U.S. Fish & Wildlife Service

Estimation of Sockeye Salmon Escapement into McLees Lake, Unalaska Island, Alaska, 2009

Alaska Fisheries Data Series Number 2010 –11

Anchorage Fish and Wildlife Field Office
Anchorage, Alaska
December 2010

The Alaska Region Fisheries Program of the U.S. Fish and Wildlife Service conducts fisheries monitoring and population assessment studies throughout many areas of Alaska. Dedicated professional staff located in Anchorage, Juneau, Fairbanks, and Kenai Fish and Wildlife Offices and the Anchorage Conservation Genetics Laboratory serve as the core of the Program's fisheries management study efforts. Administrative and technical support is provided by staff in the Anchorage Regional Office. Our program works closely with the Alaska Department of Fish and Game and other partners to conserve and restore Alaska's fish populations and aquatic habitats. Additional information about the Fisheries Program and work conducted by our field offices can be obtained at:

http://alaska.fws.gov/fisheries/index.htm

The Alaska Region Fisheries Program reports its study findings through two regional publication series. The **Alaska Fisheries Data Series** was established to provide timely dissemination of data to local managers and for inclusion in agency databases. The **Alaska Fisheries Technical Reports** publishes scientific findings from single and multi-year studies that have undergone more extensive peer review and statistical testing. Additionally, some study results are published in a variety of professional fisheries journals.

Disclaimer: The use of trade names of commercial products in this report does not constitute endorsement or recommendation for use by the federal government.

Alaska Fisheries Data Series Number 2010-11, December 2010
U. S. Fish and Wildlife Service

ESTIMATION OF SOCKEYE SALMON ESCAPEMENT INTO MCLEES LAKE, UNALASKA ISLAND, ALASKA, 2009

Derek R. Hildreth[1] and Heather Finkle[2]

Abstract

The Anchorage Fish and Wildlife Field Office operated a fixed picket weir at the outlet of McLees Lake into Reese Bay on Unalaska Island from 1 June to 18 July, 2009 to provide an accurate estimate of the sockeye salmon *Oncorhynchus nerka* escapement for management of the local subsistence fishery. Peak daily passage occurred on 2 July when 4,752 sockeye salmon were counted through the weir. Daily escapement after 14 July was extremely low and was the basis for cessation of the weir operation on 19 July. A foot survey of the only holding water below the weir was conducted to estimate remaining escapement not yet through the weir. The 750 sockeye salmon that were estimated below the weir were added to the weir count for a total escapement estimate of 10,120 sockeye salmon. The escapement was comprised primarily of age 1.2 (18%) and 1.3 (77%) fish; and males (61%). Escapements into McLees Lake have been assessed through a weir since 2001 and the 2009 escapement was the second lowest during that period. For the second consecutive year, the subsistence fishery was closed in-season as a response to the low return. Sampling for zooplankton in McLees Lake was conducted to assess freshwater rearing conditions. Zooplankton densities and species diversity were low, suggesting that food for rearing sockeye may be limiting.

Introduction

Unalaska Village, on Unalaska Island, lies approximately 1,250 km southwest of Anchorage and is probably best known for its proximity to neighboring Dutch Harbor and the commercial fishery based there. While there is no commercial harvest of sockeye salmon *Oncorhynchus nerka* in the region, this species is of great importance to local subsistence fishers. Subsistence harvest of sockeye salmon for Unalaska Village has historically been taken from nearby Unalaska Lake. However, due to declining returns throughout the 1990's, the ocean waters closest to the outlet of Unalaska Lake (approximately 100 m, either side) have been closed to subsistence fishing in an attempt to protect this stock and increase spawning escapements. In 2009, the subsistence harvest of sockeye salmon in the Unalaska Lake watershed was estimated at 267 fish and comprised only 13% of the total subsistence harvest of sockeye salmon in the Unalaska District (Hartill and Keyse 2010).

With the decline of the sockeye salmon return and fishery to Unalaska Lake, Unalaska Village residents shifted their fishing efforts to the McLees Lake sockeye salmon run, also referred to as the Wislow Island or Reese Bay sockeye fishery. This drainage is an important spawning and rearing habitat for sockeye salmon, and provides a relatively protected fishing area within Reese Bay, where the system empties into the Bering Sea. Subsistence harvests of sockeye salmon returning to McLees Lake have been monitored since 1985, and have ranged from 897 to 5,267 sockeye salmon (Tschersich and Russ 2008). In 2009, an estimated 1,337 sockeye salmon (67%

Authors: [1]U. S. Fish and Wildlife Service, Anchorage Fish and Wildlife Field Office, 605 W. 4th, Room G61, Anchorage, AK 99501; or derek_hildreth@fws.gov. [2]Alaska Department of Fish and Game, Division of Commercial Fisheries, 211 Mission Road, Kodiak, Alaska 99615; or heather.finkle@alaska.gov.

of the Unalaska District subsistence sockeye salmon harvest) were harvested from the Reese Bay fishery (Hartill and Keyse 2010).

Annual fluctuations in the Reese Bay subsistence harvest have generally corresponded to the number of permits issued for the Unalaska District subsistence fishery. Since 1985, the number of subsistence permits issued for this fishery steadily increased, from 65 in 1985 to a peak of 231 in 2002 (Tschersich and Russ 2008). The total of permits issued in 2009 was 215 (Hartill and Keyse 2010), still well above the 1985 levels. These numbers reflect the continuing importance of sockeye salmon as a subsistence resource for the Unalaska community.

Prior to 2001, management of the fishery was based on assessment of escapement based on aerial surveys, which had been conducted since 1974, and subsistence harvest data, which has been collected since 1985 (Palmer 2002). Aerial surveys were generally limited to one survey each year, and counts ranged from 300–34,000 fish (A. R. Shaul, Alaska Department of Fish and Game (ADF&G), personal communication). While aerial counts serve as an index of abundance, they are greatly influenced by several factors including time of survey, poor weather, lack of suitable aircraft, and variation among observers.

Local residents and the ADF&G were concerned that lack of reliable escapement estimates for sockeye salmon into McLees Lake could jeopardize the health of the run, as well as future opportunities for subsistence fishing. These concerns prompted the Kodiak/Aleutians Federal Subsistence Regional Advisory Council to identify an escapement monitoring project on McLees Lake as a high priority. To address these concerns, the U. S. Fish and Wildlife Service (USFWS) and the Qawalangin Tribe of Unalaska entered into a partnership agreement to monitor the sockeye salmon return to McLees Lake from 2001 to 2003; the USFWS Office of Subsistence Management provided funding to the Kenai Fish and Wildlife Field Office for the work through the Fisheries Resource Monitoring Program as project number FIS 01–059. Monitoring was continued by the King Salmon Fish and Wildlife Field Office from 2004 to 2006 as project FIS 04–404. In 2007, the King Salmon office became the Fisheries Branch of the Anchorage Fish and Wildlife Field Office (AFWFO) which has continued to conduct work on sockeye salmon in McLees Lake.

Project results for past years have been summarized by Palmer (2002 and 2003), Gates and Palmer (2004), Edwards (2005 and 2006), Edwards and Hildreth (2005), Anderson and Edwards (2008), and Hildreth (2009). This report documents findings for the 2009 season, which includes results of sockeye salmon escapement work funded through project FIS 07–405 and assessment of juvenile rearing conditions funded directly by AFWFO.

Specific objectives of project FIS 07–405 were to:

1. Enumerate the daily passage of sockeye salmon through the weir,

2. Describe the run-timing, or proportional daily passage, of sockeye salmon through the weir,

3. Estimate the sex and age composition of sockeye salmon such that simultaneous 90% confidence intervals have a maximum width of 0.20, and

4. Estimate the mean length of sockeye salmon by sex and age.

Specific objectives of the juvenile sockeye salmon rearing conditions assessment were to:

1. Estimate the species composition and biomass of zooplankton, and

2. Measure temperature, dissolved oxygen, conductivity, pH, and water clarity.

Study Area

McLees Lake is located on the north side of Unalaska Island, approximately 19 km northwest of the village of Unalaska, and empties into the Bering Sea through Reese Bay (lat. 54.0006°; long. –166.7280°: WGS84) (Figure 1).

