according to the following algorithm:

1. Analyze observed data using the Jolly-Seber method and Schwarz's adjustment described above to obtain the $\hat{N}$.
2. Sample with replacement from the observed *n* capture histories to generate a bootstrap sample of the same size *n*; analyze the bootstrap sample exactly as if it were the observed sample.
3. Repeat step (2) for 1,000 bootstrap samples to have 1,000 estimates of *N* from these bootstrap samples.
4. Calculate variance and standard error for N^* from the 1,000 bootstrap estimates of *N*.
5. Find the 95% confidence interval by taking the 0.025 and 0.975 quantiles of the 1,000 bootstrap estimates of *N*.

Because the three main spawning streams are well-separated from each other, we assumed that sockeye spawners did not migrate between them after they started entering the streams. We were able to test that assumption by examining capture histories by location. Our plan was that if migration between streams was observed in fewer than ten percent of all recaptured fish, we would sum the three separate escapement estimates (one for each stream) to estimate total escapement in Klawock Lake. If migration between streams exceeded ten percent of recaptures, we planned to pool the mark-recapture data and estimated total escapement using combined capture histories from all three locations. The total escapement estimate was expected to be less than true escapement into Klawock Lake by a small amount because at least one minor spawning area (Hatchery Creek) was not sampled. However, visual surveys in 2001–2003 showed relatively few spawners in Hatchery Creek compared to the other spawning streams (Lewis and Cartwright 2002; Cartwright and Lewis 2004; Cartwright et al. 2006).

Adult Population Age and Size Distribution

About 600 adult sockeye salmon were sampled for length, sex, and scales (scales for age determination) at the Klawock Lake weir to estimate the size and age structure of the population, by sex. Fish were selected systematically (e.g. every fifth fish) to prevent selection bias, throughout the entire run. Length of each fish was measured from mid eye to tail fork, to the nearest millimeter (mm). 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 five-year-old fish with one freshwater and three ocean years; Koo 1962). The weekly proportion in each age class, and the mean weekly proportion in each age-sex group weighted by total escapement per week, were estimated. Associated standard error was estimated using standard statistical techniques and assuming a binominal distribution (e.g. Thompson 1992). We expect that this binomial assumption would adequately approximate the standard error, even though we used a systematic sample rather than a random sample. Mean lengths by age and sex were likewise estimated from weekly means, weighted by the total escapement per week.

To test the possibility that jack sockeye salmon were escaping through the weir undetected, we compared the length distribution of all sockeye salmon measured at the weir with the length distribution of fish sampled on the spawning grounds. We compared the two empirical cumulative distribution functions graphically and using the two-sample Kolmogorov-Smirnov test (Sokal and Rohlf 1995).

Relationship Between Spawning Group and Migration Timing

To determine if the major sockeye spawning subpopulations (defined by spawning stream) had distinct timing patterns (i.e. entry into the lake), we examined the entry dates of all fish from which we recovered tags at Three-Mile, Half-Mile, and Inlet Creeks. Tags applied at the weir were grouped by week and the cumulative proportions of tags recovered, by week when tagged, were calculated for each of spawning stream. We then compared the three empirical cumulative distribution functions of the three spawning groups graphically.

LIMNOLOGY SAMPLING

Light and Temperature Profiles

Underwater light intensity was recorded at 0.5 m intervals from just below the surface to the depth where measured intensity was one percent of the surface light reading, using an electronic light sensor and meter (Protomatic). The natural log (ln) of the ratio of light intensity just below the surface to light intensity at depth z (I_0/I_z) was calculated for each depth. The vertical light extinction coefficient (K_d) was estimated as the slope of $\ln(I_0/I_z)$ versus depth. The euphotic zone depth (EZD) was defined as that depth at which light has attenuated to one percent of the intensity just below the lake surface (photosynthetically available radiation, 400–700nm) (Schindler 1971), and was calculated using the equation, $EZD = 4.6205/ K_d$ (Kirk 1994).

Temperature, in degrees centigrade (ºC) was measured with a Yellow Springs Instruments (YSI) Model 58 meter and probe. Measurements were made at one-meter intervals to the first 10 m or the lower boundary of the thermocline (defined as the depth at which the change in temperature decreased to less than 1ºC per meter). Below this depth, measurements were made at five-meter intervals.

Secondary Production

Zooplankton samples were collected at two stations in each of the two lake basins using a 0.5 m diameter, 153 µm mesh, 1:3 conical net. Vertical zooplankton tows were pulled from a maximum depth of two meters from the bottom, at a constant speed of 0.5 m sec^{-1}. The net was rinsed prior to removing the organisms, and all specimens were preserved in neutralized 10% formalin (Koenings et al. 1987). Each zooplankton tow was sub-sampled in the laboratory, and organisms in the sub-samples were identified to species or genus, counted, and measured (Koenings et al.

1987). Density (individuals per m^2 surface area) was extrapolated from counts by taxon in the sub-samples, and seasonal mean density was estimated by taking the simple average of densities across sampling dates. The seasonal mean length for each taxon, weighted by density at each sampling date, was estimated and used to calculate a seasonal mean biomass estimate (weight per m^2 surface area) based on known length-weight relationships (Koenings et al. 1987). Total seasonal mean zooplankton biomass and density were estimated by summing across all species.

RESULTS

SUBSISTENCE HARVEST ESTIMATE

Subsistence harvest of sockeye salmon, estimated from survey data collected by Klawock Cooperative Association personnel, increased each week between 7 and 30 July, 2004. Harvest numbers were obtained by interview for all but four net sets on the twelve sampling days, so sampling error due to missed interviews contributed little to the total estimate of sampling error (Tables 2 and 3). Expanding the total sampled harvest to account for missed interviews and days not sampled, we estimated a total harvest of about 4,400 sockeye salmon (95% confidence interval 4,000–4,900, CV=5%). Effort, as number of sets, and total sockeye harvest increased steadily through the four-week season (Table 3). In addition to the sockeye harvest, we estimated 94 chum and 34 coho salmon were harvested in the subsistence fishery in July.

Table 2.–Estimated daily subsistence harvest for only those days sampled in the two-stage harvest survey of the Klawock Inlet subsistence fishery in 2004; these results are not expanded for days of the week not sampled. The survey crew observed the entire fishing area during each day of the survey and counted all net sets made during that day. For most sets, they conducted an interview to determine total sockeye harvest at the end of the set. If interviews were missed for some sets in a day, the total daily harvest was estimated by dividing the average harvest per interviewed set that day by the proportion of all sets that were interviewed.

Week	Date	Sets counted	Sets interviewed	Daily sockeye harvest for days in the survey		
				Reported in interviews	Expanded for missed interviews	Std. error
1	7-Jul	18	18	139	139	0
	8-Jul	24	21	97	111	4
	9-Jul	31	31	150	150	0
2	13-Jul	26	25	175	182	2
	15-Jul	19	19	240	240	0
	16-Jul	15	15	154	154	0
3	19-Jul	37	37	237	237	0
	20-Jul	34	34	427	427	0
	21-Jul	34	34	202	202	0
4	26-Jul	76	76	482	482	0
	29-Jul	42	42	221	221	0
	30-Jul	29	29	282	282	0

Table 3.–Summary of weekly estimates of subsistence sockeye effort and harvest in the Klawock Inlet fishery, 2004.

