Shell Lake
Sockeye Salmon
Progress Report
2017

Prepared by:
Andy Wizik[1]
Erik Schoen[2]
Michael Courtney[3]
Peter Westley[3]

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1. Cook Inlet Aquaculture Association, Kenai, AK
2. Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, AK
3. College of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Fairbanks, AK

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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 for Shell Lake. This Shell Lake Progress Report encompasses data collected from May 2012 through September 2017 as well as some historical data gathered by CIAA and the Alaska Department of Fish And Game (ADF&G).

The purpose of this progress report is to provide a vehicle to distribute the information produced by the monitoring and evaluation studies. 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 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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ACKNOWLEGEMENTS

Many individuals and agencies contributed to the success of the Shell Lake Project. Appreciation is extended to seasonal assistants Jon Shivel, Olga Shivel, the many Shell Lake residents who have supported the project, Trail Ridge Aviation, and the regular CIAA staff that provided support. Special thanks go to the Matanuska-Susitna Borough and the Alaska Sustainable Salmon Fund for providing funding; the University of Alaska Fairbanks; and the Alaska Department of Fish and Game for the support they provided during this project, including but not limited to their assistance with disease sampling, northern pike aging, and stomach content analyses.

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ABSTRACT

This progress report summarizes the 2017 sockeye salmon (*Oncorhyncus nerka*) smolt and adult enumeration and research and control of northern pike (*Esox lucius*) at Shell Lake in the Yentna River Drainage. Between May 23 and June 21, 15 sockeye smolt and 6 coho smolt were enumerated as they emigrated from Shell Lake. Due to the low number of smolt, no samples were collected. A video weir was installed at Shell Lake on July 10 and ran continuously until the September 23 except for a 12-hour period on July 21 when a breaker was tripped. From July 21–September 23, 575 sockeye and 411 coho salmon passed the weir. Approximately 30,000 eggs were fertilized with milt collected from 25 females and 14 male sockeye salmon from Shell Lake on September 25. Kidney, gill, and ovarian fluid samples were collected from the fish used as broodstock and sent to the Alaska Department of Fish and Game Fish Pathology Laboratory. Otolith samples were also collected from the 39 adult sockeye salmon used as broodstock as well as from 12 sockeye salmon carcasses found throughout the lake. These 51 samples indicated that 88.2% of the salmon were from age 1.3 fish reared at the Trail Lakes Hatchery and released in 2014 and 11.8% were wild-produced fish—age 1.2 (2.0%), age 1.3 (2.0%) and age 2.2 (7.8%).

Using gillnets (during the open water season and under the ice during spring), and hoop nets, a total of 780 northern pike were harvested. Data were collected regarding age (695), sex (737), length (736), and weight (737). Fifty-one percent of the harvested northern pike with distinguishable sexual characteristics were males and 49% were females. Northern pike lengths ranged from 150 mm to 1,090 mm with an average length of 360 mm (±57 mm) for males and 388 mm (±74 mm) for females. Mean weight for the northern pike males was 0.39 kg (±0.17 kg) and 0.52 kg (±0.82 kg) for females. Stomach contents were analyzed for 127 of the harvested pike and contents of non-empty stomachs were weighed (g) and identified. Of the stomach contents analyzed, 63% were empty and 37% had food items identified and weighed. Salmonids were identified in 11 of the pike stomachs representing 34.3% of the total wet mass of all of the contents. No data was collected for the estimated 20–40 northern pike caught using gillnets under the ice due to advanced decomposition. The mean length and weight of harvested pike has decreased for most year classes from 2014–2016 but rose slightly in 2017. The average of recorded ages of captured northern pike in Shell Lake has decreased from 2.32 years in 2014, to 1.03 years in 2017. Decreases in northern pike mean lengths and weights suggest that suppression may be increasing the proportion of smaller northern pike in Shell Lake The average age of northern pike indicate that this population is being skewed younger by intensive netting activities. Because the literature indicates that smaller northern pike tend to eat more juvenile salmon Cook Inlet Aquaculture Association partnered with the University of Alaska Fairbanks fisheries scientists to determine what impacts CIAA netting is having on the Shell Lake northern pike and salmon populations. The models developed through that analysis indicates CIAA's netting effort has reduced the potential of northern pike predation on Shell Lake smolt by 81% since 2012. UAF also concluded that suppression strategies targeting all size classes of pike are more likely to be effective at reducing consumption of salmon.

