Leisure Lake
Sockeye Salmon Enhancement
Progress Report
2014

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The 2014 Leisure Lake Project was made possible through Cook Inlet Aquaculture Association Salmon Enhancement Tax and Cook Inlet Aquaculture Association Special Harvest Area Access licensing fees.

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DISCLAIMER

The Cook Inlet Aquaculture Association (CIAA) conducts salmon enhancement and restoration projects in Area H, Cook Inlet and associated waters. As an integral part of these projects a variety of monitoring and evaluation studies are conducted. The following progress report is a synopsis of the monitoring and evaluation studies conducted in 2014 for Leisure Lake. It also includes historical smolt and limnology data collected by Alaska Department of Fish and Game (ADF&G) and CIAA for comparative purposes.

The purpose of the progress report is to provide a vehicle to distribute the information produced by the monitoring and evaluation studies. These reports are intended to provide a general description of project activity and are not an exhaustive evaluation of any restoration or enhancement project. The information presented in this report has not undergone an extensive review. As reviews are completed, the information may be updated and presented in other reports.

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Our equal employment opportunity philosophy applies to all aspects of employment with CIAA including recruiting, hiring, training, transfer, promotion, job benefits, pay, dismissal, and educational assistance.

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ACKNOWLEDGEMENTS

Many individuals and agencies contributed to the success of the Leisure Lake Project. Appreciation is extended to Cook Inlet Aquaculture Association interns, seasonal assistants, and full-time staff who invested many hours in planning and executing this project. Thanks are also extended to the Kachemak State Park staff for their cooperation in accommodating our field camp and fertilizer storage sites, and to Alaska West Air and Northwind Aviation for flight service and fertilizer delivery.

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ABSTRACT

Since 1976 Leisure Lake has been stocked with sockeye salmon from three different stocks originating from Tustumena, Hidden, and English Bay lakes. Adult returns to Leisure Lake are managed as a terminal fishery due to an impassable falls located approximately 100 meters from the mouth of outlet creek at China Poot Bay. Through much of the 1980s, the sockeye salmon returning to Leisure Creek accounted for as much as 45% of the Lower Cook Inlet commercial sockeye salmon harvest but those numbers have dropped in recent years. To assess whether this decline is the result of a marine, freshwater, or a stock issue, Cook Inlet Aquaculture Association began enumerating and collecting data on the smolt outmigration in 2014.

Between May 8 and June 23, 2014, a total of 267,263 (±13,369) sockeye salmon smolt were enumerated as they emigrated from Leisure Lake. A subsample of n=600 smolt were collected throughout the run. The number of samples collected at the beginning and the end of the run varied based on the number of fish migrating. Sampled smolt were assessed for fork length, weight, and aged and thermal mark determined via otolith analysis. Sampled smolt ranged in freshwater age from 1–2 years with age-2 comprising 96.6% of the 2014 migration. Based on otolith data, these sockeye salmon smolt were determined to be from the 2012 stocking of 2,074,000 Hidden Lake stock fry (0.18 g/fry; BY 11), and the age-1 fish leaving in 2014, which comprised 3.4% of the outmigration, resulted from the stocking of 1,800,000 Hidden Lake fry (BY 12) in 2013 also at 0.18 g/fry. To estimate marine survival, adult sockeye salmon returns will be monitored and otoliths will be checked for thermal marking in 2016 and 2017. Marine survival will be assessed via sampling of harvests in the commercial, cost recovery, and sport fisheries.

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INTRODUCTION AND PURPOSE

Leisure Lake has been stocked with sockeye salmon (*Onchorynchus nerka*) beginning with the Alaska Department of Fish and Game (ADF&G) release of Tustumena Lake sockeye salmon fry from the Crooked Creek Hatchery in 1976. In 1993, Cook Inlet Aquaculture Association (CIAA) took over the Crooked Creek Hatchery as well as stocking operations at Leisure Lake, and since then has used three different stocks to supply an average of 2 million sockeye salmon fry to support this terminal fishery on an annual basis. The Tustumena Lake stock was used through brood year BY 2003 when the 9th Circuit Court of Appeals deemed the Tustumena project as incompatible with the wilderness designation of Tustumena Lake and CIAA subsequently lost the ability to use that stock as a brood source. In 2004, CIAA released the last fish from Tustumena Lake into Leisure Lake. CIAA moved on to use the Hidden Lake stock from BY 2004–2012 and transitioned to the English Bay Lakes stock for BY 2013. The purpose of this study will be to determine freshwater and marine survivals of the sockeye salmon fry stocked in this system, as well as provide a comparison on the performance of the Hidden Lake and English Bay Lakes stocks.

Data regarding sockeye salmon adult returns to Leisure Creek gathered by ADF&G between 1979 and 1984 have been widely variable and were based on commercial and personal use dip net catches from China Poot Bay. Returns for those years ranged from a high of 117,360 in 1984 to a low of 3,400 in 1982 (Bechtol et al. 1988) (appendices 6 and 7). However, no analysis was done to determine if these harvests were solely the result of Leisure Lake stocking or fish intercepted from other systems. Yearly variations in environmental conditions (e.g., wind) could lead sockeye salmon from other stocks such as Hazel Lake or Upper Cook Inlet to China Poot Bay and could skew the estimated return of Leisure Lake sockeye salmon. Beginning in 2016, CIAA plans to remove otoliths from a representative sub-sample of adult sockeye salmon harvested in the commercial and cost recovery fisheries in China Poot Bay. Pending funding, CIAA also plans to collect samples from the personal use fishery as well. This will allow CIAA staff to determine the origin of the sockeye salmon and estimate the marine survival of the sockeye smolt migrating from Leisure Lake.

In addition to the stocking program, ADF&G and CIAA have been applying liquid fertilizer to Leisure Lake. This fertilization program has been an important element of the enhancement project. The fertilizer is applied throughout the growing season to the pelagic area of the lake to stimulate algae growth, increase the zooplankton community, and bolster the food chain from the bottom up. Beginning in 2015, the ADF&G water quality lab in Soldotna plans to provide water quality data during the season so adjustments to fertilization can be made as needed and ensure the maximum benefits for sockeye fry from the fertilizer application.

This report provides data from the 2014 smolt enumeration, limnology and fertilization projects, as well as historical data regarding stocking numbers and limnological sampling.

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PROJECT AREA

Leisure Lake is located at 59º32' N latitude and 151º12' W longitude in Kachemak Bay State Park, approximately 13 kilometers southeast of Homer, Alaska (Figure 1). It has a surface elevation of 51 meters and a surface area of 1.05 x $10^6 m^2$ (Figure 2) (Bechtol and Dudiak, 1988). There are three small unnamed tributaries to Leisure Lake located on the north and east sides of the lake. The lake's discharge forms Leisure Creek, which flows 1.5 km into the China Poot Bay. A barrier falls near China Poot Bay prevents adult salmon from returning to the lake.