		Expanded totals for week				
Week	Week beginning	Sets counted	Sets interviewed	Estimated sockeye harvest	Std. error	Proportion of season total harvest
1	4-July	73	70	400	5	0.09
2	11-July	100	98	960	60	0.22
3	18-July	175	175	1,440	160	0.32
4	25-July	245	245	1,600	180	0.37
All				4,400	250	

SOCKEYE ESCAPEMENT ESTIMATES

Weir Counts and Mark-Recapture Estimate

Between 1 July and 15 October 2004, the total count of sockeye salmon through the Klawock weir was 12,442 fish. Only 5% of the total sockeye escapement was counted through the weir during the month of July, while the subsistence fishery was open (Appendix A). Peak sockeye immigration into Klawock Lake occurred on 2 August, when 1,586 sockeye salmon were counted through the weir. Moderate to large numbers of sockeye salmon entered the lake daily through August, and 50% of the sockeye escapement had entered the lake by 17 August. Sockeye immigration generally declined in September, and did not appear to be closely linked with water level (Figure 4). Sockeye jacks, considered to be all males less than 440 mm, accounted for about 6% of total sockeye numbers (Table 4). Overall, the crew tagged about 21% of the sockeye salmon that passed through the Klawock weir, totaling 2,584 fish (Table 4).

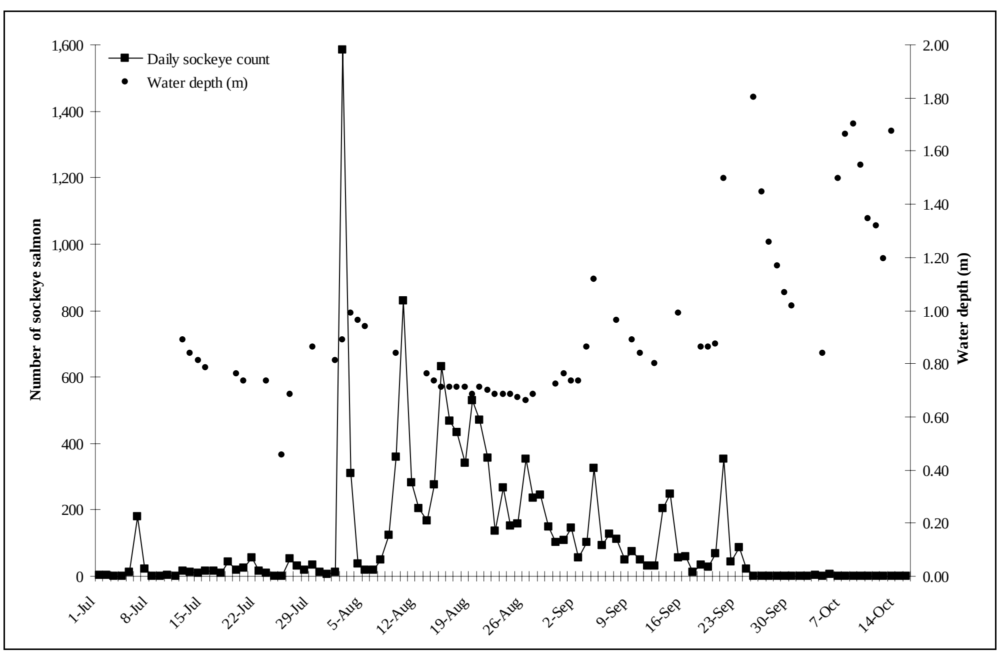

Figure 4.–Daily counts of sockeye salmon and water level in Klawock River, 2004.

The total count of coho salmon through the weir was 12,938 fish, of which over 75% were jack coho salmon (Table 4; Appendix A). Coho salmon were first counted at the weir on 7 July, but their peak escapement through the weir was not until late September and early October (Appendix A). Pink and chum salmon were counted through the weir between late July and the end of September, and peak numbers of Dolly Varden char immigrated into Klawock Lake in late August (Appendix A).

Table 4.–Summary of fish counted and marked at the Klawock Lake weir in 2004.

Sockeye salmon	**Number passed**	**Number marked**
Full-size adults	11,732	2,327
Jacks (males less than 440 mm)	710	257
All sockeye salmon	12,442	2,584
Coho salmon		
Full-size adults	3,086	
Jacks	9,852	
All coho salmon	12,938	
Other species		
Pink salmon	26,087	
Chum salmon	807	
Dolly Varden char	1,337	
Rainbow and cutthroat trout	6	

To assess mortalities of sockeye salmon due to handling at the weir, the crew recovered sockeye carcasses from the weir daily and examined them for marks and tags. Out of 359 carcasses examined between 29 August and 12 October, 22% (80 fish) had been marked and tagged at the weir. Thus, among sockeye mortalities, the proportion of tagged fish was not substantially elevated over the original proportion tagged. Furthermore, upon inspecting tag numbers, we noted that some of these fish had previously been recovered on the spawning grounds and so we assumed these fish had already spawned before floating back to the weir. We also assumed that any carcass recovered one week or more after tagging was a natural mortality. Thus, only 42 of the 80 tagged carcasses recovered at the weir were considered to be mortalities due to handling at the weir. Therefore we concluded that tagging, in itself, did not increase the rate of mortality due to handling at the weir. Tag numbers of the assumed handling mortalities were censored from the list of tags applied at the weir for purposes of the mark-recapture analysis.

The crew began mark-recovery sampling for tags applied at the weir on 6 July at Three-Mile Creek, Half-Mile Creek, and Inlet Creek, and they continued sampling approximately once per week until 24 September. Seven fish with adipose clips and lost tags were recovered on the spawning grounds, representing about 2% of 327 total recaptures (Table 5). Because observed tag loss was small, we decided the effect of lost tags on the mark-recapture estimate would be negligible and we did not include a correction for lost tags in the estimate.

Although both the Darroch and pooled Petersen estimates were very similar - well within the limits of precision of each estimate—we noted substantial variation in capture probabilities among marking strata (Table 5). This apparent variation in capture probabilities among both the marking and recapture strata led us to conclude that the pooled Petersen estimate was inappropriate (note significant goodness-of-fit tests; Table 6). After partial pooling we developed a Darroch estimate of 13,000 (95% CI: 10,600–15,400).

Table 5.–Numbers of sockeye salmon passed and marked during each week at the Klawock weir, numbers and proportions of marks recovered, and total numbers sampled on the spawning grounds in Klawock Lake, 2004. The shaded cells represent the weekly proportion of sockeye salmon marked at the weir that were more than 10% lower or higher than the 20% preseason marking goal.

				Number marks recaptured by stream and marking stratum			All recaptures, by marking stratum	
Marking stratum (week)	**Sockeye salmon passed**	**Number marked**	**Proportion marked**	**Three-Mile**	**Inlet**	**Half-Mile**	**Number recaptured**	**Proportion recaptured**
3–9 July	216	52	0.24	5	5	0	10	0.19
10–16 July	77	2	0.03	0	0	0	0	0
17–23 July	163	35	0.21	2	2	0	4	0.11
24–30 July	155	45	0.29	5	2	1	8	0.18
31 July–6 Aug	2,029	432	0.21	61	18	3	82	0.19
7–13 Aug	2,242	446	0.20	50	10	2	62	0.14
14–20 Aug	3,225	667	0.21	59	4	6	69	0.10
21–27 Aug	1,547	323	0.21	22	1	1	24	0.07
28 Aug-3 Sept	992	275	0.28	41	4	1	46	0.17
4-10 Sept	534	95	0.18	8	1	1	10	0.11
11-17 Sept	645	85	0.13	4	1	0	5	0.06
18-24 Sept	600	84	0.14	5	2	0	7	0.08
Total	12,425	2,541		262	50	15	327	
			Total sampled for marks, by stream	1,193	315	132	**All streams**	1,640
			Proportion with marks in sample	0.22	0.16	0.11	**Mean**	0.16

Table 6.–Results of goodness-of-fit tests in SPAS to detect possible violations of mark-recapture assumptions of equal capture probabilities and equal mixing between first (marking) and second (mark-recovery) samples for Klawock Lake sockeye escapement estimate in 2004.

