Tustumena Lake
Sockeye Salmon Smolt
Progress Report
2015

Prepared by:
Rodney Hobby, Biologist
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The 2015 Tustumena Lake Sockeye Salmon Smolt Project was made possible through funding provided by the Alaska Department of Fish and Game (IHP88-228); a State of Alaska Legislative Grant (15-DC-364); and enhancement taxes paid by the commercial fishermen in Area H, Cook Inlet and associated waters.

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DISCLAIMER

The Cook Inlet Aquaculture Association (CIAA) conducts salmon enhancement and restoration projects in Cook Inlet (Area H) 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 activities conducted for the 2015 Tustumena Lake sockeye salmon smolt monitoring project.

The purpose of these progress reports is to provide a vehicle to distribute the information produced by the monitoring and evaluation activities. Data collected each year are presented with a summary of the information previously collected for comparative purposes. These reports are intended to provide a general description of project activity and are not an exhaustive evaluation of any fisheries project. The information presented in each report has not undergone an extensive review. As reviews are completed, the information may be updated and presented in later progress 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 2015 Tustumena Lake sockeye salmon smolt monitoring project. Appreciation is extended to Cook Inlet Aquaculture Association (CIAA) Seasonal Assistants Rodney Hobby and Kaitlyn Emelander and regular staff who invested many hours in planning and executing this project. Special thanks go out to the Alaska Department of Fish and Game and Alaska State Parks for their support during this project.

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ABSTRACT

The 2015 Tustumena Lake smolt migration was enumerated from May19 and continued daily until July 4. Field personnel captured and identified 319,156 sockeye salmon smolt (*Oncorhynchus nerka*), 3,373 coho salmon smolt (*O. kisutch*), 273 Chinook salmon smolt (*O. tshawytscha*), 90 pink salmon fry (*O. gorbuscha*), and 27 juvenile Dolly Varden (*Salvelinus malma*) using an inclined plane smolt trap. Numerous ninespine stickleback (*Pungitius pungitius*), eulachon (*Thaleichthys pacificus*), unspecified lamprey, and slimy sculpin (*Cottus cognatus*) were also captured and recorded as being present. Recorded trap mortality during the enumeration was 209 sockeye salmon smolt. Age, weight, and length samples (N=631) from migrating sockeye salmon smolt were collected throughout the run to determine age structure and physical characteristics of the population. Age structure was analyzed by scale evaluation to classify the proportion of migrating smolt into the following age classes: age-1 class 54% (±0.10%) and age-2 class 46% (±0.13%). A mark-recapture stratified sampling design was used six times throughout the season to estimate the abundance of the migrating sockeye salmon smolt population in which the estimated weekly capture probability, or trap efficiency, ranged from 0.64% to 5.98%. Through mark-recapture analysis the total sockeye salmon smolt migration was estimated to be 9,832,522 (±1,809,261). General environmental conditions were recorded daily for accumulated precipitation, water level fluctuations, and water temperature. Air temperature and percent cloud cover were estimated.

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INTRODUCTION AND PURPOSE

The Alaska Department of Fish and Game (ADF&G) began the Tustumena Lake sockeye salmon enhancement program in 1974. Fry stocking into Tustumena Lake began in 1976 from the resultant broodstock collection. Gamete collection occurred in Bear Creek, Glacier Flats Creek, and Seepage Creek in varying combinations over the development of the program. Over the years, the program progressed in such a manner that as many as 23.6 million eggs were collected and 17.1 million fry were released into Tustumena Lake. Up to eight other lakes were stocked with fry of Tustumena origin.

Initially, Tustumena Lake sockeye salmon enhancement activities were conducted at Crooked Creek Hatchery (CCH) and in July 1993, ADF&G transferred operation of CCH to Cook Inlet Aquaculture Association (CIAA). Under CIAA operation, CCH focused solely on sockeye salmon releases to Tustumena Lake, several lower Cook Inlet lakes, and Resurrection Bay. ADF&G continued to conduct enumeration activities associated with the Tustumena Lake smolt and adult sockeye salmon migrations while CIAA accepted responsibility to oversee and conduct the broodstock collection, incubation and rearing, and fry releases.

In November 1996, CIAA terminated operations at CCH, suspended stocking activities at five lower Cook Inlet lakes, and transferred the remaining stocking programs to its Trail Lakes Hatchery and Eklutna Salmon Hatchery. In 1998, CIAA became responsible for limnological sampling at Tustumena Lake and smolt monitoring in the Kasilof River.

In 2002, issuance of a permit for the Tustumena enhancement project was legally challenged. In 2004, the United States Fish and Wildlife Service was no longer able to provide CIAA with a permit to continue operations on Tustumena Lake and all enhancement activities were suspended; however, CIAA continued to enumerate the Tustumena Lake smolt migration in the Kasilof River, the outlet of Tustumena Lake. Hatchery-incubated sockeye salmon released as fry in 2004 were projected to migrate out of Tustumena Lake through 2006. Sampling procedures to estimate the hatchery contribution to the smolt migration were discontinued after 2006, but smolt enumeration activities continued in subsequent years as the smolt migration estimates were used by ADF&G to forecast future adult sockeye salmon returns to Tustumena Lake.

This report provides data from the 2015 smolt enumeration, as well as historical data regarding the previous years.

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PROJECT AREA

Tustumena Lake is located on the Kenai Peninsula in Southcentral Alaska (Figure 1). The lake is the largest on the Kenai Peninsula and the fifth largest lake in the state of Alaska. It is a glacial lake with a surface area of 294.5 km^2 (73,942 acres) It is approximately 40 km long and 8 km wide. The mean depth is 24 m, and the maximum depth is 320 m. The lake is fed by several clear water streams and two glacial streams originating in the Harding Icefield. The lake outlet is the Kasilof River, which flows 17.4 miles to Cook Inlet. Kasilof River is listed under the Anadromous Waters Catalog code 244-30-10050 (Johnson and Blanche, 2010) that indicates the river is recognized by ADF&G as an important stream for salmon spawning and migration. The 2015 salmon smolt enumeration occurred at the confluence of Crooked Creek and Kasilof River.