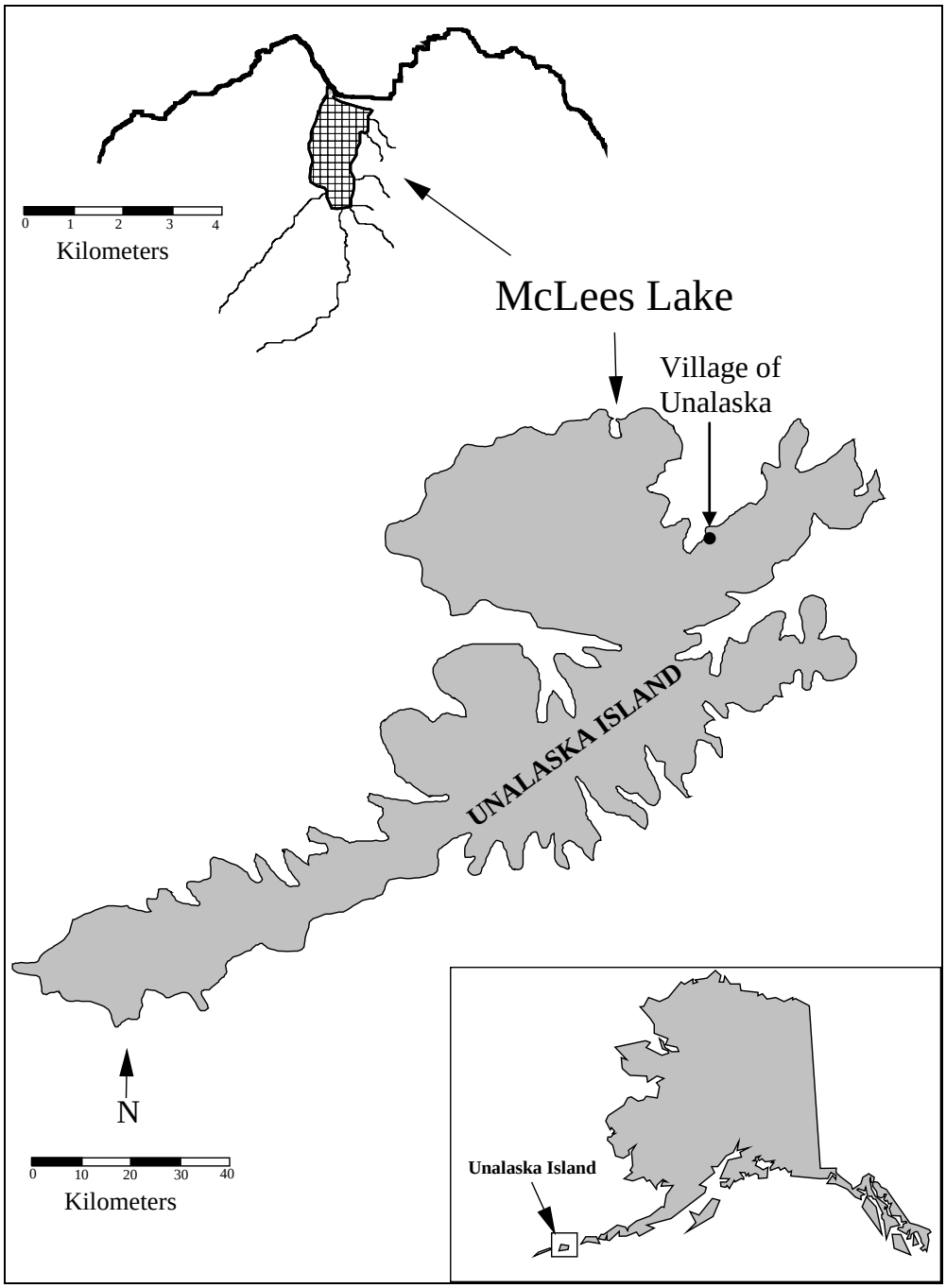

Figure 1. Map of Unalaska Island, southwest Alaska, showing proximity of Unalaska Village to the McLees Lake study area.

The McLees Lake watershed drains an area of approximately 41 km^2, and consists of a 3.98 km^2 lake fed by several small streams. The McLees Lake outlet stream is a fast moving high gradient stream that flows about 100 m before entering Reese Bay. Salmon often stage in Reese Bay and enter the McLees Lake system when migration conditions are favorable. The subsistence fishery targets salmon that are staging in Reese Bay.

The McLees Lake watershed supports substantial spawning populations of sockeye salmon, coho salmon *O. kisutch*, and Dolly Varden *Salvelinus malma*, as well as much smaller populations of chum *O. keta* and pink *O. gorbuscha* salmon. Chinook salmon *O. tshawytscha* and steelhead *O. mykiss* have also been observed at the weir site, but whether they represent viable spawning populations within this drainage is unknown.

Estimated annual escapements of sockeye salmon into McLees Lake have declined since the first four years of weir operation. During the period 2001–2004, escapements ranged from approximately 40,000–100,000 sockeye salmon. During the period 2005–2007 escapements ranged from approximately 12,000–21,000 sockeye salmon. The lowest recorded escapement through the weir occurred in 2008 and was estimated at 8,661 sockeye salmon. The Reese Bay subsistence fishery is closed annually by ADF&G during the first week of July to provide for escapement into the lake. In 2008, due to the low escapement numbers, the fishery never re-opened.

The cause for decreased sockeye salmon returns in recent years is unknown, but may be a result of the extremely large spawning escapements during 2001–2004. An assessment of 23 Alaska Peninsula and Aleutian area lakes was conducted by ADF&G between 1993 and 1995, to evaluate their potential to increase sockeye production through artificial fertilization. The authors concluded that McLees Lake had the capacity to produce approximately 22,000 sockeye salmon per year (Honnald et al. 1996). Overgrazing of zooplankton by the progeny of large sockeye escapements has been shown to reduce growth and survival of juvenile salmon (Kyle et al. 1988). It stands to reason that the large escapements of 2001–2004 may be the cause for the subsequent decline in sockeye salmon returns to McLees Lake. Additionally, poor marine rearing conditions could have also contributed to the decline. Other possible causes for the decline include competition between juvenile sockeye salmon, juvenile coho, and stickleback (Edmundson et al. 1994) and predation by Dolly Varden (Honnald et al. 1996).

Methods

Escapement Monitoring

A flexible picket weir spanning 21 m was installed at the outlet of McLees Lake and operated from 1 June to 18 July 2009. Weir pickets were composed of steel electrical-conduit with a 1.3 cm inside diameter. Picket spacing ranged from 3.5 cm for panels in shallow water near each stream bank to 2.2 cm on panels near the middle of the outlet channel where fish are more able to build up speed while trying to force their way between pickets. All pickets were 1.5 m long and strung together with 3 mm diameter aircraft cable to make panels that spanned approximately 3 m. The first step in weir installation was to extend a 6 mm diameter spanning cable bank-to-bank about 0.5 m above the surface of the water. This cable was secured on each bank using duckbill anchors and then pulled tight using turnbuckles at each end. The weir panels were supported by the spanning cable, which in turn was supported with two wooden tripods evenly spaced across the channel, as well as with angled fence posts spaced approximately every 3 m. To prevent fish from squeezing between the weir pickets, plastic snow fencing with 2.2 cm

square mesh was attached to the downstream side of the bottom third of each weir panel. A live trap was constructed on the upstream side of the weir to facilitate fish sampling. Passage of adult salmon through the weir generally involved passage through the opened trap-box. The weir and live trap were inspected daily and maintained as needed to ensure integrity.

A staff gauge was placed in the thalwag at the weir entrance and provided a relative measure of water depth. Stage height was measured daily at 8:00 am and again at 8:00 pm. Temperature data were collected hourly using an Onset Computer Corporation temperature data logger (model: 4541/9716 HOBO® Temp).

Fish were passed and counted intermittently throughout each day. The duration of each counting session varied depending on the number of fish arriving at the weir. When no fish were captured in the trap-box during 24–26 June, a detailed inspection of the weir uncovered a hole in the trap that was subsequently repaired.

Escapement counts were relayed to the AFWFO via satellite phone, which were then reported to ADF&G managers and other interested parties via e-mail to support in-season management of the Reese Bay subsistence salmon fishery.

Age, Sex, and Length Data

We collected sockeye salmon age, sex, and length (ASL) data using a temporally stratified sampling design (Cochran 1977) with statistical weeks defining strata (Table 1). Samples were collected early in the week to enhance any variation of fish characteristics found between strata. To avoid potential bias caused by the selection or capture of individual fish, all fish within the live trap were included in the sample even if the sample size goal was exceeded.

Adult salmon were measured to the nearest mm (mid-eye to tail-fork) and their sex was determined from secondary characteristics. One scale from each sockeye salmon was removed from the preferred area on left side of the fish (Jearld 1983), cleaned, and mounted on a gummed scale card. Sockeye salmon scales were pressed and aged after the field season by ADF&G personnel in Kodiak, Alaska. Salmon ages are reported according to the European method described by Jearld (1983) and Mosher (1968) where the number of winters the fish spent in fresh water and the number of winters spent in the ocean are separated by a decimal.

Table 1. Strata (time periods) used for analysis of sockeye salmon biological data, McLees Lake, 2009.

Strata	Date	Sampled
1	Jun 1–7	40
2	Jun 8–14	109
3	Jun 15–21	102
4	Jun 22–28	49
5	Jun 29–Jul 5	145
6	Jul 6–12	186
7	Jul 13–19	138
Total Sampled:		769

Maximum weekly sample size goals for sockeye salmon were established such that simultaneous 90% interval estimates of age composition for each week would have maximum widths of 0.20 based on a multinomial sampling model (Bromaghin 1993). The weekly sample size determined from Bromaghin (1993) was n = 121 based on four age categories. This was increased to 135 to account for the expected number of unreadable scales (about 10% in past years).

Within a given stratum k, the proportion of sockeye salmon passing the weir that are of sex i and age j (p_{ijk}) was estimated as (Cochran 1977)

$$\hat{p}_{ijk} = \frac{n_{ijk}}{n_{i++k}},$$

where n_{ijk} denotes the number of sockeye salmon of sex i, and age j sampled during stratum k and a subscript of "+" represents summation over all possible values of the corresponding variable, e.g., n_{i++k} denotes the total number of sockeye salmon sampled in stratum k. The variance of $\hat{p}_{ijk}$ was estimated as

$$\hat{v}(\hat{p}_{ijk}) = \left(1 - \frac{n_{i++k}}{N_{i++k}}\right) \frac{\hat{p}_{ijk}\left(1 - \hat{p}_{ijk}\right)}{n_{i++k} - 1},$$

where N_{i++k} denotes the total number of sockeye salmon passing the weir in stratum k. The estimated number of sockeye salmon of sex j and age k passing the weir in stratum k ($\hat{N}_{ijk}$) was

$$\hat{N}_{ijk} = N_{i++k}\hat{p}_{ijk},$$

with estimated variance

$$\hat{v}(\hat{N}_{ijk}) = N_{i++k}^2 \hat{v}(\hat{p}_{ijk}).$$

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

$$\hat{p}_{ij} = \sum_k \left(\frac{N_{i++k}}{N_{i+++}}\right)\hat{p}_{ijk},$$

with estimated variance

$$\hat{v}\left(\hat{p}_{ij}\right) = \sum_k \left(\frac{N_{i++k}}{N_{i+++}}\right)^2 \hat{v}\left(\hat{p}_{ijk}\right).$$

The total number of sockeye salmon in a sex, and age category passing the weir during the entire period of operation was estimated as

$$\hat{N}_{ij} = \sum_k \hat{N}_{ijk},$$

with estimated variance

$$\hat{v}\left(\hat{N}_{ij}\right) = \sum_{k} \hat{v}\left(\hat{N}_{ijk}\right).$$

If the length of sockeye salmon of sex *i*, and age *j* sampled in stratum *k* is denoted x_{ijk}, the sample mean length of sockeye salmon of sex *i*, and age *j* within stratum *k* was calculated as

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

with corresponding sample variance s_{ijk}^2 calculated as

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

The mean length of all sockeye salmon of sex *i*, and age *j* ($\hat{\bar{x}}_{ij}$) was estimated as a weighted sum of the stratum means,

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

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

$$\hat{v}\left(\hat{\bar{x}}_{ij}\right) = \sum_{k} \left\{ \hat{v}\left(\hat{N}_{ijk}\right) \left[\frac{x_{ijk}}{\sum_{x} \hat{N}_{ijx}} - \sum_{y} \frac{\hat{N}_{ijy}}{\left(\sum_{x} \hat{N}_{ijx}\right)^2} x_{ijy} \right]^2 + \left(\frac{\hat{N}_{ijk}}{\sum_{x} \hat{N}_{ijx}} \right)^2 s_{ijk}^2 \right\}.$$

Limnological Sampling

Between 1993 and 1995, the ADF&G conducted a limnological and fishery assessment of 23 Alaska Peninsula and Aleutian area lakes in order to estimate baseline conditions and lake productivity and the potential to increase sockeye salmon production (Honnold et al. 1996). McLees Lake was one of the lakes sampled. Limnological sampling in the present study was conducted in accordance with established procedures (Thomsen et al. 2002). Sample and data collection were conducted by the weir crew.