Test name	Assumptions tested[a]	X^2 value	Degrees of freedom	*p*-value
Complete Mixing	2 and 3	39.69	11	< 0.001
Equal Proportions	1	12.40	2	0.002

[a] Mark-recapture assumptions:
1. All fish have an equal probability of capture during the marking phase, or
2. All fish have an equal probability of capture during the recovery phase, or
3. Marked and unmarked fish mix completely between the marking and recovery phase.

Spawning Grounds Mark-Recapture Study

At Three-Mile Creek, the crew sampled 1,178 sockeye salmon at the mouth and in the channel of the stream (Table 7). The seven sampling events were on 25–27 August, 1–2 September, 7–8 September, 14–15 September, 21 September, 27–28 September, and 4 October (5–6 days apart). During this time, the hatchery crew took at least 126 tagged sockeye salmon from the mouth of Three Mile Creek for broodstock. Due to different work priorities, the hatchery crew may not have collected complete tag data. A discrepancy between hatchery and ADF&G records indicates that up to 25 additional tagged fish may have been removed. However, the fish removed for broodstock did not contribute to the spawning ground mark-recapture estimate of escapement. Not including the fish removed for broodstock, only about 6% of tagged fish (65 fish) were recaptured again after their first capture. The longest observed time between first capture and recapture was about 19 days. The low recapture rate, and the observation that about two-thirds of these fish were recaptured in the event immediately following the first capture, indicated a short residence time for sockeye spawners in Three-Mile Creek. Using the Jolly-Seber method, we estimated a total spawning population of about 9,000 sockeye salmon in Three-Mile Creek (95% CI: 6,000–15,000; CV=25%).

Table 7.–Summary of capture-recapture histories of sockeye salmon sampled on at spawning grounds at Three-Mile Creek in Klawock Lake, 2004. Capture histories have one digit for each of seven sampling events, in chronological order: a "1" indicates sampling events in which the fish was caught, and a "0" indicates sampling events in which the fish was not caught. A "2" indicates a sampling event in which the fish was removed for hatchery broodstock. The number of fish with each observed capture history is shown.

Capture-recapture category	Capture history	Number of fish
Captured only once and released	1000000	121
	0100000	166
	0010000	369
	0001000	250
	0000100	24
	0000010	53
	0000001	4
Sub-total		987
Captured and released, then recaptured and released at next event	1100000	12
	0110000	8
	0011000	19
	0001100	2
Sub-total		41
Captured and released, not captured in next event, but recaptured and released in a later event	1010000	2
	0101000	5
	0001010	7
	0000101	1
	1001000	1
	0010010	2
	0001001	3
Sub-total		21
Recaptured and released more than once	1110000	2
	0111000	1
Sub-total		3
Removed for broodstock	0200000	25
	0020000	44
	0002000	48
	0000200	4
	1200000	1
	0120000	2
	0001200	1
	1020000	1
Sub-total		126
Total sampled		1,178
Total released		1,052

At Inlet Creek, the crew sampled 316 sockeye salmon at the mouth and in the channel of the stream. The five sampling events were 2–4 September, 10 September, 17 September, 22 September, and 29 September (5–7 days apart). Only about 3% (nine fish) were recaptured again after their first capture (Table 8), an even lower recapture rate than at Three-Mile Creek. This very low recapture rate, and the observation that no fish were recaptured more than once, indicated a very short stream residence time for sockeye spawners in Inlet Creek. The Jolly-Seber estimate of the total spawning population in Inlet Creek was about 1,700 sockeye salmon (95% CI: 500–4,800; CV=80%).

At Half-Mile Creek, the crew found few fish and sampled only 125 sockeye spawners. The six sampling events were 30 August, 3 September, 9 September, 16 September, 27 September, and 4 October. About 12% (15 fish) of the fish sampled at Half-Mile Creek were recaptures (Table 8), a higher proportion than at the other two streams. The estimated escapement at Half-Mile was very small, about 260 fish (95% CI: 190–430; CV=22%).

Table 8.–Summaries of capture-recapture histories of sockeye salmon sampled on the spawning grounds at Inlet Creek and Half-Mile Creek in Klawock Lake, 2004. Capture histories have one digit for each sampling event (five events at Inlet and six at Half-Mile Creek), in chronological order: a "1" indicates sampling events in which the fish was caught, and a "0" indicates sampling events in which the fish was not caught. The number of fish with each observed capture history is shown.

Inlet Creek		
Capture-recapture category	**Capture history**	**Number of fish**
Captured once	10000	113
	01000	101
	00100	56
	00010	24
	00001	13
Subtotal		307
Captured once, then recaptured at next event	11000	5
	01100	1
	00110	2
Subtotal		8
Recaptured in later event	10100	1
Subtotal		1
Total sampled		316
Half-Mile Creek		
Capture-recapture category	**Capture history**	**Number of fish**
Captured once	100000	20
	010000	6
	001000	33
	000100	22
	000010	27
	000001	2
Subtotal		110
Captured once, then recaptured at next event	011000	3
	001100	9
	000110	1
Subtotal		13
Recaptured in later event	101000	1
	001010	1
Subtotal		2
Total sampled		125

We examined all 1,619 capture history records for movement between streams, and found that seven fish were captured at both Half-Mile and Three-Mile Creeks, and one fish was captured at both Inlet and Three-Mile Creeks. Because of the very low (<1%) observed incidence of movement between spawning streams, we considered the fish in each stream to be a separate spawning population, and consequently, we summed rather than pooled the escapement estimates. The sum of the escapement estimates for Three-Mile, Inlet, and Half-Mile Creeks was about 11,000 fish (CV=23%). Given the large sampling error, the Jolly-Seber estimate was not statistically different from the whole-lake closed population estimate or the weir count, even though the Jolly-Seber estimate was about 2,000 fish lower.

Adult Population Age and Size Distribution

Length and sex data and scale samples were collected from 506 sockeye salmon at the Klawock River weir, and ages were determined for 430 of these fish. Over 56% of sockeye salmon in the 2004 escapement were returns from the 1999 brood year, about equally split between the age-1.3 and age-2.2 classes (Table 9). However, the largest single age class in the escapement was age-1.2 (brood year 2000). Fish that spent one year in freshwater as juveniles (age-1.2, age-1.3, and age-1.1 jacks) comprised about two-thirds (67%) of the 2004 escapement. As expected, sockeye salmon that had spent three years in the ocean (age-1.3 and age-2.3) were larger, within the respective freshwater age classes, than fish with two ocean years (age-1.2 and age-2.2; Table 10). Of the few jacks in the sample, those in the age-1.1 class averaged under 400 mm in length, but those in the age-2.1 class averaged slightly over 400 mm. Age-1.3 fish, with three ocean years, were the largest age class in the escapement in the early season, but starting in late July the weekly percentages of age-1.2 fish equaled or exceeded weekly percentages of the older fish. Together, fish with two ocean years, in the age-1.2 and -2.2 classes, dominated weekly escapements after 25 July (Table 11).