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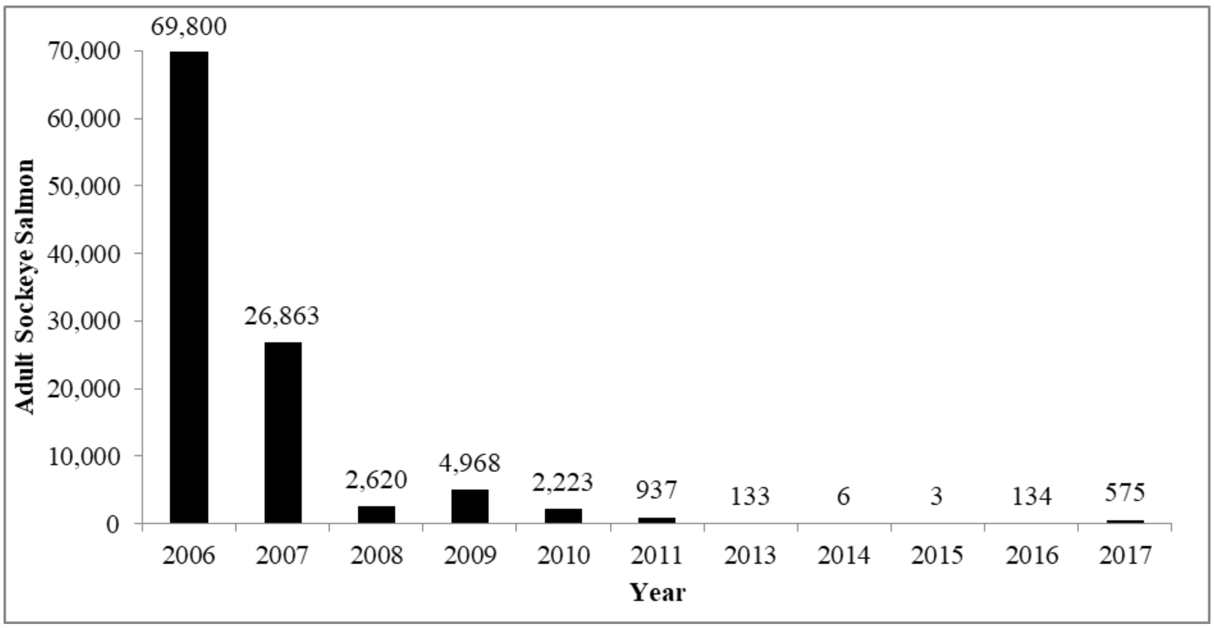
INTRODUCTION AND PURPOSE

In Southcentral Alaska invasive northern pike (*Esox lucius*) have been introduced and spread into several sockeye salmon streams and rearing lakes. This is a troubling trend because northern pike are an aggressive piscivorous fish that can have negative impacts on salmon populations. In the Susitna Valley, it is hypothesized that northern pike are a factor that may be driving salmon declines in some areas within the watershed (Sepulveda et al., 2013). Natural sockeye salmon (*Oncorhynchus nerka*) production in Shell Lake (which also has invasive northern pike) have declined precipitously since 2009 (Figure 1).



*No weir count was available for 2012

Figure 1: Weir counts at Shell Lake, 2006–2011, 2013–2017.

As part of the continued evaluation of lakes in the Susitna River watershed to determine the sockeye salmon abundance in key salmon producing lakes with and without northern pike, Cook Inlet Aquaculture Association (CIAA) and the Alaska Department of Fish and Game (ADF&G) agreed to monitor sockeye salmon smolt migrations from Shell Lake from 2007 to 2012 and adult returns to the lake from 2006 to 2007. Between 2013 and 2017, CIAA continued to monitor both smolt and adult salmon and harvest northern pike from Shell Lake and anticipates this project will continue in the future.

