Leisure Lake
Sockeye Salmon Enhancement
Progress Report
2016

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The 2016 Leisure Lake Project was made possible was made possible through enhancement taxes paid by the commercial fishermen in Area H, Cook Inlet and associated waters and through the harvest and sale of surplus fish.

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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 2016 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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ABSTRACT

The 2016 Leisure Lake smolt migration was enumerated from May 5 to June 12, 2016. A total count of 180,607 sockeye salmon smolt emigrated from Leisure Lake during this time period. A sample of 0.2% of the smolt population, n=360, were collected throughout the run of which the otoliths from n=359 were readable. Sampled smolt were assessed for fork length, weight, and aged; and the thermal mark determined via otolith analysis. Sampled smolt ranged in freshwater age from 1–3 years with age-2 comprising 73.2% (±4.6%) of the 2016 migration. Based on otolith data, the age-2 sockeye salmon smolt were determined to be from the 2014 stocking of 1,353,000 English Bay Lakes stock fry (0.24 g/fry; BY 13). The age-1 fish leaving in 2016, which comprised 26.8% (±4.6%) of the outmigration, resulted from the stocking of 1,051,000 English Bay Lakes stock fry (0.20g/fry; BY 14). An additional 0.3% of the outmigration was made up of age-3 BY 12 Hidden Lake stock released as 0.18 g fry in 2013. To estimate marine survival, adult sockeye salmon returns will be monitored and otoliths will be checked for thermal marking. Marine survival will be assessed via sampling of harvests in the commercial, and cost recovery 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 1.7 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 access to the stock as a brood source. In 2004, CIAA released the last fish from Tustumena Lake into Leisure Lake. After this, CIAA used the Hidden Lake stock from BY 2004–2012 and transitioned to the English Bay Lakes stock for BY 2013. During the summer of 2016, no sockeye salmon were stocked in Leisure Lake due to a shortage of available eggs. 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 and Dudiak, 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. In 2016, CIAA analyzed otoliths from a representative sub-sample of adult sockeye salmon harvested in the commercial purse seine fishery in China Poot Bay. Pending funding, CIAA also plans to analyze samples from the purse seine fishery in 2017–2018 as well. This will allow CIAA staff to determine the origin of the sockeye salmon and estimate the contribution to the commercial harvest and estimate marine survival rates of the sockeye 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.

This report provides data from the 2014–2016 smolt enumeration efforts, 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-east, east, and south-west sides of the lake, and several vernal streams. 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.

