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Estimation of Sockeye Salmon Escapement into McLees Lake, Unalaska Island, Alaska, 2010

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Estimation of Sockeye Salmon Escapement into McLees Lake, Unalaska Island, Alaska, 2010

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 on Unalaska Island from 2 June to 23 July, 2010 to provide an accurate estimate of the sockeye salmon *Oncorhynchus nerka* escapement to assist in the in-season management of the local subsistence fishery. Final estimate of sockeye salmon was 32,842. Peak daily passage occurred on 9 July when 4,226 sockeye salmon were counted through the weir. There were 828 sockeye sampled consisting primarily of age 1.2 (35 percent) and 1.3 (63 percent) fish and of females (55 percent). The return of over 32,000 sockeye in 2010 fell within the escapement goal range of 10,000 to 60,000. The subsistence fishery was open in 2010 and harvest records estimate that 3,583 sockeye salmon were taken by the Reese Bay subsistence fishery. Water level at the weir peaked on 21 June at 1.85 ft and was at the lowest point on 23 July. Water temperature ranged from a low of 7 °C during the first week of weir operation to a high of 13.7 °C on 23 July. Sampling for zooplankton to assess freshwater rearing conditions in McLees Lake was conducted for the second year. The low zooplankton densities and species diversity were similar to that seen in 2009 suggesting that food for rearing sockeye may be a limiting factor.

Introduction

Unalaska Village lies approximately 1,270 km southwest of Anchorage on Unalaska Island, about 200 km off the Alaska Peninsula. The remote nature of the area encourages a subsistence life-style for much of the population and sockeye salmon *Oncorhynchus nerka* is one of the primary resources available to local subsistence fishers. Subsistence harvest of sockeye salmon for Unalaska Village has historically come primarily from Unalaska Lake, which is closest in proximity to the village. However, due to declining returns throughout the 1990's, approximately 100 m of the ocean waters surrounding the outlet of Unalaska Lake have been closed to subsistence fishing in an attempt to protect this stock and increase spawning escapement. In 2010 the subsistence harvest of sockeye salmon in the Unalaska Lake drainage was estimated at 181 fish and comprised only 5 percent of the total subsistence harvest of sockeye salmon in the Unalaska District (Hartill & Keyse, 2011).

With the decline of the Unalaska Lake sockeye salmon return and fishery, Unalaska Village residents shifted their fishing efforts to the McLees Lake (also referred to as Wislow Island or Reese Bay) sockeye salmon run. This drainage is an important spawning and rearing habitat for sockeye salmon, and Reese Bay, where the system empties into the Bering Sea, provides a relatively protected fishing area. 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 2010 an estimated 3,583 sockeye salmon (90 percent of the Unalaska District subsistence sockeye salmon harvest) were harvested from the Reese Bay fishery (Hartill and Keyse, 2011).

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.

Annual fluctuations in 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). A total of 217 permits were issued in 2010 (Hartill and Keyse, 2011) placing the number of permits in 2010 within the top five years of permit issuance on record. These numbers emphasize the importance of sockeye salmon as a subsistence resource for the Unalaska community.

Limited aerial surveys were used to monitor the system from 1967 to 2003 (Witteveen et al., 2009). While aerial counts served as an index of abundance, they were greatly influenced by several factors (time of survey, poor weather, lack of suitable aircraft, variation among observers) and counts ranged from 300 to 34,000 fish (A. R. Shaul, Alaska Department of Fish and Game (ADFG), personal communication). Local residents and ADFG were concerned that a 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 (Service) 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 U.S. Fish and Wildlife Service Office of Subsistence Management (OSM) 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 (King Salmon 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 (Anchorage Office) and continued the project through 2009 as project 07–405. The year 2009 was to have marked the end of involvement of the Service in the McLees sockeye project but because of the low escapements occurring at the end of a nine year project, it was continued in order to monitor the run while interested parties investigated the need to conduct a long-term project. The Service received mid-cycle funding from OSM to continue the project for an additional two years. The project now continues the monitoring of escapement through 2011 as project 10–407.

Throughout the projects' history, ADFG staff stationed in Dutch Harbor has been relied upon to provide logistical support in the way of crew transport to and from the project site and bi-weekly re-supplies of food, fuel, and replacement equipment to the camp. ADFG staff in Sand Point/Kodiak, Alaska (Kodiak ADFG) has contracted with the Service to determine the age of fish sampled at the project site. For the past two years, the Kodiak ADFG has also been providing protocols, analysis, and interpretation of limnological data and planktonological samples to help determine the productivity potential of McLees Lake.

Project results for past years have been summarized by Palmer (2002; 2003), Gates and Palmer (2004), Edwards (2005; 2006), Edwards and Hildreth (2005), Anderson and Edwards (2008), Hildreth (2009), and Hildreth and Finkle (2010). This document summarizes findings for the 2010 season.

Specific objectives of the project were to:

1. Enumerate the daily passage of sockeye salmon through the weir;
2. Describe the proportional daily passage (run-timing) of sockeye salmon through the weir;

3. Estimate the sex and age composition of sockeye salmon such that simultaneous 90 percent confidence intervals have a maximum width of 0.20 (Bromaghin, 1993) and;
4. Estimate the mean length of sockeye salmon by sex and age.

Due to the low escapement of 2008 an additional objective was added to assess the quality of conditions in McLees Lake as rearing habitat for juvenile sockeye:

5. Estimate the capacity of McLees Lake for rearing juvenile sockeye salmon.

Specifically, sampling was conducted in McLees Lake to measure species composition and biomass of zooplankton as well as the measurement of several water clarity parameters. In a separate report these values will be compared to previous estimates documented in an assessment of 23 Alaska Peninsula and Aleutian area lakes conducted by ADFG between 1993 and 1995 (Honnald et al., 1996).

Study Area

McLees Lake is located on the north side of Unalaska Island, approximately 19 km northwest of the village of Unalaska (latitude 54.0006°; longitude –166.7280°: WGS84; Figure 1). The McLees Lake drainage spans an area of approximately 40 km^2 and consists of a 4 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 drainage supports substantial spawning populations of sockeye salmon and an undetermined number of Chinook salmon *O. tshawytscha*, chum salmon *O. keta*, coho salmon *O. kisutch*, pink salmon *O. gorbuscha*, and steelhead *O. mykiss*. Whether these other species represent viable spawning populations within this drainage is unknown. McLees Lake also supports resident fishes such as Dolly Varden *Salvelinus malma*, sculpin (spp.), and stickleback (spp.).

Estimated annual escapements of sockeye salmon into McLees Lake declined after the first four years of weir operation (Table 1). During the period 2001–2004, escapements averaged about 70,000 sockeye salmon and ranged from approximately 40,000–100,000. During the period 2005–2009 escapements averaged about 13,000 and ranged from approximately 8,500–21,000 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 ADFG during the first week of July to provide for enhanced escapement into the lake. In 2008 and 2009, due to the low escapement numbers, the fishery never re-opened.

Table 1. Yearly escapement, subsistence harvest, and exploitation rate for McLees Lake, 2001-2009.

Year	McLees Lake Escapement	Total Escapement	Subsistence Harvest	Harvest 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

The resources of McLees Lake were evaluated as part of a 1993–1995 assessment to estimate the potential of 23 Alaska Peninsula and Aleutian area lakes to increase sockeye production through artificial fertilization. At that time, the authors concluded that McLees Lake had the capacity to support an escapement of approximately 22,000 sockeye (Honnald et al. 1996). Although the cause for the sockeye salmon decline during 2005–2009 is unknown, it may be the result of the extremely large spawning escapements during 2001–2004 which could have resulted in large brood numbers placing a heavy burden on food resources. Once restructured in this way, zooplankton communities can be slow to respond to decreased grazing pressure by a diminished predator population, which can lead to a prolonged reduction in growth and survival of juvenile salmon (Kyle et al., 1988). Other factors that may have contributed to the decline include poor marine rearing conditions and inter-species competition for resources by stickleback and juvenile coho (Edmundson et al. 1994) as well as predation by Dolly Varden (Honnald et al. 1996; Keonings and Kyle, 1997).