In addition to salmon monitoring and northern pike harvest, CIAA performs beaver dam surveys on several streams important to salmon migration in the Susitna Valley including Shell Creek. Using helicopters CIAA staff surveys the entire length of Shell Creek looking for the presence of beaver dams. If salmon are gathered near the bottom of the dams and they are deemed too high for the salmon to pass upstream, staff removes a 3–5 ft wide section of the dam using hand tools allowing the salmon below the dams to pass.

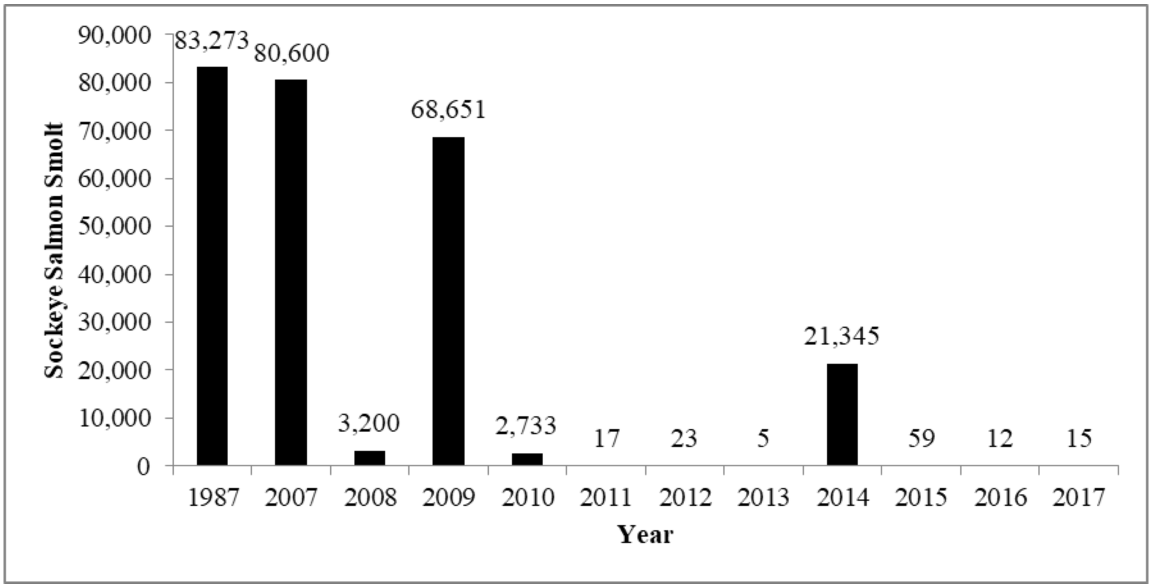
Shell Lake was once a significant contributor to sockeye production in the Susitna River watershed. Based on a euphotic volume model, Shell Lake can potentially contribute approximately 10% to the sockeye salmon return to the Susitna River watershed (Tarbox and Kyle, 1989). While euphotic volume is not always a good predictor of production, it does give a relative estimation of available sockeye rearing habitat and Shell Lake, along with Chelatna, Judd, and Hewitt lakes, have long been considered top producers of sockeye in the Yentna system (King & Walker, 1997).

Another way to consider Shell Lake's significance to salmon abundance is to look at the inriver abundance estimates from the Susitna and compare it to Shell Lake estimated escapement. Total estimated inriver abundance estimate from 2006 to 2011 for the Susitna is 1,774,326 sockeye salmon (Willette et al., 2016; Yanusz et al., 2007; Yanusz et al., 2011a; Yanusz et al., 2011b). Total estimated escapement to Shell Lake during the same time period is 107,411 sockeye salmon (Wizik, 2016). Based on these data Shell Lake represents 6.1% of the sockeye salmon return to the Susitna between 2006 and 2011.