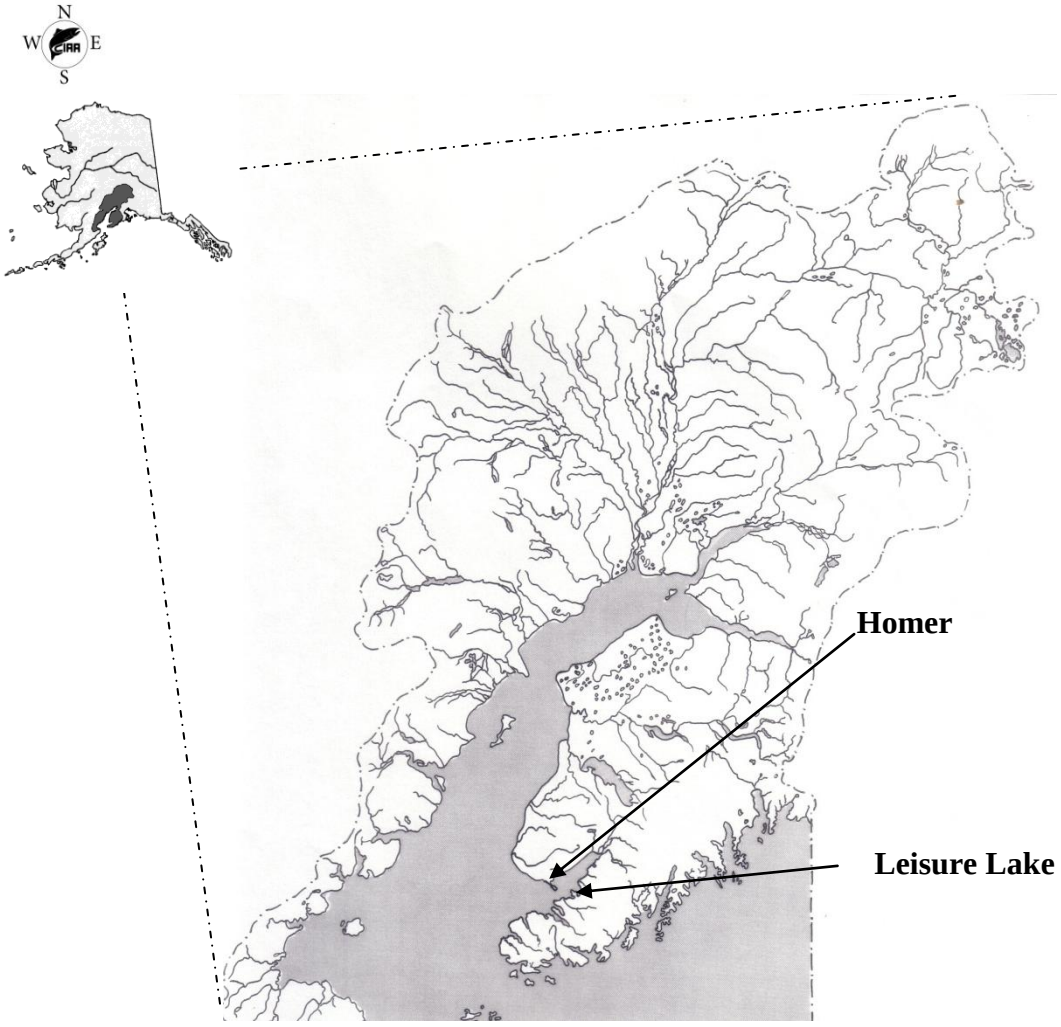

Figure 1: Leisure Lake in relation to Cook Inlet and Alaska

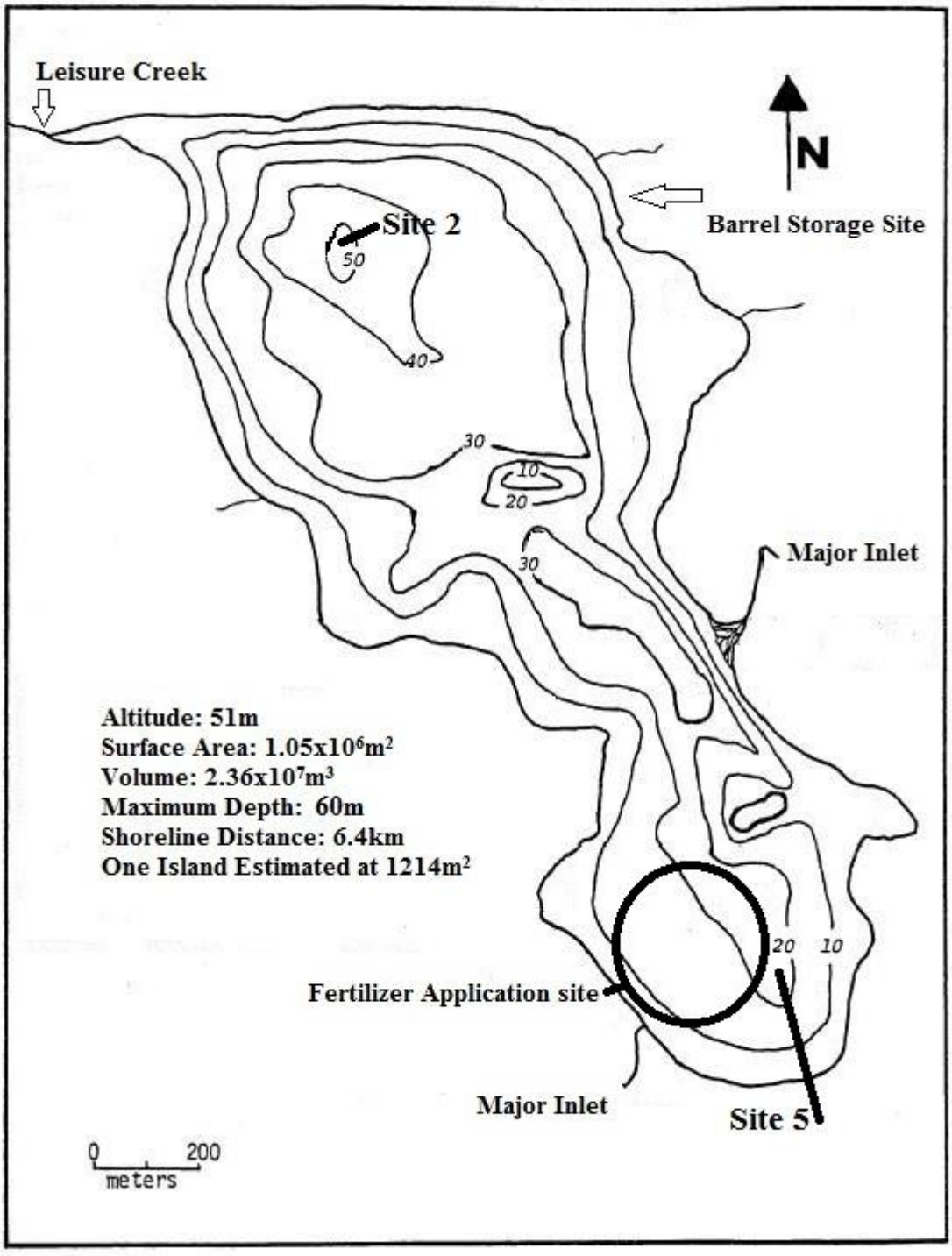

Figure 2: Bathymetric map of Leisure Lake

METHODS

Limnological Sampling & Environmental Conditions

During 2016, water quality samples were collected four times during the open water season on May 25, June 23, July 26, and August 23. 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 et al., 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, 2016).

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 random sample of the migrating smolts. The CIAA procedures manual sets forth a protocol for the collection of random AWL and otolith samples totaling 0.2% of the smolt outmigration, or every 500^{th} migrating smolt. Three-hundred and sixty sockeye smolt otoliths and AWL measurements were collected throughout the run. Of the otoliths collected, n=359 were readable, or 0.2% of the total outmigration. 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 from the smolt and placed in an ethyl alcohol solution for subsequent age determination at the CIAA lab (Glick and Shields, 1993). The Leisure Lake Smolt Procedures Manual outlines the AWL procedures (CIAA, 2016).

The sockeye smolt characteristic data regarding weight and length, 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 and no wild produced smolt were detected in any of the samples from 2014–2016, 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,

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

$f = n / N$, 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.

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

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

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

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

Confidence interval (90%) 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 in 2016 with no sub-sampling required.

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). To ensure that the appropriate dosage of fertilizer is applied to Leisure Lake, CIAA estimates the nitrogen and phosphorus application rate based on limnology samples from the previous year. The application rate may be adjusted based on the results of samples collected during the spring of the current year. Calculations made using the total phosphorus from this in-season analysis indicated no change in fertilizer dosage was needed.

RESULTS AND DISCUSSION

Limnological & Environmental Conditions

During the 2016 smolt migration, staff monitored environmental conditions at 5:00 PM from May 5 through June 12. Water levels in the creek were monitored for the same time period and water levels fluctuated 0.34 ft during that time period (Figure 3). Stream temperatures averaged 9.5ºC (±1.7ºC) [mean ± standard deviation] and ranged from 6.0 to 12.0ºC (Table 1). Air temperatures averaged 12.1ºC (±2.1 ºC) and ranged from 8.0 to 16.0ºC. Twenty-four percent of the days were clear, 26% were less than 50% cloud covered, 16% were more than 50% cloud covered, 32% were completely overcast and 39% had measured rainfall (Table 2). A total of 22.8 mm of rain fell during that period.