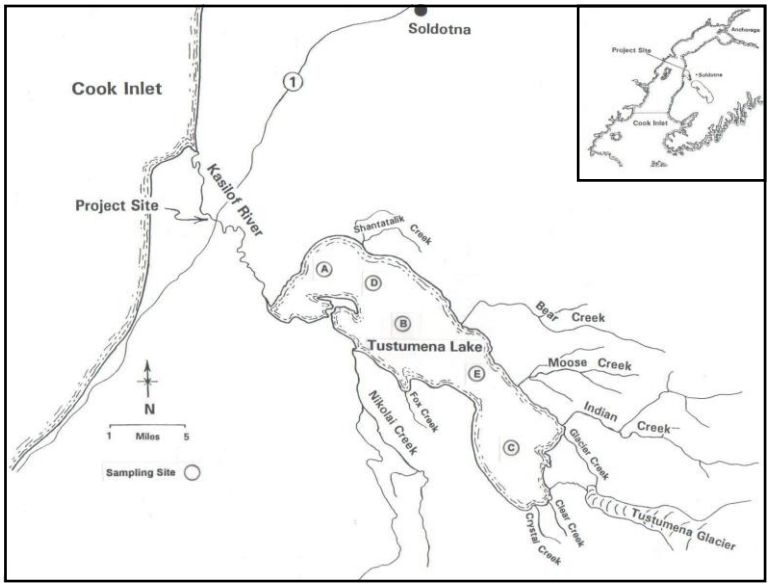

Figure 1. Tustumena Lake in relation to Cook Inlet
The circled letters are zooplankton sampling sites.

In 1992, Kyle characterized Tustumena Lake is oligotrophic with mean open-water season total phosphorus (corrected for turbidity and inorganic phosphorus), total Kjeldahl nitrogen and chlorophyll a concentrations of 3.7 μ/L, 155 μ/L, and 0.45 μ/L, respectively. The lake is turbid with glacial silt and light penetration is limited to the upper two meters and the euphotic zone is less than 1% of the lake's volume. The zooplankton community consists of two copepods, *Diaptomus pribilofensis* and *Cyclops columbianus.* Sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), Chinook salmon (*O. tshawytscha*), pink salmon (*O. gorbuscha*), and chum salmon (*O. keta*) are found in the Tustumena Lake system; however, it is mainly sockeye salmon that use the limnetic area of the lake. Resident fish species include rainbow trout (*O. mykiss*), lake trout (*Salvelinus namaycush*), Dolly Varden char (*S. malma*), threespine stickleback (*Gasterosteus*

aculeatus), coastrange and slimy sculpin (*Cottus aleuticus* and *C. cognatus*, and round whitefish (*Prosopium cylindraceum*) (Kyle, 1992).

METHODS

Environmental Conditions

To assess the environmental conditions during the sockeye salmon smolt migration personnel recorded estimated percent cloud cover, water level measured to the nearest tenth of a foot, precipitation measured to the nearest millimeter, and water and air temperatures measured to the nearest degree centigrade. All measurements were recorded at 5:00 PM each day per procedures manual for Tustumena Lake (CIAA Staff, 2015).

Zooplankton samples were collected by CIAA staff at the designated sample sites (Figure 1) in 2014 and 2015 for future reference. If there are any changes with the salmon population at Tustumena Lake, the zooplankton samples may be analyzed to help understand any anomalies.

Smolt Enumeration

To conduct the Tustumena Lake sockeye salmon smolt monitoring project, one inclined plane smolt trap, or collection facility, was placed near confluence of Crook Creek and mile 6.2 Kasilof River. The trap consisted of a double compartment live box (Figure 2) supported by a twin pontoon raft (Todd, 1994). The trap was operational on May 19 and was the focal point for enumeration of smolts/species, sub-sampling for smolt characteristics, and for determining trap efficiency until July 4.

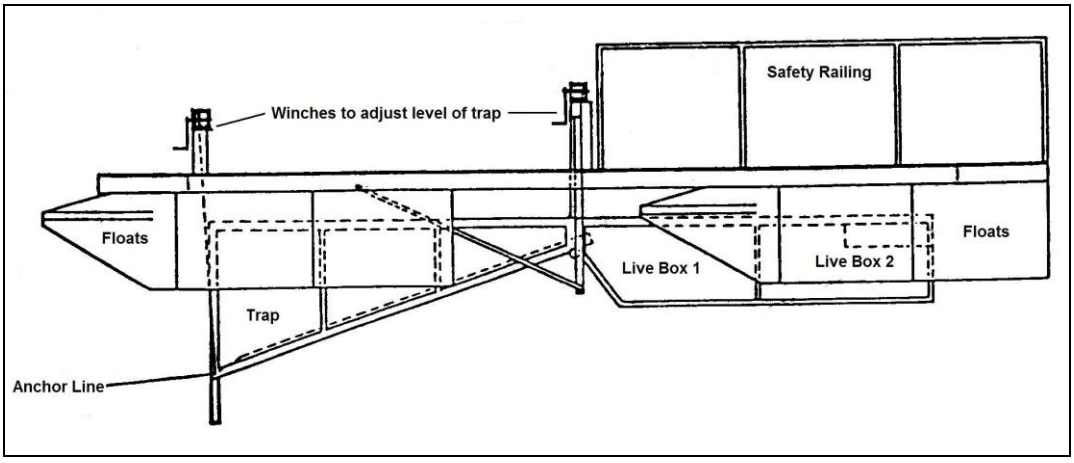

Figure 2. Schematic diagram of the Kasilof River smolt trap

Field personnel physically identified each fish by species and released the fish unharmed downstream of the trap to continue their migration. The daily capture count was used with trap efficiencies to determine the total estimated sockeye salmon smolt out-migration.

The mark-recapture technique used in this project involved a stratified sampling design in which approximately 1,000 sockeye smolt were color marked with dye and released from mile 7.1 once per week (Figure 3).

Figure 3. Smolt trap and release site, Kasilof River, 2015

Personnel conducted the mark-recapture tests weekly. Once the smolt were collected for the mark-recapture test, personnel transferred the fish into a container containing the dye solution Bismarck Brown Y (1 gram of dye per 30.4 liters of water) and monitored the health of the fish for approximately 45 minutes (Figure 4). Upon release, approximately 10–15 dyed smolt were set aside in a smaller container and monitored for an additional hour to record the quality of dye retention as well as vitality. Personnel monitored the number of daily recaptured dyed sockeye smolt at the trap for five days following release of dyed fish at mile 7.1. Any sockeye smolt mortality was not included in the total number released. The number of smolt recaptured in the trap was then used to estimate the proportion of migrating smolts captured (the trap capture efficiency) and the total estimated smolt migration.