Because of the notable decline in smolt leaving Shell Lake starting in 2010 (Figure 2) and a similar trend in adult counts, CIAA decided to initiate rehabilitation efforts using funds from the Salmon Enhancement Tax and cost recovery licensing. Beginning in 2012, the project included smolt and adult enumeration, salmon stocking, disease screening, harvesting of invasive northern pike, beaver dam surveys and removal, and the evaluation of what effect that harvest of northern pike may have on both northern pike and salmon populations in terms of numbers and characteristics.

In 2011, several pre-spawning mortalities among sockeye salmon in Shell Lake were noted. Though most of the fish appeared healthy and had no obvious external lesions, several samples taken from Shell Lake pre-spawning sockeye salmon were sent to the ADF&G pathology lab for examination in 2012. The necropsy revealed that *Loma salmonae* was most likely the cause of the majority of the pre-spawning mortality of the Shell Lake sockeye sent for examination. The pathology report was completed in 2012 and amended in 2013 (Bentz and Ferguson, 2013).[4] The complete amended pathology report can be found in Appendix 8.

4. The report was amended by ADF&G after Jayde Ferguson consulted an expert in the field and determined that the renal myxozoans in the figures were not likely the PKX myxozoan and were instead two different species—*Sphaerospora* sp. in the lumen and *Chloromyxum* in the epithelium.



*Data for 2014 includes stocked smolt released in 2014

Figure 2: Sockeye smolt counts 1987, 2007–2017.

Under the Trail Lakes Hatchery Basic Management Plan, CIAA initiated efforts to maintain the genetic lineage of the Shell Lake sockeye population through the collection of broodstock and gametes and back stocking to Shell Lake. The goal of this effort is to rebuild the Shell Lake sockeye salmon population to a sustainable level. Gametes were collected in 2012, 2016, and 2017. From 2013–2015, adult returns were insufficient to allow gamete collection.

This progress report describes the 2017 monitoring of sockeye salmon smolt and adults at Shell Lake, gamete collection, surveying of beaver dams, a bioenergetics modeling of Shell Lake northern pike using data collected from 5 seasons of intensive harvesting, and the salmon stocking efforts from 2012–2017. Other historical data are provided for reference.

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PROJECT AREA

Shell Lake is located in the Yentna River basin of the larger Susitna River drainage (Figure 3). Shell Lake is listed as an anadromous waterbody in the Anadromous Waters Catalog number 247-41-10200-2053-3205-4052-0010 (Johnson and Blanche, 2010), and is recognized by ADF&G as an important water body for salmon spawning and migration. The lake covers 523.4 ha, has a maximum depth of 28.7 m, a mean depth of 11.9 m, 16.6 km of shoreline, and is located at an elevation 123 m above sea level (Figure 4) (Kyle, et al. 1993). Shell Lake has 7 small tributaries and discharges southeast via Shell Creek which runs approximately six river miles to the Skwentna River.