Table 1: Environmental summary, Leisure Lake, 2016

	Precipitation (mm)	Stage Height (ft)	Water Temperature (◦C)	Air Temperature (◦C)
Total	22.8			
Average	0.6	0.8	9.5	12.1
Minimum	0.0	0.6	6.0	8.0
Maximum	5.0	0.9	12.0	16.0

Table 2: Summary of cloud cover, Leisure Lake, 2014–2016

	Number of Days								Temperature (C)			
			<50%	>50%			Days		Air		Water	
Year	Total Days	Clear	Cloud Cover	Cloud Cover	100% Overcast	Rain	Measurable Precipitation	Precipitation (mm)	Average	Range	Average	Range
2014	50	22%	26%	20%	24%	8%	18	52.6	13.7	10.0–17.0	10.2	8.0–12.0
2015	48	33%	17%	17%	15%	10%	16	56.6	13.6	7.0–20.0	9.1	5.0–13.0
2016	38	24%	26%	16%	32%	3%	15	22.8	12.1	8.0–16.0	9.5	6.0–12.0

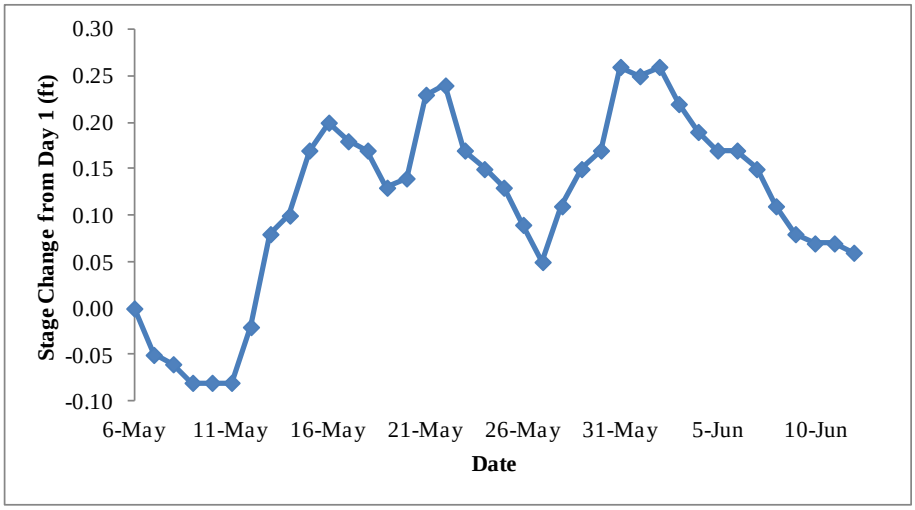

Figure 3: Stream fluctuations, Leisure Lake, 2016

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

Table 3: Nutrients and primary productivity, Leisure Lake, 2016

Date	Sta	Depth (m)	TP (ug/l)	TFP (ug/l)	FRP (ug/l)	TKN (ug/l)	NH3+NH4 (ug/l)	NO2+NO3 (ug/l)	TN:TP		RSi (ug/l)	Org C (ug/l)	Chla (ug/l)	Phaeo (ug/l)	Site	EZD (m)
5/25/2016	2	1	2.5	2.2	2.7	151.0	11.5	682.2	143.9	:1	2,979	199	0.83	0.26	2	19.9
5/25/2016	2	40	3.3	1.6	1.1	154.1	3.9	687.4	106.0	:1	3,013	89	0.28	0.14		
5/25/2016	5	1	12.5	1.5	1.1	188.4	0.0	683.5	33.4	:1	2,890	189	0.92	0.26	5	19
5/25/2016	5	15	6.1	1.5	1.0	188.7	3.1	679.6	69.6	:1	3,025	154	1.20	0.44		
6/23/2016	2	1	4.7	1.8	1.3	180.6	4.5	483.8	87.2	:1	2,473	181	0.96	0.40	2	17.8
6/23/2016	2	29	2.8	1.4	1.3	154.2	1.2	700.3	122.9	:1	2,973	69	0.53	0.34		
6/23/2016	5	1	19.7	7.1	6.8	290.1	36.2	552.0	36.7	:1	2,585	231	1.25	0.46	5	17.3
6/23/2016	5	17	3.5	2.3	1.3	179.0	12.3	651.7	121.0	:1	3,108	166	2.58	1.15		
7/26/2016	2	1	12.9	2.5	1.5	283.0	4.7	242.4	49.4	:1	1,700	552	6.05	1.72	2	13.6
7/26/2016	2	40	2.6	3.6	2.6	144.8	0.0	699.6	123.3	:1	2,997	58	0.43	0.19		
7/26/2016	5	1	11.0	3.6	2.2	281.9	2.8	240.5	57.3	:1	1,768	588	5.59	2.26	5	10.7
7/26/2016	5	14	3.4	2.1	1.1	183.6	5.1	607.8	122.9	:1	3,031	172	3.02	1.47		
8/23/2016	2	1	4.4	3.5	1.1	175.2	11.4	226.0	93.9	:1	1,241	266	4.27	0.91	2	13.5
8/23/2016	2	17	3.4	1.7	1.6	191.0	18.2	601.9	137.9	:1	3,391	161	2.96	1.42		
8/23/2016	5	1	4.1	1.6	1.0	185.7	10.2	223.4	105.5	:1	1,231	273	3.72	0.89	5	17.5
8/23/2016	5	40	1.8	2.2	0.8	112.9	6.2	679.9	146.5	:1	3,057	66	0.33	0.27		
Mean	1 - Meter		9.0	3.0	2.2	217.0	10.2	416.7	75.9	:1	2,108	310	2.95	0.90	Mean	16.2
Min			2.5	1.5	1.0	151.0	0.0	223.4	33.4	:1	1,231	181	0.83	0.26	Min	10.7
Max			19.7	7.1	6.8	290.1	36.2	683.5	143.9	:1	2,979	588	6.05	2.26	Max	19.9
Mean	Hypolimnion		3.4	2.1	1.4	163.5	6.3	663.5	118.8	:1	3,074	117	1.42	0.68		
Min			1.8	1.4	0.8	112.9	0.0	601.9	69.6	:1	2,973	58	0.28	0.14		
Max			6.1	3.6	2.6	191.0	18.2	700.3	146.5	:1	3,391	172	3.02	1.47		