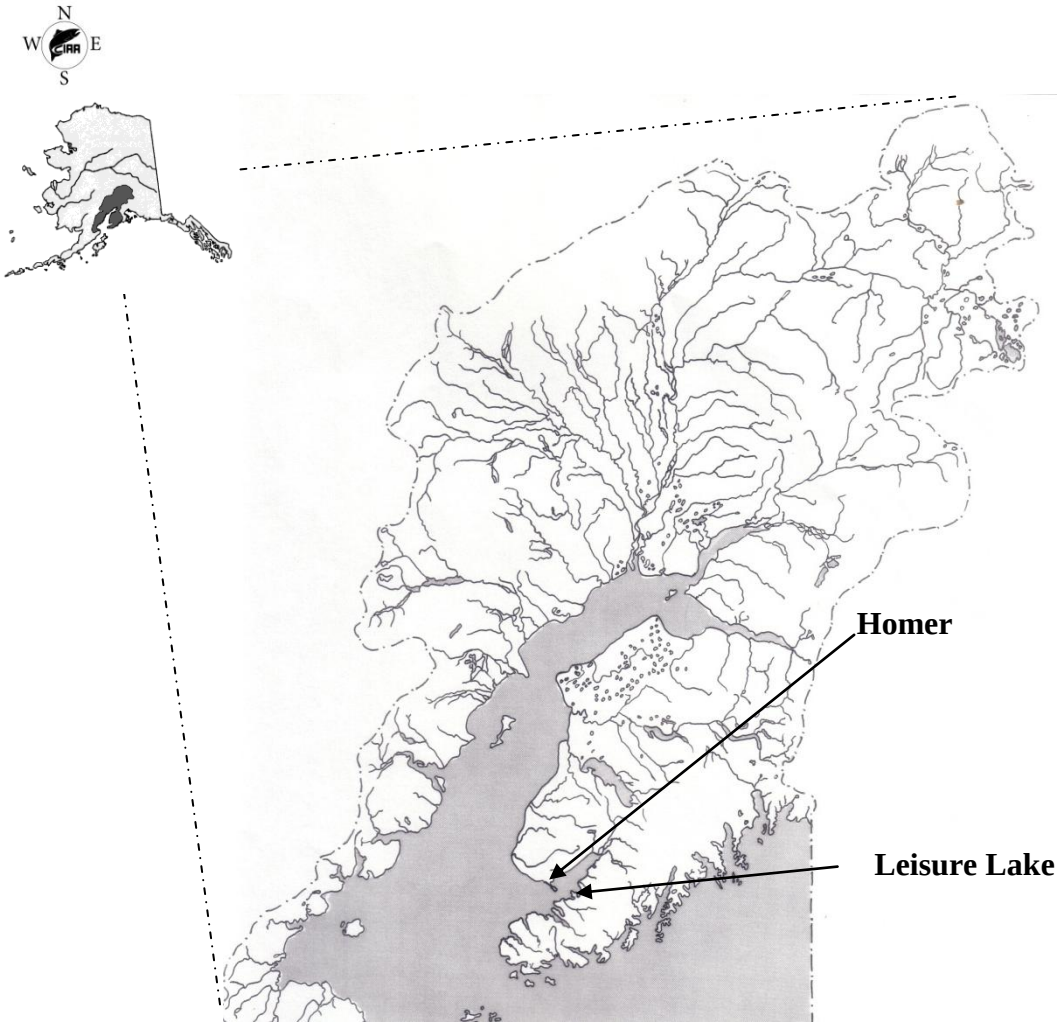

Figure 1: Leisure Lake in Relation to Cook Inlet and Alaska

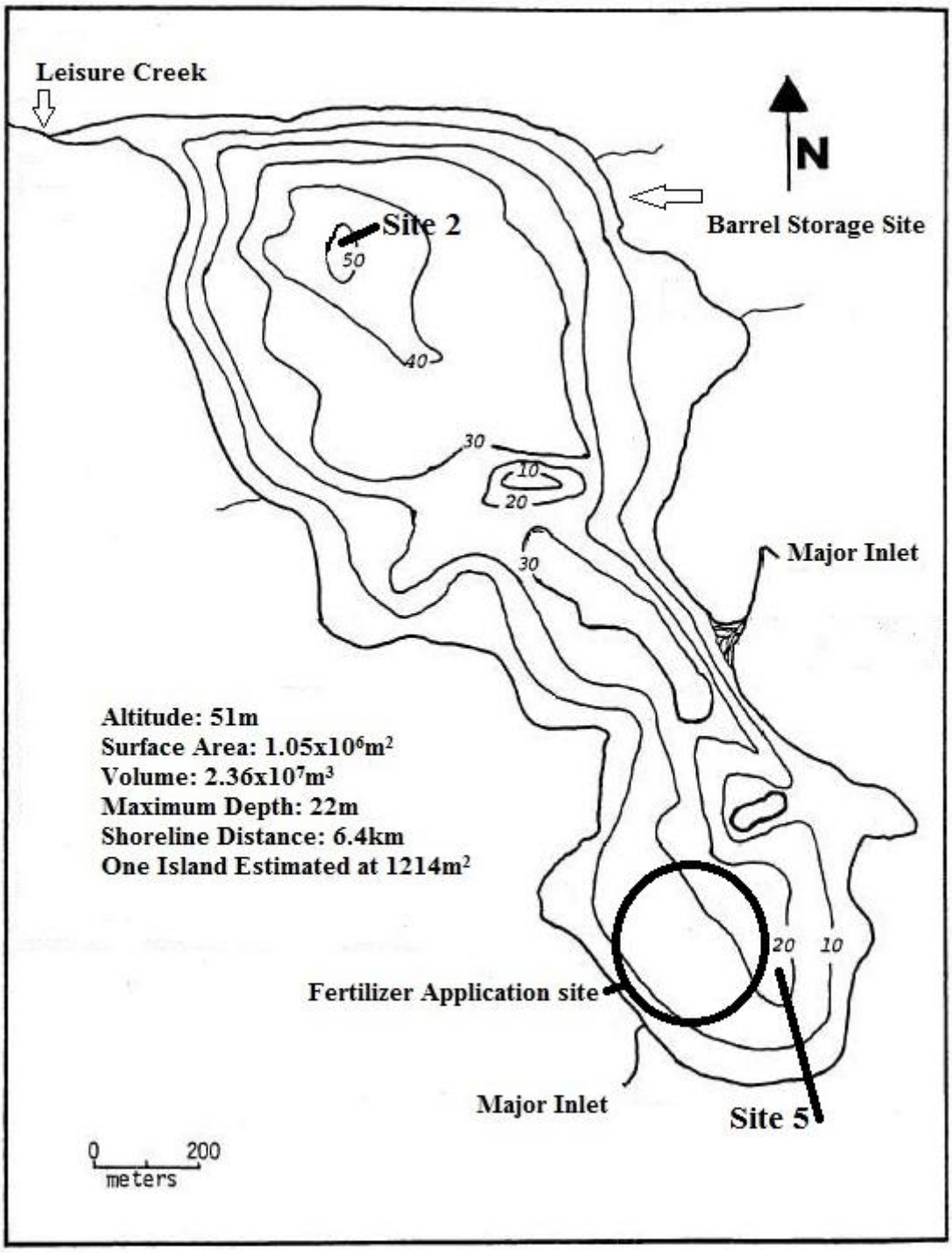

Figure 2: Bathymetric Map of Leisure Lake

METHODS

Limnological Sampling & Environmental Conditions

During 2014, water quality samples were collected four times during the open water season in June, July, August, and September. Two primary sites, Stations 2 and 5 (Figure 2) were sampled for dissolved oxygen, temperature, and light transmission profiles, Secchi disk transparency, and zooplankton densities. Samples for analysis of phosphorus, carbon, chlorophyll *a*, phaeophytin *a*, nitrogen, calcium, magnesium, iron, conductivity, pH, alkalinity, turbidity, and color were also collected with a horizontal Van Dorn beta sampler one meter below the surface and from the midhypolimnion.

The water sample procedures followed are described in the Limnology Field and Laboratory Manual: Methods for Assessing Aquatic Production (Koenings, Edmundson, Edumndson, & Kyle, 1986). Analysis was completed by ADF&G.

In addition to the limnological samples collected from Leisure Lake, percent cloud cover was visually estimated, water level in the creek recorded to the nearest 0.1 foot, precipitation measured to the nearest millimeter, and water and air temperatures (Celsius) were recorded at 5:00 PM daily. Standard CIAA procedures were followed for collecting these observations (CIAA, 2014).