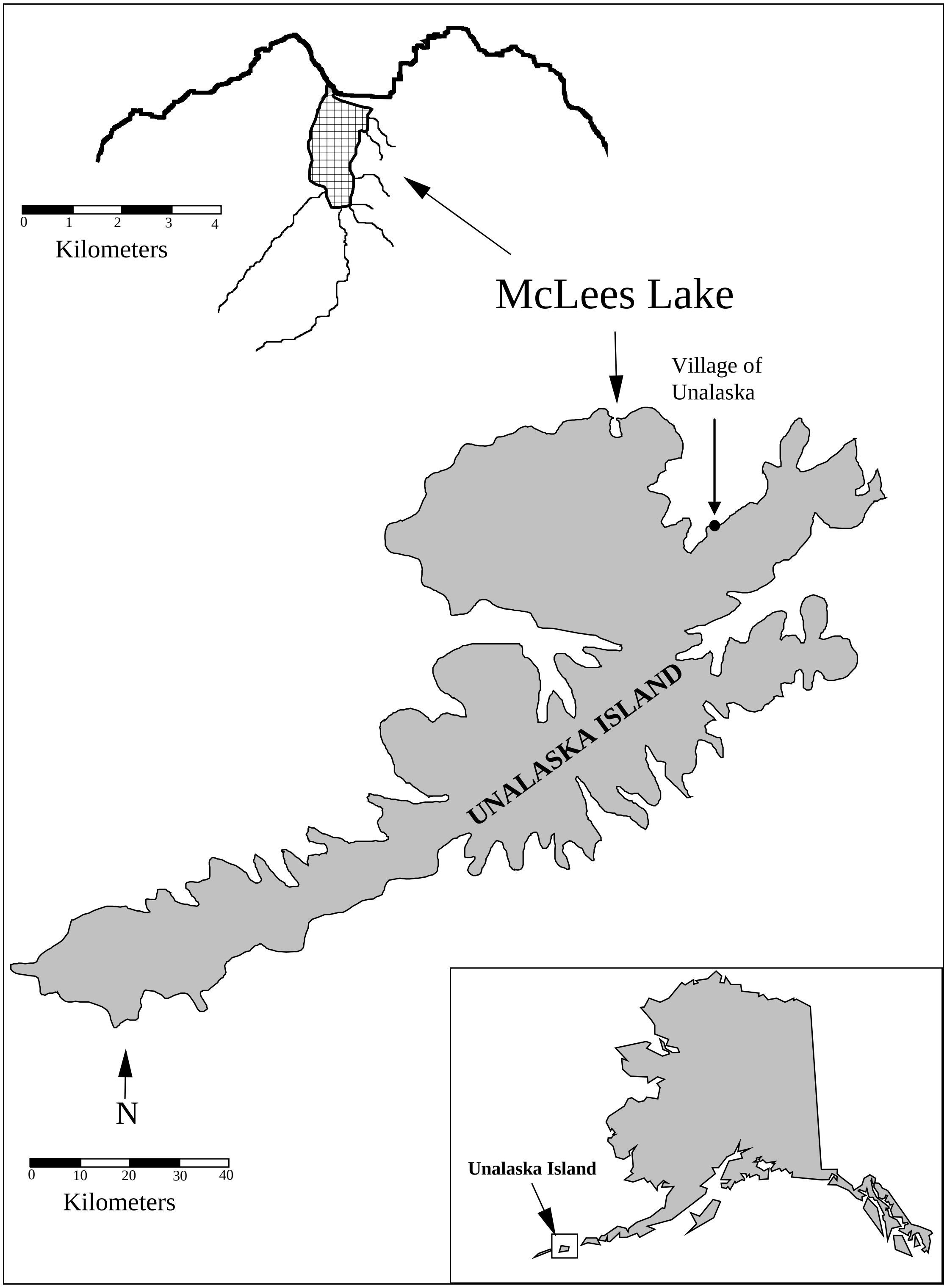

Figure 1. Map of Unalaska Island, southwest Alaska, showing proximity of Unalaska Village to the McLees Lake study area.

Methods

Escapement Monitoring

A rigid-frame aluminum picket weir (Figure 2) spanning 23 m was installed at the outlet of McLees Lake and operated from 2 June through 23 July 2010. Picket frames were of a "saw-horse" nature comprised of angle-aluminum 64 mm x 64 mm x 5 mm fashioned into bi-pods (sets of two legs) 1.5 m in length held in an inverted–V shape by cross-members 1 m in length. Picket rails were 64 mm x 64 mm x 5 mm lengths of angle-aluminum having 28 mm diameter picket holes spaced approximately 30 mm apart along the length of the rails. Two bi-pods located at the middle section of the weir were separated by two 1.8 m lengths of picket rails each spaced 0.5 m from the top and bottom of the upstream (south) legs. There were two, 1.8 m support rails on the downstream (north) side affixed at the top and the middle of the downstream legs. This middle section of the weir incorporated a chute leading to a fish-trap immediately upstream of the weir. The remaining panels, two on the east side, and four on the west side, were similarly constructed but were each 3.6 m in length.

The 1.8 m middle section set of rails had approximately 30 picket holes; the 3.6 m sections had approximately 60 pickets per panel. Panels were connected by an overlap of approximately 50 mm at the ends of each picket rail, as well as by an overlap of the downstream support rails. Because pickets were not attached firmly to the picket rails and were free to slide up and down the pickets were able to conform to the contour of the uneven, rocky substrate (Figure 3). Pickets were aluminum pipe with a 25 mm outside diameter and a length of either 1.0 m or 1.5 m. Longer pickets were used for regular picket expanses. The shorter pickets were used in and around the trap-box. With pickets installed, the weir was about 1.5 m high.

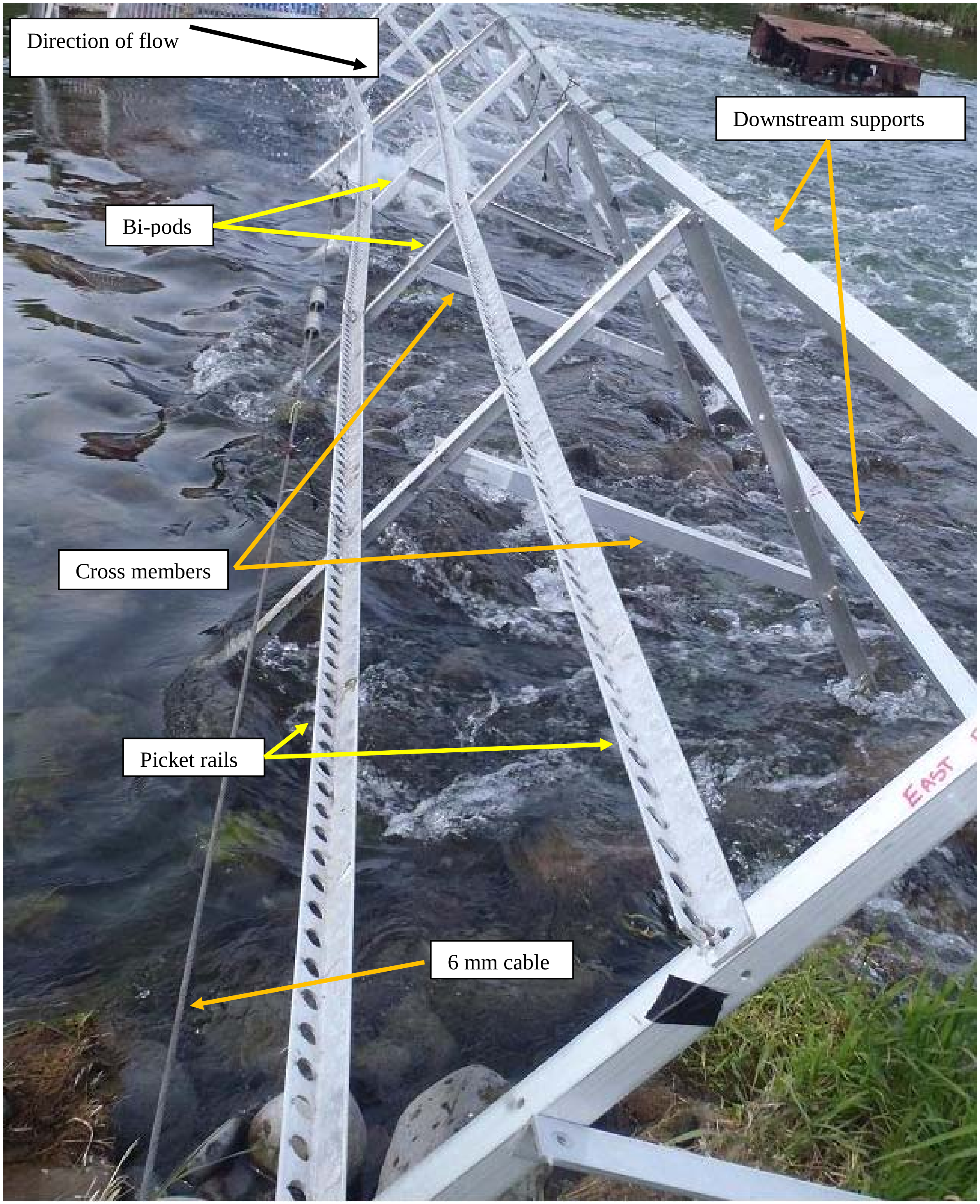

Figure 2. Weir frame, McLees, 2010.