Figure 4. Dyed sockeye salmon smolt for trap efficiency test, 2015

Statistical procedures for estimating the population of migrating smolts (*N*) followed the *simple stratified M-R design* for One-Site sampling experiments described by Carlson et al. (1998) where:

U = total unmarked population size;
N = total population size;
N_h = total population size in stratum h;
u_h = total number of unmarked smolts captured in stratum h;
M_h = number of marked smolts released in stratum h;
m_h = number of marked smolts recaptured in stratum h;
L = number of strata or periods; and

$$\hat{U} = \sum_{h=1}^{L} \hat{N}_h - M_h = \sum_{h=1}^{L} \frac{u_h\left(M_h + 1\right)}{m_h + 1}$$

The variance of the population estimate $v(N)$ and the 95% confidence interval (CI) were estimated as:

$$v(\hat{N}) = \sum_{h=1}^{L} v(\hat{N}_h) = \sum_{h=1}^{L} \frac{(M_h + 1)(n_h + 1)(M_h - m_h)(n_h - m_h)}{(m_h + 1)^2 (m_h + 2)};$$

And,

$$(CI) = \hat{N} \pm 1.96\sqrt{v(\hat{N})}\,.$$

This method assumes:

- All marked fish released upstream pass the trap before the next release of marked fish;
- The probability that a dyed or unmarked fish enters the trap equals the trap efficiency for all dyed or marked fish;
- Fish are captured or not captured in the trap independently of the fate of other fish;
- All fish entering the trap are counted, and;
- Trap efficiencies do not change substantially during the mark-recapture period.

The proportions of age-1, age-2, and age-3 smolt were calculated using the data computed from the aforementioned notations and formulas with the following notations and formulas:

U_i = total unmarked population size for age class = *i*;
U_h = total unmarked population size for stratum = *h*;
U_{hi}= total unmarked population size for age class *i*, in stratum = *h*;
P_i = proportion of unmarked smolt for age class = *i*;
P_h = proportion of unmarked smolt for stratum = *h*;
P_{hi}= proportion of unmarked smolt for age class = *i*, in stratum = *h*;
a_i = total number of samples of age class = *i;*

The estimated number of migrating age = i smolt was calculated as:

$$U_i = \sum U_h P_{hi}$$

Proportion of age = i smolt was calculated as:

$$P_i = \frac{1}{U} \sum U_h P_{hi}$$

The variance of the proportion of age = i smolt in stratum = h was calculated as:

$$v(P_{hi}) = \frac{P_{hi}(1 - P_{hi})}{a_h - 1}$$

The variance of the number of age = i smolt in stratum = h was calculated as:

$$v(U_{hi}) = U_h^2 v(P_{hi}) + P_{hi}^{\ 2}(U_h) - v(U_h)(P_{hi})$$

Therefore, the variance of the estimated number of age = i smolt was calculated as:

$$v(U_i) = \sum v(U_{hi})$$

Confidence intervals (95%) estimates for number of age = i smolts are:

$$U_i \pm 1.96\sqrt{v(U_i)}$$

Smolt Characteristics

To evaluate sockeye smolt characteristics, CIAA personnel collected a sample of sockeye smolt migrating from the lake to determine age, weight, and length characteristics of the population. Samples were collected daily by collecting every 500th sockeye smolt counted from the trap. Each sockeye smolt collected for evaluation was first measured to the nearest millimeter for fork length[1] and then weighed to the nearest 0.1 gram. Several scales were removed from the primary growth area[2] and mounted on a glass slide for subsequent age determination.

Sockeye smolt characteristics (average weight and length) for captured smolts were estimated with the following notations and formulas.

If:

y = weight or length of fish

c_i = number of age = i smolts sample

Mean weight or length was calculated as:

$$\bar{y}_i = \frac{\sum y_i}{c_i}$$

The standard deviation for weight and length of each age class was calculated as:

$$\sigma_{y_i} = \sqrt{\frac{c_i \sum y_i - \left(\sum y_i\right)^2}{c_i\left(c_i - 1\right)}}$$

Confidence intervals (95%) for the mean weight and length are, therefore:

$$\bar{y}_i = \pm 1.96\left(\frac{\sigma_{y_i}}{\sqrt{c_i}}\right)$$

[1]Standard fork length was measured from the tip of the snout to the fork of the tail.

[2]Located above the lateral line on a diagonal from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin.

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RESULTS AND DISCUSSION

Environmental Conditions

Environmental conditions were monitored daily from May 19 to July 4, 2015. During this period, water level fluctuated +2.15 feet (Figure 5); river temperatures averaged 9.2°C and ranged from 3 to 18°C. Air temperatures averaged 16.8°C and ranged from 11 to 28°C (Table 1). Seventeen percent of the days were clear, 30% were less than 50% cloud cover, 22% were more than 50% cloud cover and 24% were completely overcast (Table 2). A total of 46 mm of rain fell during this period.

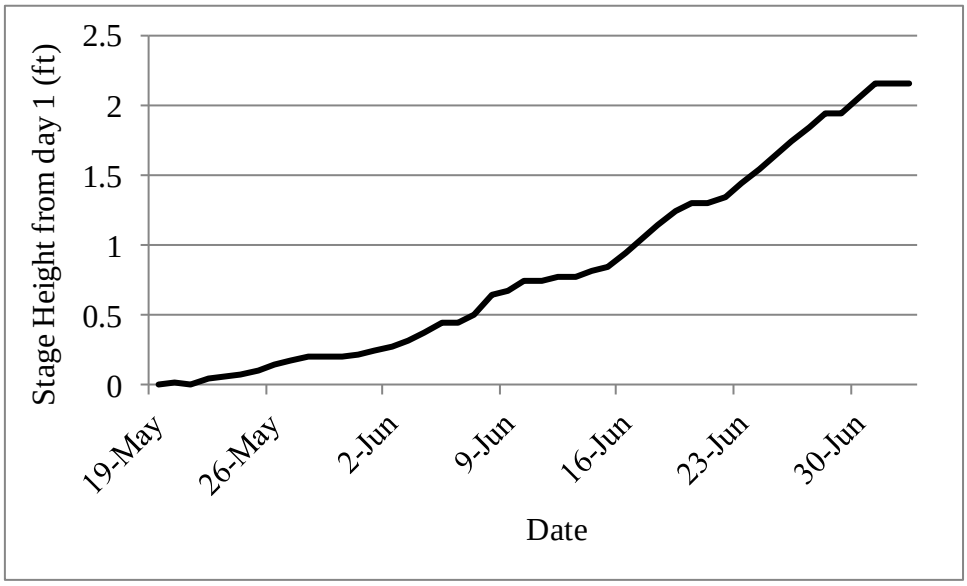

Figure 5. River stage, Kasilof River, 2015

Table 1. Environmental summary, Kasilof River, 2015

	Sky	Precip. (in)	Precip (mm)	Staff Gauge (ft)	Water Temp. (°C)	Air Temp. (°C)
Total		1.8	46.1	2.2		
Avg.	3	0.0	1.0	0.9	9.2	16.8
Min.	5	0	0	0	3	11
Max.	2	0.9	22.0	2.2	18.0	28.0