Table 9.–Age composition of sockeye salmon in the Klawock Lake escapement by sex, 2004. Percentages in each age group were weighted by weekly escapement. Estimated numbers in each age class, based on total escapement counted through the weir are also shown.

Brood Year	**2001**	**2000**	**1999**	**2000**	**1999**	**1998**	
Age Class	**1.1**	**1.2**	**1.3**	**2.1**	**2.2**	**2.3**	**All aged**
Male							
Number	9	73	73	9	38	1	203
Percent	2.4%	17.7%	12.4%	2.4%	10.3%	0.5%	45.7%
SE (%)	0.7%	1.8%	1.6%	0.7%	1.5%	0.3%	2.4%
Female							
Number		71	75		77	4	227
Percent		19.5%	14.8%		19.1%	0.9%	54.3%
SE (%)		1.9%	1.7%		1.9%	0.4%	2.4%
All Fish							
Number	9	144	148	9	115	5	430
Percent	2.4%	37.2%	27.2%	2.4%	29.4%	1.3%	100.0%
SE (%)	0.7%	2.3%	2.1%	0.7%	2.2%	0.6%	0.0%
Escapement by age class	299	4,630	3,378	304	3,664	166	12,442

Table 10.–Length composition of adult sockeye salmon in the Klawock Lake escapement, by age class and sex, 2004. Mean lengths were weighted by weekly escapement.

Age Class	1.1	1.2	1.3	2.1	2.2	2.3
Male						
Sample size	9	73	73	9	38	1
Mean length (mm)	376	517	573	405	525	580
SE (mean length)	3.4	3.2	2.4	5.2	3.7	
Female						
Sample size		71	75		77	4
Mean length (mm)		512	549		516	548
SE (mean length)		3.2	3.1		3.0	
All Fish						
Sample size	9	144	148	9	115	5
Mean length (mm)	376	516	562	405	520	551
SE (mean length)	3.4	2.3	2.1	5.2	2.3	

Table 11.–Age composition in the Klawock Lake escapement by week in 2004, based on total number of fish sampled per week.

Week beginning	Percent of weekly total sample, by age class						Number sampled	Weir count
	1.1	1.2	1.3	2.1	2.2	2.3		
4-Jul	0	35.7%	42.9%	0	21.4%	0	14	216
11-Jul	0	5.6%	83.3%	0	11.1%	0	36	77
18-Jul	0	24.1%	69.0%	0	6.9%	0	29	163
25-Jul	7.1%	35.7%	35.7%	7.1%	14.3%	0	28	155
1-Aug	5.7%	37.1%	37.1%	2.9%	17.1%	0	35	2,029
8-Aug	0	34.0%	26.4%	3.8%	35.8%	0	53	2,242
15-Aug	1.0%	35.4%	22.2%	2.0%	38.4%	1.0%	99	3,225
22-Aug	3.2%	27.0%	23.8%	1.6%	39.7%	4.8%	63	1,547
29-Aug	9.1%	54.5%	27.3%	0	9.1%	0.0%	22	992
5-Sep	0	50.0%	34.6%	0	15.4%	0	26	534
12-Sep	0	60.0%	6.7%	0	33.3%	0	15	645
19-Sep	0	30.0%	20.0%	10.0%	30.0%	10.0%	10	600

To test for the possibility that some small sockeye salmon (i.e. jacks) escaped undetected through the weir, we compared the length distribution of the 505 fish sampled at the weir with the length distribution of 395 fish sampled on the spawning grounds (Figure 5). Formal comparison of the two distributions with the Kolmogorov-Smirnov test yielded a highly significant (p-value<0.01) result. However, the two empirical cumulative distribution functions are nearly identical for fish with lengths up to about 460 mm—well above the threshold for jacks. Therefore we concluded small fish did not escape undetected through the weir. With such large sample sizes, this hypothesis test would be very sensitive to small size bias in the sampling gear used on the spawning grounds. The statistical difference in the length distributions for fish >460 mm between the weir and spawning grounds is not attributable to a biologically meaningful difference in the two populations.

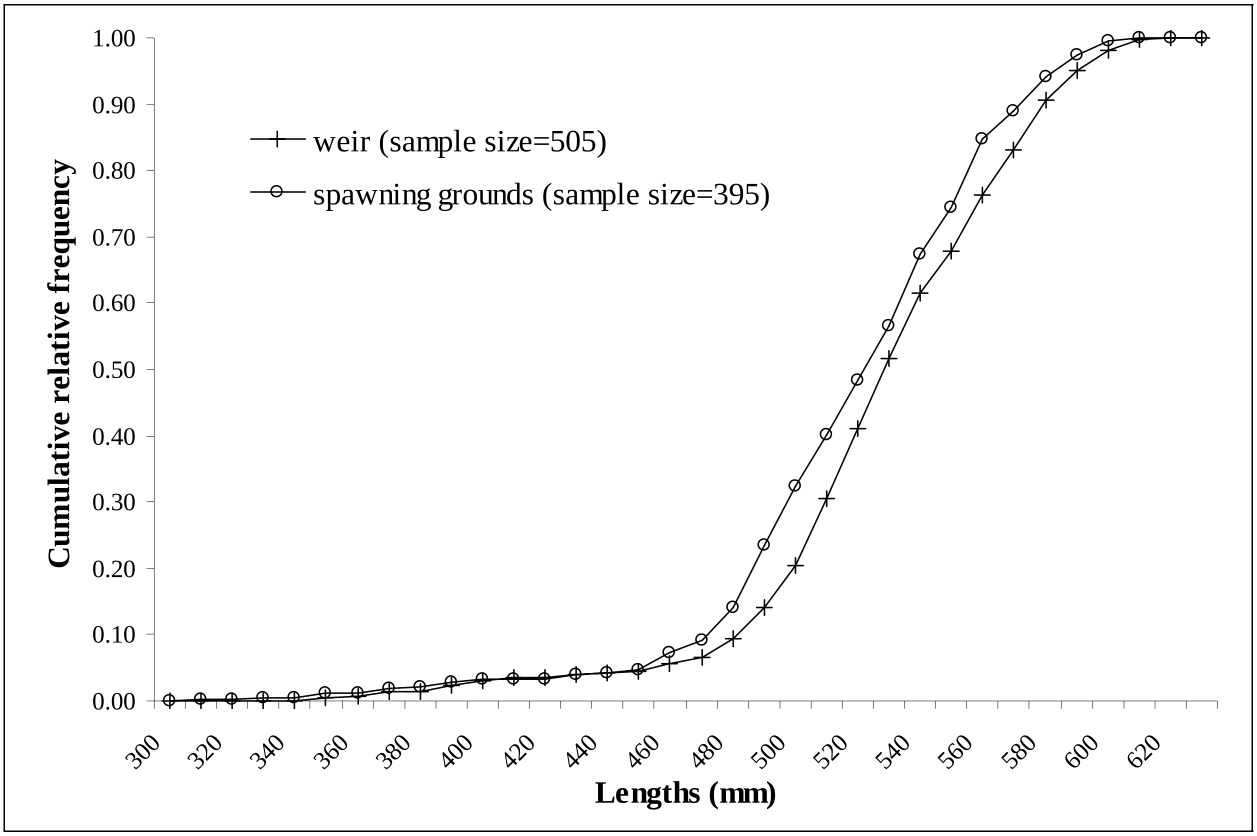

Figure 5.–Graphical comparison of empirical cumulative distribution functions for samples of sockeye salmon measured at the Klawock River weir (*n*=505) and on the spawning grounds in Klawock Lake (*n*=395) in 2004.