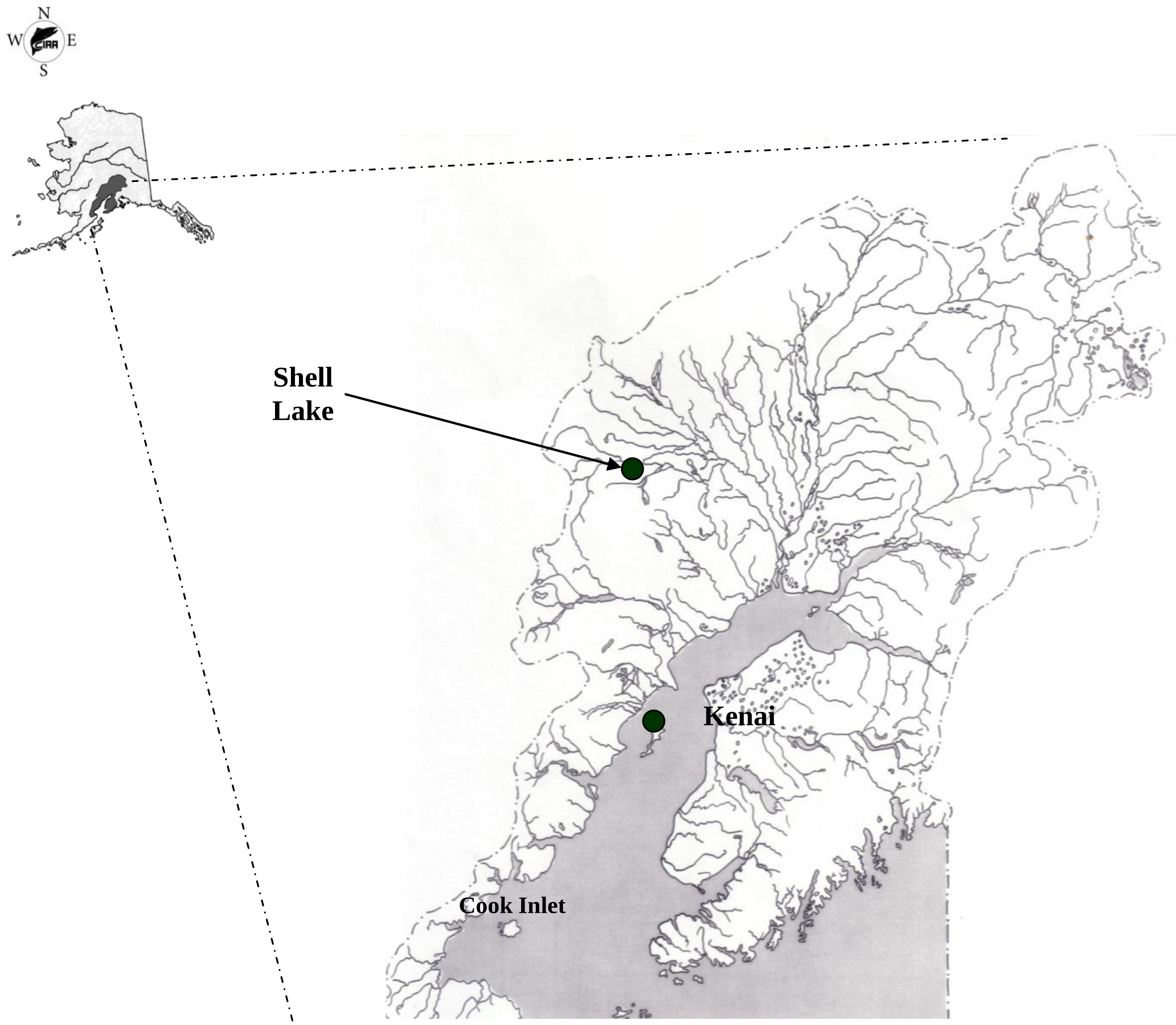
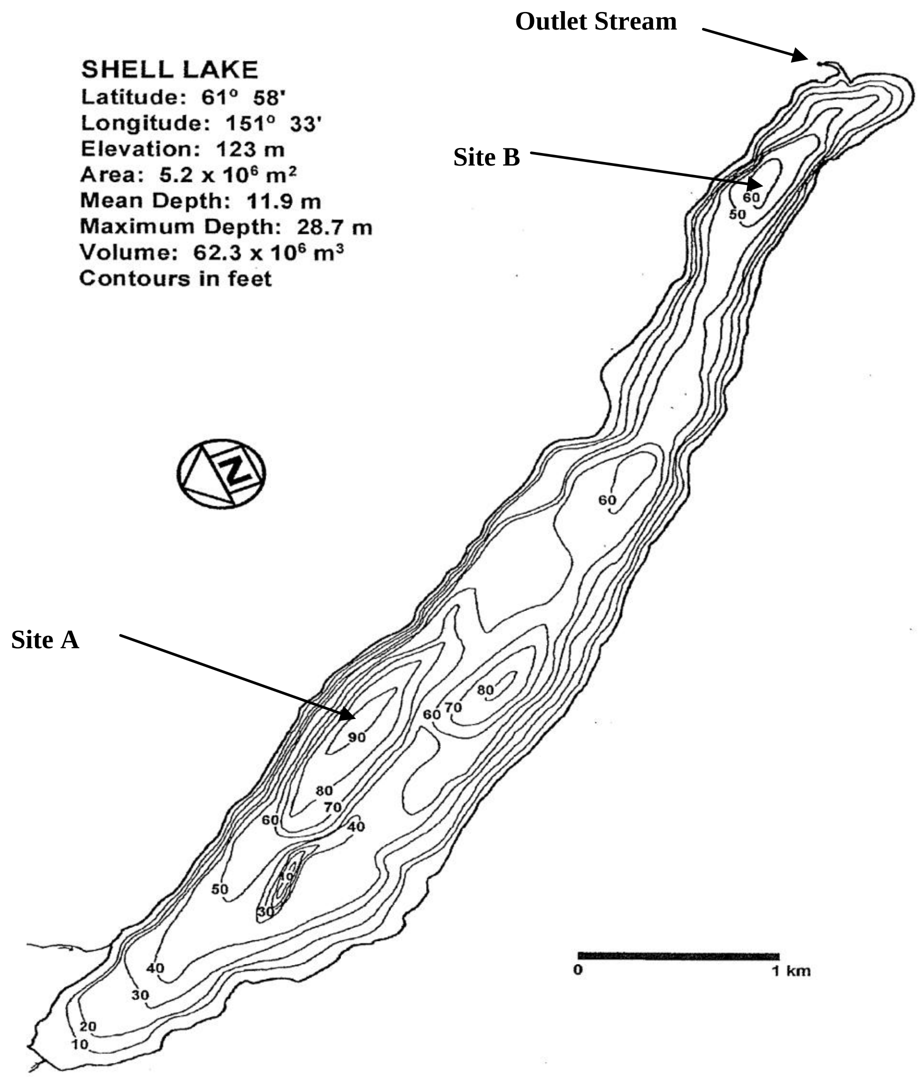