Items Shaded in gray have values inconsistant with the models (total phosphorus is less than the sum of components)

Fertilizer Application

Approximately 300 gallons of fertilizer were applied weekly for nine weeks from June–August. During that time frame, 85 barrels totaling 2,550 gallons or approximately 15 tons of fertilizer were applied to Leisure Lake.

Table 4: General tests and metals, Leisure Lake, 2016

Date	Sta	Depth (m)	Sp. Cond (umhos/cm)	pH (SU)	Alk (mg/l)	Turb (NTU)	Color (Pt)	Ca (mg/l)	Mg (mg/l)	Fe (ug/l)	Secchi Sta	Secchi (meters)
5/25/2016	2	1	71	7.0	29.2	0.6	5	12.8	0.6	5	2	6.2
5/25/2016	2	40	73	7.0	28.0	0.2	6	13.2	0.0	< 3		
5/25/2016	5	1	73	7.3	28.1	1.1	6	13.6	0.6	5	5	7.5
5/25/2016	5	15	75	7.1	28.0	0.4	6	13.3	0.3	< 3		
6/23/2016	2	1	88	7.5	29.6	0.4	4	13.0	0.8	< 3	2	5.1
6/23/2016	2	29	88	7.1	28.9	0.2	6	13.2	0.0	3		
6/23/2016	5	1	90	7.5	29.2	0.9	4	13.4	0.3	3	5	5.3
6/23/2016	5	17	87	7.0	28.2	0.4	5	13.1	0.0	3		
7/26/2016	2	1	94	8.4	29.1	0.8	4	13.6	0.5	3	2	2.5
7/26/2016	2	40	92	7.0	28.4	0.4	5	13.3	0.2	< 3		
7/26/2016	5	1	95	8.7	29.5	1.1	4	13.2	0.9	11	5	2.3
7/26/2016	5	14	92	7.0	28.4	0.2	5	12.6	0.6	< 3		
8/23/2016	2	1	89	7.6	29.0	1.0	6	12.8	1.0	10	2	4.0
8/23/2016	2	17	86	6.6	30.3	0.3	6	13.2	0.0	8		
8/23/2016	5	1	90	8.0	29.5	0.8	5	12.9	0.9	7	5	3.0
8/23/2016	5	40	87	6.7	26.7	1.0	8	12.7	0.9	3		
Mean	1 - Meter		86	7.8	29.2	0.8	5	13.1	0.7	6	Mean	4.5
Min			71	7.0	28.1	0.4	4	12.8	0.3	3	Min	2.3
Max			95	8.7	29.6	1.1	6	13.6	1.0	11	Max	7.5
Mean	Hypolimnion		85	6.9	28.4	0.4	6	13.1	0.2	4		
Min			73	6.6	26.7	0.2	5	12.6	0.0	3		
Max			92	7.1	30.3	1.0	8	13.3	0.9	8		

Smolt Enumeration and Characteristics

The Leisure Lake smolt migration was enumerated from May 5 through June 12, 2016. During that time 180,967 sockeye salmon smolt were enumerated while migrating from Leisure Lake (figures 4 and 5). The peak migration was 22,385 smolt, which occurred on May 13. The daily and cumulative smolt migration for 2016 is depicted (in red) in figures 4–5 along with the smolt migration data averaged from 2014–2015 (in black) for comparative purposes.