Relationship Between Spawning Group and Migration Timing

A total of 327 out of 2,584 tags applied to sockeye salmon at the weir were recovered in the three major spawning streams in the Klawock Lake system in 2004. The majority of these tags were recovered in Three-Mile Creek (*n*=262), followed by Inlet Creek (*n*=50) and Half-Mile Creek (*n*=15)(Table 5). Fish tagged earlier in the season made up a higher proportion of total tag recoveries in Inlet Creek than in the other two streams. About half of total tag recoveries in Inlet Creek were from fish tagged from the beginning of the season through the week of 1 August (ending date 7 August). In contrast, during this tagging period, only about 22% of the total sockeye escapement had passed the weir (Appendix A), and only 22% of the total tags had been applied (Figure 6). Including fish tagged through the week of 15 August (ending date 21 August) brought cumulative proportions up to 80% of total tag recoveries from both Inlet and Half-Mile Creek, but only about 70% of total tag recoveries from Three-Mile Creek (Figure 6). By 21 August, about 65% of total sockeye escapement had passed the weir (Appendix A), and 66% of total tags had been applied. The pattern of tag recoveries from Three-Mile Creek closely matched the proportions of fish tagged at the weir over time (Figure 6, dotted line), whereas the pattern of tag recoveries from Inlet Creek deviated from the proportions tagged over time. However, this pattern is based on very small weekly numbers of tag recoveries.

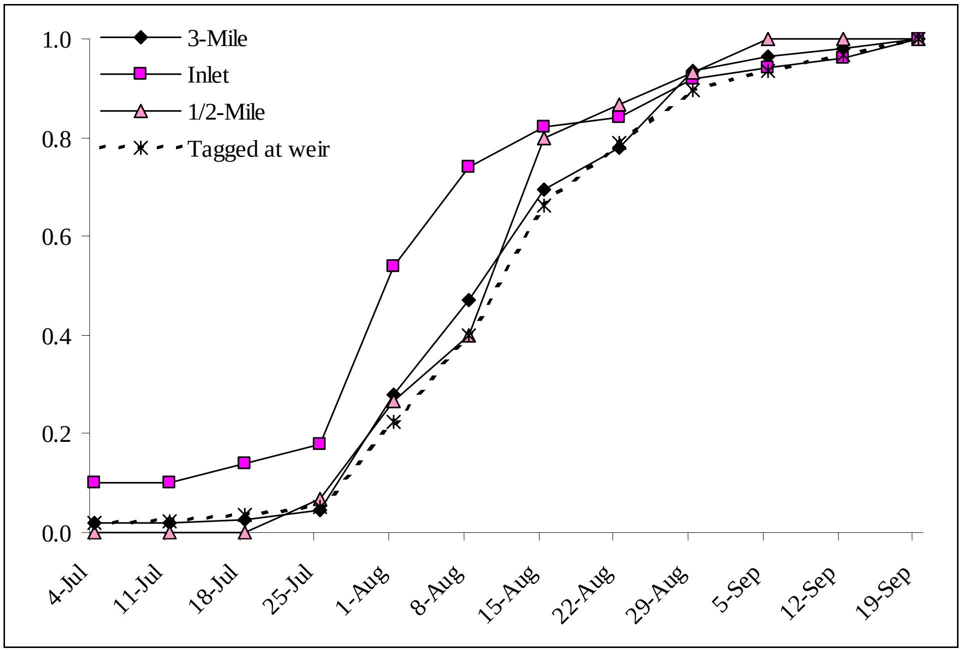

Figure 6.–Cumulative proportions of tagged sockeye salmon recovered in the three major spawning streams, by week tagged at the weir, compared with cumulative proportion of fish tagged at the weir by week.

LIMNOLOGY SAMPLING

Light and Temperature Profiles

The euphotic zone was slightly deeper throughout the season in Basin B, the smaller but deeper of the two main basins in Klawock Lake. The euphotic zone depth increased through the summer months, but was shallower again by mid-October (Table 12).

Table 12.–Klawock Lake estimated euphotic zone depths in the two main lake basins in 2004.

Date	Euphotic Zone Depth (m)	
	Basin A	Basin B
29-Apr	4.3	4.4
17-Jun	4.7	5.1
14-Jul	5.1	5.3
30-Aug	5.9	6.4
12-Oct	3.8	5.2
Season mean	4.8	5.3

Surface warming of Klawock Lake is evident in the 29 April temperature profiles. By the 17 June sampling date, a thermocline had begun to form, more pronounced in Basin B. By the 14 July sampling date, the thermocline was well developed at 4–8 m in Basin A and 3–9 m in Basin B (Figure 7). Temperature profiles were not measured after 14 July.