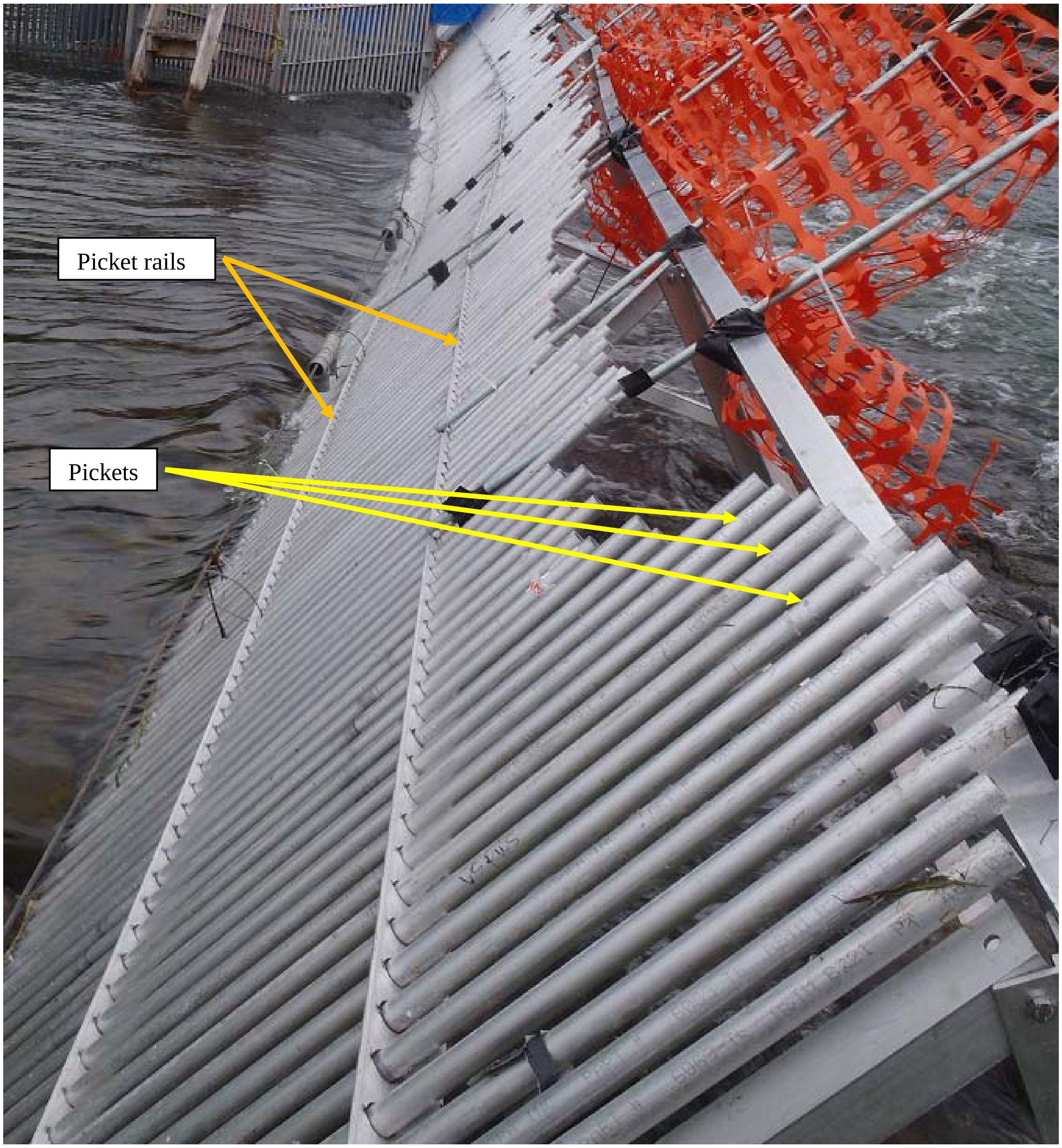

Figure 3. McLees weir, 2010.

The first step in weir installation was to extend a 6 mm diameter spanning cable bank-to-bank about 0.25 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 wired to the cable using 2 mm aircraft cable at several locations along the weir. Two wooden tripods were spaced evenly across the channel and angled fence posts were spaced approximately every 3 m to further secure the weir.

Early in the season sockeye salmon were observed to launch themselves out of the water in efforts to by-pass the weir; several injured themselves by striking the tops of the pickets. To prevent injury and undetected escapement plastic snow fencing (22 mm square mesh) was placed above the pickets adding another 1.0 m to the height of the weir. A live trap was constructed on the upstream side of the weir to facilitate fish sampling. Two duck-bill anchors were driven into the substrate on either side and slightly upstream of the fish-trap to help secure it. 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. 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. Escapement counts were relayed to the Anchorage Office via satellite phone who then reported the information to ADFG managers and other interested parties via e-mail to support in-season management of the Reese Bay subsistence salmon fishery.

A staff gauge placed in the thalwag at the weir entrance provided a relative measure of water depth. This 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) that was calculated to give daily average temperatures.

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 2). Samples were collected early in the week to enhance the likelihood of detecting any differences in ASL characteristics among strata.

Minimum weekly sample size goal for sockeye salmon were based on a multinomial sampling model (Bromaghin, 1993). The weekly sample size determined from the model was 121. This sample size satisfied the criteria that each respective estimated sex- (male and female) and age- (1.2 and 1.3) proportion was simultaneously within $\leq$0.2 of the true sex- and age- proportions in the population (within a stratum) with 90 percent probability. This sample size goal was increased to 145 (about 15 percent) to allow for the occurrence of fish with unreadable scales. 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 weekly sample size goal was exceeded.

Table 2. Strata (time periods) used for analysis of sockeye salmon biological data, McLees Lake, 2010.

Strata	Date	Sampled
1	June 02 – June 15	77
2	June 16 – June 22	163
3	June 23 – June 29	145
4	June 30 – July 06	146
5	July 07 – July 13	145
6	July 14 – July 23	152
Total Sampled:		828

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). Each scale was cleaned and then mounted on a gummed scale card. Sockeye salmon scales were pressed and aged after the field season by Kodiak ADFG personnel. 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.

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 ADFG conducted a limnological and fishery assessment of 23 Alaska Peninsula and Aleutian area lakes in order to estimate baseline conditions and lake productivity and to assess 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—Two limnology stations were established in McLees Lake. One, near the center and in the deepest portion of McLees Lake, was established at WGS84 global positioning system (GPS) waypoint 53.98375W; −166.73305N (accuracy to 6 m). The other, closer to the lake outlet and in the next deepest waters of the lake, was established at WGS84 GPS waypoint 53.99152W; −166.73013N. The stations were each set and marked with a buoy at their locations to ensure consistency. Prior to each sampling session GPS coordinates were taken to ensure concordance with the recorded site coordinates. A total of four sampling days were selected approximately evenly spaced throughout the two months of the project (weather permitting). Bottom depth was measured to determine the appropriate depth from which to collect samples and data. During each sampling day at each station water clarity was measured and a zooplankton sample was taken. Sample data was recorded on all-weather field notebooks and later transcribed to a computer spreadsheet.

Dissolved Oxygen, Temperature, Conductance, and Water Clarity—The Digital Instruments (DI) model 850086 water quality meter that was to be used to measure dissolved oxygen, temperature, and conductance at the sampling stations failed and measurements of these parameters were not collected. Water temperature measurements were made throughout the season at the weir site via a temperature logger. Only water clarity was measured at sampling stations. This was done using a Secchi disk lowered on a metered line into the water on the shaded side of the boat. The depth of visibility (m) was recorded at the point at which the Secci disk disappeared from view. Visibility depth was again recorded when the Secci disk became visible during its retrieval 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 at both stations (Figure 4). 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 device. This device was then removed from the net and all sample contents were emptied into a labeled 125 ml bottle. A 95 percent solution of ethyl alcohol was used to rinse the collection device and flush any remaining contents into the bottle. Ethyl alcohol was added to the bottle until it was approximately half full. The bottle was capped and sealed with electrical tape to prevent the contents from leaking. Sample bottles were stored at room temperature (20°C) and later sent to ADFGs' 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, 2001) 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).

Figure 4. Plankton net used to sample McLees Lake productivity, 2010.

Results

Escapement Monitoring

The McLees Lake weir was installed on 2 June and fish were allowed passage every day until the removal of the weir on 23 July 2010. During this period 32,842 sockeye salmon were counted through the weir (Figure 5; Appendix A). Peak daily passage occurred on 9 July when 4,226 sockeye salmon were counted through the weir, although there were two other days in which almost as many were passed (28 June: 3,992; 3 July: 4,119). Twenty-two sockeye salmon died after becoming trapped between pickets or while attempting to jump over the top of the weir. Other fish species passing the weir were not counted.