Station Placement and Sample Collection—One limnology station was established near the center and deepest portion of McLees Lake, at WGS84 global positioning system (GPS) waypoint 53.984667W, −166.731083N. The station was set and marked with a buoy at this location to ensure consistency. Depth of the lake was measured each sampling day to ensure a precise sampling location was maintained throughout the season. A total of 12 sampling days

were selected during the two months of the project using a simple random sampling scheme in which each day had an equal probability of being selected for sampling. During each sampling day, dissolved oxygen, temperature, conductance, and water clarity were measured, and a zooplankton sample was taken at the station. Sample data was recorded on all-weather field notebooks, and later transcribed to a computer spreadsheet.

Dissolved Oxygen, Temperature, Conductance, and Water Clarity—Prior to sampling, the bottom depth at the station was determined by lowering a weighted, metered line. The bottom depth was used to help verify that the same sampling location was maintained throughout the season in case the station buoy had shifted and GPS readings could not be taken.

A Digital Instruments (DI) model 850086 water quality meter fitted with removable probes was used to measure dissolved oxygen (ppm; DI model 850087 probe), temperature (°C; DI model 850082 probe), and conductance (µS standardized to 25°C; DI model 850084 probe). The DI meter was calibrated according to the manufacturer's instructions prior to use and surface readings were taken to help corroborate the functioning of each probe. The membranes on the dissolved oxygen and conductance probes were examined for wear (tears, folds, and air bubbles), and the meter's integrated thermometer was tested by comparing its reading at the water surface to that from a handheld thermometer. Using the probes, dissolved oxygen, temperature, and conductance measurements were then taken just below the water surface and at 1 m depth. Water clarity was measured using a Secchi disk. This device was lowered on a metered line into the water on the shaded side of the boat. The depth (m) was recorded at the point at which the Secci disk disappeared from view and again when it became visible during its return to the boat. The depth of the disk when it disappeared and the depth when it reappeared were averaged to estimate water clarity.

Zooplankton Sampling—A 0.2 m diameter, 153 micron mesh, conical net was used to collect zooplankton samples during vertical tows. Prior to use, the tow-net and attached collection bucket were cleaned of any debris by rinsing with filtered water. The plankton tow-net was lowered at a steady rate, to ensure that the weighted cod-end stayed below the opening of the net until the cod-end was approximately 1 m from the lake bottom. The net was manually retrieved at a constant rate of approximately 0.5 m sec^{-1}, stopping when the rim of the net was just above the water's surface. Contents of the net were then washed with filtered water into the collection bucket. The bucket was removed from the net and all sample contents were emptied into a labeled, 125 ml bottle filled with a 95% solution of ethyl alcohol. Filtered water was used to rinse the collection bucket and flush any remaining contents into the bottle, ending with a solution of approximately 80% ethyl alcohol. The bottle was capped and sealed with electrical tape to prevent the contents from leaking.

The sample bottles were stored at room temperature (20°C) and later sent to the ADF&G Near Island Limnology Lab in Kodiak where macro-zooplankton taxa were identified and enumerated following established protocols (Koenings et al. 1987; Thomsen et al. 2002). Triplicate 1 ml sub-samples from each sample bottle were analyzed. Each sub-sample was taken with a graduated pipette and placed in a Sedgewick-Rafter counting chamber. Within each sub-sample, all zooplankter's were identified according to taxonomic keys (Pennak 1989; Thorp and Covich 1991) and enumerated. Fifteen individuals of each species were measured to the nearest 0.01 mm. Mean body lengths were calculated for each taxon, and biomass was estimated from species-specific linear regression equations between length and dry weight (Koenings et al. 1987).

Results

Escapement Monitoring

The McLees Lake weir was installed on 1 June, and fish were allowed passage every day until the removal of the weir on 19 July 2009. During this period, 9,370 sockeye salmon were counted through the weir (Figure 2; Appendix A) with another 750 estimated to be below the weir at the time of its removal, making a total estimated escapement of 10,120. Peak daily passage occurred on 2 July when 4,752 sockeye salmon were counted through the weir. Fifteen sockeye salmon died after becoming trapped between pickets while attempting to pass the weir. Chum and pink salmon and Dolly Varden were also seen passing the weir but were not counted.

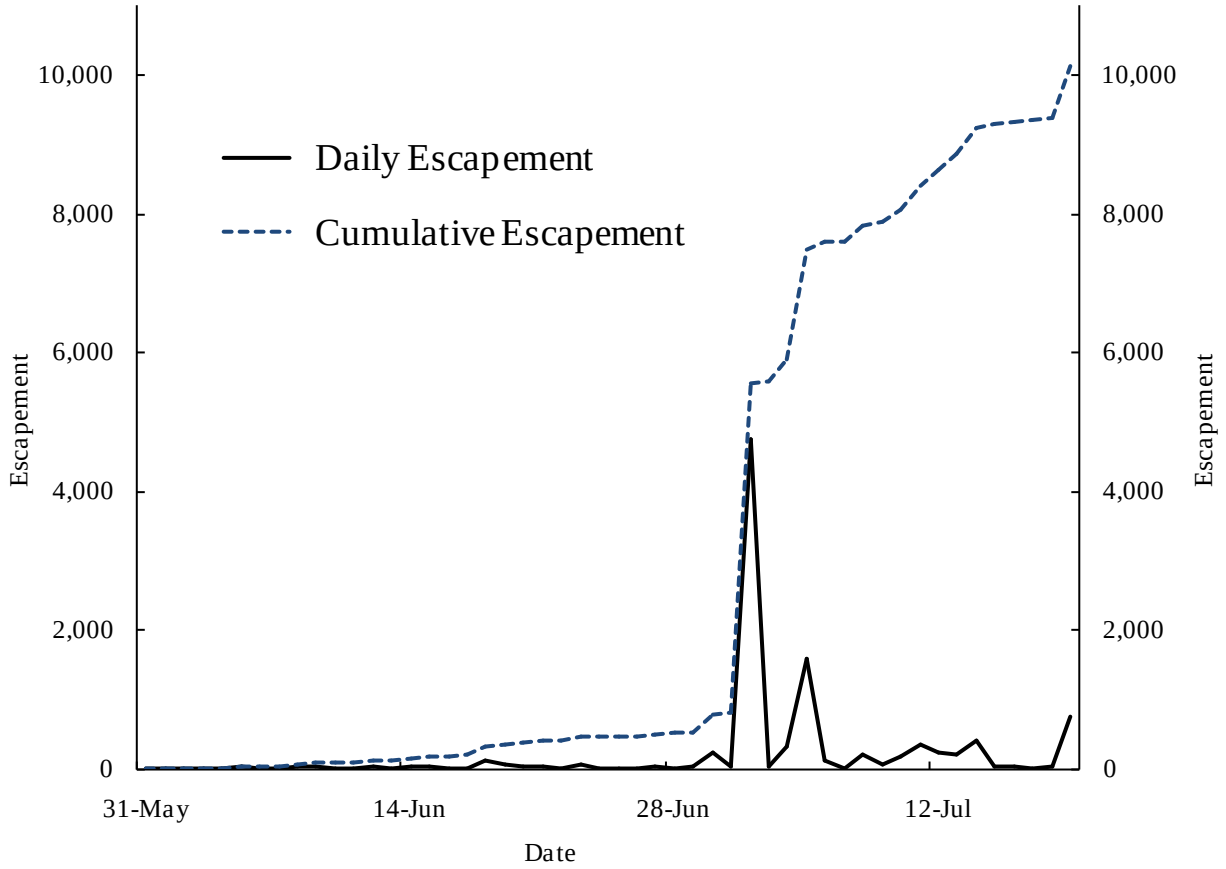

Figure 2. Daily and cumulative escapement of sockeye salmon, McLees Lake, 2009.

The 2009 sockeye salmon escapement into McLees Lake was one of the lowest recorded since the start of this weir project in 2001 (Figure 3); only the 2008 escapement of 8,661 sockeye salmon was lower. Run-timing in 2009 was substantially later than average until early July (Figure 4). This may have been due, in part, to low water levels (Figure 5) which roughly corresponded with the arrival of the salmon. Due to this low water level, weir panels were rolled back on both sides of the trap-box on 18 June to encourage fish to migrate upstream and pass the weir. Thereafter the sockeye salmon run accelerated and subsequently achieved average run timing. The weir was opened in this fashion every day for the remainder of the season.