Smolt Enumeration and Characteristics

To enumerate the smolt migration, a collection facility was temporarily placed in Leisure Creek, approximately 50 meters upstream from the mouth of the creek. A trap installed in early May, which was comprised of a modified fyke net attached to a double compartment live box, was positioned in the main flow of the creek. There were 2 leads composed of vexar® paneling, which were anchored upstream to each bank and functioned by directing smolts into the trap. The use of the paneling enabled staff to sample the entire width of the creek to ensure a total smolt count.

Typically, staff checked the trap at least four times daily and all smolts were enumerated. Age (otolith), weight, and length (AWL) data were collected from a subsample of the migrating smolts. Random samples (up to n=40 for sockeye salmon) were collected daily. A subsample of n=600 smolt were collected throughout the run. The number of samples collected at the beginning and the end of the run varied based on the number of fish migrating. Each smolt sacrificed for evaluation was first anesthetized with a lethal dose of MS-222, then measured for fork length[1] to the nearest millimeter and weighed to the nearest gram. Otoliths were removed

[1] Fork length is defined as the length from the tip of the snout to the fork of the tail.

from the smolt and placed in an ethyl alcohol solution for subsequent age determination at the CIAA lab (Glick et al. 1993). The Leisure Lake Smolt Procedures Manual (CIAA, 2014) outlines the AWL procedures.

Sockeye smolt characteristics, the proportion of enhanced sockeye smolt and the proportion of age 1, and 2 sockeye smolt in the migrating population, were estimated with the following notations and formulas provided by ADF&G. Since no wild stock exists in Leisure Lake, q_h=0.

If:

N = total number of migrating smolts,

N_h = number of smolts in stratum h, $\left(N = \sum N_h\right)$,

n = total number of smolts sampled,

n_h = number of smolts sampled in stratum h, $\left(n = \sum n_h\right)$,

a = total number of enhanced smolts sampled,

a_h = number of enhanced smolts sampled in stratum h, $\left(a = \sum a_h\right)$,

$p_h = a_h / n_h$, The proportion of enhanced smolts in stratum h,

$q_h = 1 - p_h$, The proportion of wild smolts in stratum h,

c_i = number of age $= i$ smolts sampled,

c_{hi} = number of age $= i$ smolts sampled in stratum h, $\left(c_i = \sum c_{hi}\right)$,

$l_{hi} = c_{hi} / n_{hi}$, The proportion of age $= i$ smolts in stratum h,

$m_{hi} = 1 - l_{hi}$, The proportion of other than age $= i$ smolts in stratum h,

$f = n / N$, The sampling fraction (assumed equal in all strata),

$W_h = N_h / N$, The stratum weight, and,

$y =$ the weight or length of the smolt.

Then the proportion of enhanced smolts, $\hat{P}$, was estimated as:

$$\hat{P} = a / n; \quad \text{with a variance of} \quad v(\hat{P}) = (1 - f)(1/n)\sum W_h p_h q_h;$$

which, under proportional allocation, is like the usual simple random sample estimate.

The total number of enhanced smolts, $\hat{A}$, was also estimated as:

$$\hat{A} = N(a/n) = N\hat{P};$$

with a variance of:

$$v(\hat{A}) = N^2(1 - f)(1/n)\sum W_h p_h q_h = N^2 v(\hat{P}).$$

Since samples sizes were fairly large and $\hat{P}$ was not extreme, the normal approximation, without a correction for continuity, could be used to develop the relative error. Thus, the 95% confidence interval estimate for $\hat{P}$ and $\hat{A}$ is:

$$\hat{P} \pm 1.96\sqrt{v(\hat{P})} \quad \text{and} \quad \hat{A} \pm 1.96\sqrt{v(\hat{A})};$$

and, the relative error is:

$$R.E. = \left(1.96\sqrt{v(\hat{P})} \Big/ (\hat{P})\right)100 \quad \text{and} \quad R.E. = \left(1.96\sqrt{v(\hat{A})} \Big/ (\hat{A})\right)100.$$

The proportion of age $= i$ smolt in the smolt migration was also estimated as:

$$\hat{L}_i = c_i / n; \quad \text{with a variance of} \quad v(\hat{L}_i) = (1 - f)\frac{1}{n}\sum_h W_h l_{hi} m_{hi};$$

and, the total number of age $= i$ smolts was estimated as:

$$\hat{C}_i = N(\hat{L}_i); \quad \text{with a variance of} \quad v(\hat{C}_i) = N^2 v(\hat{L}_i).$$

Confidence interval (95%) estimates for age-class proportion and abundance, assuming 2 age-classes, are:

$$\hat{L}_i \pm 2.24\left(\sqrt{v(\hat{L}_i)}\right) \qquad \text{and} \qquad \hat{C}_i \pm 2.24\left(\sqrt{v(\hat{C}_i)}\right).$$

Mean weight or length of age = i smolt was also estimated as:

$$\bar{y}_i = \frac{\sum_h \sum_j y_{hij}}{c_i};$$

with an approximate variance estimate of:

$$v(\bar{y}_i) \cong \frac{1}{\hat{C}_i^2} \sum_h \frac{N_h^2(1-f)}{n_h(n_h-1)} \left[\sum_j (y_{hij} - \bar{y}_{hi})^2 + c_{hi}(1 - {}^{c_{hi}}\!/_{n_h})(\bar{y}_{hi} - \bar{y}_i)^2 \right].$$

The confidence interval (95%) estimate for the mean weight and length is:

$$\bar{y}_i \pm 1.96\left(\sqrt{v(\bar{y}_i)}\right).$$

A total count of smolt migrating from Leisure Lake was made until the migration of fish exceeded 1,000 to 2,000 fish per hour. At migrations rates greater than 2,000 fish per hour, fish densities in the trap become too great and the fish become stressed. To avoid stressing the fish during periods of peak migration, a 10% sub-sampling procedure was used to enumerate the fish.

To enumerate migrating smolt with the 10% sub-sampling procedure, the counting day was divided into 20-minute intervals. During each 20-minute interval, migrating fish were directed into the live-box for two minutes and counted. During the remaining 18 minutes, migrating smolt passed through the trap uncounted. To estimate the number of smolt migrating during the 20-minute interval, the two-minute smolt count was multiplied by 10.

Assuming the two-minute sub-sampling intervals were randomly distributed throughout sub-sampling2 and smolt moved through the weir randomly, the total smolt migration was estimated as follows:

If:

[2]Predetermined random 2-minute sampling intervals assured random distribution within each 20-minute period.

T_c = number of fish counted with the total count procedure,

$\hat{T}_s$ = number of fish counted with the 10% sub-sampling procedure,

$\hat{T}$ = the total smolt migration,

y = the number of fish counted in each two minute sub-sampling interval,

n = the number of two minute sub-sampling intervals sampled, and

N = the number of possible two minute sub-sampling intervals,

Then, the total smolt migration ($\hat{T}$) is:

$$\hat{T} = T_c + \hat{T}_s;$$

with a variance of:

$$v\left(\hat{T}_s\right) = N^2\left((N-n)/N\right)\sum\left(y_i - \bar{y}\right)^2 / \left(n(n-1)\right);$$

and 95% confidence limits of:

$$\hat{T}_s \pm 2\sqrt{v\left(\hat{T}_s\right)}.$$

The variance about the estimated smolt migration, $\hat{T}$, is equal to the variance about $\hat{T}_s$, because T_c is a total count with 0 variance.

Fertilization

To enhance the food source of juvenile salmon in Leisure Lake, liquid fertilizer composed of 20% nitrogen, 5% phosphorus, and 0% potassium was mixed with lake water and sprayed from the back of a small skiff. A 12 volt Bean® pump and a sprayer manifold attached to the stern of the skiff were used to mix and deliver the fertilizer. To assure that the nutrients were evenly distributed, spatially and temporally, several transects were run over the application area, i.e., the southern portion of the lake (Figure 2). Three-hundred gallons of fertilizer were applied weekly for nine weeks from June–August. During that time frame, 90 barrels totaling 2,700 gallons or approximately 15 tons of fertilizer were applied to Leisure Lake.