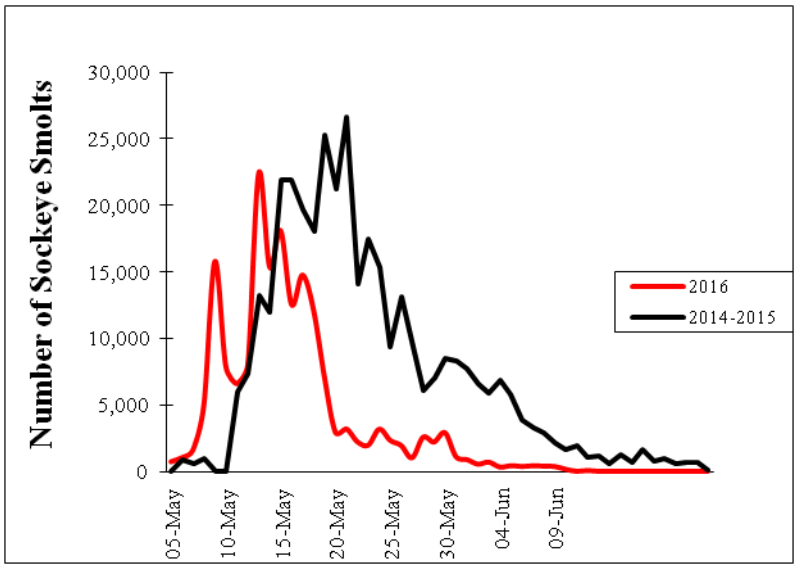

Figure 4: Daily smolt migration, Leisure Lake, 2014–2015 average, 2016

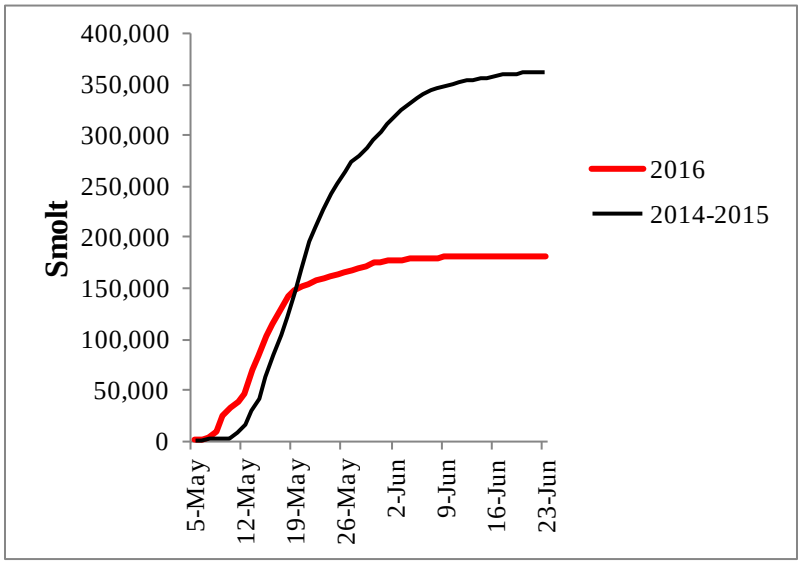

Figure 5: Cumulative smolt migration, Leisure Lake, 2014–2015 average, 2016

Throughout the migration, staff collected 360 sockeye salmon smolt (0.20% of total estimated population), and took otolith samples, weight, and measurements for fork length. Based on the 359 otolith samples that were readable, there were 3 age classes observed during the migration. Within the sample, age-2 was the most abundant age class comprising 73.2% (±4.6) of the outmigration, age-1 smolt accounted for 26.8% (±4.6) and age-3 smolt (only one sample) accounted for 0.3% (±4.6). The average length of the sampled age-1 sockeye salmon smolt was 77.1 mm (±0.2 mm) and the average weight was 3.81 g (±0.03 g). The average length of the age-2 sockeye salmon smolt was 95.8 mm (±0.1 mm) and the average weight was 7.11 g (±0.02 g) (Table 5).

Table 5: Sockeye salmon smolt AWL summary, Leisure Lake, 2014–2016

	Age Class (%)				Mean length (mm)				Mean weight (g)			
Smolt	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.
2014	3.4%	1.4%	96.6%	1.4%	77.1	3.3	94.5	0.8	4.09	0.56	6.85	0.18
2015	61.4%	4.4%	38.4%	4.4%	79.9	0.3	98.9	0.8	4.70	0.05	7.95	0.15
2016	26.80%	4.60%	73.20%	4.60%	77.1	0.2	95.8	0.1	3.81	0.03	7.11	0.02

Fish Stocking

No Sockeye salmon were stocked into Leisure Lake in 2016 due to a shortage of available eggs Table 6 summarizes stocking from 2012 to 2016.

Table 6: Stocking summary, Leisure Lake, 2012–2016

Brood Year	Brood Source	Species	Weight (g)	Number Released	Thermal Mark	Release Date
2011	Hidden Lake	Sockeye	0.18	2,074,000	2,2H	6/29/2012
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
2014	English Bay Lake	Sockeye	0.20	1,051,000	2,2H	6/9/2015
2015	None Available	NA	NA	0	NA	NA

NA=Not Applicable

Survival data are variable both between stocks, and between years. Although no clear trend regarding fry to smolt survival is apparent, BY-2013 English Bay Lakes stock experienced the highest fry to smolt survival during the study. Highlighting the variability, BY-2014 English Bay Lakes stock may have the lowest fry to smolt survival rate if the proportion of 2-year fresh water smolt in 2017 matches the age-1 and age-2 breakdown from 2015–2016. Because no smolt counts will take place at Leisure Lake in 2017, that proportion will not be known. Brood year survival is summarized in Table 7.

Table 7: Brood year survival comparison, Leisure Lake, 2011–2014

Hidden Lake Smolt

Brood Year 2011	Smolt Age	Smolt Total	Fry Released	Brood Year 2012	Smolt Age	Smolt Total	Fry Released
2012	0.0	ND		2013	0.0	ND	
2013	1.0	ND		2014	1.0	9,060	
2014	2.0	258,203		2015	2.0	177,332	
2015	3.0	778		2016	3.0	542	
Total		258,981	2,074,000	Total		186,934	1,800,000
Fry to Smolt Survival		**12.5%**		Fry to Smolt Survival		**10.4%**	

English Bay Lakes Smolt

Brood Year 2013	Smolt Age	Smolt Total	Fry Released	Brood Year 2014	Smolt Age	Smolt Total	Fry Released
2014	0.0	0		2015	0.0	0	
2015	1.0	283,109		2016	1.0	48,431	
2016	2.0	132,176		2017	2.0	ND	
2017	3.0	ND		2018	3.0	ND	
Total		415,285	1,353,000	Total		48,431	1,051,000
Fry to Smolt Survival		**30.7%**		Fry to Smolt Survival		**4.6%**	

ND=No data are available for that year

Gray shading indicates incomplete brood year

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RECOMMENDATIONS

CIAA will continue to monitor adult returns using otolith data from the commercial catches in 2017–2018 to estimate the marine survival of sockeye smolt counted between 2014 and 2016. Because all of the sockeye salmon leaving Leisure Lake and nearby Hazel Lake are thermally marked with unique patterns, CIAA will be able to identify Leisure Lake stock in the mixed-stock fishery.

In 2016 CIAA received water quality data during the season to aid in the adjustment of fertilizer calculations. While no adjustment was needed, CIAA would like to continue receiving these data in season to ensure that the fertilizer applications are appropriate for Leisure Lake.