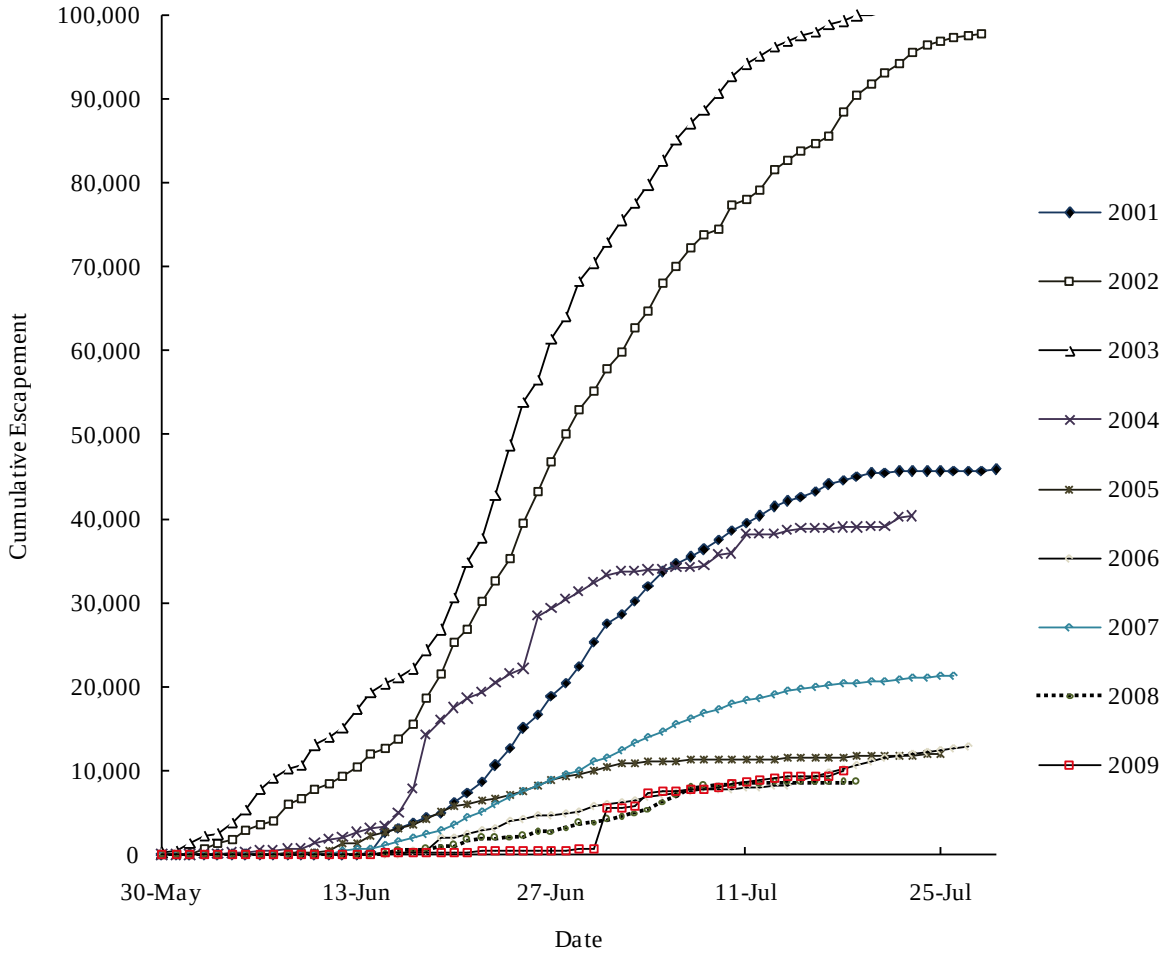

Figure 3. Cumulative escapement of sockeye salmon, McLees Lake, 2001–2009.

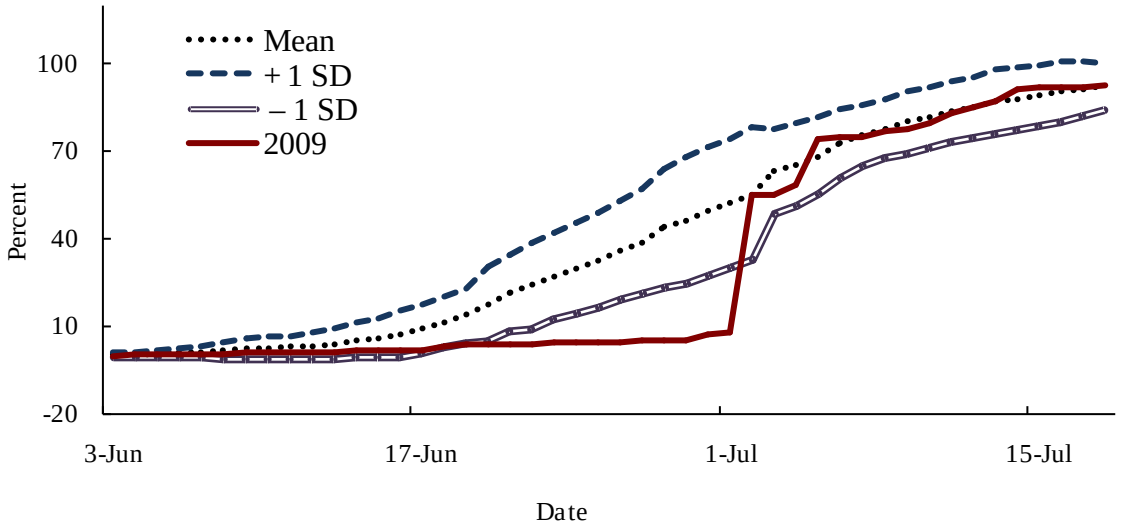

Figure 4. Sockeye salmon cumulative proportions, McLees Lake, 2001–2009: black dotted line depicts average run-timing; dashed lines depict one standard deviation above and below the mean, respectively; solid line depicts 2009 run-timing.

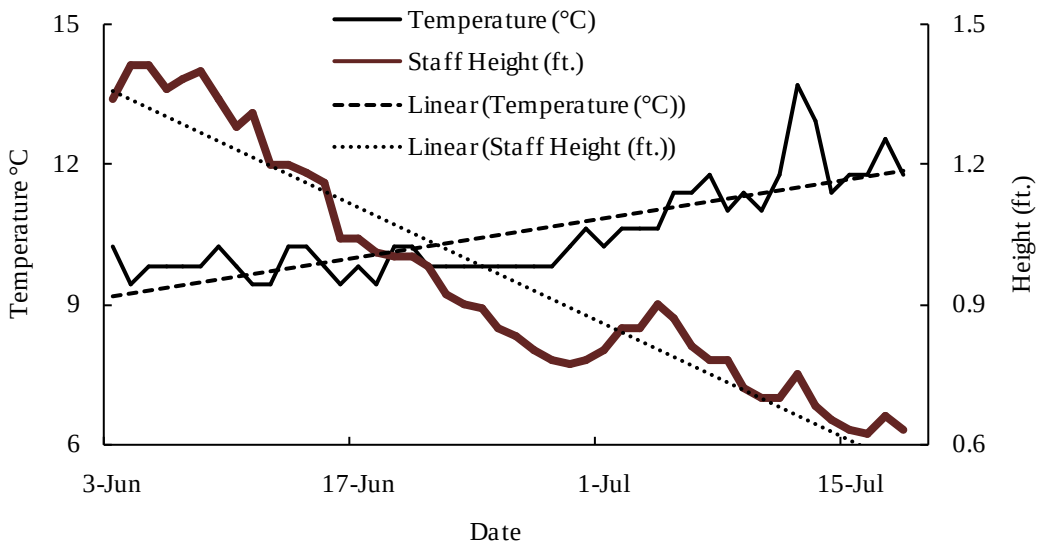

Figure 5. Water temperature and relative water height with trend lines, McLees Lake, 2009.

Length, Sex, and Age Data

A total of 769 sockeye salmon were sampled during the season. Lengths of all of these were measured and ranged from 462 to 591 mm for females and from 499 to 619 mm for males (Figure 6; Table 2). Sex was determined for 765 of the sampled fish, and females comprised 39% of these sampled; males: 61% (Table 3).

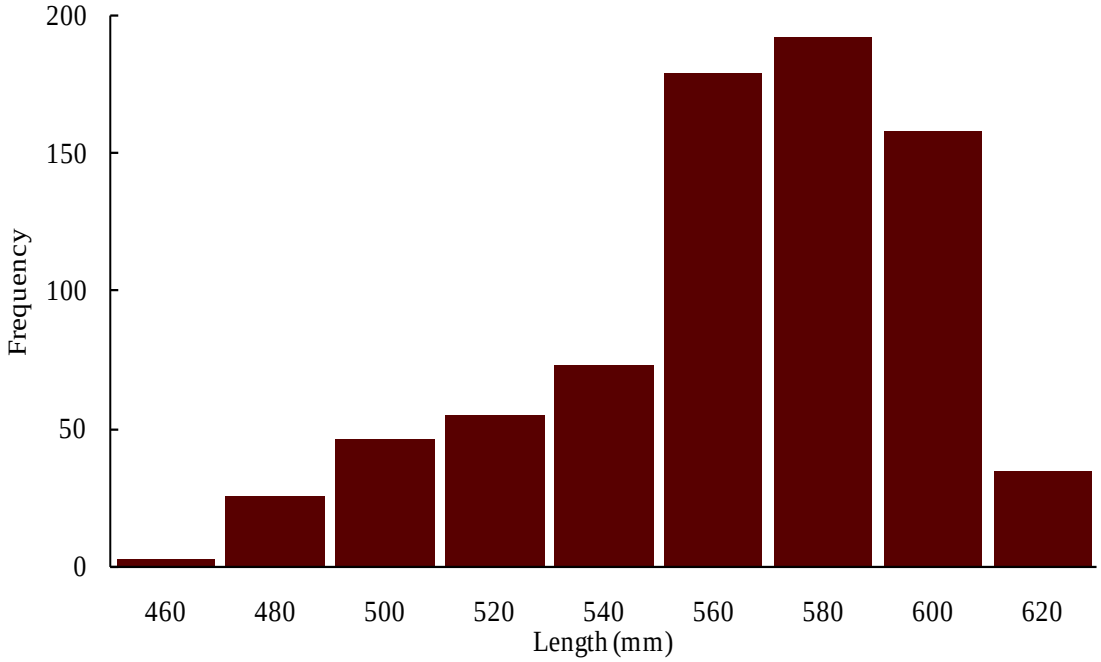

Figure 6. Length-frequency distribution of 769 sockeye salmon sampled, McLees Lake, 2009.