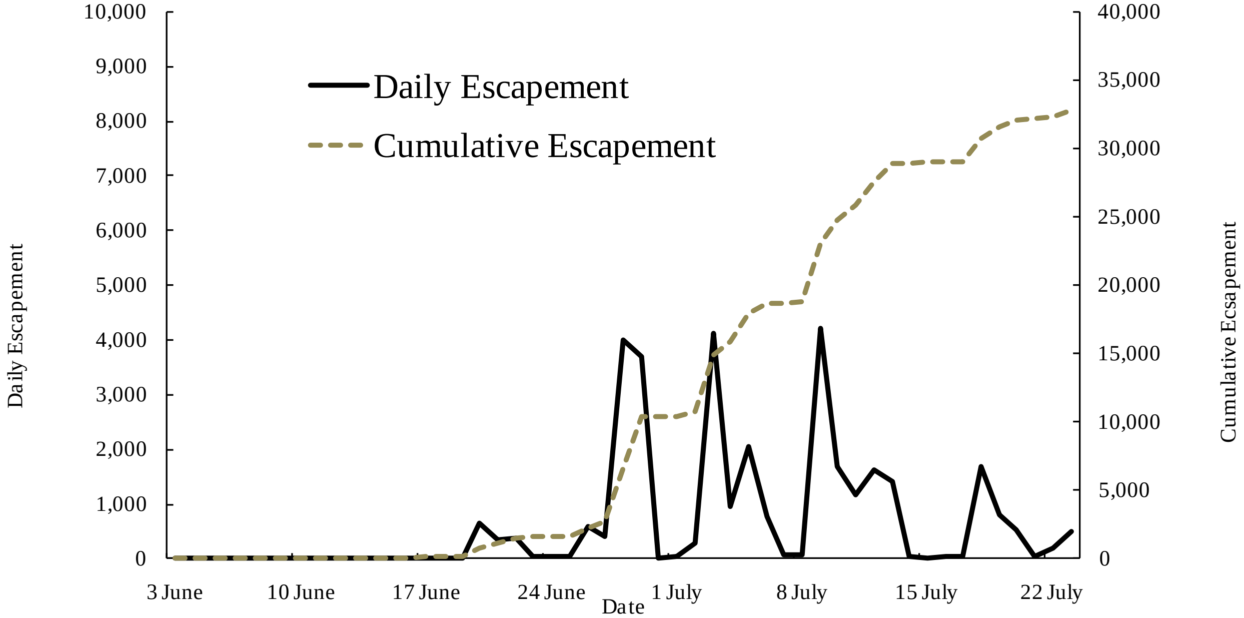

Figure 5. Daily and cumulative escapement of sockeye salmon, McLees Lake, 2010.

The 2010 McLees Lake sockeye salmon escapement of 32,842 was within 16 percent of the 10 year mean average of 39,000 (Figure 6). The 2010 run can be characterized as having average timing because the 2010 run, except for two or three days in June, was always within one standard deviation of the mean curve (Figure 7). Also, run timing, usually expressed in relation to the 50 percent point of the run, was reached at much the same date as the nine year mean.

Relative water levels were not monitored for the first week. Measured levels peaked at 1.85 ft on 21 June and dropped to a low of 0.74 ft on 23 July (Figure 8). Weir pickets were removed from both sides of the trap-box during counting on 28 June to enhance fish passage. The weir was opened in this fashion every day for the remainder of the season. Average water temperature was 7.4° C on 2 June, generally rose steadily until reaching 13.7° C on 23 July.

Mean

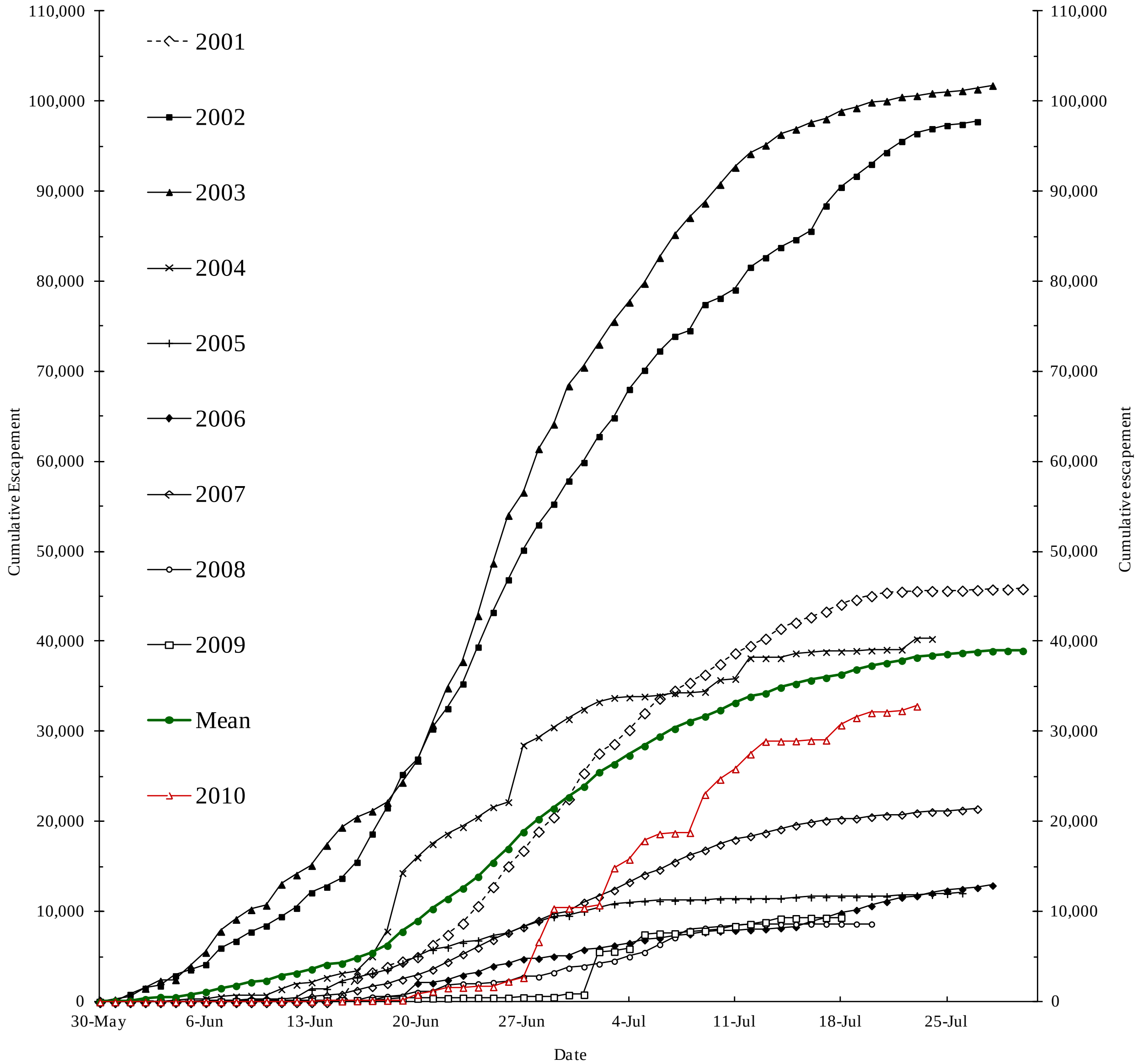

Figure 6. Cumulative escapement of sockeye salmon, 2001–2010 (2010 in red; mean escapement, 2001-2009 in green), McLees Lake.