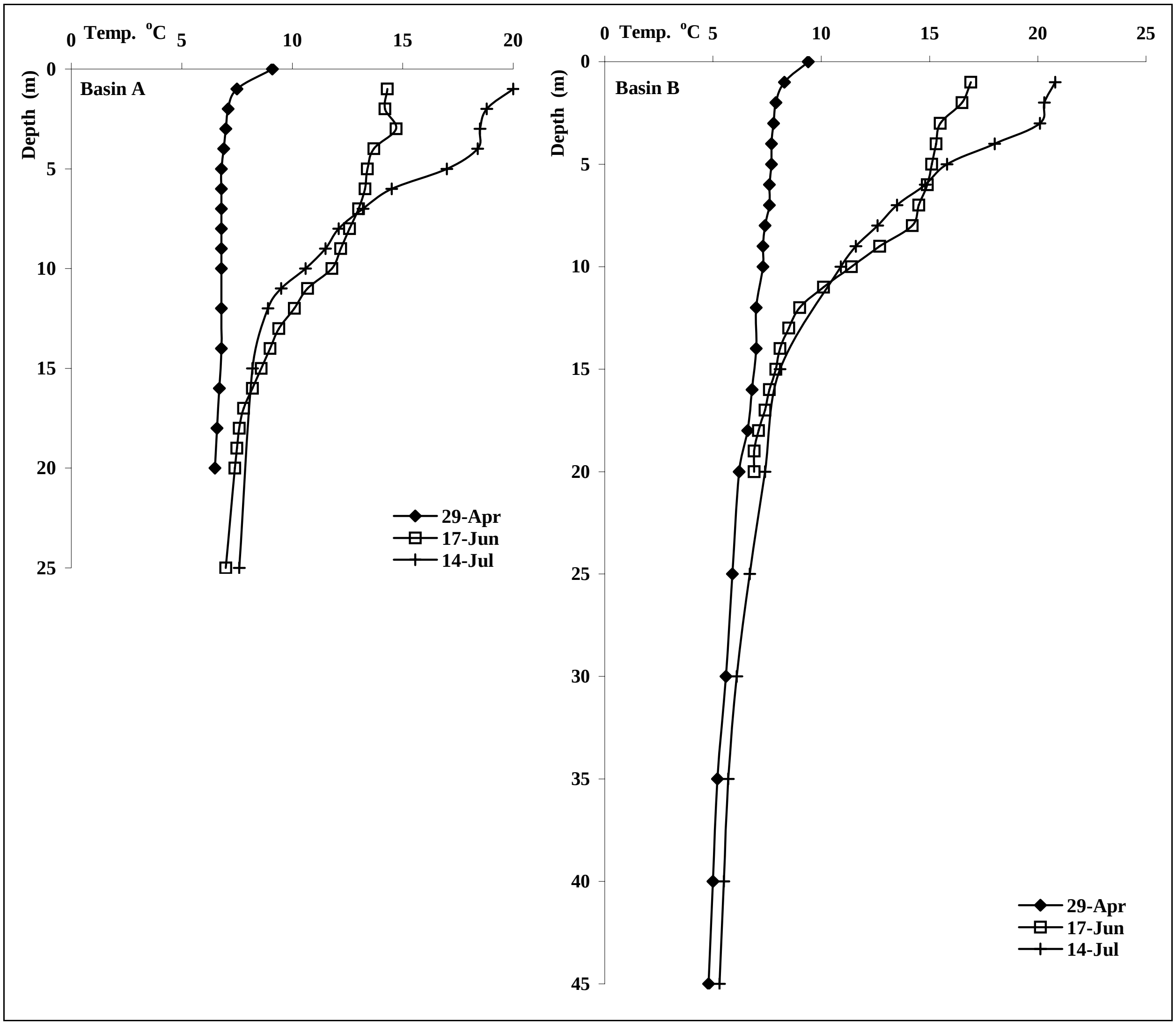

Figure 7.–Water column temperature profiles for Klawock Lake Basins A and B, 2004.

Secondary Production

Copepods, of which *Cyclops* sp. were the most abundant, dominated the Klawock Lake zooplankton assemblage, and this dominance was especially pronounced in Basin B. Although the small cladoceran *Bosmina* sp. was the second largest taxon numerically in Klawock Lake, the large-bodied *Daphnia* sp. comprised nearly half of the Cladoceran biomass. *Daphnia rosea*, averaging over 1.0 mm in length, was the major *Daphnia* species present. Zooplankton density and biomass were almost three times greater in Basin B than Basin A. Maximum zooplankton abundance was found on 14 July at both stations, and abundance of all major taxa generally followed this pattern (Table 13).

Table 13.–Zooplankton species composition and mean numerical density, size, and biomass estimates between two sampling stations in the two main basins in Klawock Lake in 2004. Density is average number of zooplankters in the water column, per square meter of surface area. Percentage composition of the total zooplankton assemblage by taxon is also shown. Seasonal mean body lengths were weighted by density and averaged between the two stations. Seasonal mean biomass is a function of seasonal mean body size and density. Ovigerous (egg-bearing) members of several taxa were counted and measured separately.

	Density (thousands · m^{-2}), by date						Percent of total number	Mean length (mm)	Seasonal mean biomass ($mg \cdot m^{-2}$)	Percent of total biomass
Basin A average (Stations A & C)	**4/29**	**6/17**	**7/14**	**8/30**	**10/12**	**Seasonal mean**				
Epischura	0	5.7	5.0	8.9	4.2	4.8	5.4%	1.21	37.2	23.7%
Cyclops	53.9	81.0	97.8	26.7	24.3	56.7	63.1%	0.65	81.9	52.1%
Ovig. *Cyclops*	0.2	0.1	0	0	0.1	0.1	0.1%	0.73	0.2	0.1%
Nauplii	12.2	1.4	0	0.3	0.6	2.9	3.2%			
Bosmina	4.6	26.0	45.2	15.0	2.4	18.6	20.6%	0.33	18.7	11.9%
Ovig. *Bosmina*	0	0	0	0.2	0.3	0.1	0.1%	0.38	0.1	0.0%
Daphnia longiremis	0.1	0.3	5.1	2.2	0.3	1.6	1.8%	0.73	3.7	2.4%
Ovig. *D. longiremis*	0	0	0	0	0.1	0	0.0%		0	0.0%
Daphnia rosea	0.1	2.4	9.5	5.2	1.0	3.6	4.2%	1.03	14.1	8.9%
Holopedium	1.5	0.7	0	0	0	0.4	0.5%	0.55	1.5	0.9%
Ovig. *Holopedium*	0	0.7	0	0	0	0.1	0.2%			
Immature Cladocera	0.8	0.5	2.4	0.6	0.2	0.9	1.0%			
Totals	73	119	165	59	33	90			157	
Basin B average (Stations B & D)										
Epischura	0.2	12.6	17.0	6.1	5.3	8.2	3.2%	1.17	58.2	13.1%
Cyclops	75.5	125.0	298.0	327.0	198.3	204.7	80.9%	0.67	316.2	71.0%
Ovig. *Cyclops*	0.2	0.7	0	0	0	0.2	0.1%	0.89	0.5	0.1%
Nauplii	19.0	0.3	1.0	1.4	0	4.3	1.7%			
Bosmina	5.0	70.0	39.4	6.8	3.4	24.9	9.7%	0.35	28.3	6.4%
Ovig. *Bosmina*	0.1	0	0	0	0	0	0.0%	0.44	0	0.0%
Daphnia longiremis	0	1.7	1.7	1.0	1.7	1.2	0.5%	0.73	2.8	0.6%
Ovig. *D. longiremis*										
Daphnia rosea	0	4.8	30.9	2.0	1.5	7.9	3.0%	1.02	29.4	6.6%
Holopedium	5.0	4.1	0	0	0	1.8	0.7%	0.79	10.0	2.2%
Ovig. *Holopedium*	0	0.7	0	0	0		0.0%			
Immature Cladocera	0.8	0.7	1.0	0	0.8	0.7	0.2%			
Totals	106	220	389	344	211	254			445	

DISCUSSION

Although we have studied the Klawock Lake sockeye stock for only four years, we found the stability of the escapement and the return to Klawock Inlet to be remarkable. All four escapement estimates (2001–2004) have been within 15% of mean escapement for the four-year period, with the lowest estimate of 12,600 in 2004 (Table 14). The stability in the subsistence harvest in Klawock Inlet is not surprising, as the food needs for subsistence harvest are determined by the size of the human population with access to this sockeye stock. This food need appears to be about 6,000 sockeye salmon per year, assuming there were no significant harvests after the subsistence sockeye fishery closed, during the years of study.

Table 14.–Estimated subsistence harvest and escapement of sockeye salmon in the Klawock Lake system for 2001–2004. In all four years, subsistence harvest was estimated using on-site surveys in the Klawock Inlet fishery area. In all four years, escapement was estimated by means of a weir and a mark-recapture study.

Year	Estimated subsistence harvest	95% confidence interval for subsistence harvest	Estimated escapement	95% confidence interval for escapement
2001	6,400	5,300–7,400	13,000	8,000–18,000
2002	6,000	5,300–6,800	12,600	11,500–15,100
2003	6,000	5,000–7,000	21,000	18,000–27,000
2004	4,500	3,800–5,100	12,400	12,000–14,000
Mean	5,700		14,800	

If the subsistence harvests were consistently and substantially larger than the commercial harvests over the last four years, then the harvest rates on this stock would seem low by comparison to other studied Southeast Alaska sockeye stocks (Geiger et al. 2004). However, we do not, at this time, have any way to estimate the harvest of Klawock Lake salmon in any commercial fisheries. This lack of stock-specific commercial harvest estimates remains the most obvious hole in our ability to assess the Klawock Lake sockeye stock.