Table 2. Summary of cloud cover, Kasilof River, 2015

	No. Days	Percent of season
1 = Clear	8	17%
2 < 50% Clouds	14	30%
3 > 50% Clouds	10	22%
4 = Overcast	11	24%
5 = Rain	3	7%

Smolt Enumeration

The smolt migration was monitored daily from May 19 through July 4 (Figure 6). During this time, field personnel captured and identified 319,156 sockeye salmon smolt (*O. nerka*), 3,373 coho salmon smolt (*O. kisutch*), 273 Chinook salmon smolt (*O. tshawytscha*), 90 pink salmon fry (*O. gorbuscha*), and 27 juvenile Dolly Varden (*S. malma*). Numerous ninespine stickleback (*Pungitius pungitius*), eulachon (*Thaleichthys pacificus*), unspecified lamprey, and slimy sculpin (*Cottus cognatus*) were also captured and recorded as being present. Recorded trap mortality during the enumeration was 209 sockeye salmon smolt.

The highest recorded single day capture was on June 10 when field personnel counted and identified 37,438 sockeye salmon smolt (Figure 6). The peak of the total daily smolt trap capture was reached by June 3 when a total of 202,836 sockeye salmon smolt were counted and identified (Figure 7).

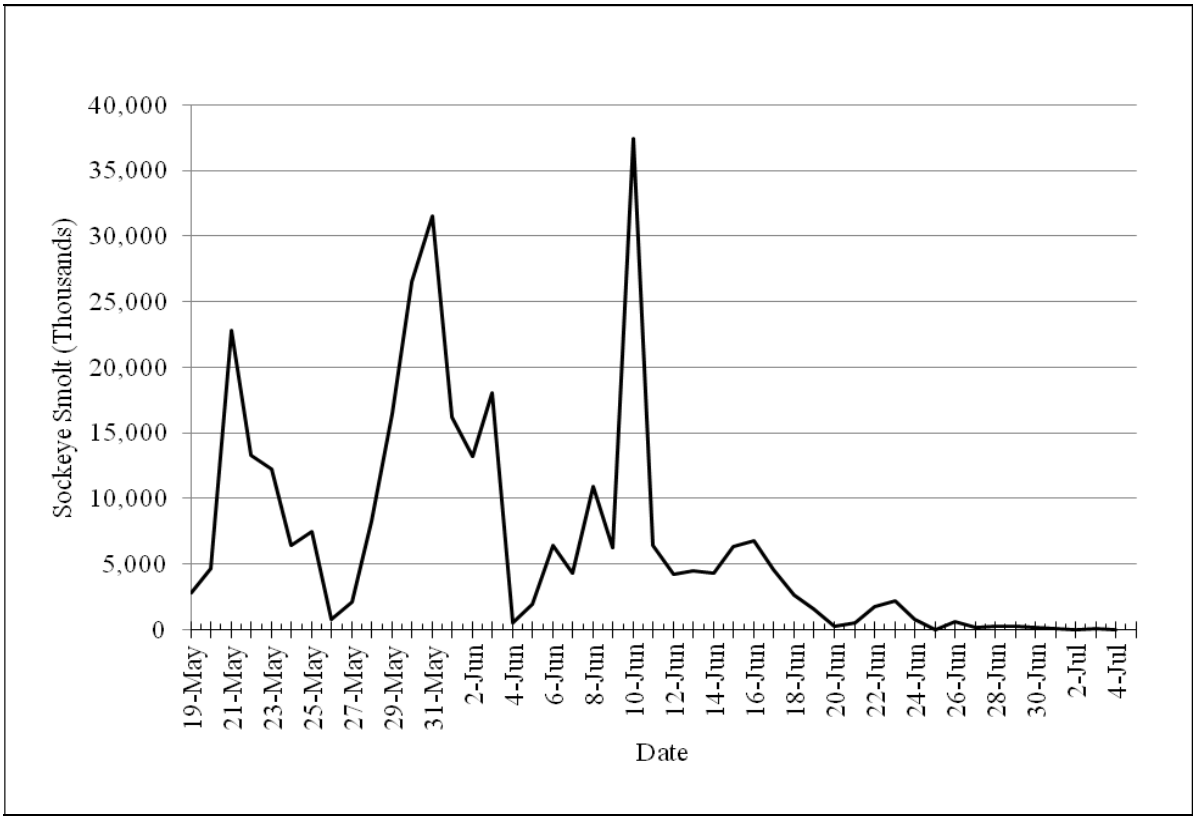

Figure 6. Daily trap capture, sockeye smolt, Tustumena Lake, 2015

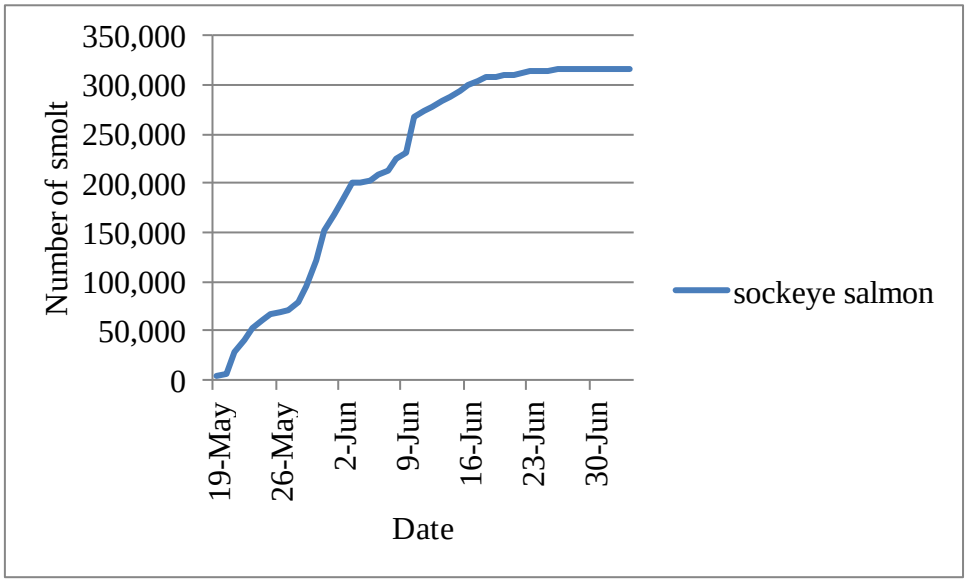

Figure 7. Cumulative trap capture, sockeye salmon smolt, Tustumena Lake, 2015

From May 21 through June 26, six mark-recapture tests were conducted estimating weekly trap efficiency ranging from 0.64% to 5.98% with an average of 3.87 (Appendix 3). The mark-

recapture analysis concluded the total sockeye salmon smolt migration from May 19 through July 4 was an estimated 9,832,522 (±1,809,261) sockeye salmon smolt (Table 3).