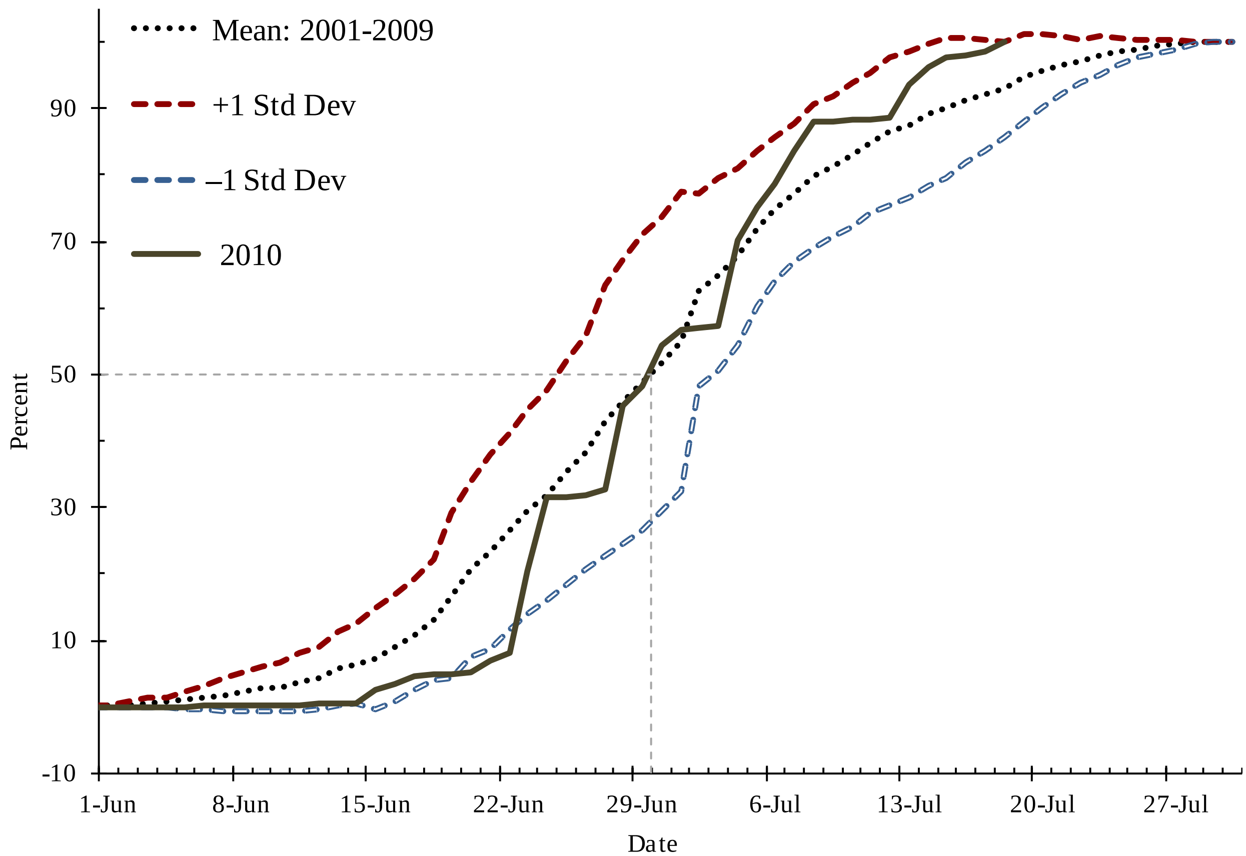

Figure 7. Sockeye salmon cumulative proportions, McLees Lake: black dotted line depicts average run-timing, 2001–2009; red and blue dashed lines depict one standard deviation above and below the mean, respectively; solid line depicts 2010 run-timing; grey dashed lines indicate 50 percent escapement and date when this occurred.

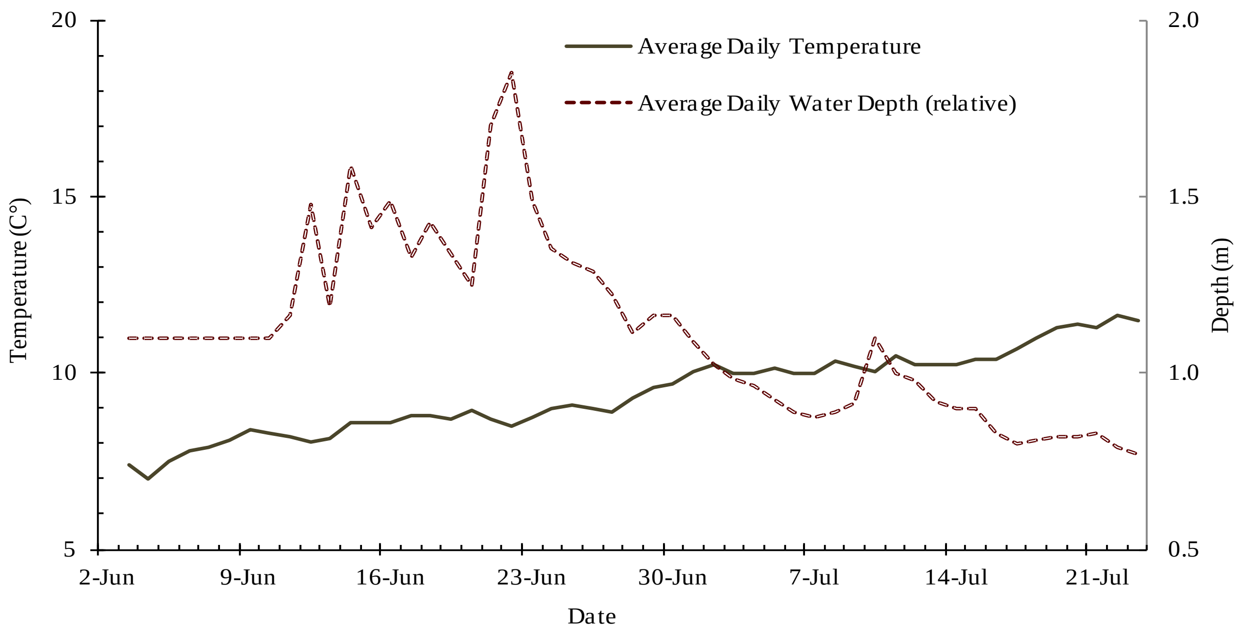

Figure 8. Water temperature and relative water height, McLees Lake, 2010.

Length, Sex, and Age Data

A total of 828 sockeye salmon were sampled during the season. The median length was 528 mm and the mode was 535 (*n* = 16; Figure 9) Measured lengths ranged from 412 to 608 mm for females and from 438 to 630 mm for males (Table 3).

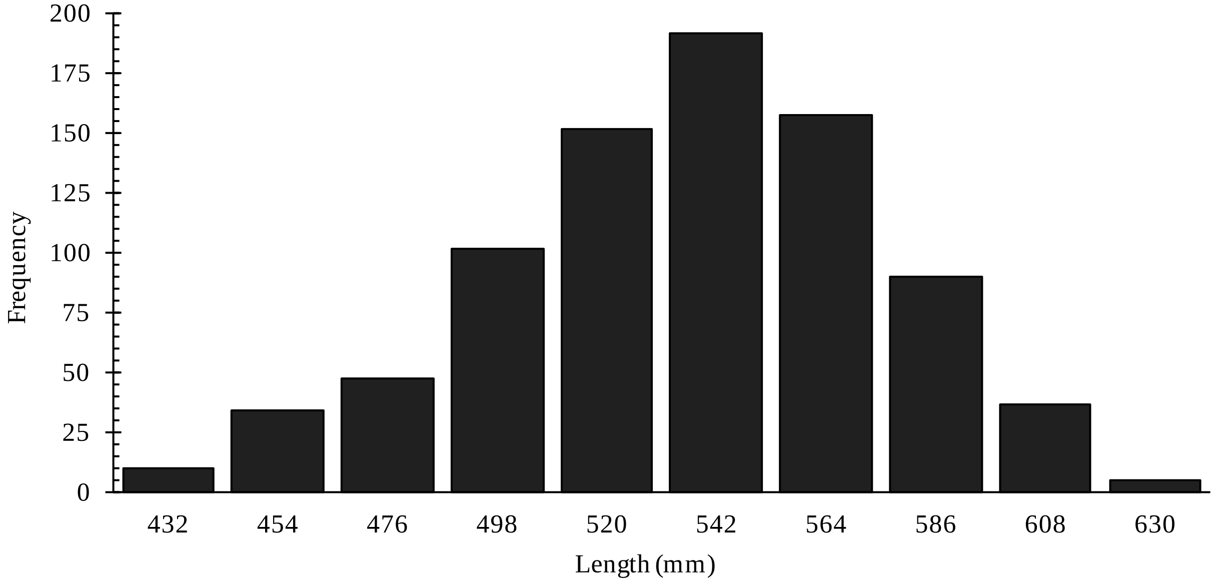

Figure 9. Length-frequency distribution of 828 sockeye salmon sampled, McLees Lake, 2010.

Table 3. Sockeye salmon mean length (mm), standard error (SE), range, and sample size by sex and age, McLees Lake, 2010.

	Age Class					
Length	1.2	1.3	1.4	2.2	2.3	Total *n*
			Female			
Mean	486	528	552	505	555	
SE	15.1	13.4	–	11.2	–	
Min	412	424	528	495	551	
Max	573	608	555	524	555	
n	157	213	2	3	1	376
			Male			
Mean	519	564	592	521	551	
SE	15.0	12.1	–	–	–	
Min	454	486	592	510	551	
Max	582	630	592	537	565	
n	85	228	1	3	3	320
			Total			
Mean	499	546	556	513	553	
SE	17.3	16.7	9.0	12.5	2.8	
Min	412	424	528	495	551	
Max	582	630	592	537	565	
n	245	442	3	6	4	700*
Total % ages	35.0	63.1	0.4	0.9	0.6	

* includes four fish of unknown sex.

Sex was determined for 824 of the sampled fish and females comprised 55 percent of these (Table 4). While length measurements were taken on all 828 sockeye salmon only 700 (85 percent) could be aged from the collected scales (Table 5).

Table 4. Estimated sex composition of sockeye salmon by stratum, McLees Lake, 2010.

Stratum	*n*	Female (%)	Male (%)	SE (%)	Escapement
1	77	51.9	48.1	0.9	79
2	161	44.7	55.3	3.7	1,464
3	143	57.3	42.7	4.1	8,826
4	146	55.5	44.5	4.1	8,291
5	145	54.5	45.5	4.1	10,265
6	152	53.9	46.1	4.0	3,917
Total	*824	55.0	45.0	2.0	32,842

*excludes four fish of unknown sex.