Figure 3: Shell Lake in relation to Cook Inlet and Alaska.



Source: (Sparfard and Edmundson, 2000)

Figure 4: Bathymetric map of Shell Lake.[5]

5. Site A and Site B refer to water quality collection sites, which are discussed in the next section of the report.

METHODS

Environmental Conditions and Limnological Sampling

During 2017, water quality samples were collected four times during the open water season near the end of the months of May, June, July and August.

One primary site, Station A (Figure 4) was sampled for dissolved oxygen, temperature and light transmission profiles. Secchi disk transparency and zooplankton densities were collected at sites A and B (Figure 4). 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 at Station A only.

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.

To assess the environmental conditions during the salmon smolt migration to Shell Lake, percent cloud cover was visually estimated, stream fluctuations 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 (CIAA, 2017b).

Smolt Enumeration

To enumerate the smolt migration, a smolt trap was temporarily placed in Shell Creek. The smolt trap consisted of a modified fyke net with Vexar® netting leads and a double compartment live-box. The leads and fyke net funneled migrating smolt into the live-box. A swing gate remotely controlled by the trap operators directed smolt into one of two live-box compartments where they were enumerated. A total count was made during the smolt migrations.

Smolt Characteristics

No smolt samples were taken from Shell Lake in 2017 due to low numbers of sockeye smolt migrating.

Adult Enumeration and Beaver Dam Monitoring

To enumerate adult salmon, staff installed a video weir during the 2017 field season in Shell Creek. The weir was constructed of 1.9-cm galvanized pipe and 7.6-cm aluminum channel. The galvanized pipe was picketed through 1.9-cm holes in the aluminum channel spaced 2.54-cm apart. A gap approximately 2.5-ft wide located in the center of the weir allowed fish to pass the weir into a passage chute without handling stress. Attached to the passage chute was a camera box that was triggered by motion and filmed all passing fish (Figure 5). Footage downloaded from the video weir was segregated into motion events allowing the reviewer to count all passing fish while eliminating all non-event footage (CIAA 2017c).