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APPENDICES

Appendix 1: Environmental Conditions, Leisure Lake 2016

Date	Sky	Precip. (mm)	Staff Height (ft)	Stage Change (ft)	Water Temp. (◦C)	Air Temp. (◦C)
5-May					6	7
6-May	2	0.0	0.67	0.0	6	8
7-May	1	0.5	0.62	-0.1	6	9
8-May	4	0.5	0.61	-0.1	7	9
9-May	4	0.6	0.59	-0.1	7	10
10-May	4	0.0	0.59	-0.1	8	11
11-May	3	0.0	0.59	-0.1	8	15
12-May	2	0.0	0.65	0.0	8	11
13-May	1	0.0	0.75	0.1	8	15
14-May	2	0.0	0.77	0.1	8	14
15-May	1	0.0	0.84	0.2	9	14
16-May	4	0.0	0.87	0.2	9	10
17-May	2	0.0	0.85	0.2	9	12
18-May	2	0.0	0.84	0.2	9	12
19-May	4	0.0	0.80	0.1	9	10
20-May	4	5.0	0.81	0.1	9	12
21-May	3	0.9	0.90	0.2	9	10
22-May	3	0.4	0.91	0.2	8	10
23-May	1	3.0	0.84	0.2	9	10
24-May	1	0.0	0.82	0.2	9	13
25-May	4	0.0	0.80	0.1	9	12
26-May	1	0.0	0.76	0.1	10	13
27-May	1	0.0	0.72	0.0	10	15
28-May	1	0.0	0.78	0.1	10	13
29-May	3	0.0	0.82	0.2	10	13
30-May	2	1.3	0.84	0.2	11	14
31-May	3	0.7	0.93	0.3	11	15
1-Jun	4	0.0	0.92	0.3	11	13
2-Jun	4	0.0	0.93	0.3	12	13
3-Jun	2	0.0	0.89	0.2	11	11
4-Jun	5	1.0	0.86	0.2	12	12
5-Jun	2	1.9	0.84	0.2	10	11
6-Jun	4	2.0	0.84	0.2	11	11
7-Jun	2	0.6	0.82	0.2	11	13
8-Jun	1	0.0	0.78	0.1	11	16
9-Jun	2	0.0	0.75	0.1	11	13
10-Jun	4	0.0	0.74	0.1	12	13
11-Jun	4	4.2	0.74	0.1	12	12
12-Jun	3	0.2	0.73	0.1	11	12
Total		22.8				
Avg.		0.6	0.8	0.1	9.5	12.1
Min.		0.0	0.6	-0.1	6.0	8.0
Max.		5.0	0.9	0.3	12.0	16.0

*Gray shaded areas indicate no data was collected for that category

Appendix 2: Daily Sockeye Smolt Migration, Leisure Lake 2016

	Sockeye Smolt			
Date	Daily	Otoliths	Total	% Sampled
05-May	719	1	718	0.14%
06-May	1,029	2	1,745	0.19%
07-May	1,596	4	3,337	0.25%
08-May	4,999	6	8,330	0.12%
09-May	15,765	14	24,081	0.09%
10-May	7,875	29	31,927	0.37%
11-May	6,582	23	38,486	0.35%
12-May	7,966	12	46,440	0.15%
13-May	22,385	52	68,773	0.23%
14-May	15,350	22	84,101	0.14%
15-May	18,086	37	102,150	0.20%
16-May	12,529	31	114,648	0.25%
17-May	14,743	54	129,337	0.37%
18-May	12,145	0	141,482	0.00%
19-May	7,076	5	148,553	0.07%
20-May	2,932	9	151,476	0.31%
21-May	3,187	10	154,653	0.31%
22-May	2,225	9	156,869	0.40%
23-May	1,960	0	158,829	0.00%
24-May	3,169	7	161,991	0.22%
25-May	2,323	3	164,311	0.13%
26-May	1,938	2	166,247	0.10%
27-May	1,008	4	167,251	0.40%
28-May	2,564	4	169,811	0.16%
29-May	2,204	3	172,012	0.14%
30-May	2,899	5	174,906	0.17%
31-May	1,101	3	176,004	0.27%
01-Jun	883	3	176,884	0.34%
02-Jun	541	1	177,424	0.18%
03-Jun	689	2	178,111	0.29%
04-Jun	321	0	178,432	0.00%
05-Jun	420	1	178,851	0.24%
06-Jun	366	0	179,217	0.00%
07-Jun	416	1	179,632	0.24%
08-Jun	391	0	180,023	0.00%
09-Jun	366	1	180,388	0.27%
10-Jun	157	0	180,545	0.00%
11-Jun	3	0	180,548	0.00%
12-Jun	59	0	180,607	0.00%
Total	180,967	360	180,607	