We note the agreement between the weir count and the mark-recapture estimate of escapement in 2004, which confirmed the weir count of about 12,400 sockeye salmon as our official estimate of escapement. As we previously noted, the weir count and the mark-recapture estimates diverged in 2001 and 2003. Improvements to the weir in 2004 may have contributed to the agreement, but there were no large floods during the sockeye run in 2004. Because there is no guarantee that the water level will not exceed the weir height in any given year, we recommend a mark-recapture backup estimate for the weir at Klawock Lake for each year the weir is operated. We still view a mark-recapture verification of the weir estimate as essential to the complete analysis of the sockeye escapement into this system. Of course, we make the same recommendation for all weir-based escapement studies in Southeast Alaska, for the obvious reason that there is no other way to detect a large undercount if it occurs.

In 2004, the sum of the open-population estimates of sockeye salmon in the three main spawning streams was similar to the weir count and closed-population estimate. In the future, decision makers may need to look for ways to reduce the cost of this project. If so, then these open-population mark-recapture studies in the inlet streams might provide an adequate, if less precise and less accurate, estimate of escapement level. We see these inlet-stream-only studies as a possible path to a reasonable and less expensive indicator of substantial changes in the escapement level for this system. At minimum, we would like to see these open-population mark-recapture estimates remain similar to the weir counts in 2005 and 2006 before we would recommend monitoring the sockeye population in this system with open-population estimates instead of a weir count.

We noticed a potential problem with the management of this stock, as all of the subsistence harvest was taken from the first part of the run in 2004. This same problem was described by Lewis and Cartwright (2002) Cartwright and Lewis (2004) and Cartwright et al. (2006) for the

2001–2003 return years. By 31 July of 2004, 4,500 sockeye salmon had been harvested, but only 616 sockeye salmon, or 5% of the total escapement of 12,400 fish, had entered the lake (Appendix A). Because run timing is a heritable trait in salmonids, Stewart et. al. (2002) and many others have pointed out that failing to preserve run timing could erode stock productivity.

Another aspect of this problem of harvesting only the early part of the run is that run timing could be very different to the different inlet streams. If so, and if early harvest resulted in disproportionately high harvest rates on fish returning to a particular spawning stream, then stock productivity could be quickly eroded by leaving some spawning areas unseeded. Although the evidence is not strong, due to small sample sizes, we did note that fish tagged earlier in the run made up a greater overall proportion of spawners recovered in Inlet Creek than in the other two streams (Figure 6). Another observation was that sockeye salmon were present in Three-Mile Creek about one week earlier than in Half-Mile and Inlet Creeks, and far more spawners were present through the season in Three-Mile Creek. A shortened spawning season and reduced numbers of fish spawning in these streams suggests some loss of productivity in Half-Mile and Inlet Creeks.

Although outside the scope of our study, we remain concerned about alterations of watersheds feeding the important tributary streams. The removal of forest canopy and construction of roads and housing across stream channels appears to have increased the severity of flooding and stream scouring following fall storms. The 2004 inlet-stream tagging study confirmed that sockeye salmon had short residence times in the spawning streams, and the recapture rates were low. We think this may indicate that sockeye spawners had a hard time remaining in the spawning areas, or that spawners were, at times, flushed out of the streams. Also, we wonder if changes in the lake rearing environment, due to flooding and higher sediment input, may have affected sockeye fry survival and growth.

Although we have no verifiable historical estimates of sockeye run sizes in Klawock Lake, it appears run sizes in the 1930s could have easily have averaged 70,000 sockeye salmon or even higher. By comparison, in the last four years, we have estimated run sizes between 17,000 and 27,000 sockeye salmon, plus an unknown number of fish removed in commercial fisheries. The freshwater age composition of sockeye salmon returning to spawn, and zooplankton biomass and species composition - two indicators of productivity in Klawock Lake - were about the same in 2004 as in 2003 (Cartwright et al. 2006). Judging by the age composition of adult sockeye salmon in the escapement, about one third of the fish that returned to spawn in 2004 had spent two years in the lake as fry. It would seem that the older fry needed an extra year to achieve the critical size for smolting in this system. This certainly suggests food limitation within the lake. The Klawock Lake zooplankton assemblage was dominated in 2004, as in previous years, by the small copepod *Cyclops* sp. and the small cladoceran *Bosmina* sp., both less desirable prey for sockeye fry. Compared with other small sockeye rearing lakes in Southeast Alaska (e.g. Conitz and Cartwright 2005), *Daphnia* biomass in Klawock Lake was relatively low in 2004. Because *Daphnia* are preferred by sockeye fry, they can be an important indicator of the potential productivity of a sockeye rearing lake (Mazumder and Edmundson 2002).

We can easily speculate that this system was once capable of producing many more sockeye salmon that it has recently. However, the realities in this system in recent years include extensive habitat degradation caused by clear-cut logging of the watershed and a relatively high proportion of sockeye salmon with two years of freshwater growth, which may indicate food limitation. Given these realities, and the gauzy nature of historic run-size information, we cannot conclude that sockeye production in this system is depressed in the short-term nor limited by low escapements. From the point of view of sustaining the subsistence fishery in Klawock Inlet, we suggest that a realistic goal for this system would be escapements necessary to consistently allow a subsistence harvest of about 6,000 sockeye salmon.

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APPENDIX

Appendix A.–Daily and cumulative counts of fish passed through the Klawock Lake weir in 2004.

	Sockeye salmon			Coho salmon			Pink salmon		Chum salmon		Dolly Varden char			
Date	**Adults daily**	**Jacks daily**	**Cumulative-all**	**Adults daily**	**Jacks daily**	**Cumulative-all**	**Daily**	**Cumulative**	**Daily**	**Cumulative**	**Daily**	**Cumulative**	**Water Temp (^oC)**	**Water Depth (m)**
07/01	2	0	2											
07/02	1	1	4											
07/03	1	0	5											
07/04	1	0	6											
07/05	12	0	18											
07/06	178	0	196											
07/07	22	0	218	1		1							15.0	
07/08	1	0	219	0		1							15.0	
07/09	0	0	219	0		1							15.0	
07/10	2	0	221	3		4							15.0	
07/11	0	0	221	0		4							16.0	
07/12	16	0	237	0		4								0.88
07/13	12	0	249	0		4							16.0	0.83
07/14	9	1	259	0		4							16.0	0.80
07/15	13	1	273	0		4							16.0	0.77
07/16	14	1	288	0		4							16.0	
07/17	9	1	298	0		4								
07/18	40	2	340	4		8							17.0	
07/19	19	1	360	0		8							18.0	0.75
07/20	21	3	384	0		8							18.0	0.72
07/21	51	4	439	1		9							19.0	
07/22	12	2	453	2		11							18.0	
07/23	6	2	461	0		11							17.0	0.72
07/24	0	0	461	0		11								
07/25	1	0	462	1		12							18.5	0.44
07/26	48	4	514	11		23			2	2			18.5	0.67
07/27	27	3	544	14		37			0	2			19.0	
07/28	19	1	564	1		38	1	1	0	2			19.5	
07/29	29	4	597	18		56	0	1	0	2			18.5	0.85
07/30	13	0	610	9		65	0	1	0	2			18.5	
07/31	6	0	616	2		67	0	1	0	2				
08/01	10	2	628	0		67	0	1	0	2				0.80
08/02	1,531	55	2,214	53		120	12	13	0	2			18.0	0.88
08/03	306	3	2,523	0		120	0	13	0	2			19.0	0.98
08/04	34	3	2,560	0		120	0	13	0	2			19.0	0.95
08/05	17	2	2,579	0		120	16	29	0	2			18.5	0.93
08/06	12	6	2,597	1		121	13	42	0	2			18.0	