Table 3. Sockeye salmon smolt migrations and hatchery contribution, Tustumena Lake, 1998–2015

Year[a]	Total (million)	95% C.I.	Wild	Hatchery	% Hatchery	95% C.I.
1998	4.6	(±395,000)	3,872,000	727,000	15.8	(±2.2)
1999	4.5	(±461,000)	3,555,000	945,000	21.0	(±2.5)
2000	4.3	(±526,000)	3,986,000	316,000	7.4	(±1.8)
2001	5.3	(±612,000)	5,155,000	105,000	1.9	(±1.0)
2002	3.5	(±618,000)	3,474,000	0	0	0
2003[b]	12.9	(±2,437,000)	10,619,000	2,329,000	18.0	(±4.6)
2004	6.4	(±997,000)	3,155,000	3,140,000	49.9	(±12.6)
2005	11.2	(±2,152,000)	7,631,000	3,592,000	32.0	(±7.4)
2006	2.8	(±756,000)	2,833,000	10,600	0.4	(±0.5)
2007	3.2	(±832,000)	3,231,000	0	0	
2008	5.4	(±2,149,000)	5,418,000	0	0	
2009	3.6	(±885,000)	3,614,000	0	0	
2010	1.9	(±885,000)	1,949,000	0	0	
2011	ND	ND	8,282[c]	0	0	
2012	7.3	(±1,026,115)	7,383,018	0	0	
2013	7.0	(±2,697,000)	7,087,523	0	0	
2015	9.8	(±1,809,261)	9,832,522	0	0	
Avg	5.9		4,920,000	1,240,511	16.3	

ND = No Data
a. The project was not operated in 2014.
b. CIAA discontinued stocking program at Tustumena Lake in 2003 and remaining enhanced fish outmigrated by 2006.
c. This was the actual number of smolt counted; there were no results from the mark recapture study.

The Tustumena Lake smolt migration project it is a tool that can be use to predict future returns for (ADF&G) on the returning sockeye salmon stocks to Cook Inlet. During last four years of smolt monitoring at Tustumena Lake (2010, 2012–2013, 2015), CIAA personal have observed a shift in the timing of the smolt migration. For those years, there appears to be a shift in sockeye emigration timing with the 2015 outmigration occurring 14 days earlier than 2012 (Figure 7). According to the Kasilof weather station (Weather Underground 2015), there was a warming trend with the average mean temperature increase of 2.1°F since 2010 (Figure 8). The National Park Service monitoring program in Southwest Alaska Network (SWAN) shows the number of days Tustumena Lake is covered with ice (Table 4) through 2014 (NPS 2014). Although SWAN data for 2015 are not available as of this writing, it is suspected that warmer weather and no ice cover on Tustumena Lake led to an early migration in this year.