Table 5. Estimated age composition (%) of the 700 sockeye salmon with legible scales by stratum, McLees Lake, 2010.

	Age Class					
	1.2	1.3	1.4	2.2	2.3	Totals
			Stratum 1 (June 02 – June 15)			
%	22.2	76.4	0.0	0.0	1.4	100
SE	1.5	1.5	–	–	0.4	–
n	16	55	0	0	1	72
			Stratum 2 (June 16 – June 22)			
%	12.5	86.8	0.0	0.0	0.7	100
SE	2.7	2.8	–	–	0.7	–
n	17	118	0	0	1	136
			Stratum 3 (June 23 – June 29)			
%	20.6	77.9	1.5	0.0	0.0	100
SE	3.4	3.6	1.0	–	–	–
n	27	102	2	0	0	131
			Stratum 4 (June 30 – July 06)			
%	35.7	62.0	0.0	2.3	0.0	100
SE	4.2	4.3	–	1.3	–	–
n	46	80	0	3	0	129
			Stratum 5 (July 07 – July 13)			
%	46.8	52.3	0.0	0.9	0.0	100
SE	4.7	4.7	–	0.9	–	–
n	52	58	0	1	0	111
			Stratum 6 (July 14 – July 23)			
%	71.9	24.0	0.8	1.7	1.7	100
SE	4.1	3.8	0.8	1.1	1.1	–
n	87	29	1	2	2	121
			Total*			
%	35.0	63.1	0.3	1.4	0.5	100
SE	1.8	1.8	0.3	0.6	0.4	–
n	245	442	3	6	4	700*

*includes four fish of unknown sex.

Of the 700 sockeye salmon that were aged, 696 could also be identified to sex. Of the original eight weekly sampling strata the first two and the last two were combined in order to have enough samples in each stratum to estimate the age composition of sockeye salmon such that simultaneous 90 percent confidence intervals had a maximum width of 0.20 (Appendix B).

Of the six age classes identified, ages 1.2 (35.0 percent) and 1.3 (63.1 percent) accounted for approximately 98 percent of all sockeye salmon sampled. Details are not reported for the remaining age groups (ages 0.3, 1.1, 1.4, 2.2, 2.3 and 2.4) because they accounted for less than 2 percent 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 two dominant age classes since sampling was initiated in 2001 and exhibit an alternate-year pattern of abundance: age 1.2 sockeye salmon are more abundant in even years and age 1.3 sockeye salmon are more abundant in odd years (Table 6).

Table 6. Sockeye salmon sex composition and age composition, McLees Lake, 2001–2010.

	Gender			Age* (%)			
Year	Female %	Male %	SE[1]	1.2	SE[1]	1.3	SE[1]
2001[a]	42	58	–	4	–	94	–
2002[a]	43	57	–	60	–	32	–
2003[a]	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	2.9	18	2.4	77	2.6
2010	55	45	2.0	35	2.1	63	2.0

* = age 0.3, 1.1, 1.4, 2.2, 2.3 and 2.4 not reported because each was < 3% of the total.
a = estimate.
1 = standard error not reported for estimates.

Limnological Data

Four water clarity and plankton-tow samples were obtained from each of the two stations established in McLees Lake for the 2010 season (Table 7). Over the course of the season, water clarity ranged from 2.7 m to 4.8 m on sampling days. Vertical plankton tow depths varied probably as a result of the boat being slightly off station or from natural fluctuations in lake depth.

Table 7. Limnological sampling data collected at an established station, McLees Lake, 2010.

Station	Sample	Date	Time	Bottom Depth (m)	Tow Depth (m)	Visibility (m)
1	1	6/22/2010	10:35	8.8	7.8	2.7
1	2	6/28/2010	10:01	9.6	8.7	4.1
1	3	7/13/2010	16:30	10.1	9.1	3.1
1	4	7/25/2010	22:00	9.4	8.2	2.9
2	1	6/22/2010	10:48	9.1	8.2	2.7
2	2	6/28/2010	10:16	9.1	8.2	4.8
2	3	7/13/2010	17:30	9.5	8.5	2.7
2	4	7/25/2010	22:25	9.0	7.9	3.2

Analysis of 2010 McLees Lake zooplankton samples indicated that abundance was low (Figure 9), species diversity was limited, biomass was very low at ~9.8 to 28.6 mg m ^{2} (Honnold et al. 1996, p.18; Figure 10), and average size was small (Figure 11). The species composition was dominated by the copepod *Cyclops* with lower numbers of the cladocerans *Daphnia* and *Bosmina* (Figure 9).

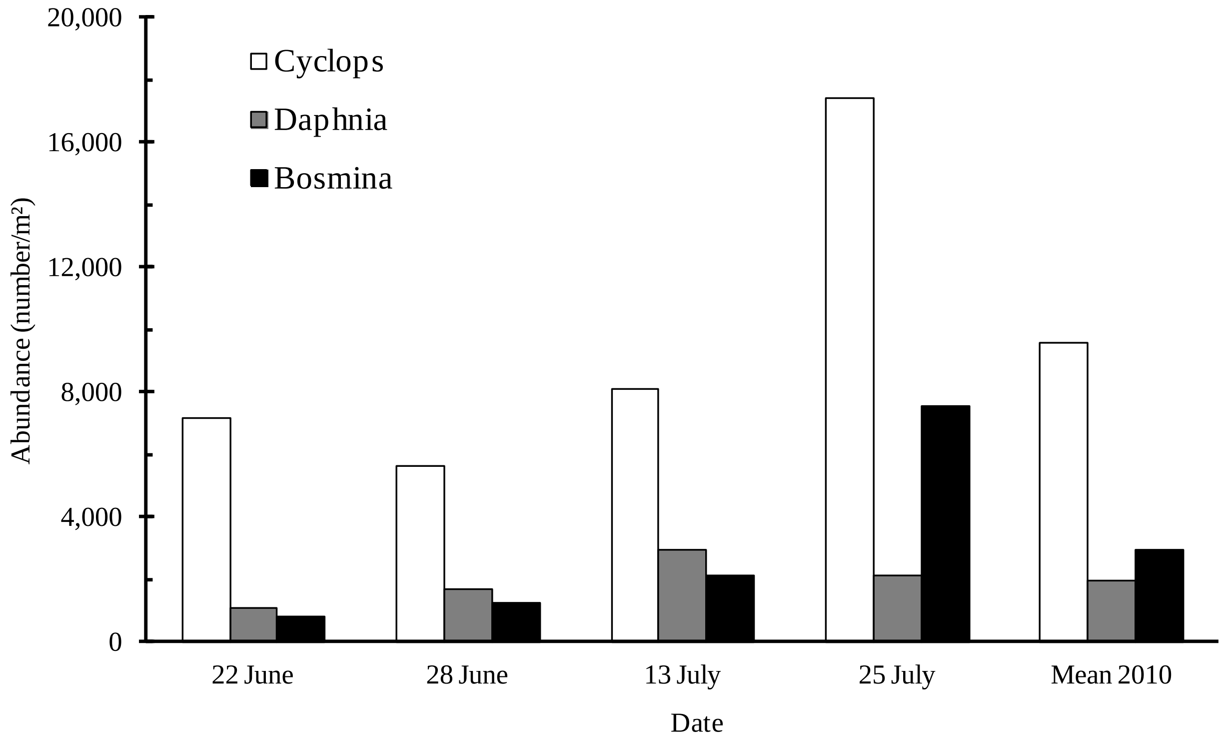

Figure 9. McLees Lake zooplankton abundance and seasonal mean, 2010.

Low biomass levels persisted throughout the sampling period, despite moderate increases in *Cyclops* and *Bosmina* biomass from June through July (Figure 10).