Table 2. Sockeye salmon mean length (mm), standard error (SE), range, and sample size by sex and age, McLees Lake, 2009.

	Age Class								
Length	0.3	1.1	1.2	1.3	1.4	2.2	2.3	2.4	Total *n*
				Female					
Mean	–	–	489	548	555	500	551	–	
SE	–	–	10.7	13.6	3.5	13.6	6.7	–	
Min	–	–	458	462	528	490	515	–	
Max	–	–	597	591	575	510	571	–	
n	–	–	54	173	9	2	9	–	247
				Male					
Mean	556	0	511	578	580	528	570	586	
SE	–	0.0	16.3	10.9	13.0	5.3	7.5	5.0	
Min	556	358	456	499	557	496	530	579	
Max	556	372	594	619	608	537	586	614	
n	1	2	69	311	5	4	7	3	402
				Total					
Mean	556	40	502	567	557	515	559	586	
SE	0.0	0.0	15.8	16.1	3.7	18.5	11.9	5.0	
Min	556	358	456	462	528	490	515	579	
Max	556	372	597	619	608	537	586	614	
n	1	2	124	485	14	6	16	3	649
Total %	0.2%	0.3%	19.1%	74.7%	2.2%	0.9%	2.5%	0.5%	

Table 3. Estimated sex composition of sockeye salmon by stratum, McLees Lake, 2009.

Stratum	*n*	Female (%)	Male (%)	SE (%)	Escapement
1	38	32	68	2	40
2	109	36	64	0	109
3	100	32	68	4	259
4	49	37	63	5	104
5	145	39	61	4	6,977
6	186	44	56	3	1,158
7	138	38	62	4	1,473
Total	765	39	61	3	10,120

Of the 769 sockeye salmon sampled, 651 (84%) could be aged from the collected scales (Table 4). Of the 651 sockeye salmon that could be aged, 649 also had corresponding sex and length data. We were able to estimate the age composition of sockeye salmon in seven weekly strata, such that simultaneous 90% confidence intervals had a maximum width of 0.20 (Appendix B). Of the seven age classes identified, ages 1.2 (18%) and 1.3 (77%), accounted for 95% of all sockeye salmon sampled. Details are not reported for the six remaining age groups (ages 0.3, 1.1, 1.4, 2.2, 2.3, and 2.4) because they accounted for less than 3% of the total run. The weekly proportions of age 1.2 sockeye salmon tended to increase over the course of the run, while those for age 1.3 sockeye salmon tended to decrease.

Age 1.2 and 1.3 sockeye salmon have been the dominant age classes since sampling was initiated in 2001. These two age classes exhibit an odd-year even-year pattern to their age composition ratios. Although age 1.3 sockeye salmon almost always outnumber age 1.2 sockeye salmon, age 1.2 sockeye salmon comprise a much greater percentage of the run during even-numbered years

Table 4. Estimated age composition (%) of the 651 sockeye salmon with legible scales, by stratum, McLees Lake, 2009.

	Age Class							
	0.3	1.1	1.2	1.3	1.4	2.2	2.3	2.4
				Stratum 1 (1 - 7 June)				
%	–	–	2.9	91.4	5.7	–	–	–
SE	–	–	1.0	1.7	1.4	–	–	–
n	–	–	1	32	2	–	–	–
				Stratum 2 (8 - 14 June)				
%	–	–	14.4	80.4	2.1	1.0	2.1	–
SE	–	–	1.2	1.3	0.5	0.3	0.5	–
n	–	–	14	78	2	1	2	–
				Stratum 3 (15 - 21 June)				
%	–	–	18.5	74.1	2.5	1.2	3.7	–
SE	–	–	3.6	4.1	1.4	1.0	1.8	–
n	–	–	15	60	2	1	3	–
				Stratum 4 (22 - 28 June)				
%	–	–	20.9	69.8	7.0	–	2.3	–
SE	–	–	4.8	5.4	3.0	–	1.8	–
n	–	–	9	30	3	–	1	–
				Stratum 5 (29 June - 5 July)				
%	–	–	16.3	80.5	0.8	–	1.6	0.8
SE	–	–	3.3	3.6	0.8	–	1.1	0.8
n	–	–	20	99	1	–	2	1
				Stratum 6 (6 - 12 July)				
%	0.6	1.3	23.2	69.0	2.6	–	1.9	1.3
SE	0.6	0.8	3.2	3.5	1.2	–	1.0	0.8
n	1	2	36	107	4	–	3	2
				Stratum 7 (13 - 19 July)				
%	–	–	24.8	67.5	–	3.4	4.3	–
SE	–	–	3.8	4.2	–	1.6	1.8	–
n	–	–	29	79	–	4	5	–
				Total				
%	0.1	0.1	18.3	77.1	1.0	0.5	2.1	0.7
SE	0.1	0.1	2.4	2.6	0.6	0.2	0.8	0.6
n	1	2	124	485	14	6	16	3

than in odd-numbered years (Table 5). The age 1.3 sockeye salmon comprise a much greater percentage of the run in odd-numbered years than they do in even-numbered years.

Table 5. Sockeye salmon sex and age composition, McLees Lake, 2001-2009.

	Gender			Age (%)			
Year	Female %	Male %	SE[1]	1.2	SE[1]	1.3	SE[1]
2001a	42	58	–	4	–	94	–
2002a	43	57	–	60	–	32	–
2003a	46	54	–	8	–	78	–
2004	43	57	2.2	54	2.2	32	2.0
2005	38	62	2.2	8	1.3	88	1.5
2006	45	55	2.1	38	2.0	58	2.1
2007	38	62	1.7	1	0.4	87	1.3
2008	54	46	2.1	68	2.0	30	1.9
2009	39	61	4.0	19	15.8	74	16.1

a = estimate
1 = standard error not reported for estimates

Limnology Data

A total of 12 water quality and plankton-tow samples were obtained from the station established in McLees Lake for the 2009 season (Table 6). Over the course of the season, water clarity decreased from 11.4 to 8.2 ft, temperature increased from 10.0 to 13.5°C and conductivity decreased from 0.058 to 0.042 µS. No consistent trend was observed for dissolved oxygen, and there were four days that the DO probe did not function; therefore measurements for this parameter could not be obtained. When DO readings were recorded, the probe again failed to function properly, yielding spurious and inaccurate measurements. Subsequently, these data were not included in any summaries or analyses. Vertical tow depths for plankton samples were the same for eight of the 12 samples taken (27.0 ft). The depths of the tows made on the first two

Table 6. Limnological sampling data collected at an established station, McLees Lake, 2009.

No.	Date	Time	Depth(ft)	Visibility(ft)	Temp(°C)	Conductivity(µS)	Tow Depth(ft)
1	06/08/09	12:00	27.8*	11.4	10.0	0.058	24.5*
2	06/07/09	12:25	30.2*	7.4	10.4	0.051	27.0*
3	06/18/09	14:30	31.1	9.0	10.3	0.050	27.8
4	06/24/09	14:57	31.1	9.8	10.1	0.044	27.8
5	06/25/09	15:10	31.1	9.8	10.4	0.044	27.8
6	06/26/09	15:09	31.1	9.8	10.3	0.046	27.8
7	07/04/09	17:59	31.1	9.0	11.6	0.043	27.8
8	07/07/09	15:55	31.1	8.2	11.9	0.043	27.8
9	07/10/09	14:00	31.1	8.2	12.3	0.042	27.8
10	07/14/09	19:34	31.1	8.2	13.0	0.042	27.8
11	07/15/09	16:35	31.1	8.2	13.4	0.043	27.8
12	07/16/09	16:58	31.1	8.2	13.5	0.042	27.8

sampling days were somewhat shallower (24.5 to 27.0 ft), probably as a result of being slightly off station due to the unavailability of a GPS signal.

Analysis of McLees Lake zooplankton samples indicated that species diversity was limited, with most of the sampled population composed of the copepod *Cyclops* and the cladocerans *Bosmina* and *Daphnia* (Figure 7; Table 7). Similar results have been obtained in other shallow Alaska Peninsula lakes (Finkle and Ruhl 2009), and are common when top-down or bottom-up pressures (such as over grazing or reduced water clarity) are being experienced (Thorpe and Covich 2001; Wetzel 1983).