Appendix 3: Historical Limnological Data, Leisure Lake

	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	43	0.1				69	6.2	24.0		2.5	36.5	0.2
1982	78.4	7.3	26.4		5.9	95	0.3			102	79	7.2	26.6		4.7	90.0	0.4
1983	87.1	7.4	29.6		3.1	56	0.4			45	87	7.3	31.2		3.6	66.4	1.0
1984	80.6	7.4	30.0	1.2	6.9	98	0.9			66	85	7.1	28.0	1.0	4.5	73.7	0.6
1985	88.3	7.8	31.4	4.0	7.2	147	4.7			501	83	7.2	31.4	1.8	6.4	95.2	1.4
1986	80.4	7.9	29.1	2.3	9.5	140	2.3			615	85	7.0	28.1	1.2	4.2	71.3	0.5
1987	80.3	7.9	26.7	1.2	9.2	145	5.6			181	80	7.3	25.9	0.6	4.5	81.8	0.8
1988	77.8	7.6	23.7	1.6	7.1	101	5.4			318	81	7.2	25.1	0.9	6.3	67.4	2.7
1989	83.5	7.8	27.3	1.7	8.1	171	2.7			826	85	7.2	27.2	0.9	6.4	119.3	1.4
1990	84.6	7.7	28.9	1.6	6.3	101	0.5			966	85	7.3	27.9	0.8	3.7	62.6	0.5
1991	90.7	7.8	27.8	0.8	7.3	146	1.0			421	94	7.2	28.7	0.6	5.2	99.8	0.5
1992	91.4	7.5	27.2	1.4	8.5	150	3.0			1,151	95	7.1	27.5	0.9	5.5	108.9	1.5
1993	93.6	7.5	27.9	1.1	9.9	171	3.4			615	95	7.1	29.0	0.8	7.0	116.2	2.6
1994	95.9	7.0	28.0	1.3	5.6	100	1.6			895	96	6.8	29.0	0.8	4.0	88.2	1.3
1995	91.3	7.7	29.0	1.9	10.1	133	2.0			1,315	94	7.0	29.7	1.4	4.9	92.3	0.8
1996	98.5	7.5	31.5	1.0	7.4	123	2.2			1,611	99	7.0	31.7	0.8	4.7	90.0	1.6
1997	96.5	7.9	32.4	0.8	8.7	135	2.3			1,174	100	7.2	33.9	0.9	5.7	88.3	1.5
1998	88.3	7.5	28.9	1.3	7.2	155	1.9			817	90	7.2	29.1	1.7	6.0	145.9	1.0
1999	86.3	7.2	26.3	1.2	5.1	107	0.3			307	89	7.2	27.8	1.1	3.0	96.4	0.4
2000	92.3	7.2	27.6	1.1	8.3	126	2.4			447	94	7.0	28.2	1.0	3.8	85.4	3.0
2001	86.4	7.0	25.6	0.8	3.0	78	0.4			681	89	6.9	25.5	0.6	3.0	80.1	0.6
2002	83.5	7.1	28.2	0.7	10.9	123	3.7			327	88	7.0	28.9	0.6	7.8	125.4	2.6
2003	89.8	6.8	27.3	0.9	4.4	82	0.6	16.6	7.5	457	87	6.8	26.6	0.8	7.5	130.4	0.6
2004	85.0	7.1	27.9	1.0	18.5	209	1.7	20.3	6.4	713	85	6.9	27.9	7.5	35.0	300.3	1.9
2005	93.2	6.7	27.1	0.4	7.7	128	1.1	18.8	6.5	1,399	92	6.8	27.0	0.9	9.2	147.7	1.1
2006	92.2	6.5	26.4	0.4	4.9	113	0.5	19.4	7.5	1,217	93	6.6	26.7	0.4	5.2	116.0	0.5
2007	91.6	6.7	28.2	0.4	8.8	107	1.0	19.3	6.0	700	93	6.6	28.7	0.3	5.8	81.2	0.7
2008	86.2	7.2	27.6	0.8	10.1	83	0.5	14.8	6.7	228	87	7.1	27.6	1.1	6.5	74.7	0.8
2009	90.7	7.1	28.8	0.5	6.9	111	0.5	16.7	8.0	187	91	6.9	28.7	0.4	6.8	137.1	7.6
2010	87.9	7.1	26.0	0.6	4.7	ND	0.8	17.2	5.8	157	91	6.8	27.4	0.4	5.2	ND	5.0
2011	93.4	7.7	30.0	0.7	5.7	ND	2.3	17.0	5.3	254	93	7.4	30.4	0.5	6.5	ND	2.5
2012	92.6	7.5	28.5	0.6	6.0	ND	2.3	20.7	5.8	319	95	7.4	29.5	0.5	4.4	ND	1.3
2013	91.1	8.0	26.8	0.6	11.2	ND	4.5	15.2	4.8	304	93	7.0	27.6	0.5	4.5	ND	1.4
2014	85.0	6.7	27.0	0.5	9.1	ND	2.3	18.5	3.7	587	92	7.0	28.5	0.8	4.7	ND	1.5
2015	90.3	7.2	27.5	0.7	6.6	220	1.3	17.9	4.1	142	88	7.0	28.6	0.7	5.9	109	1.9
2016	86.3	7.8	29.2	0.8	9.0	217	3.0	16.2	4.5	460	90	7.0	28.2	1.6	3.4	164	1.4

Blank cells = no data were gathered for that parameter during the time specified.

Averages based off data from both sampling sites.

Water quality data for 2014 has been amended to correct errors

Numbers reported from previous years have also been corrected to reflect an accurate number of significant figures

Appendix 4: Zooplankton Density Site 2, Leisure Lake, 2016

Macrozooplankton Density - Site 2 - Depth 60m
(No/m2)

	25-May	23-Jun	26-Jul	23-Aug	Mean (No/m2)	Seasonal Mean (No/m2)
Ergasilus						
Ovig Ergasilus						
Epischura		287				
Ovig Epischura						
Diaptomus	478	3,248	1,592	892	1,553	1,553
Ovig Diaptomus			159			
Cyclops	4,204	51,115	13,535	35,223	26,019	26,019
Ovig. Cyclops			318	6,242	3,280	1,640
Bosmina	510	6,401	20,541	101,656	32,277	32,277
Ovig. Bosmina	191	1,146	9,236	14,713	6,322	6,322
Daphnia l.	860	4,873	37,261	187,261	57,564	57,564
Ovig. Daphnia l.	255	1,720	12,898	60,191	18,766	18,766
Daphnia g.						
Chydorinae	96	96			96	48
Ovig. Chydorinae			159		159	40
Harpacticoid	32				32	8
Total:	6,626	68,886	95,699	406,178	146,067	144,236
Ave:	828	8,611	10,633	58,025	14,607	14,424
STDEV:	1,390	17,317	12,401	67,022	19,161	19,291

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

Appendix 5: Zooplankton Density Site 5, Leisure Lake, 2016

Macrozooplankton Density - Site 5 - Depth 27m
(No/m2)