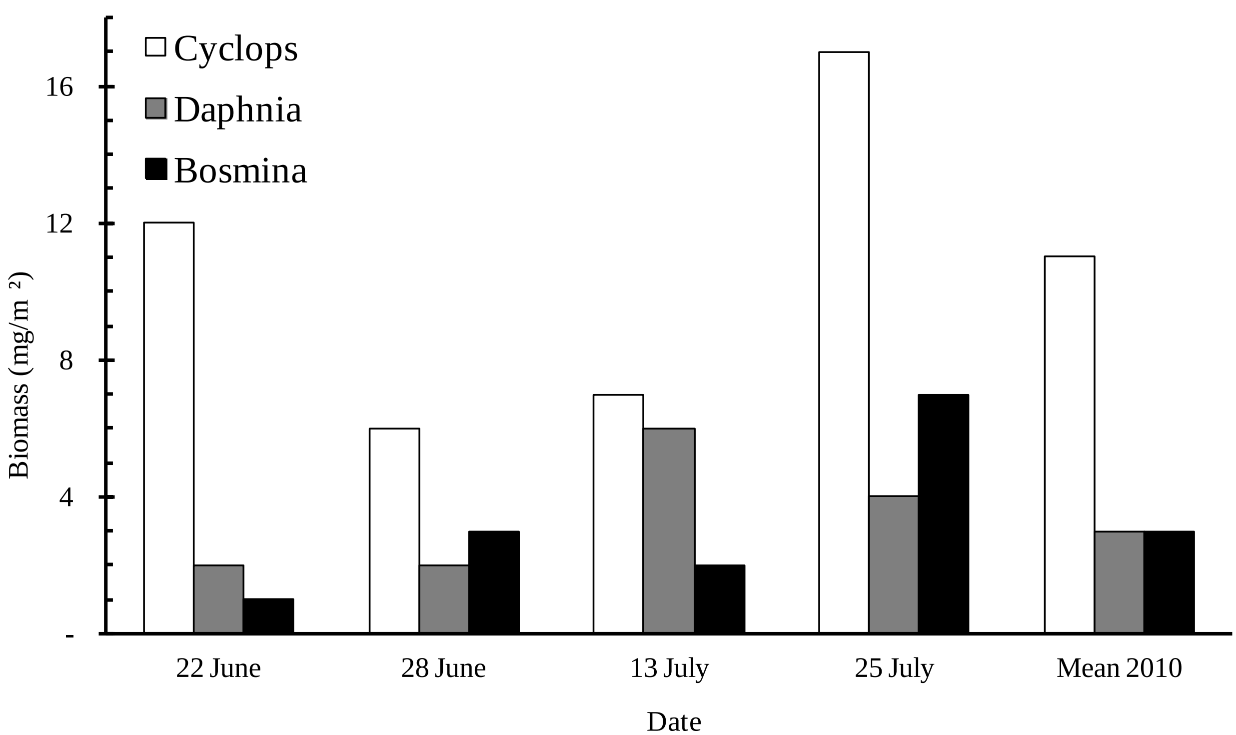

Figure 10. Biomass of the three most abundant zooplankters by collection date and with seasonal mean, McLees Lake, 2010.

Cyclops had an average length of 0.65 mm over the course of the sampling season which was above the juvenile sockeye salmon feeding threshold size of 0.40 mm (Figure 11). Mean lengths of *Daphnia* (0.53 mm) and ovigerous (egg-bearing) *Daphnia* (0.76 mm) were above the threshold size on each sampling date. *Bosmina* had an average length of 0.31 mm over the course of the sampling season which was below the feeding threshold size for juvenile sockeye salmon although ovigerous *Bosmina* had an average length of 0.45 mm in length which was greater than the juvenile sockeye salmon feeding threshold size.

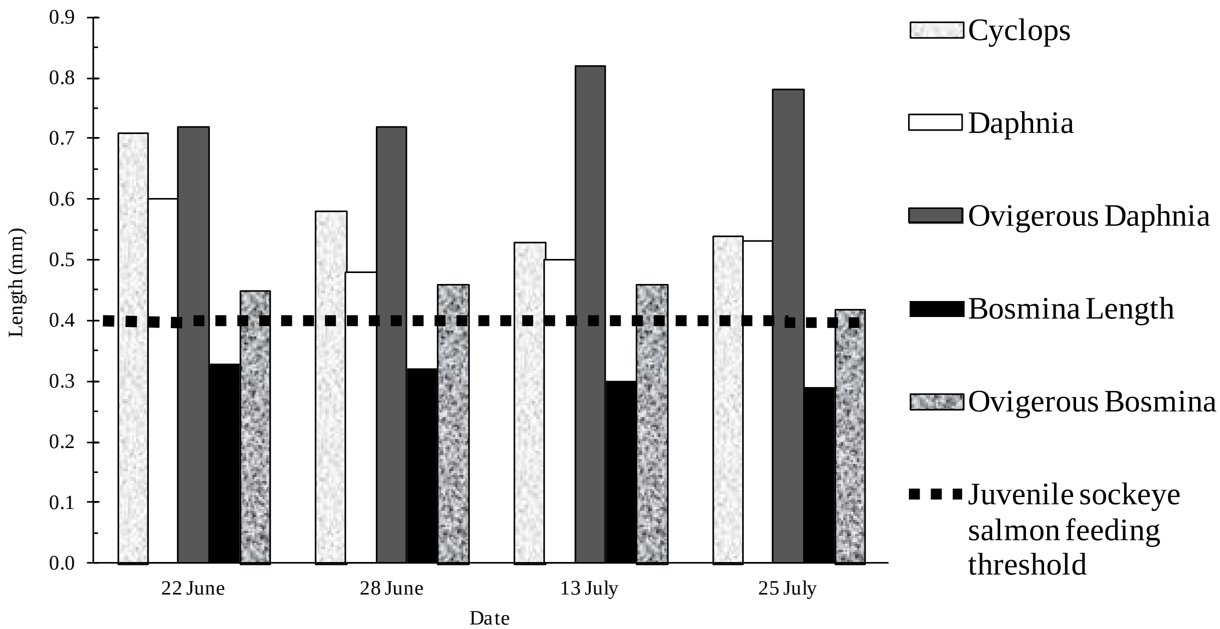

Figure 11. Average lengths (mm) of Cyclops, Daphnia, Ovigerous Daphnia, Bosmina, and Ovigerous Bosmina, relative to the juvenile sockeye salmon feeding threshold size determined by Kyle (1992), McLees Lake, 2010.

Discussion

We think that most sockeye salmon entering the McLees Lake system to spawn were counted during the time the weir was in operation. It is unlikely that many sockeye salmon entered McLees Lake prior to weir installation, which was on 2 June, as no fish were seen to pass through the weir until 3 June (Appendix A). Although sockeye salmon were still migrating past the site when the weir was removed on 23 July, daily passage rates had been less than 1 percent of the total escapement since 21 July. No attempt was made to estimate any fish that were holding in a pool just downstream from the weir-site at the time of weir removal.

Since 2005, sockeye salmon escapements have been substantially lower than those recorded in the first four years of the study (Figure 12). This has generally resulted in greater exploitation rates for these five years than the previous five years, although the actual number of sockeye salmon harvested has generally declined (Hartill and Keyse, 2011).

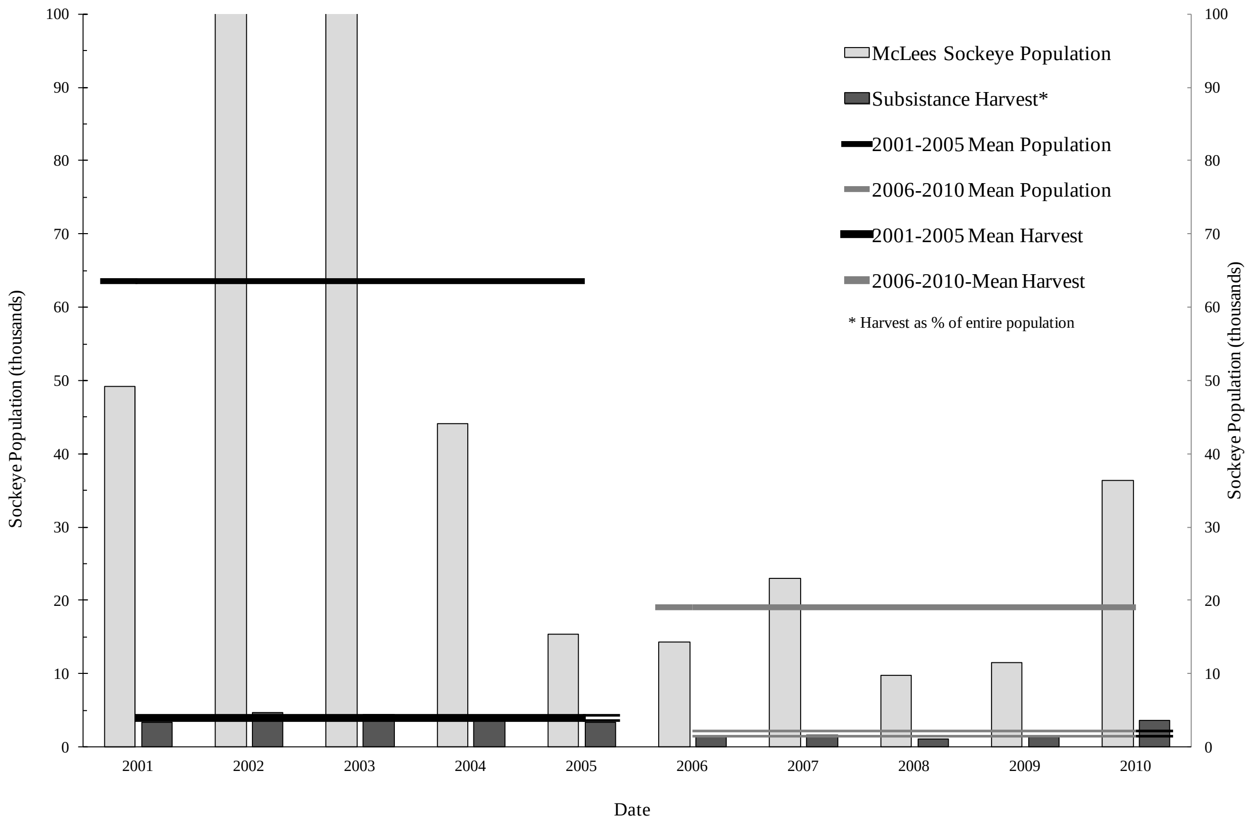

Figure 12. Annual sockeye salmon escapement and subsistence harvest, 2001–2010 and five year means for 2001–2005 and 2006–2010, McLees Lake (harvest data from Hartill and Keyse, 2011).