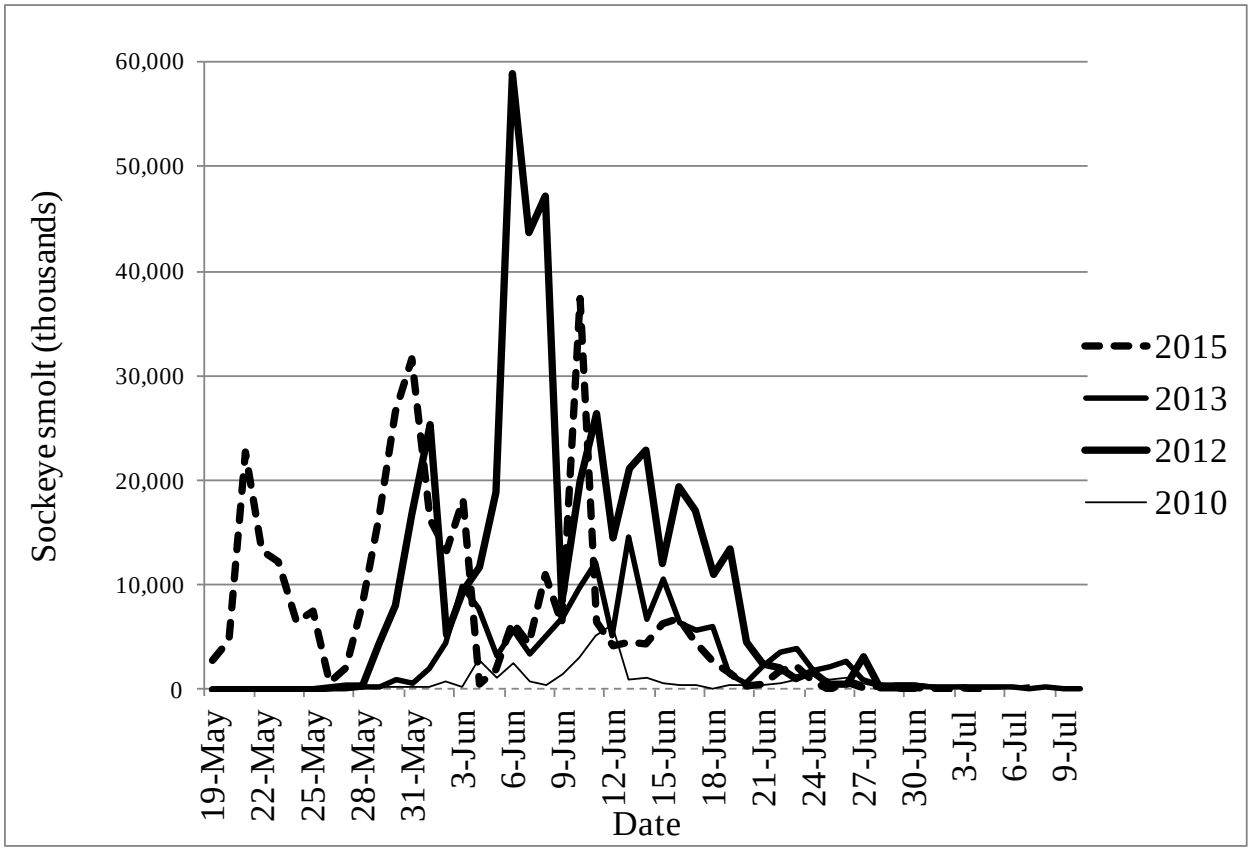

Figure 8. Daily sockeye smolt migration, Tustumena Lake, 2010, 2012, 2013, 2015

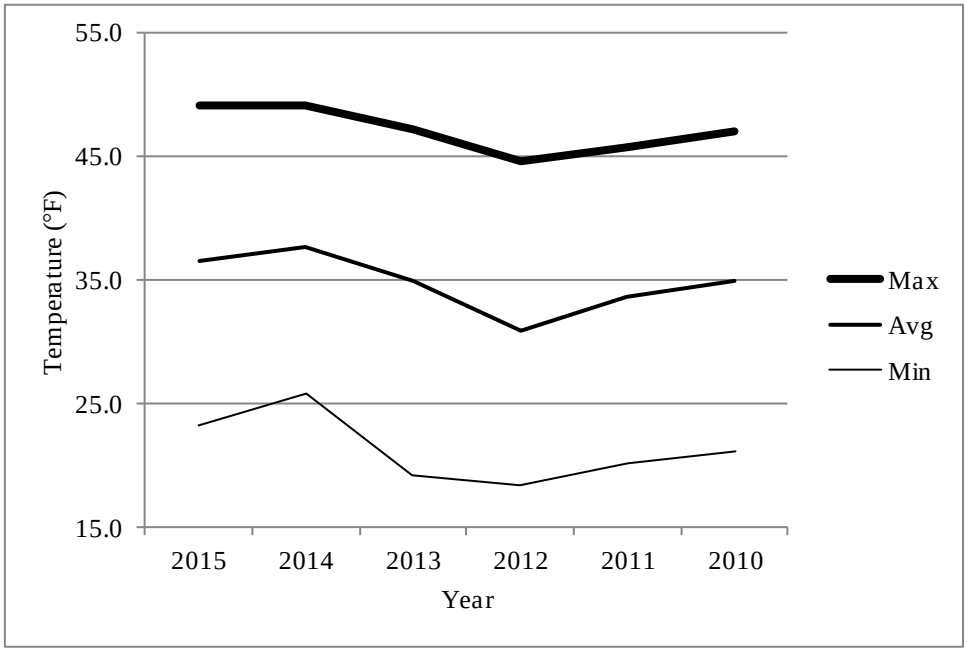

Figure 9. Average mean temperature for Kasilof, Alaska, 2010–2015

Table 4. Ice cover, Tustumena Lake, 2010–2014.

Year[a]	Freeze start	Freeze final	Breakup start	Breakup final	Number of ice days
2010	1/12/2010	1/29/2010	2/19/2010	4/20/2010	21
2011	12/18/2010	12/30/2010	4/24/2011	5/6/2011	126
2012	12/28/2011	1/4/2012	4/30/2012	5/5/2012	121
2013[b]	ND	ND	ND	ND	ND
2014	12/14/2013	no ice cover	no ice cover	4/2/2014	0

a. 2015 data not available
b. ND = no data collected

Smolt Characteristics

Age, weight, and length (AWL) samples (N=631) were collected from May 19 through July 4 from migrating sockeye salmon smolt to determine age structure and physical characteristics of the population. Age structure was analyzed by scale evaluation to classify the proportion of migrating smolt into the following age classes: age-1.0 class 54% (±0.10%) and age-2.0 class 46% (±0.13%) (Table 5). Sockeye salmon smolt in the age-1 class had an average weight and length of 5.19 g (±0.17 g) and 85.4 mm (±1.5 mm). Sockeye salmon smolt in the age-2 class had an average weight and length of 7.62 g (±0.19 g) and 98.9 mm (±1.5 mm). No measurements were collected on any other species. The 15-year and 5-year averages for age-1.0 class are 73%, and the age-2.0 classes are 27%. In 2015, the age-1.0 class was 54% and for age-2.0 class it was 46%. This may indicate that the age-2.0 fish are staying longer in the freshwater environment before migrating to sea, comparing to the historical data there were more age-1.0 age class leaving.

Table 5. Sockeye salmon smolt characteristics, Tustumena Lake, 1998–2013, 2015

	Age Class (%)				Mean length (mm)				Mean weight (g)			
Smolt Year	Age 1.0	95% C.I.	Age 2.0	95% C.I.	Age 1.0	95% C.I.	Age 2.0	95% C.I.	Age 1.0	95% C.I.	Age 2.0	95% C.I.
1998	80	(±2.8%)	21	(±2.8%)	75	(±0.4%)	85	(±1.0%)	3.8	(±0.1%)	5.4	(±0.2%)
1999	78	(±9.6%)	22	(±3.8%)	77	(±0.3%)	89	(±0.7%)	3.9	(±0.1%)	5.8	(±0.1%)
2000	81	(±11.5%)	19	(±4.2%)	73	(±0.3%)	86	(±0.7%)	3.2	(±0.1%)	5.0	(±0.1%)
2001	61	(±9.5%)	38	(±6.3%)	72	(±0.4%)	84	(±0.5%)	3.3	(±0.1%)	5.1	(±0.1%)
2002	39	(±24.1%)	61	(±24.8%)	74	(±0.4%)	82	(±0.6%)	3.7	(±0.1%)	5.2	(±0.1%)
2003	74	(±16.2%)	25	(±6.4%)	78	(±0.4%)	91	(±0.2%)	4.8	(±0.1%)	7.2	(±0.1%)
2004	65	(±13.3%)	35	(±8.1%)	79	(±0.4%)	92	(±0.6%)	4.3	(±0.1%)	6.6	(±0.1%)
2005	91	(±19.0%)	9	(±2.3%)	76	(±0.3%)	91	(±0.7%)	3.9	(±0.7%)	6.4	(±1.2%)
2006	91	(±26.3%)	9	(±3.6%)	82	(±0.9%)	98	(±2.3%)	4.5	(±0.1%)	7.4	(±0.6%)
2007	81	(±19.0%)	19	(±6.0%)	75	(±0.5%)	90	(±1.3%)	3.5	(±0.1%)	5.9	(±0.4%)
2008	79	(±32.0%)	21	(±19.0%)	78	(±0.8%)	96	(±1.4%)	3.9	(±0.1%)	7.1	(±0.3%)
2009	58	(±15.0%)	42	(±12.0%)	81	(±0.6%)	92	(±1.4%)	4.7	(±0.1%)	6.8	(±0.2%)
2010	88	(±27.0%)	12	(±42.0%)	83	(±0.7%)	103	(±2.2%)	5.0	(±0.1%)	9.0	(±0.5%)
2011	98	(±0.0%)	2	(±14.0%)	87	(±1.4%)	113	(±1.0%)	5.9	(±0.3%)	12.0	(±0.1%)
2012	68	(±0.0%)	31	(±0.1%)	87	(±0.3%)	101	(±0.6%)	5.8	(±0.2%)	12.3	(±2.5%)
2013	57	(±0.1%)	43	(±0.1%)	85	(±0.4%)	106	(±0.7%)	5.4	(±0.4%)	9.6	(±0.2%)
2015	54	(±0.1%)	46	(±0.1%)	85	(±1.5%)	99	(±1.5%)	5.2	(±0.2%)	7.6	(±0.2%)
15 Yr Avg	73		27		80		94		4.4		7.4	
10 Yr Avg	77		23		82		99		4.8		8.4	
5 Yr Avg	73		27		86		104		5.5		10.1	