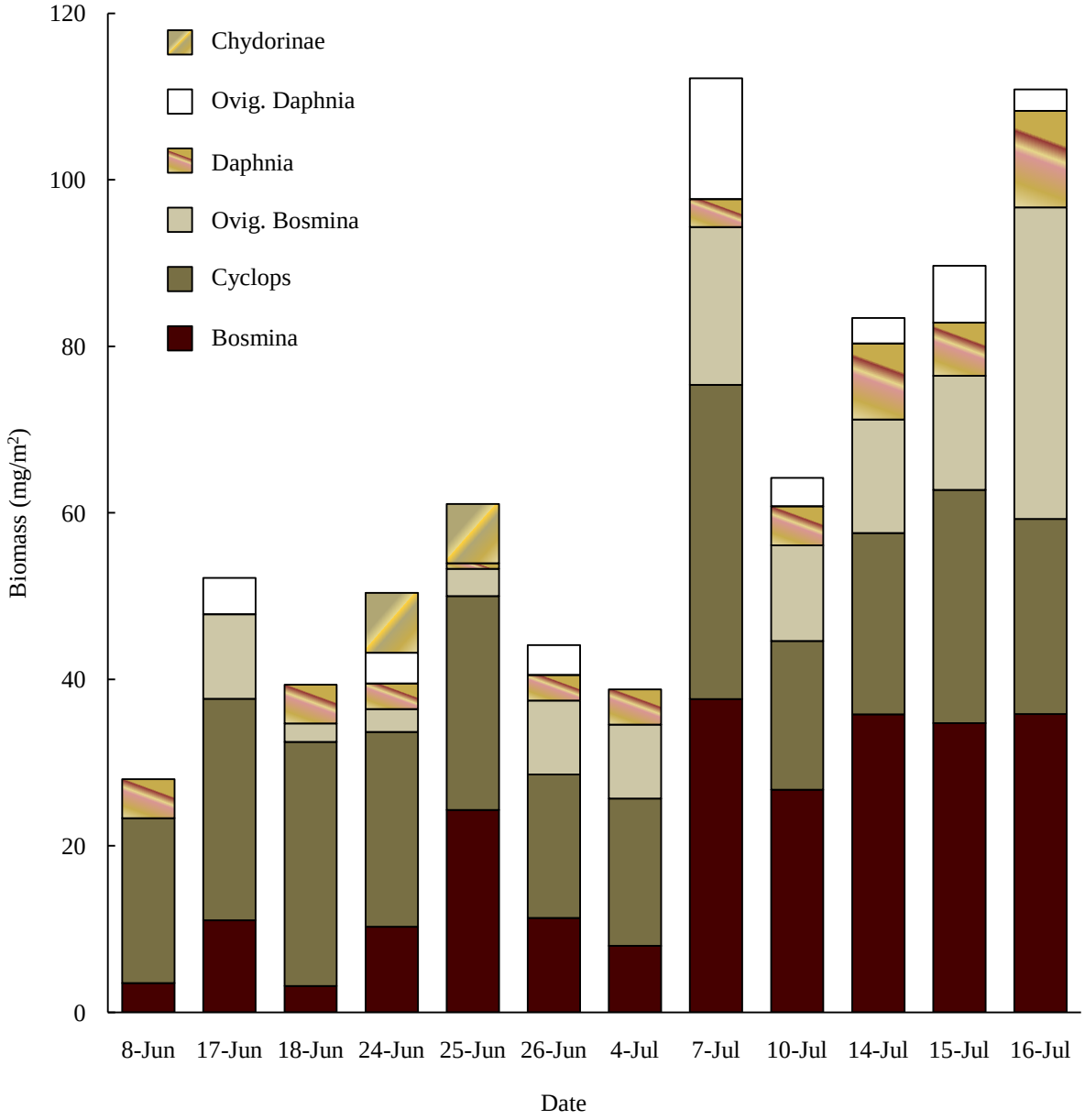

Figure 7. Weighted zooplankton biomass by sample day, McLees Lake, 2009.

The total zooplankton biomass of McLees Lake remained at low levels for the duration of the 2009 sampling season (28.0 to 112.2 mg/m^2) despite consistent increases in *Bosmina* biomass from June to July (Table 7; Figure 8).

Table 7. Weighted biomass (mg/m2) by taxa by sample date and seasonal average, McLees Lake, 2009.

	Weighted Biomass (mg/m^2)												Seasonal Average
Taxa Date	8-Jun	17-Jun	18-Jun	24-Jun	25-Jun	26-Jun	4-Jul	7-Jul	10-Jul	14-Jul	15-Jul	16-Jul	(mg/m^2)
Copepods													
Ergasilis	–	–	3.1	–	–	–	–	–	–	–	–	–	3.1
Epischura	–	–	–	–	–	–	–	–	–	–	–	–	–
Ovig. Epischura	–	–	–	–	–	–	–	–	–	–	–	–	–
Diaptomus	–	–	–	–	–	–	–	–	–	–	–	–	–
Ovig Diaptomus	–	–	–	–	–	–	–	–	–	–	–	–	–
Cyclops	19.8	26.6	29.3	23.4	25.7	17.2	17.7	37.7	17.8	21.8	28.0	23.4	24.0
Ovig. Cyclops	–	–	–	–	–	–	–	–	–	–	–	–	–
Harpaticus	–	–	–	–	–	–	–	–	–	–	–	–	–
Total Copepods	19.8	26.6	32.4	23.4	25.7	17.2	17.7	37.7	17.8	21.8	28.0	23.4	24.3
Cladocerans													
Bosmina	3.5	11.1	3.2	10.3	24.3	11.4	8.0	37.6	26.8	35.8	34.7	35.9	20.2
Ovig. Bosmina	–	10.1	2.2	2.7	3.3	8.9	8.9	18.9	11.5	13.7	13.7	37.4	11.9
Daphnia l.	4.7	–	4.7	3.1	0.7	3.1	4.3	3.4	4.7	9.1	6.4	11.6	5.0
Ovig. Daphnia l.	–	4.4	–	3.7	–	3.6	–	14.5	3.4	3.1	6.8	2.6	5.3
Daphnia g.	–	–	–	–	–	–	–	–	–	–	–	–	–
Holopedium	–	–	–	–	–	–	–	–	–	–	–	–	–
Ovig. Holopedium	–	–	–	–	–	–	–	–	–	–	–	–	–
Chydorinae	–	–	–	7.2	7.1	–	–	–	–	–	–	–	7.1
Polyphemus	–	–	–	–	–	–	–	–	–	–	–	–	–
Total Cladocerans	8.2	25.6	10.0	27.0	35.4	26.9	21.1	74.4	46.4	61.6	61.7	87.5	40.5
Total Biomass	28.0	52.2	42.4	50.4	61.1	44.1	38.8	112.2	64.2	83.4	89.7	110.9	64.8

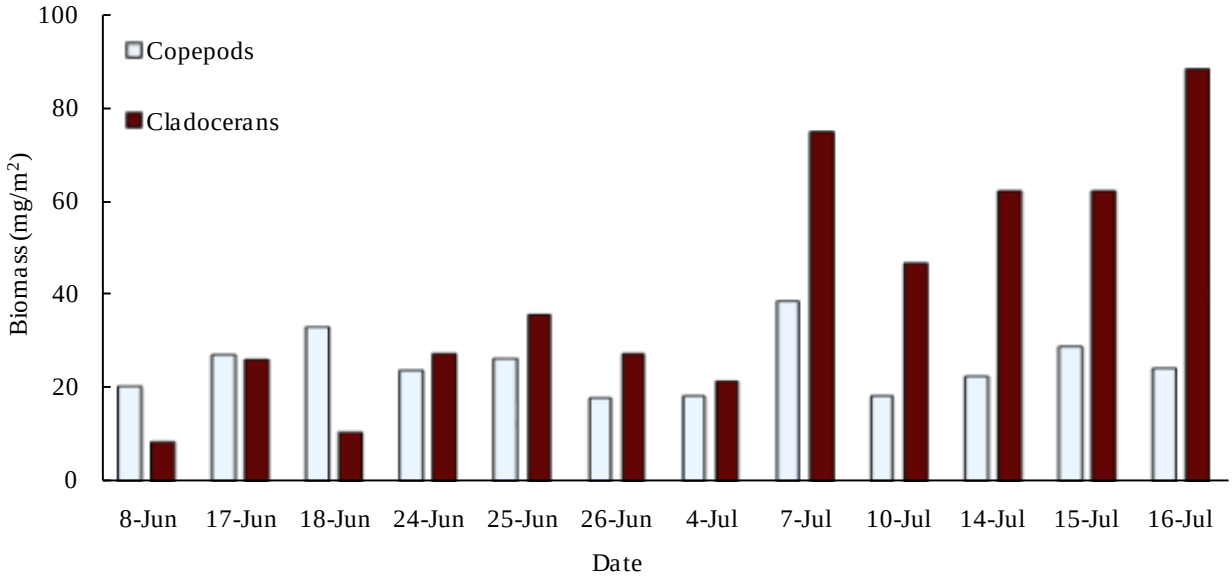

Figure 8. Mean biomass per m² of copepods and cladocerans by sample date, McLees Lake, 2009.

The predominant genus of zooplankton in June was *Cyclops* with a shift to *Bosmina* in July. The small size of *Bosmina*, which averaged 0.31 mm in length over the course of the sampling

season, was well below the feeding threshold size for juvenile sockeye salmon on all 12 sampling days (Table 8; Figure 9). However, ovigerous (egg-bearing) *Bosmina*, which averaged 0.41 mm in length, were usually just below or above the juvenile sockeye salmon feeding threshold size of 0.40 mm during the 12 sampling days.

Table 8. Lengths (mm) of zooplankton by sample date, McLees Lake, 2009.

	Length (mm)												Average length	Weighted Average
Taxa	Date	8-Jun	17-Jun	18-Jun	24-Jun	25-Jun	26-Jun	4-Jul	7-Jul	10-Jul	14-Jul	15-Jul	16-Jul	(mm)	(mm)
Copepods															
Ergasilis		–	–	0.90	–	–	–	–	–	–	–	–	–	0.90	0.90
Cyclops		0.63	0.60	0.64	0.64	0.62	0.69	0.62	0.63	0.58	0.67	0.66	0.57	0.63	0.62
Cladocerans															
Bosmina		0.35	0.32	0.29	0.35	0.33	0.29	0.31	0.28	0.30	0.30	0.29	0.29	0.31	0.30
Ovig. Bosmina		–	0.45	0.47	0.38	0.41	0.47	0.39	0.41	0.38	0.37	0.38	0.37	0.41	0.39
Daphnia l.		0.59	–	0.59	0.59	0.40	0.59	0.53	0.58	0.51	0.53	0.53	0.56	0.54	0.55
Ovig. Daphnia l.		–	0.95	–	0.88	–	0.87	–	0.90	0.80	0.92	0.80	0.85	0.87	0.87
Chydorinae		–	–	–	0.24	0.26	–	–	–	–	–	–	–	0.25	0.25