RESULTS AND DISCUSSION

Limnological & Environmental Conditions

During the 2014 smolt migration, staff monitored environmental conditions at 5:00 PM from 09 May through 23 June. Water levels in the creek were monitored from 22 May through 23 June and water levels fluctuated 2.2 ft during that time period (Figure 3). Stream temperatures averaged 10ºC (±0.9) [mean ± standard deviation] and ranged from 8 to 12ºC (Table 1). Air temperatures averaged 14ºC (±1.5) and ranged from 10 to 17ºC. Twenty-two percent of the days were clear, 26% were less than 50% cloudy, 20% were more than 50% cloud covered, 24% were completely overcast and 8% had measured rainfall (Table 2). A total of 53 mm of rain fell during that period.

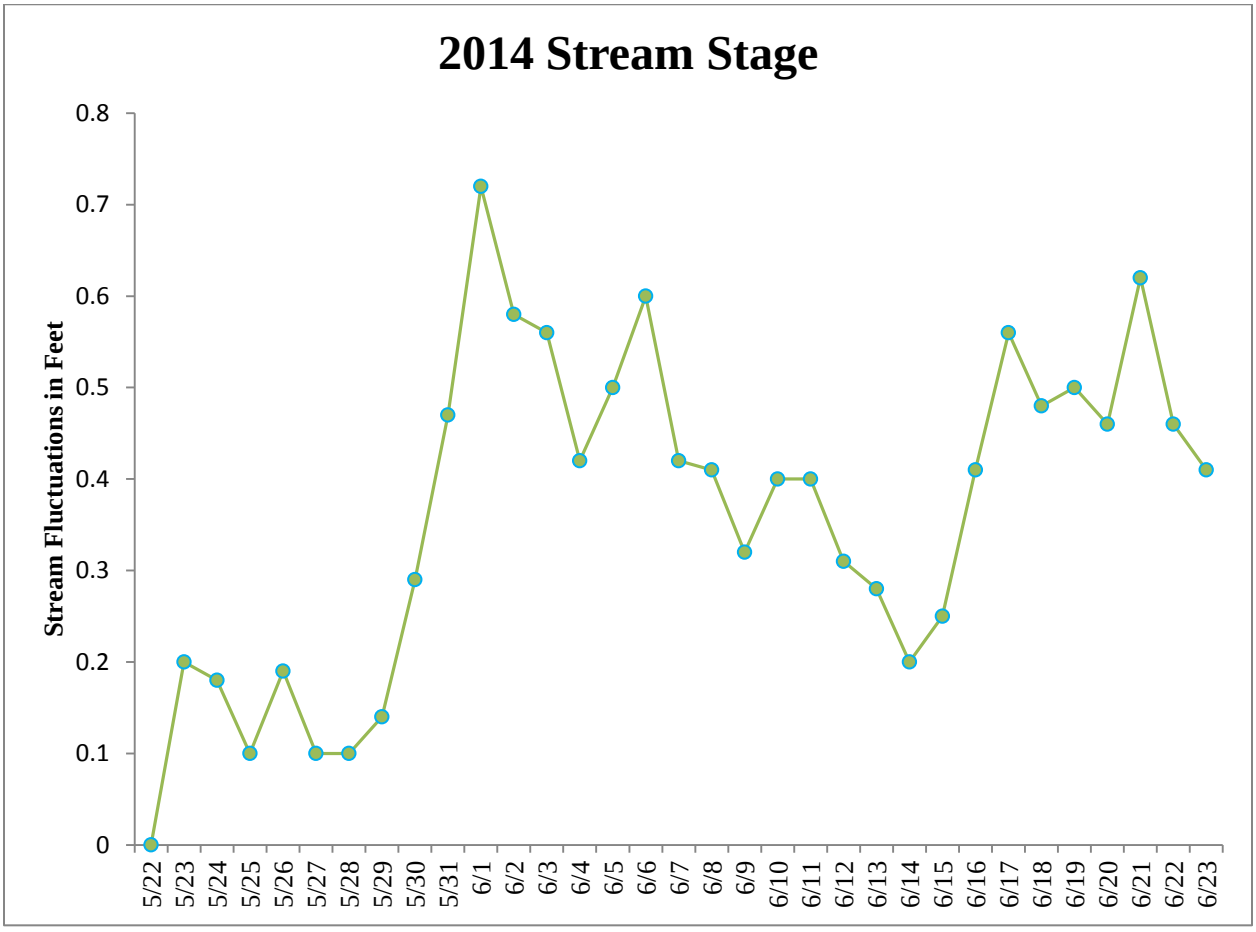

Figure 3: Stream Stage, Leisure Lake, 2014

Table 1: Environmental Summary, Leisure Lake, 2014

	Sky	Precip. (in)	Precip. (mm)	Staff Gauge (ft)	Water Temp. (^{o}C)	Air Temp. (^{o}C)
Total		3.0	52.6			
Avg.	3.0	0.1	1.4	1.3	10.2	13.7
Min.	1.0	0.0	0.0	0.8	8.0	10.0
Max.	5	0.79	10.922	3	12	17

Table 2: Summary of Cloud Cover, Leisure Lake, 2014

	No. Days	Percent of season
1=Clear	11	22%
2<50% Clouds	13	26%
3>50% Clouds	10	20%
4=Overcast	12	24%
5=Rain	4	8%

Water samples were analyzed by ADF&G staff in the ADF&G lab in Soldotna (tables 3 and 4). Limnological results and zooplankton information is presented in appendices 3–5.

Table 3: Nutrients and Primary Productivity, Leisure Lake, 2014

Date	Sta	Depth	TP	TFP	FRP	TKN	NH3+NH4	NO2+NO3	TN:TP	RSi	Org C	Chla	Phaeo	EZD	
		(m)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)		(ug/l)	(ug/l)	(ug/l)	(ug/l)	(m)	
6/10/2014	2	1	3.3	2.3	1.6	ND	8.4	533.0	ND :1	3110	187	0.49	0.19	2	25.5
6/10/2014		44	3.4	3.1	1.9	ND	6.9	557.0	ND :1	3272	107	0.25	0.19		
6/10/2014	5	1	3.4	2.1	1.9	ND	2.2	539.0	ND :1	3079	346	0.67	0.33	5	20.4
6/10/2014		17	7.0	3.2	2.1	ND	6.8	431.0	ND :1	3632	395	3.97	0.73		
7/8/2014	2	1	12.8	3.9	2.4	ND	8.8	398.0	ND :1	2691	576	6.28	1.38	2	24.8
7/8/2014		45	3.4	1.7	2.8	ND	4.6	540.0	ND :1	3337	148	0.49	0.25		
7/8/2014	5	1	10.2	3.3	2.4	ND	5.1	390.0	ND :1	2556	543	3.73	0.70	5	19.4
7/8/2014		14	8.5	3.1	3.3	ND	22.5	386.0	ND :1	4080	546	1.88	1.18		
8/15/2014	2	1	11.4	3.7	0.5	ND	12.4	268.0	ND :1	86	389	3.48	0.80	2	17.2
8/15/2014		40	ns	1.0	0.9	ND	37.1	539.0	ND :1	ns	92	0.48	0.36		
8/15/2014	5	1	19.0	3.9	1.3	ND	53.8	288.0	ND :1	69	113	0.91	1.08	5	11.8
8/15/2014		18	6.3	2.2	1.2	ND	5.9	352.0	ND :1	4045	326	3.30	1.07		
9/10/2014	2	1	6.4	1.8	0.5	ND	4.8	225.0	ND :1	465	593	2.59	0.74	2	18.4
9/10/2014		35	3.5	1.9	0.8	ND	2.7	542.0	ND :1	3382	104	0.63	0.43		
9/10/2014	5	1	6.2	3.0	1.0	ND	52.9	220.0	ND :1	584	139	0.41	0.38	5	10.8
9/10/2014		17	5.3	3.3	1.8	ND	5.8	361.0	ND :1	4255	421	1.26	0.39		
Mean	1 - Meter		9.1	3.0	1.4		18.5	357.6		1580.0	360.7	2.3	0.7	Mean	18.5
Min			3.3	1.8	0.5		2.2	220.0		69.0	112.6	0.4	0.2	Min	10.8
Max			19.0	3.9	2.4		53.8	539.0		3110.0	593.0	6.3	1.4	Max	25.5
Mean	Hypolimnion		4.7	2.4	1.8		11.5	463.5		3714.7	267.3	1.5	0.6		
Min			3.4	1.0	0.8		2.7	352.0		3272.0	91.8	0.3	0.2		
Max			8.5	3.3	3.3		37.1	557.0		4255.0	546.2	4.0	1.2		

ND = TKN was not reported due to the inability of ADF&G to provide this analysis in 2014.