	25-May	23-Jun	26-Jul	23-Aug	Mean (No/m2)	Seasonal Mean (No/m2)
Ergasilus						
Ovig Ergasilus						
Epischura						
Ovig Epischura						
Diaptomus	573	2,580	255	2,548	1,489	1,489
Ovig Diaptomus						
Cyclops	4,363	35,350	10,955	12,102	15,693	15,693
Ovig. Cyclops			382	3,822	2,102	1,051
Bosmina	987	3,917	18,471	124,204	36,895	36,895
Ovig. Bosmina		1,338	8,280	17,197	8,938	6,704
Daphnia l.	287	2,771	16,433	522,930	135,605	135,605
Ovig. Daphnia l.		96	3,822	71,338	25,085	18,814
Daphnia g.						
Chydorinae	64		1,019		542	271
Ovig. Chydorinae			127		127	32
Harpacticoid	64				64	16
Total:	6,338	46,052	59,744	754,141	226,540	216,569
Ave:	1,056	7,675	6,638	107,734	22,654	21,657
STDEV:	1,657	13,621	7,238	188,498	41,607	41,778

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

Appendix 6: Zooplankton Biomass Site 2, Leisure Lake, 2016

	Body Size - Site 2 - Depth 60m (mm)				Seasonal Means				
	25-May	**23-Jun**	**26-Jul**	**23-Aug**	Mean Length (mm)	Weighted Length (mm)	Biomass (mg/m2)	Weighted Biomass (mg/m2)	% by Species
Ergasilus									
Ovig Ergasilus									
Epischura		1.16			1.16	1.16	0.5	0.5	0%
Ovig Epischura									
Diaptomus	0.75	1.01	1.35	1.26	1.09	1.11	8.6	9.0	2%
Ovig Diaptomus			1.49						
Cyclops	0.69	0.92	1.08	1.06	0.94	0.98	81.6	89.5	24%
Ovig. Cyclops			1.22	1.20					
Bosmina	0.41	0.38	0.38	0.39	0.39	0.39	45.1	44.7	12%
Ovig. Bosmina	0.40	0.40	0.40	0.41	0.40	0.41	9.5	9.6	3%
Daphnia l.	0.67	0.63	0.79	0.75	0.71	0.75	125.9	143.3	39%
Ovig. Daphnia l.	0.79	0.89	1.00	0.90	0.90	0.92	67.9	71.5	19%
Daphnia g.									
Chydorinae	0.42	0.32							0%
Ovig. Chydorinae			0.31						0%
Harpacticoid	0.52								0%
TOTAL:							339.0	368.0	100%

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

Appendix 7: Zooplankton Biomass Site 5, Leisure Lake, 2016

	Body Size - Site 5 - Depth 27m (mm)				Mean Length (mm)	Weighted Length (mm)	Biomass (mg/m2)	Weighted Biomass (mg/m2)	% by Species
	25-May	**23-Jun**	**26-Jul**	**23-Aug**					
Ergasilus									
Ovig Ergasilus									
Epischura									0%
Ovig Epischura									
Diaptomus	0.74	0.92	1.33	1.37	1.09	1.11	8.2	8.7	2%
Ovig Diaptomus									
Cyclops	0.72	0.82	1.03	1.07	0.91	0.90	46.2	44.9	12%
Ovig. Cyclops			1.17	1.19	1.18	1.19	5.4	5.5	1%
Bosmina	0.39	0.38	0.39	0.37	0.38	0.37	49.5	46.9	13%
Ovig. Bosmina	0.39	0.43	0.41	0.40	0.41	0.40	10.3	10.1	3%
Daphnia l.	0.67	0.68	0.75	0.79	0.72	0.79	308.1	372.1	101%
Ovig. Daphnia l.	0.73	0.83	0.90	0.87	0.83	0.87	58.1	64.2	17%
Daphnia g.									
Chydorinae	0.31		0.34		0.33	0.34	0.1	0.1	0%
Ovig. Chydorinae			0.33		0.33	0.33	0.0	0.0	0%
Harpacticoid	0.64				0.64	0.64	0.0	0.0	0%
TOTAL:							486.0	552.6	100%

Appendix 8: 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 9: Salmon Stocking, Leisure Lake 1990–2015

Leisure Lake Sockeye Salmon Stocking				
Brood Year	Release Year	No. Released (Millions)	Brood Source	Age
1989	1990	2.0	Tustemena Lake	Fry
1990	1991	2.0	Tustemena Lake	Fry
1991	1992	2.0	Tustemena Lake	Fry
1992	1993	2.0	Tustemena Lake	Fry
1993	1994	1.6	Tustemena Lake	Fry
1994	1995	1.5	Tustemena Lake	Fry
1995	1996	2.0	Tustemena Lake	Fry
1996	1997	1.9	Tustemena Lake	Fry
1997	1998	0.3	Tustemena Lake	Fry
1998	1999	1.7	Tustemena Lake	Fry
1999	2000	0.1	Tustemena Lake	Fry
2000	2001	2.2	Tustemena Lake	Fry
2001	2002	2.2	Tustemena Lake	Fry
2002	2003	2.0	Tustemena Lake	Fry
2003	2004	2.3	Hidden Lake	Fry
2004	2005	0.7	Hidden Lake	Fry
2005	2006	2.3	Hidden Lake	Fry
2006	2007	2.1	Hidden Lake	Fry
2007	2008	1.2	Hidden Lake	Fry
2008	2009	1.9	Hidden Lake	Fry
2009	2010	1.4	Hidden Lake	Fry
2010	2011	NA	No Fish Released	
2011	2012	2.1	Hidden Lake	Fry
2012	2013	1.8	Hidden Lake	Fry
2013	2014	1.4	English Bay Lakes	Fry
2014	2015	1.1	English Bay Lakes	Fry
2015	2016	NA	No Fish Released	