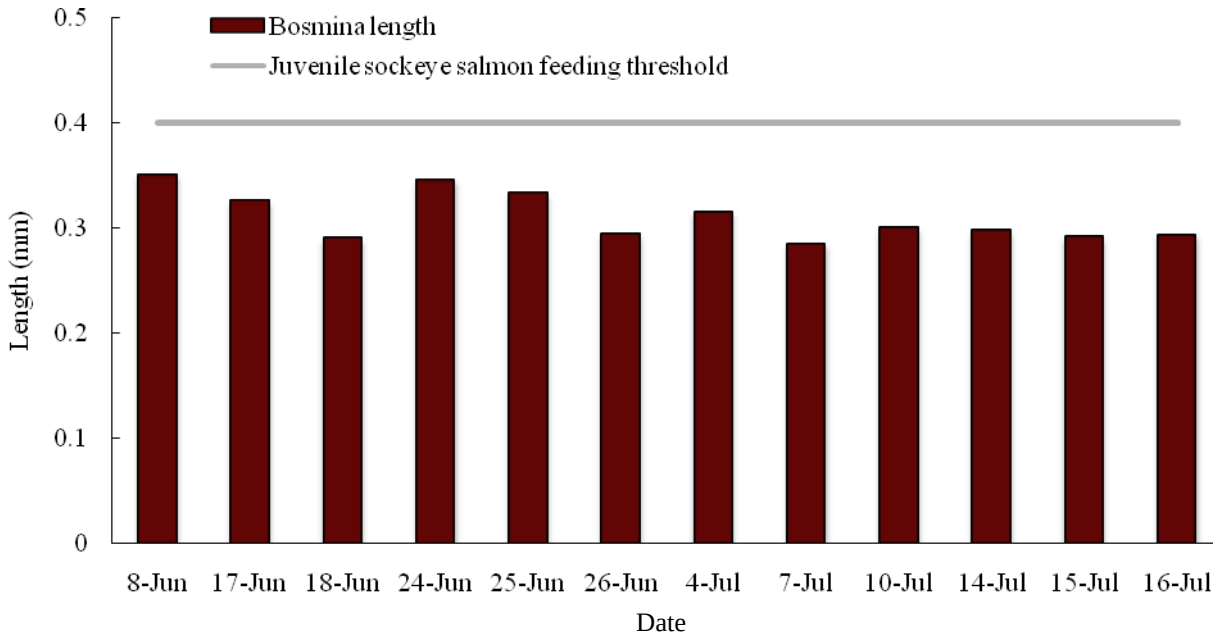

Figure 9. Average lengths (mm) of Bosmina relative to the juvenile sockeye salmon feeding threshold size determined by Kyle (1992), McLees Lake, 2009.

Discussion

We think that most sockeye salmon entering the McLees Lake system to spawn were counted during the time the weir was in operation (Appendix A). It is unlikely that many sockeye salmon entered McLees Lake prior to weir installation, which was on 1 June, since only one sockeye salmon was observed at the weir on that date and only 10 were counted through the weir by 4 June. While some sockeye salmon were able to pass through a breach in the weir during late June without being counted, the breech occurred and was fixed approximately a week prior (on 26 June) to peak passage in early July. The breach was discovered and repaired. Prior to that date, no sockeye salmon had been caught and counted in the trap for three days, so it is likely the sockeye salmon had been moving through the breach undetected during those days. Daily passage immediately before and after the time of the breach was not great, ranging from 0 to 48

during 21–23 June and from 15 to 41 during 27–29 June; we did not attempt to estimate daily estimates for 24–26 June. Finally, although sockeye salmon were still migrating past the site when the weir was removed on 18 July, daily passage rates had been less than 1% of the total escapement since 15 July, and only 750 sockeye salmon were estimated to be below the weir on 18 July. Therefore it is not likely that enough sockeye salmon escaped detection prior to, during, or after the weir was operated to have made a meaningful change in either run strength assessment or fishery management decisions.

Since 2005, sockeye salmon escapements have been substantially lower than those recorded in the first four years of the study. This has generally resulted in greater exploitation rates for these five years (2005–2009 mean = 12.0%) than the previous four years (2001–2004 mean = 5.4%), although the number of sockeye salmon harvested has declined (2005–2009 mean = 1,887; 2001–2004 mean = 4,061; Table 9; Figure 10).

Table 9. Yearly escapement, subsistence harvest, and exploitation rate, McLees Lake, 2001-2009.

Year	McLees Lake Escapement	Total Escapement	Subsistence Harvest	Exploitation Rate *
2001	45,866	49,255	3,389	6.9
2002	97,780	102,474	4,694	4.6
2003	101,793	106,181	4,388	4.1
2004	40,328	44,099	3,771	8.6
2005	12,088	15,451	3,363	21.8
2006	12,936	14,387	1,451	10.1
2007	21,428	23,033	1,605	7.0
2008	8,661	9,788	1,127	11.5
2009	10,120	11,457	1,337	11.7
2001 – 2004 mean	71,442	75,502	4,061	5.4
2005 – 2009 mean	13,047	14,823	1,777	12.0

* harvest as % of total escapement

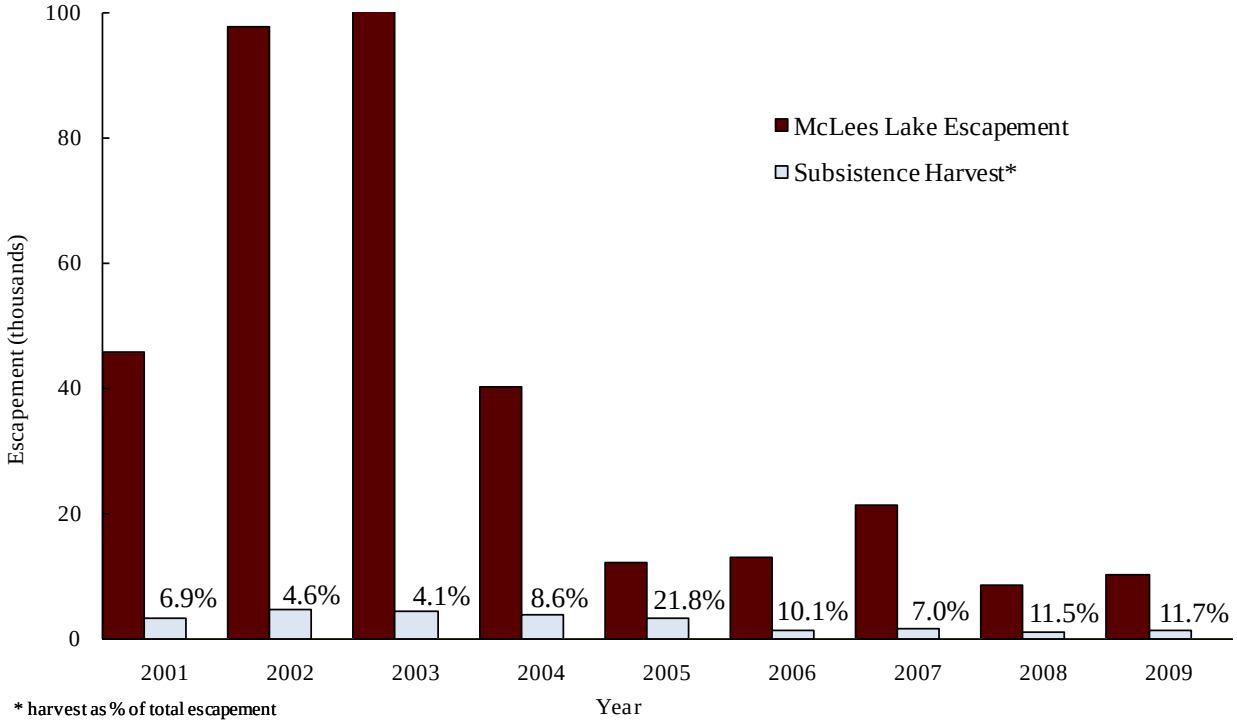

Figure 10. Annual sockeye salmon escapement and subsistence harvest, McLees Lake, 2001 to 2009.

Due to the decline in sockeye salmon abundance, Unalaska residents have not been able to harvest sockeye salmon at the outlet of Unalaska Lake, the location nearest the community, since that area was closed to subsistence fishing in 1997. As a result, the more distant Reese Bay fishery has been of great importance for subsistence uses over the past decade. However, based on discussions with local fishers and ADF&G personnel, residents have been making multiple trips to Reese Bay, fishing longer, and catching fewer fish. This has made it more expensive to catch sockeye salmon as well as more dangerous, since fishers need to traverse the open ocean to reach Reese Bay.

Between 1 July and 9 July, ADF&G typically suspends Reese Bay subsistence fishing from an area extending 150 m on either side of the McLees Lake outlet into Reese Bay (Aaron Potter, ADF&G, personal communication). The poor sockeye salmon escapement in 2008 led ADF&G to maintain the 150 m closure for the remainder of the season. Because the 2009 escapement was nearly as poor, the management response was identical to that in 2008. The escapement of 10,120 salmon was the 2nd lowest since 2001 making it one of the poorest harvests since the weir was first installed (Table 9). One possible cause for the poor sockeye salmon runs to McLees Lake since about 2005 is a decrease in juvenile sockeye salmon production resulting from insufficient zooplankton abundance as a result of the extremely large spawning escapements experienced during 2001-2004. While information is not available prior to 2009, we found that the overall levels of zooplankton biomass estimated from 2009 McLees Lake samples was probably at or close to starvation levels for juvenile sockeye salmon (Mazumder and Edmundson 2002). Be that as it may, some of the juvenile sockeye have been finding enough to eat so that they can smolt; accounting for the 10,000+ adults counted at the weir this year. Because zooplankton may not be uniformly distributed and we only sampled a single station in the lake, it is possible that there are more productive areas for plankton growth in this system. If zooplankton levels were to increase, the lake should be capable of supporting greater numbers of juvenile sockeye salmon, which could lead to greater adult returns. In other shallow Alaska Peninsula lakes, aquatic insects contribute to the food web of rearing sockeye salmon (Finkle and Ruhl 2009). Because of the shallow nature of McLees Lake, aquatic insects may also contribute to juvenile sockeye salmon forage base and subsequent salmonid productivity.

Evidence of overgrazed zooplankton populations can be reflected by a reduction in cladoceran body length (Schindler 1992). The small size of *Bosmina* (Table 8; Figure 7) suggested that grazing pressure was present. However, since egg-bearing *Bosmina* were not substantially below, and on occasion were above, the feeding threshold size (0.40 mm) for juvenile sockeye salmon (Kyle 1992), it is possible that grazing pressure had less influence upon the cladoceran population than other factors such as turbidity or temperature. Similarly, the shift in the predominant genus of zooplankton from *Cyclops* in June to *Bosmina* in July may have been due to environmental factors rather than a reduction in grazing pressure with the outmigration of sockeye salmon smolt. Thorpe and Covich (2001) reported that algal blooms and increased precipitation or temperature can create conditions that are favorable to foraging *Bosmina.*

Recommendations

Escapements and subsistence harvest should continue to be monitored. Escapement levels needed to sustain subsistence harvests and maintain healthy salmon runs to McLees Lake were recently enacted by ADF&G, placing the minimum/maximum escapement at 10,000–60,000

(Witteveen et al. 2009). Reliable and timely estimates of escapement are needed to manage for this escapement goal.