Table 4: General Tests and Metals, Leisure Lake, 2014

Date	Sta	Depth	Sp. Cond	pH	Alk	Turb	Color	Ca	Mg	Fe	Secchi	
		(m)	(umhos/cm)	(SU)	(mg/l)	(NTU)	(Pt)	(mg/l)	(mg/l)	(ug/l)	Sta	(meters)
6/10/2014	2	1	89.6	7.1	28.5	0.1	4	13.5	1.4	6.5	2	
6/10/2014		44	87.9	6.9	28.8	0.1	4	13.3	1.3	12.0		ns
6/10/2014	5	1	88.1	7.3	29.0	0.2	4	12.8	1.4	9.2	5	
6/10/2014		17	89.2	6.8	29.9	0.1	5	13.1	1.3	20.3		ns
7/8/2014	2	1	98.0	7.3	28.5	0.4	5	13.3	2.1	7.9	2	
7/8/2014		45	97.6	6.8	28.4	0.3	4	13.2	1.3	14.4		3.5
7/8/2014	5	1	96.9	7.7	29.3	0.6	4	13.2	1.5	6.5	5	
7/8/2014		14	97.8	6.6	30.3	0.4	5	13.2	1.2	27.2		3.5
8/15/2014	2	1	95.2	7.6	33.6	1.0	5	13.3	1.6	20.3	2	
8/15/2014		40	ns	ns	ns	ns	ns	ns	ns	ns		3.5
8/15/2014	5	1	95.5	7.7	31.0	1.1	5	13.3	1.5	36.9	5	
8/15/2014		18	94.8	6.9	32.1	1.1	5	13.2	1.4	16.2		2.8
9/10/2014	2	1	100.8	7.6	32.3	0.6	4	13.8	1.5	20.3	2	
9/10/2014		35	99.4	7.0	29.7	0.1	4	13.5	1.4	14.8		4.5
9/10/2014	5	1	101.3	7.9	31.2	0.6	5	13.6	1.5	24.5	5	
9/10/2014		17	99.2	6.9	31.5	0.7	4	13.1	1.4	30.0		4.5
Mean	1 - Meter		85.0	6.7	27.0	0.5	4.0	11.9	1.4	14.7	Mean	3.7
Min			88.1	7.1	28.5	0.1	4.0	12.8	1.4	6.5	Min	2.8
Max			101.3	7.9	33.6	1.1	5.0	13.8	2.1	36.9	Max	4.5
Mean	Hypolimnion		95.1	6.9	30.1	0.4	4.4	13.2	1.3	19.3		
Min			87.9	6.6	28.4	0.1	4.0	13.1	1.2	12.0		
Max			99.4	7.0	32.1	1.1	5.0	13.5	1.4	30.0		

NS=No sample was taken for Station 2 mid-hypolimnion on August 15, 2014

Smolt Enumeration and Characteristics

The Leisure Lake smolt migration was enumerated from 08 May through 23 June 2014. During that time, 267,263 (±13,369) sockeye salmon smolt were enumerated while migrating from Leisure Lake (figures 4 and 5). The peak migration was 31,359 smolt, which occurred on May 19. Ten percent sub-sampling was performed on 30.9% of the run (82,010 fish).