Note: 2001 smolt migration included 1.1% (±0.07%) age class 3 smolt
Note: 2003 smolt migration included 1% (±0.8%) age class 3 smolt
Note: 2012 smolt migration included 0.5% (±0.9%) age class 3 smolt
Note: 2014 no funding for the smolt migration project

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RECOMMENDATIONS

Tustumena Lake is an important sockeye salmon producer in the Cook Inlet watershed. It is recommended that the Tustumena Lake sockeye salmon smolt enumeration project continue consistent with previous monitoring efforts in order to provide further comparative data and to compliment adult salmon monitoring performed by ADF&G. The collection of smolt migration data aids in the management of this important salmon-producing system.

The last couple of years the winters on the Kenai Peninsula were seasonally warmer than the previous years. From 2010–2015, there has been an air temperature increase of 2.1°F. During 2014 and 2015 Tustumena Lake was ice free. Because of this warmer weather, it is important to continue to monitor the smolt migration to identify changes to the Tustumena Lake sockeye smolt migration.

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APPENDICES

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Appendix 1. Environmental conditions, Tustumena Lake, 2015

Date	Sky	Precip. (mm)	Water Level (ft)	Water Temp. (◦C)	Air Temp. (◦C)
19-May	4	0	0.15	ND	12
20-May	3	0	0.17	ND	18
21-May	3	0	0.16	3	13
22-May	2	0	0.19	4	12
23-May	5	22.0	0.21	5	12
24-May	4	0.0	0.23	5	11
25-May	3	3.2	0.25	7	19
26-May	2	1.8	0.3	9	11
27-May	2	0.0	0.32	7	12
28-May	1	0.0	0.35	ND	15
29-May	1	0.0	0.36	10	18
30-May	1	0	0.36	14	19
31-May	1	0	0.37	13	18
1-Jun	3	0.0	0.39	13	17
2-Jun	3	1.8	0.42	5	12
3-Jun	2	1.6	0.47	5	13
4-Jun	4	0.5	0.52	5	15
5-Jun	4	7.3	0.59	5	13
6-Jun	5	3.0	0.60	8	14
7-Jun	3	1.3	0.65	9	13
8-Jun	3	0.5	0.80	7	15
9-Jun	5	0.6	0.82	7	13
10-Jun	3	0.4	0.90	8	14
11-Jun	2	0.0	0.90	8	16
12-Jun	2	0.0	0.92	6	17
13-Jun	2	0.0	0.93	12	22
14-Jun	2	0.0	0.96	14	25
15-Jun	1	0.0	1.00	15	28
16-Jun	2	0.0	1.10	17	28
17-Jun	1	0.0	1.20	18	24
18-Jun	2	0.0	1.30	13	21
19-Jun	2	0.0	1.40	7	22
20-Jun	4	0.0	1.45	7	15
21-Jun	4	0.0	1.45	7	14
22-Jun	2	0.0	1.50	10	18
23-Jun	2	0.0	1.60	10	16
24-Jun	3	0.0	1.70	9	19
25-Jun	2	0.0	1.80	7	18
26-Jun	4	1.4	1.90	7	13
27-Jun	4	0.2	2.0	9.0	18.0
28-Jun	4	0.1	2.10	12	18
29-Jun	4	0.3	2.10	10	19
30-Jun	3	0.1	2.20	10	17
1-Jul	4	0.1	2.30	12	16
2-Jul	1	0.0	2.30	11	17
3-Jul	1	0.0	2.30	14	23
Total		46			
Avg.		1	1.00	9	17
Min.		0	0.15	3	11
Max.		22	2.30	18	28