An additional two years of study has been approved by the U.S. Fish and Wildlife Service Office of Subsistence Management to continue monitoring the escapements into McLees Lake in order to assist the in-season management of the Reese Bay subsistence fishery. Assessments of freshwater production will be performed to provide a better understanding of the large fluctuations in escapement. Following the collection of limnology data in 2011, data from the 2009-2011 field seasons will be compiled and compared to data collected from 1993-1995 by Honnold et al. (2006). Physical and zooplankton data will be examined for temporal differences and trends. Simple habitat-based limnology models, such as the euphotic volume (Koenings and Kyle 1997) model, will also be employed to re-estimate adult production levels and rearing capacity.

If escapements continue to decline, further restrictions of the subsistence fishery may be needed to protect the population of sockeye salmon and maintain a healthy subsistence harvest. If poor returns to McLees Lake persist, it is likely that Unalaska residents will shift their attention to other subsistence fishery resources which could result in the need to more closely monitor additional stocks.

Acknowledgements

We would like to thank Jeremy Carlson and Jonathon Gustufson for operating the McLees Lake weir in 2009. We also thank the Qawalangin Tribe for providing fisheries technicians for the project. We also thank Forrest Bowers, Alaska Department of Fish and Game, and his staff for their assistance in transporting supplies and personnel from Dutch Harbor to the weir site, providing logistical support, and for providing bunkhouse space for the crew while in Dutch Harbor. We also thank Matt Foster of the Alaska Department of Fish and Game in Kodiak, AK for scoring the scale-cards used to produce age data in this report. The U. S. Fish and Wildlife Service Office of Subsistence Management provided funding for this work through the Fisheries Resource Monitoring Program as project number FIS 10–406.

References

Anderson, J. E. and M. R. Edwards. 2008. Estimation of sockeye salmon escapement into McLees Lake, Unalaska Island, Alaska, 2007. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series Report Number 2008–9, Anchorage, Alaska.

Bromaghin, J. F. 1993. Sample size determination for interval estimation of multinomial probabilities. The American Statistician. 47: 203–206.

Cochran, W. G. 1977. Sampling techniques, 3rd edition. John Wiley and Sons, New York.

Edmundson, J.A., L.E. White, S.G Honnold, and G.B. Kyle. 1994. Assessment of sockeye salmon production in Akalura Lake. Alaska Department of Fish and game, Commercial Fisheries Management and Development Division. Regional Information Report No. 4J94–17, Juneau.

Edwards, M. R. 2005. Estimation of sockeye salmon escapement into McLees Lake, Unalaska Island, Alaska, 2004. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series Report Number 2005–4, King Salmon, Alaska.

Edwards, M. R. 2006. Estimation of sockeye salmon escapement into McLees Lake, Unalaska Island, Alaska, 2006. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series Report Number 2006–12, King Salmon, Alaska.

Edwards, M. R. and D. R. Hildreth. 2005. Estimation of sockeye salmon escapement into McLees Lake, Unalaska Island, Alaska, 2005. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series Report Number 2005–16, King Salmon, Alaska.

Finkle, H., and D. C. Ruhl. 2009. Sockeye salmon smolt investigations on the Chignik River, 2008. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fishery Data Series 09–16, Anchorage.

Gates, K. S. and D. E. Palmer. 2004. Estimation of the sockeye salmon escapement into McLees Lake, Unalaska Island, Alaska, 2003. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series Report Number 2004–1, Kenai, Alaska.

Hartill, T.G. and M.D. Keyse. 2010. Annual summary of the commercial, subsistence, and personal use salmon fisheries and salmon escapements in the Alaska Peninsula, Aleutian Islands, and Atka-Amilia Islands management areas, 2009. Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services, Fishery Management Report No. 10–21. Anchorage, Alaska.

Hildreth, D. R. 2009. Estimation of sockeye salmon escapement into McLees Lake, Unalaska Island, Alaska, 2008. Alaska Fisheries Data Series Report Number 2009–7, Anchorage, Alaska.

Honnold, S.G., J.A. Edmundson, and S. Schrof. 1996. Limnological and fishery assessment of 23 Alaska Peninsula and Aleutian area lakes, 1993–1995: An evaluation of potential sockeye and coho salmon production. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K96–52. Kodiak, Alaska.

Jearld, A. 1983. Age determination. Pages 301–324 *in* L. A. Nielsen and D. L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Koenings, J. P., and G. B. Kyle. 1997. Consequences to juvenile sockeye salmon and the zooplankton community resulting from intense predation. Alaska Fisheries Research Bulletin 4(2):120–135.

Koenings, J.P., J.A. Burkett, and J.M. Edmundson. 1987. Limnology field and laboratory manual; methods for assessing aquatic production. Alaska Department of Fish and Game, FRED Division Report Series 71. Juneau, Alaska.

Kyle, G. B. 1992. Assessment of lacustrine productivity relative to juvenile sockeye salmon (*Oncorhynchus nerka)* production in Chignik and Black Lakes: Results from 1991 surveys. Alaska Department of Fish and Game, FRED Division Report 119.

Kyle, G.B., J.P. Koenings, and B.M. Barrett. 1988. Density dependent trophic levels responses to an introduced run of sockeye salmon *Oncorhynchus nerka* at Frazer Lake, Kodiak Island, Alaska. Canadian Journal of Fisheries and Aquatic Sciences. 45: 856–867.

Mazumder, A., and J.A. Edmundson. 2002. Impact of fertilization and stocking on trophic interactions and growth of juvenile sockeye salmon (*Oncorhynchus nerka*). Canadian Journal of Fisheries and Aquatic Sciences. 59:1361–1373.

Mosher, K. H. 1968. Photographic atlas of sockeye salmon scales. Fishery Bulletin 67:243–280.

Palmer, D. E. 2002. Estimation of the sockeye salmon escapement into McLees Lake, Unalaska Island, Alaska, 2001. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series Report Number 2002–2, Kenai, Alaska.

Palmer, D. E. 2003. Estimation of the sockeye salmon escapement into McLees Lake, Unalaska Island, Alaska, 2002. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series Report Number 2003–4, Kenai, Alaska.

Pennak, R.W. 1989. Fresh–water invertebrates of the United States, 2nd. John Wiley and Sons. New York.

Schindler, D. E. 1992. Nutrient regeneration of sockeye salmon (*Oncorhynchus nerka*) fry and subsequent effects on zooplankton and phytoplankton. Canadian Journal of Fisheries and Aquatic Sciences. 49:2498–2506.

Seber, G. A. F. 1982. The Estimation of Animal Abundance and Related Parameters, 2nd edition. Maxmillan, New York.

Thomsen, S.E., S. Honnold, S. Schrof, and K. Spalanger. 2002. Kodiak Island Lake Assessment/Limnology Project Laboratory Analysis Operational Plan. Alaska Department of Fish and Game, Division of Commercial Fisheries. Kodiak, Alaska.

Thorp, J.H. and A.P. Covich. 1991. Ecology and classification of North American freshwater invertebrates. Academic Press. San Diego.

Tschersich, P. and E. Russ. 2008. Annual summary of the commercial, subsistence and personal use salmon fisheries and salmon escapements in the Alaska Peninsula, Aleutian Islands, and Atka-Amlia Islands management areas, 2007. Alaska Department of Fish and Game, Fishery Management Report No. 08–22, Anchorage, Alaska.

Wetzel, R. G. 1983. Limnology. New York. CBS College Publishing.

Witteveen, M. J., H. Finkle, M. B. Foster, and J. W. Erickson. 2009. Review of salmon escapement goals in the Alaska Peninsula and Aleutian Islands management areas; a report to the Alaska Board of Fisheries, 2010. Alaska Department of Fish and Game, Division of Sport Fish, Research, and Technical Services, Fishery Manuscript No. 09–09, Anchorage, Alaska.

Appendix A. Daily and cumulative escapement of sockeye salmon, McLees Lake, 2009.

Date	Daily Count	Cumulative Escapement
1-Jun	1	1
2-Jun	3	4
3-Jun	0	4
4-Jun	6	10
5-Jun	27	37
6-Jun	0	37
7-Jun	3	40
8-Jun	24	64
9-Jun	26	90
10-Jun	0	90
11-Jun	14	104
12-Jun	20	124
13-Jun	2	126
14-Jun	23	149
15-Jun	35	184
16-Jun	6	190
17-Jun	2	192
18-Jun	115	307
19-Jun	53	360
20-Jun	25	385
21-Jun	23	408
22-Jun	0	408
23-Jun	48	456
24-Jun	0	456
25-Jun	0	456
26-Jun	0	456
27-Jun	41	497
28-Jun	15	512
29-Jun	20	532
30-Jun	238	770
1-Jul	38	808
2-Jul	4,752	5,560
3-Jul	38	5,598
4-Jul	307	5,905
5-Jul	1,584	7,489
6-Jul	105	7,594
7-Jul	15	7,609
8-Jul	211	7,820
9-Jul	69	7,889
10-Jul	172	8,061
11-Jul	354	8,415
12-Jul	232	8,647
13-Jul	203	8,850
14-Jul	395	9,245
15-Jul	43	9,288
16-Jul	37	9,325
17-Jul	14	9,339
18-Jul	31	9,370
19-Jul	750	10,120

Appendix B. Standard errors (SE) and estimated confidence intervals (CI) for estimates of sockeye salmon age and sex, McLees Lake, 2009.

Parameter	Age Class		Gender	
	1.2	1.3	Female	Male
%	18.0	77.0	39.0	61.0
SE	2.4	2.6	2.9	2.9
n	124	485	292	473
Critical value (Zar, 1999)	1.285	1.284	1.284	1.284
CI	3.084	3.338	3.724	3.724
Upper CI	0.211	0.803	0.427	0.647
Lower CI	0.149	0.737	0.353	0.573
Difference	0.062	0.067	0.074	0.074

0.3, 1.1, 1.4, 2.2, 2.3, 2.4 not reported because each was < 3% of the total.