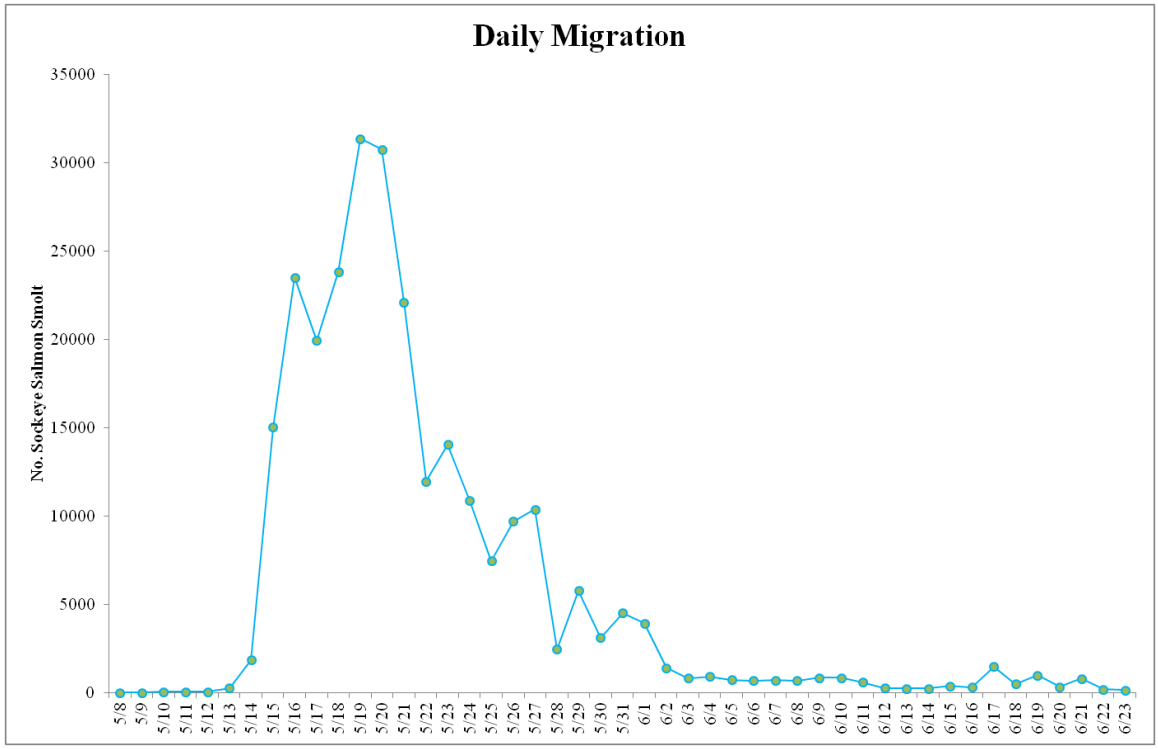

Figure 4: Daily Smolt Migration, Leisure Lake, 2014

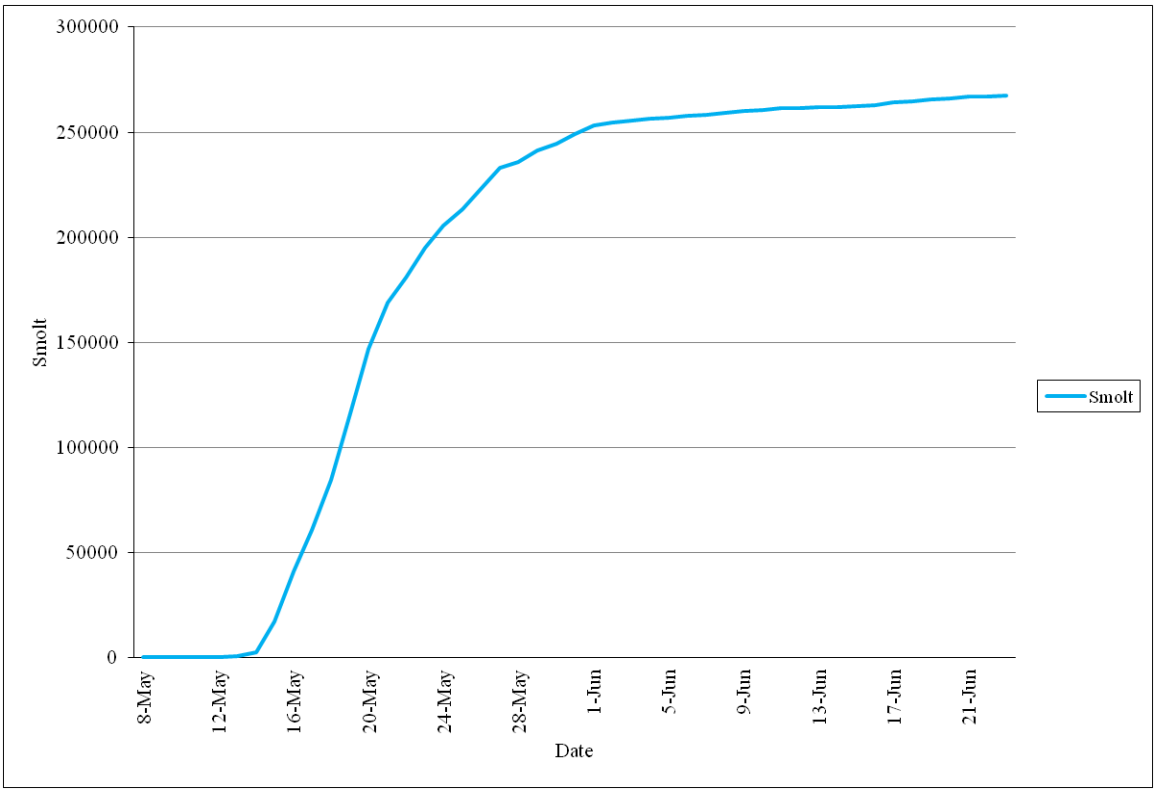

Figure 5: Cumulative Smolt Migration, Leisure Lake, 2014

Throughout the migration, staff collected 600 sockeye salmon smolt (0.22% of total estimated population), and took otolith samples, weight, and measurements for fork length. Seven otolith samples were unreadable, leaving 593 for analysis. Based on the samples read, there were 2 age classes observed during the migration. Within the sample, age-2 was the most abundant age class with 96.6% of the out migration, and age one smolts accounted for the remaining 3.4%. The average length of the sampled age-1 sockeye salmon smolt was 77.1 mm (±3.3 mm) and the average weight was 4.1 g (±0.6 g). The average length of the age-2 sockeye salmon smolt was 94.5 mm (±0.8 mm) and the average weight was 6.9 g (±0.2 g) (Table 5).

The high proportion of two-year smolt is atypical for Hidden Lake stock that generally migrates as one-year-olds from Hidden Lake. Additionally, the smolt size was much smaller than what typically migrates from Hidden Lake. Smolt enumeration in 2015 should be comprised primarily of the final out migration of the Hidden Lake stock as two-year smolt with any one-year smolt being from English Bay Lakes stock. This will allow future comparisons to be made between the two stocks to determine if brood stock source is playing a role in the variable sockeye salmon returns at Leisure Lake or the timing of the out migration.

It is unknown as to whether the English Bay stock (BY13 thermal mark 4,1,3H), which is also expected to migrate as age-1 smolts in 2015, will show the same age class breakdown as that of the Hidden Lake stock. Should the majority of English Bay Lakes stock emigrate as one-year

smolt during the spring of 2015, there may be a significantly larger number of outmigrants next year. Additionally, it will be interesting to note if the number of smolts and the time of peak migration is consistent regardless of the stock choice.

Table 5: Sockeye Salmon Smolt AWL Summary, Leisure Lake, 2014

Age Class (%)					Mean length (mm)				Mean weight (g)			
Smolt 2014	Age 1	95% C.I.	Age 2	95% C.I.	Age 1	95% C.I.	Age 2	95% C.I.	Age 1	95% C.I.	Age 2	95% C.I.
Sockeye	3.4%	1.4%	96.6%	1.4%	77.1	3.3	94.5	0.8	4.1	0.6	6.9	0.2

Fish Stocking

On June 7, 2014 CIAA released fed sockeye salmon fry into Leisure Lake. Stocking information from 2013–2014 is summarized in Table 6.

Table 6: Stocking Summary, Leisure Lake, 2013–2014

Brood Year	Stock	Species	Weight (g)	Number	Thermal Mark	Release Date
2012	Hidden Lake	Sockeye	0.18	1,800,000	H2,2	6/25/2013
2013	English Bay Lake	Sockeye	0.24	1,353,000	1,3H	6/7/2014

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RECOMMENDATIONS

Cook Inlet Aquaculture Association may have access to water quality data during the field season in 2015 making it possible to adjust the rate of fertilization to maximize the benefits to primary production. Special attention should be paid to the levels of chlorophyll to ensure the best possible results for the fry stocked in Leisure Lake.

The smolt out-migration at Leisure Lake will be monitored in 2015 and 2016. Additionally, CIAA will begin the monitoring of adult returns in 2016–2018 to estimate the marine survival of smolts counted between 2014 and 2016. Because all of the salmon leaving Leisure Lake and nearby Hazel Lake are thermally marked with unique patterns, CIAA will be able to determine the source of the fish returning to China Poot Bay.

Smolt sampling was capped at 40 fish per day in 2014. To better reflect the entire run, smolt should be sampled directly in proportion to migrating fish with no cap on daily samples. This may improve the strength of the statistics and more accurately reflect the age breakdown of the smolt population.

It was noted that Leisure Creek responds quickly to precipitation within the watershed, which lead to difficulties in keeping the integrity of smolt trap. For future monitoring the trap should be constructed with greater reinforcement to avoid any loss in trap integrity.

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APPENDICES

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Appendix 1: Environmental Conditions, Leisure Lake 2014