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 due to declining run abundance. As a result the more distant Reese Bay has become a major source of subsistence salmon harvests over the past decade. Annual subsistence sockeye salmon harvests taken from Reese Bay during the years 2006 through 2009 were much less than those taken during the previous five years. The official annual harvest went from a high of 4,694 sockeye salmon in 2002 down to an average of 1,380 for the four years prior to 2010. The return of over 36,000 sockeye in 2010 was met by an increase in subsistence harvest (Hartill and Keyse 2011).

Between 1 and 9 July ADFG typically closes Reese Bay subsistence fishing from an area extending 150 m on either side of the McLees Lake outlet into Reese Bay. However, the poor sockeye salmon escapements of 2008 and 2009 led ADFG to maintain the 150 m closure after 9 July for the remainder of those harvest seasons. In 2010, the escapement of over 32,000 sockeye resulted in ADFG allowing subsistence fishing to resume within the 150 m area surrounding the outlet after the seasonal July closure.

Cause for the low sockeye runs to McLees Lake during 2005–2009 is unknown. Theories include predation by other species, inter- and intra-specific competition for resources, and insufficient food supplies. The relatively large spawning escapements that occurred during 2001–2004 could have resulted in intra-specific competition for available food and may have depleted the zooplankton population and altered its species composition and size. While zooplankton information is not available prior to 2009 we found overall levels of zooplankton biomass and species diversity to be quite low in samples from both 2009 and 2010. For both years the average lengths of all species, with the exception of *Bosmina*, were above the threshold size for juvenile sockeye salmon feeding, however, the zooplankton biomass estimates were at or close to reported starvation levels for juvenile sockeye salmon (Kyle 1992; Mazumder and Edmundson 2002). This trend has been observed in other shallow Alaska Peninsula lakes (Finkle and Ruhl, 2009) and is not uncommon when top-down or bottom-up pressures (such as over grazing or reduced water clarity) persist in the ecosystem (Thorpe and Covich, 2001; Wetzel, 1983). Evidence of overgrazed zooplankton populations can be reflected by a reduction in cladoceran body length (Schindler, 1992) and the small size of *Bosmina* in 2010 suggests that grazing pressure was present. However, egg-bearing *Bosmina* were not below the juvenile sockeye salmon feeding threshold size of 0.40 mm (Kyle, 1992). This may indicate that grazing pressure had less influence upon the cladoceran population than other factors such as turbidity or temperature. A moderate increase in *Cyclops* and *Bosmina* biomass did occur from June through July 2010 and increased cladoceran abundance has been observed to coincide with algal blooms and increased precipitation or temperature (Thorpe and Covich, 2001). While increased abundance could have been the result of increased phytoplankton production creating conditions favorable to foraging zooplankters, it could also have been due to a reduction in grazing pressure as juvenile sockeye salmon smolted and migrated seaward from McLees Lake. More importantly, even with zooplankton biomass increases from June through July the total zooplankton biomass of McLees Lake remained at very low levels for the duration of the 2010 sampling season (9.8 to 28.6 mg m ^{2}) when compared to the 1993–1994 mean of 291.7 mg m ^{2} (Honnold et al. 1996). Since only two years of data are available we do not know whether the condition of the zooplankton population is a recent occurrence. Also, since we only sampled two deep-water stations in the lake we do not know whether these stations are representative of the entire basin. Since over 32,000 sockeye salmon adults were counted at the weir site this year it is apparent that some juveniles have been finding enough food to eat to survive and grow large enough to smolt. This suggests that feeding conditions in the lake when these returning adults were juveniles may have been better than those currently recorded or that that there are more productive areas for zooplankton growth in this system than at the two stations we sampled. Additionally, sockeye salmon may have adapted their rearing strategies to deal with changes to their forage base or habitat. Since McLees Lake is shallow, aquatic insects may play an important role in the juvenile sockeye salmon forage base and could help offset deficiencies in zooplankton availability. However, the availability of other juvenile sockeye salmon forage is unknown and any effects from any alternative forage bases are an uncertainty.

Recommendations

Escapements and subsistence harvests should continue to be monitored. Escapement levels needed to sustain harvests and maintain healthy salmon runs to McLees Lake were recently evaluated by ADFG resulting in adoption of a Sustainable Escapement Goal of 10,000–60,000 sockeye salmon that is to be used only during years in which a weir is operated (Witteveen et al. 2009). Reliable and timely in-season estimates of escapement are needed to manage for this escapement goal. Continued long-term documentation of escapements and harvests would also allow forecasts of future run strength to be made, evaluations of the escapement goal to be conducted, and proactive management strategies to be developed. Only one more year of monitoring by this project will be funded through OSM.

Assessment of freshwater parameters should also continue in order to better understand the contribution of freshwater conditions to sockeye salmon production including the large fluctuations in salmon runs. In order to design an efficient and effective long-term freshwater monitoring program, limnology data from the 2009–2011 field seasons should be compiled and compared to data collected from 1993–1994 by Honnold et al. (1996). Physical and zooplankton data should be examined for temporal differences and trends and simple, habitat-based limnology models, such as the euphotic volume model (Koenings and Kyle 1997), should be used to assess current adult production levels and lake rearing capacity.

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Appendix A. Daily and cumulative escapement of sockeye salmon, McLees Lake, 2010.

Date	Daily Count	Cumulative Escapement	% Total Escapment
2 Jun	0	0	0.0
3 Jun	1	1	0.0
4 Jun	3	4	0.0
5 Jun	0	4	0.0
6 Jun	0	4	0.0
7 Jun	1	5	0.0
8 Jun	4	9	0.0
9 Jun	12	21	0.0
10 Jun	2	23	0.0
11 Jun	14	37	0.0
12 Jun	19	56	0.1
13 Jun	3	59	0.0
14 Jun	13	72	0.0
15 Jun	7	79	0.0
16 Jun	26	105	0.1
17 Jun	26	131	0.1
18 Jun	26	157	0.1
19 Jun	24	181	0.1
20 Jun	639	820	1.9
21 Jun	351	1,171	1.1
22 Jun	372	1,543	1.1
23 Jun	53	1,596	0.2
24 Jun	31	1,627	0.1
25 Jun	50	1,677	0.2
26 Jun	601	2,278	1.8
27 Jun	403	2,681	1.2
28 Jun	3,992	6,673	12.2
29 Jun	3,696	10,369	11.3
30 Jun	23	10,392	0.1
1 Jul	54	10,446	0.2
2 Jul	303	10,749	0.9
3 Jul	4,119	14,868	12.5
4 Jul	962	15,830	2.9
5 Jul	2,060	17,890	6.3
6 Jul	770	18,660	2.3
7 Jul	69	18,729	0.2
8 Jul	71	18,800	0.2
9 Jul	4,226	23,026	12.9
10 Jul	1,686	24,712	5.1
11 Jul	1,167	25,879	3.6
12 Jul	1,639	27,518	5.0
13 Jul	1,407	28,925	4.3
14 Jul	31	28,956	0.1
15 Jul	26	28,982	0.1
16 Jul	49	29,031	0.1
17 Jul	32	29,063	0.1
18 Jul	1,678	30,741	5.1
19 Jul	820	31,561	2.5
20 Jul	544	32,105	1.7
21 Jul	47	32,152	0.1
22 Jul	186	32,338	0.6
23 Jul	504	32,842	1.5
24 Jul	pull weir		

Appendix B. Standard errors (SE) and estimated confidence intervals (CI) for estimates of sockeye salmon age and sex, McLees Lake, 2010.

Parameter	Age Class*		Gender	
	1.2	1.3	Female	Male
%	35.0	63.1	54.9	45.0
SE	1.8	1.8	2.0	2.0
n	245	442	376	320
Critical value (Zar, 1999)	1.285	1.283	1.284	1.284
CI	2.313	2.309	2.568	2.568
Upper CI	0.373	0.654	0.575	0.476
Lower CI	0.327	0.608	0.523	0.424
Difference (< 0.20)	0.046	0.046	0.051	0.051

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