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Date	Sockeye salmon Adults daily	Sockeye salmon Jacks daily	Sockeye salmon Cumulative-all	Coho salmon Adults daily	Coho salmon Jacks daily	Coho salmon Cumulative-all	Pink salmon Daily	Pink salmon Cumulative	Chum salmon Daily	Chum salmon Cumulative	Dolly Varden char Daily	Dolly Varden char Cumulative	Water Temp (°C)	Water Depth (m)
08/07	39	9	2,645	2		123	9	51	0	2				
08/08	109	14	2,768	38		161	38	89	0	2				
08/09	324	36	3,128	0		161	0	89	0	2			20.0	0.83
08/10	793	36	3,957	0		161	0	89	0	2			19.5	
08/11	267	16	4,240	0		161	6	95	0	2			19.5	
08/12	184	20	4,444	0		161	11	106	1	3			19.0	
08/13	148	19	4,611	1		162	2	108	0	3				0.75
08/14	264	12	4,887	0		162	5	113	0	3				0.72
08/15	579	51	5,517	11		173	26	139	15	18				0.70
08/16	432	36	5,985	2		175	13	152	3	21				0.70
08/17	405	27	6,417	9		184	9	161	8	29			19.5	0.70
08/18	312	28	6,757	12		196	32	193	11	40			20.0	0.70
08/19	480	48	7,285	34		230	132	193	27	40	34	34	19.5	0.67
08/20	439	32	7,756	71		301	63	388	25	92	112	146		0.70
08/21	347	9	8,112	0		301	133	521	7	99	159	305		0.69
08/22	122	14	8,248	17		318	67	588	41	140	110	415	20.0	0.67
08/23	248	18	8,514	15		333	24	612	6	146	193	608	19.5	0.67
08/24	139	13	8,666	17		350	25	637	12	158	146	754	18.0	0.67
08/25	156	3	8,825	42	0	392	50	687	45	203	110	864	18.5	0.66
08/26	324	28	9,177	51	49	492	704	1,391	61	264	110	974	19.0	0.65
08/27	230	6	9,413	5	44	541	1,804	3,195	24	288	44	1,018	18.5	0.67
08/28	235	11	9,659	4	71	616	1,734	4,929	12	300	14	1,032		
08/29	137	13	9,809	201	124	941	1,794	6,723	73	373	46	1,078		
08/30	94	8	9,911	0	62	1,003	687	7,410	23	396	36	1,114	18.0	0.71
08/31	103	6	10,020	134	10	1,147	964	8,374	9	405	13	1,127	18.0	0.75
09/01	135	11	10,166	57	60	1,264	1,557	9,931	30	435	24	1,151	17.5	0.72
09/02	54	2	10,222	1	50	1,315	1,025	10,956	18	453	30	1,181	17.5	0.72
09/03	102	1	10,325	4	64	1,383	1,172	12,128	16	469	37	1,218	18.0	0.85
09/04	324	2	10,651	3	49	1,435	3,599	15,727	2	471	15	1,233	16.5	1.10
09/05	88	4	10,743	249	154	1,838	4,905	20,632	6	477	4	1,237		
09/06	122	4	10,869	4	157	1,999	816	21,448	1	478	2	1,239		
09/07	105	5	10,979	3	142	2,144	1,080	22,528	8	486	17	1,256	17.5	0.95
09/08	49	2	11,030	7	300	2,451	131	22,659	2	488	1	1,257	16.5	
09/09	69	6	11,105	19	218	2,688	118	22,777	1	489	2	1,259	17.0	0.88
09/10	47	3	11,155	14	239	2,941	135	22,912	2	491	6	1,265	16.0	0.83
09/11	30	0	11,185	0	279	3,220	78	22,990	1	492	7	1,272		
09/12	28	4	11,217	0	340	3,560	241	23,231	4	496	9	1,281		0.79
09/13	197	8	11,422	255	409	4,224	135	23,366	14	510	3	1,284	16.0	
09/14	238	10	11,670	3	123	4,350	559	23,925	128	638	5	1,289	15.5	

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Date	Sockeye salmon			Coho salmon			Pink salmon		Chum salmon		Dolly Varden char		Water	Water Depth
	Adults daily	Jacks daily	Cumulative-all	Adults daily	Jacks daily	Cumulative-all	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative	Temp (°C)	(m)
09/15	56	1	11,727	1	196	4,547	218	24,143	11	649	1	1,290	15.0	0.98
09/16	52	6	11,785	37	235	4,819	374	24,517	62	711	4	1,294	15.0	
09/17	12	0	11,797	0	182	5,001	94	24,611	16	727	2	1,296	15.0	
09/18	32	1	11,830	0	338	5,339	268	24,879	20	747	4	1,300		0.85
09/19	23	4	11,857	51	202	5,592	158	25,037	7	754	1	1,301		0.85
09/20	66	1	11,924	20	148	5,760	42	25,079	2	756	3	1,304		0.85
09/21	340	14	12,278	269	1,236	7,265	225	25,304	37	793	3	1,307	15.0	1.49
09/22	40	2	12,320	3	485	7,753	321	25,625	6	799	1	1,308	15.0	
09/23	87	1	12,408	2	381	8,136	330	25,955	6	805	0	1,308		
09/24	20	1	12,429	1	52	8,189	111	26,066	2	807	1	1,309		
09/25	1	0	12,430	0	39	8,228	11	26,077	0	807	1	1,310		1.79
09/26	0	0	12,430	1	190	8,419	4	26,081	0	807	3	1,313		1.43
09/27	1	0	12,431	0	99	8,518	2	26,083	0	807	2	1,315		1.24
09/28	1	0	12,432	2	233	8,753	3	26,086	0	807	0	1,315		1.16
09/29	0	0	12,432	0	28	8,781	0	26,086	0	807	0	1,315		1.05
09/30	0	0	12,432	0	130	8,911	0	26,086	0	807	0	1,315		1.00
10/01	1	0	12,433	0	177	9,088	1	26,087	0	807	0	1,315		
10/02	0	0	12,433	0	118	9,206	0	26,087	0	807	1	1,316		
10/03	2	0	12,435	0	212	9,418	0	26,087	0	807	3	1,319		
10/04	0	0	12,435	21	201	9,640	0	26,087	0	807	6	1,325		0.83
10/05	3	2	12,440	747	1,745	12,132	0	26,087	0	807	0	1,325		
10/06	1	0	12,441	84	138	12,354	0	26,087	0	807	0	1,325		1.49
10/07	0	0	12,441	43	109	12,506	0	26,087	0	807	1	1,326		1.65
10/08	0	0	12,441	1	0	12,507	0	26,087	0	807	6	1,332		1.9
10/09	0	0	12,441	25	5	12,537	0	26,087	0	807	1	1,333		1.54
10/10	0	0	12,441	10	2	12,549	0	26,087	0	807	0	1,333		1.33
10/11	1	0	12,442	40	0	12,589	0	26,087	0	807	0	1,333		1.31
10/12	0	0	12,442	26	5	12,620	0	26,087	0	807	0	1,333		1.18
10/13	0	0	12,442	159	19	12,798	0	26,087	0	807	4	1,337		1.66
10/14	0	0	12,442	133	3	12,934	0	26,087	0	807	0	1,337		
10/15	0	0	12,442	4	0	12,938	0	26,087	0	807	0	1,337		
Totals	**11,732**	**710**	**12,442**	**3,086**	**9,852**	**12,938**	**26,087**	**26,087**	**807**	**807**	**1,337**	**1,337**		