Date	Sky	Precip. (in)	Precip. (mm)	Staff Gauge (ft)	Water Temp. (°C)	Air Temp. (°C)
5/9/2014	2	0.0	ND	ND	8.0	13.0
5/10/2014	1	0.0	ND	ND	8.0	13.0
5/11/2014	1	0.0	ND	ND	9.0	13.0
5/12/2014	4	0.0	ND	ND	9.0	11.0
5/13/2014	1	0.0	ND	ND	9.0	13.0
5/14/2014	1	0.0	ND	ND	9.0	16.0
5/15/2014	1	0.0	ND	ND	9.0	14.0
5/16/2014	1	0.0	ND	ND	9.0	16.0
5/17/2014	1	0.0	ND	ND	9.0	14.0
5/18/2014	2	0.0	0.0	2.0	9.0	15.0
5/19/2014	4	0.0	0.0	3.0	9.0	14.0
5/20/2014	4	0.0	0.0	3.0	9.0	14.0
5/21/2014	4	0.0	0.0	1.8	10.0	17.0
5/22/2014	4	0.0	0.0	0.8	10.0	15.0
5/23/2014	1	0.0	0.0	1.0	9.0	15.0
5/24/2014	1	0.0	0.0	1.0	11.0	17.0
5/25/2014	2	0.0	0.0	0.9	10.0	15.0
5/26/2014	3	0.0	0.0	1.0	11.0	12.0
5/27/2014	4	0.0	0.1	0.9	11.0	13.0
5/28/2014	4	0.2	5.6	0.9	11.0	13.0
5/29/2014	4	0.0	0.0	0.9	10.0	13.0
5/30/2014	3	0.3	6.6	1.1	10.0	13.0
5/31/2014	2	0.8	2.0	1.3	10.0	14.0
6/1/2014	3	0.2	5.8	1.5	9.0	10.0
6/2/2014	2	0.0	0.0	1.4	10.0	12.0
6/3/2014	1	0.0	0.0	1.4	10.0	13.0
6/4/2014	1	0.0	0.0	1.2	11.0	17.0
6/5/2014	2	0.0	0.0	1.3	11.0	13.0
6/6/2014	3	0.0	0.0	1.4	12.0	13.0
6/7/2014	5	0.2	5.6	1.2	11.0	14.0
6/8/2014	2	0.0	0.0	1.2	11.0	15.0
6/9/2014	4	0.0	1.0	1.1	10.0	12.0
6/10/2014	2	0.0	0.0	1.2	10.0	13.0
6/11/2014	2	0.0	0.3	1.2	11.0	15.0
6/12/2014	4	0.0	0.0	1.1	11.0	13.0
6/13/2014	5	0.2	5.8	1.1	10.0	14.0
6/14/2014	2	0.0	0.0	1.0	11.0	14.0
6/15/2014	4	0.0	0.0	1.1	11.0	14.0
6/16/2014	5	0.2	0.4	1.2	11.0	13.0
6/17/2014	3	0.4	10.9	1.4	11.0	15.0
6/18/2014	4	0.0	0.0	1.3	11.0	14.0
6/19/2014	2	0.0	0.0	1.3	12.0	13.0
6/20/2014	2	0.0	0.0	1.3	12.0	12.0
6/21/2014	5	0.3	7.6	1.4	12.0	12.0
6/22/2014	4	0.0	0.0	1.3	12.0	14.0
6/23/2014	2	0.0	0.8	1.2	12.0	14.0
Total		3.0	52.6			
Avg.	3	0.1	1.4	1.3	10.2	13.7
Min.	1	0.0	0.0	0.8	8.0	10.0
Max.	5	0.8	10.9	3.0	12.0	17.0

ND indicates no data were collected for that time period.

Appendix 2: Daily Sockeye Smolt Migration, Leisure Lake 2014

Daily Migration

Date	No.	YTD Total	% of total run
5/8	3	3	0.00%
5/9	15	18	0.01%
5/10	53	71	0.03%
5/11	58	129	0.05%
5/12	65	194	0.07%
5/13	275	469	0.18%
5/14	1,849	2,318	0.87%
5/15	15,030	17,348	6.49%
5/16	23,517	40,865	15.29%
5/17	19,930	60,795	22.75%
5/18	23,815	84,610	31.66%
5/19	31,359	115,969	43.39%
5/20	30,758	146,727	54.90%
5/21	22,101	168,828	63.17%
5/22	11,969	180,797	67.65%
5/23	14,060	194,857	72.91%
5/24	10,876	205,733	76.98%
5/25	7,467	213,200	79.77%
5/26	9,710	222,910	83.40%
5/27	10,385	233,295	87.29%
5/28	2,455	235,750	88.21%
5/29	5,770	241,520	90.37%
5/30	3,118	244,638	91.53%
5/31	4,516	249,154	93.22%
6/1	3,931	253,085	94.70%
6/2	1,420	254,505	95.23%
6/3	817	255,322	95.53%
6/4	931	256,253	95.88%
6/5	744	256,997	96.16%
6/6	682	257,679	96.41%
6/7	707	258,386	96.68%
6/8	691	259,077	96.94%
6/9	841	259,918	97.25%
6/10	846	260,764	97.57%
6/11	587	261,351	97.79%
6/12	269	261,620	97.89%
6/13	252	261,872	97.98%
6/14	247	262,119	98.08%
6/15	382	262,501	98.22%
6/16	303	262,804	98.33%
6/17	1,488	264,292	98.89%
6/18	509	264,801	99.08%
6/19	992	265,793	99.45%
6/20	343	266,136	99.58%
6/21	798	266,934	99.88%
6/22	187	267,121	99.95%
6/23	142	267,263	100.00%

Appendix 3: Historical Limnological Data, Leisure Lake

Leisure Lake Water Quality Summary

	AVERAGE WATER QUALITY - 1 METER										AVERAGE WATER QUALITY - HYPOLIMNION						
Year	Sp. Cond (umhos/cm)	pH (SU)	Alk (mg/l)	Turb. (NTU)	TP (ug/l)	TKN (ug/l)	Chl a (ug/l)	EZD (m)	Secchi (m)	Zooplankton (mg/m2)	Sp. Cond (umhos/cm)	pH (SU)	Alk (mg/l)	Turb. (NTU)	TP (ug/l)	TKN (ug/l)	Chl a (ug/l)
1981	72.5	6.2	19.5		2.1	42.6	0.07				69.0	6.2	24.0		2.5	36.5	0.21
1982	78.4	7.3	26.4		5.9	95.4	0.27			102	78.6	7.2	26.6		4.7	90.0	0.40
1983	87.1	7.4	29.6		3.1	56.2	0.43			45	86.9	7.3	31.2		3.6	66.4	1.03
1984	80.6	7.4	30.0	1.2	6.9	97.5	0.95			66	84.6	7.1	28.0	1.0	4.5	73.7	0.56
1985	88.3	7.8	31.4	4.0	7.2	146.6	4.65			501	82.9	7.2	31.4	1.8	6.4	95.2	1.42
1986	80.4	7.9	29.1	2.3	9.5	140.1	2.33			615	84.9	7.0	28.1	1.2	4.2	71.3	0.54
1987	80.3	7.9	26.7	1.2	9.2	145.4	5.62			181	79.8	7.3	25.9	0.6	4.5	81.8	0.84
1988	77.8	7.6	23.7	1.6	7.1	101.2	5.40			318	80.6	7.2	25.1	0.9	6.3	67.4	2.66
1989	83.5	7.8	27.3	1.7	8.1	170.8	2.70			826	85.0	7.2	27.2	0.9	6.4	119.3	1.38
1990	84.6	7.7	28.9	1.6	6.3	101.0	0.53			966	84.8	7.3	27.9	0.8	3.7	62.6	0.49
1991	90.7	7.8	27.8	0.8	7.3	146.1	1.00			421	94.4	7.2	28.7	0.6	5.2	99.8	0.54
1992	91.4	7.5	27.2	1.4	8.5	149.6	3.05			1151	94.7	7.1	27.5	0.9	5.5	108.9	1.46
1993	93.6	7.5	27.9	1.1	9.9	170.9	3.35			615	95.4	7.1	29.0	0.8	7.0	116.2	2.58
1994	95.9	7.0	28.0	1.3	5.6	99.8	1.61			895	96.2	6.8	29.0	0.8	4.0	88.2	1.30
1995	91.3	7.7	29.0	1.9	10.1	132.7	2.05			1315	93.6	7.0	29.7	1.4	4.9	92.3	0.77
1996	98.5	7.5	31.5	1.0	7.4	122.9	2.16			1611	99.4	7.0	31.7	0.8	4.7	90.0	1.62
1997	96.5	7.9	32.4	0.8	8.7	135.2	2.27			1174	99.5	7.2	33.9	0.9	5.7	88.3	1.54
1998	88.3	7.5	28.9	1.3	7.2	154.8	1.86			817	89.6	7.2	29.1	1.7	6.0	145.9	0.96
1999	86.3	7.2	26.3	1.2	5.1	106.6	0.29			307	89.0	7.2	27.8	1.1	3.0	96.4	0.41
2000	92.3	7.2	27.6	1.1	8.3	126.0	2.43			447	93.9	7.0	28.2	1.0	3.8	85.4	3.03
2001	86.4	7.0	25.6	0.8	3.0	78.1	0.38			681	89.4	6.9	25.5	0.6	3.0	80.1	0.55
2002	83.5	7.1	28.2	0.7	10.9	123.3	3.66			327	87.6	7.0	28.9	0.6	7.8	125.4	2.63
2003	89.8	6.8	27.3	0.9	4.4	81.5	0.55	19.40	9.50	457	86.5	6.8	26.6	0.8	7.5	130.4	0.64
2004	85.0	7.1	27.9	1.0	18.5	209.3	1.74	20.40	5.90	713	85.3	6.9	27.9	7.5	35.0	300.3	1.86
2005	93.2	6.7	27.1	0.4	7.7	128.0	1.06	18.80	6.50	1399	92.2	6.8	27.0	0.9	9.2	147.7	1.13
2006	92.2	6.5	26.4	0.4	4.9	113.4	0.53	19.50	7.60	1217	93.1	6.6	26.7	0.4	5.2	116.0	0.53
2007	91.6	6.7	28.2	0.4	8.8	107.4	1.03	19.40	6.40	700	93.3	6.6	28.7	0.3	5.8	81.2	0.65
2008	86.2	7.2	27.6	0.8	10.1	83.0	0.49	14.80	6.70	228	87.2	7.1	27.6	1.1	6.5	74.7	0.78
2009	90.7	7.1	28.8	0.5	6.9	110.6	0.52	16.30	8.30	187	90.6	6.9	28.7	0.4	6.8	137.1	7.63
2010	87.9	7.1	26.0	0.6	4.7		0.80	17.30	5.90	157	91.0	6.8	27.4	0.4	5.2		4.97
2011	93.4	7.7	30.0	0.7	5.7		2.32	17.10	5.30	254	93.0	7.4	30.4	0.5	6.5		2.53
2012	92.6	7.5	28.5	0.6	6.0		2.34	20.80	5.80	319	95.1	7.4	29.5	0.5	4.4		1.34
2013	91.1	8.0	26.8	0.6	11.2		4.48	15.20	4.80	304	93.3	7.0	27.6	0.5	4.5		1.41
2014	95.7	7.5	30.4	0.6	9.1		2.32	18.50	3.70	619	95.1	6.9	30.1	0.4	5.3		1.53