Summary of Cloud Cover - Percent of Days

No. Days	Meas. Rain	Overcast	Partly Cloudy	Clear
46	39%	30%	52%	17%

ND = No Data

1 = Clear
2 = Cloud Cover <50%
3 = Cloud Cover>50%
4 = Overcast
5 = Rain

Appendix 2. Daily smolt migration, Tustumena Lake, 2015

	Sockeye						Coho	Chinook	Pink	Chum	Dolly Varden
Date	Daily Capture	Total Capture	Daily Mortality	Trap Efficiency	Daily Estimate	Cumulative[a] Outmigration	No. Observed	No. Observed	No. Observed	No. Observed	No. Observed
19-May	2840	2,840	1	5.98%	47,489	47,489	4	1	26	0	0
20-May	4651	7,491	1	5.98%	77,771	125,259	24	1	3	0	27
21-May	22777	30,268	6	5.98%	380,861	506,121	108	0	9	0	0
22-May	13313	43,581	0	5.98%	222,611	728,731	33	0	9	0	0
23-May	12258	55,839	0	5.98%	204,970	933,701	103	0	3	0	0
24-May	6447	62,286	0	5.98%	107,802	1,041,504	59	0	6	0	0
25-May	7472	69,758	0	5.98%	124,942	1,166,445	76	3	3	0	0
26-May	746	70,504	0	5.98%	12,474	1,178,919	9	0	0	0	0
27-May	2069	72,573	0	3.25%	63,637	1,242,557	135	17	0	0	0
28-May	8240	80,813	1	3.25%	253,442	1,495,999	153	11	0	0	0
29-May	16453	97,266	0	3.25%	506,054	2,002,054	181	6	0	0	0
30-May	26537	123,803	0	3.25%	816,214	2,818,267	166	11	0	0	0
31-May	31556	155,359	0	3.25%	970,586	3,788,853	340	103	3	0	0
1-Jun	16216	171,575	40	3.25%	498,765	4,287,618	152	12	3	0	0
2-Jun	13169	184,744	0	3.25%	405,047	4,692,665	181	1	2	0	0
3-Jun	18092	202,836	29	3.25%	556,466	5,249,131	289	0	2	0	0
4-Jun	529	203,365	0	3.25%	16,271	5,265,402	12	0	1	0	0
5-Jun	1894	205,259	0	4.93%	38,428	5,303,830	190	8	2	0	0
6-Jun	6429	211,688	0	4.93%	130,441	5,434,271	104	4	7	0	0
7-Jun	4326	216,014	0	4.93%	87,772	5,522,043	58	1	1	0	0
8-Jun	10910	226,924	0	4.93%	221,358	5,743,401	76	8	0	0	0
9-Jun	6276	233,200	0	4.93%	127,337	5,870,738	115	9	3	0	0
10-Jun	37438	270,638	0	4.93%	759,597	6,630,335	113	6	2	0	0
11-Jun	6398	277,036	0	1.90%	337,074	6,967,409	28	3	2	0	0
12-Jun	4218	281,254	0	1.90%	222,222	7,189,631	83	6	3	0	0
13-Jun	4460	285,714	0	1.90%	234,972	7,424,603	53	3	0	0	0
14-Jun	4332	290,046	0	1.90%	228,228	7,652,831	78	16	0	0	0
15-Jun	6324	296,370	0	1.90%	333,175	7,986,005	57	6	0	0	0
16-Jun	6795	303,165	0	1.90%	357,989	8,343,995	51	10	0	0	0
17-Jun	4593	307,758	0	1.90%	241,979	8,585,973	77	10	0	0	0
18-Jun	2590	310,348	0	1.90%	136,452	8,722,425	15	3	0	0	0
19-Jun	1575	311,923	0	0.84%	187,228	8,909,654	35	4	0	0	0
20-Jun	228	312,151	0	0.84%	27,104	8,936,757	36	0	0	0	0
21-Jun	549	312,700	0	0.84%	65,262	9,002,019	26	0	0	0	0
22-Jun	1757	314,457	0	0.84%	208,863	9,210,883	41	6	0	0	0
23-Jun	2204	316,661	0	0.84%	262,001	9,472,883	39	2	0	0	0
24-Jun	788	317,449	0	0.84%	93,674	9,566,557	28	0	0	0	0
25-Jun	4	317,453	0	0.84%	476	9,567,032	1	0	0	0	0
26-Jun	650	318,103	131	0.64%	101,183	9,668,216	4	0	0	0	0
27-Jun	173	318,276	0	0.64%	26,930	9,695,146	2	0	0	0	0
28-Jun	256	318,532	0	0.64%	39,851	9,734,997	4	0	0	0	0
29-Jun	224	318,756	0	0.64%	34,869	9,769,866	6	0	0	0	0
30-Jun	200	318,956	0	0.64%	31,133	9,800,999	4	0	0	0	0
1-Jul	73	319,029	0	0.64%	11,364	9,812,363	2	0	0	0	0
2-Jul	13	319,042	0	0.64%	2,024	9,814,387	6	0	0	0	0
3-Jul	93	319,135	0	0.64%	14,477	9,828,864	16	2	0	0	0
4-Jul	21	319,156	0	0.64%	3,269	9,832,133	0	0	0	0	0
Total	319,156		209				3,373	273	90	0	27

a. Cumulative Migration has not been statistically evaluated and only serves as reference.

Appendix 3. Mark-recapture test and population estimates, Tustumena Lake, 2015

Event	Sample Period	Release Date & Time	Total Captured	Total Mortality	Total Dyed Released	Total Dyed Recaptured	Trap efficiency
1	5/21-5/26	5/21/15 11:25 PM	1,020	1	1,019	60	5.98%
2	5/27-6/1	5/22/15 11:25 PM	1,020	6	1,014	32	3.25%
3	6/6-6/11	6/6/15 12:30 AM	1,020	250	770	37	4.93%
4	6/11-6/16	6/11/15 12:00 AM	1,020	20	1,000	18	1.90%
5	6/19-6/23	6/19/15 12:00 AM	1,040	90	950	7	0.84%
6	6/26-7/2	6/26/2015 12:00AM	650	184	466	2	0.64%

Appendix 4. Estimate of the total smolt migration, Tustumena Lake, 2015

Estimate of the Total Smolt Migration for 2015											
Sample Periods			Total Caught During Sample Periods (nh)	Total Dyed Smolts Released M_h	Total Dyed Smolts Recovered m_h	Trap Efficiency eh (%) e_h	Migration Estimate of Unmarked Smolts N_h	Variance Estimate $v(U_h)$	$SE(U_h)$	95% C.L.
No. (=h)	begin	end								
1	19-May	26-May	70,504	1,019	60	5.98%	1,178,935	21,058,689,673	145,116	284,428
2	27-May	4-Jun	132,861	1,014	32	3.25%	4,086,512	475,077,455,788	689,259	1,350,947
3	5-Jun	10-Jun	67,273	770	37	4.93%	1,364,953	45,391,618,860	213,053	417,584
4	11-Jun	18-Jun	39,710	1,000	18	1.90%	2,092,142	214,596,272,442	463,245	907,961
5	19-Jun	25-Jun	7,105	950	7	0.84%	844,725	78,529,155,017	280,231	549,252
6	26-Jun	4-Jul	1,703	466	2	0.64%	265,255	17,446,417,632	132,085	258,886
Total			**319,156**	**3,803**	**147**	**3.87%**	**9,832,522**	**852,099,609,413**	**923,092**	**1,809,261**

Appendix 5. Tustumena Lake 2015 - Update

Smolt Migration			
Dates: 19-May to 4-Jul	No.	%	CI.
Sockeye			
Total Capture	319,156		
Trap Efficiency Range[a]	0.64 – 5.98		
Total Estimated Migration	9,832,522	100%	(± 1,809,261)
Mortalities	209	0.002%	
Estimated Age 1	314	54%	0.10%
Estimated Age 2	290	46%	0.13%
Coho	3,373		
Chinook	273		
Pink	90		
Dolly Varden	27		

a. Trap efficiency is designated for sockeye salmon. The other species are not included in trap efficiency.