Blank cells = no data were gathered for that parameter during the time specified.
Averages based off data from both sampling sites.

Appendix 4: Zooplankton Density Site 2, Leisure Lake, 2014

Macrozooplankton Density - Site 2 - Depth 35m–45m

(No/m2)

					Mean	Seasonal Mean
	19-Jun	**8-Jul**	**15-Aug**	**10-Sep**	(No/m2)	(No/m2)
Ergasilus						
Ovig Ergasilus						
Epischura						
Ovig Epischura						
Diaptomus	4,968	5,350	1,529	1,561		3,352
Ovig Diaptomus			191			48
Cyclops	15,669	20,637	9,554	10,255		14,029
Ovig. Cyclops			955	1,561		629
Bosmina	2,006	33,822	117,898	34,777		47,126
Ovig. Bosmina	4,777	13,185	33,439	1,561		13,241
Daphnia l.	7,261	28,854	159,363	313,439		127,229
Ovig. Daphnia l.	1,433	14,140	65,350	43,471		31,099
Daphnia g.						
Ovig. Daphnia g.						
Chydorinae	191		955	2,229		844
Ovig. Chydorinae	96			446		136

Blank cells indicate that the species indicated was not detected in the sample

Appendix 5: Zooplankton Density Site 5, Leisure Lake, 2014

Macrozooplankton Density - Site 5 - Depth 14m–18m

(No/m2)

					Mean	Seasonal Mean
	19-Jun	**8-Jul**	**15-Aug**	**10-Sep**	(No/m2)	(No/m2)
Ergasilus						
Ovig Ergasilus						
Epischura						
Ovig Epischura						
Diaptomus	2,293	3,822	1,529	510		2,039
Ovig Diaptomus						0
Cyclops	955	17,357	26,752	24,713		17,444
Ovig. Cyclops			4,968	8,153		3,280
Bosmina	4,682	22,930	172,357	128,408		82,094
Ovig. Bosmina	6,401	19,745	96,306	1,274		30,932
Daphnia l.		19,427	202,166	356,178		144,443
Ovig. Daphnia l.	191	4,299	95,541	1		25,008
Daphnia g.						
Ovig. Daphnia g.						
Chydorinae		637	4586	1529		1,688
Ovig. Chydorinae				764		191

Blank cells indicate that the species indicated was not detected in the sample

Appendix 6: Stocking and Adult Returns, Leisure Lake 1976–1989

Year	Fish Stocked (millions)[a]	Source	Age	Smolt Migration[b]	Age 1[c]	Age 2[c]	Age 3[c]	Adult Return[d]
1976	0.06	Glacier	Presmolt					
1977	0.092	Glacier	Presmolt	31,316	31,316			
1978	0.077	Glacier	Presmolt	49,900-66,900	48,000-65,000	1,900		
1979		Glacier	Fry	58,826	54,061	1,353	3,412	650
1980	0.53	Glacier	Fry	3,857	ND	3,857		14,000
1981	1.09	TUSTUMENA LK	Fry	240,659	240,658		1	11,500
1982	1.53	TUSTUMENA LK	Fry	319,502	315,176	4,326		3,400
1983	2.1	TUSTUMENA LK	Fry	416,940	326,643	90,297		90,420
1984	2.1	TUSTUMENA LK	Fry	229,222	177,678	51,544		117,360
1985	2	TUSTUMENA LK	Fry	178,100	46,500	131,600		65,930
1986	2.2	TUSTUMENA LK	Fry	372,000	220,000	152,000		18,800
1987	2	TUSTUMENA LK	Fry		861,000			23,700
1988	2.1	TUSTUMENA LK	Fry	>650,000	642,880			93,915
1989	2	TUSTUMENA LK	Fry					89,000

Blank cells indicate that: a=Fish were not stocked, b=No migration occurred or no count was made, c=Year class was not detected in samples, d=No adult return for that year

Appendix 7: Salmon Stocking, Leisure Lake 1990–2014

Brood Year	Fish Stocked (millions)	Brood Source	Age
1990	2.0	TUSTUMENA LK	Fry
1991	2.0	TUSTUMENA LK	Fry
1992	2.0	TUSTUMENA LK	Fry
1993	2.0	TUSTUMENA LK	Fry
1994	1.6	TUSTUMENA LK	Fry
1995	1.5	TUSTUMENA LK	Fry
1996	2.0	TUSTUMENA LK	Fry
1997	1.9	TUSTUMENA LK	Fry
1998	0.3	TUSTUMENA LK	Fry
1999	1.7	TUSTUMENA LK	Fry
2000	0.1	TUSTUMENA LK	Fry
2001	2.2	TUSTUMENA LK	Fry
2002	2.2	TUSTUMENA LK	Fry
2003	2.0	TUSTUMENA LK	Fry
2004	2.3	HIDDEN LK 244-30	Fry
2005	0.7	HIDDEN LK 244-30	Fry
2006	2.3	HIDDEN LK 244-30	Fry
2007	2.1	HIDDEN LK 244-30	Fry
2008	1.2	HIDDEN LK 244-30	Fry
2009	1.9	HIDDEN LK 244-30	Fry
2010	1.4	HIDDEN LK 244-30	Fry
2011		No Fish Stocked	
2012	2.1	HIDDEN LK 244-30	Fry
2013	1.8	HIDDEN LK 244-31	Fry
2014	1.4	ENGLISH BAY LAKES	Fry