Figure 5: Video weir camera box and passage chute.

During the summer of 2017, beaver dams were monitored in Shell Creek for blockage to fish passage during the adult migration. An aerial survey was conducted on August 25 beginning at the confluence of Shell Creek and Skwentna River and continued upstream approximately 3.8 miles “as the crow flies.” When beaver dams were found to be blocking the upstream movements of salmon, the crew made a notch approximately 3–5-ft wide in the dam to allow them to pass. After notching each dam, staff placed a coyote decoy laced with coyote urine near the notch to delay the beaver’s attempts at rebuilding the dam (Figure 6).

Figure 6: Notched beaver dam on Shell Creek, showing a coyote decoy, August 25, 2017.

Adult Characteristics

For field season 2017, no physical data such as sex, and standard fork length were collected. Age data was collected via otolith analysis for 39 sockeye salmon used as broodstock and 11 sockeye salmon carcasses collected from Shell Lake after they had succumbed to post spawning mortality.

Northern Pike Harvest

Northern pike harvesting and sampling procedures were based on the “Susitna Lakes Pike Sampling Procedures Manual” (Glick, 2010). Methods used to capture northern pike included 1-in bar mesh gillnets and hoop nets.

On March 9, 2017, CIAA set 3 gillnets were set under the ice near known northern pike spawning areas on the south end of Shell Lake. Those nets were pulled after ice-out on May 19 and were intended to intercept northern pike prior to spawning. No data were collected for these northern pike due to advanced decomposition.

During the open water season, from May 31–September 3, up to ten 1-inch bar mesh gillnets and one hoop net were deployed throughout the littoral zone of Shell Lake and checked daily. Each captured northern pike was sampled for age, weight, and length; and stomach contents were identified.

Personnel collected the left cleithrum of harvested pike for subsequent age verification (Euchner, 1988). Each fish was weighed to the nearest 10 g, and length was measured to the nearest millimeter from tip of snout to fork of the tail. Cleithrum were analyzed at the CIAA headquarters lab following the field season. Stomach contents were weighted to the nearest tenth of a gram for individual prey items. Approximately 44 northern pike had no measurements taken due to river otters (*Lontra Canadensis*) partially eating the netted fish and stomach contents were only analyzed for 127 of the captured pike due to issues with the scale. Northern pike that were not partially eaten by otters were donated to local residents for consumption after samples had been collected.

Catch per unit effort (CPUE) has been calculated for gillnet effort since CIAA began netting northern pike from Shell Lake to gauge the relative abundance of northern pike between years. The CPUE is calculated as n/(N*t)=CPUE where n=number of northern pike caught, N=number of nets, t=total time the nets are in the water.

Gamete Collection and Fish Stocking

Gamete collection followed the Alaska Sockeye Salmon Culture Manual (McDaniel et al., 1994). Directed by the guidance of the ADF&G Gene Conservation Laboratory, CIAA functionally increased the genetic diversity of the progeny resulting from the egg take by dividing each of the first 11 female's egg lots in half and mixing each half of the egg lots with milt from 22 different males (the remaining 3 females had their eggs fertilized by one male each). In using the milt of two males for each of the first 11 females CIAA was able to nearly double the effective population size of the fish used for egg take from 14 crosses to 25 unique 1-to-1 crosses. Kidney, gill, and ovarian samples were collected from fish used for egg collection and sent to the ADF&G Fish Pathology Laboratory in Anchorage. Equipment was disinfected between each fish. Iced coolers of eggs and milt in individual containers were transported to Trail Lakes Hatchery. Containers were disinfected prior to admission to the facility.

University of Alaska Fairbanks Pike Data Analysis

A field data and a bioenergetics model were used to estimate the per-capita consumption rates of northern pike ages 1–5 in Shell Lake. Model inputs included pike growth rates (initial and final weights), diet composition, water temperatures from Shell Lake, and energy density estimates from the literature. The per-capita consumption rates of each cohort were scaled up to the population level using the CPUE of gillnet sampling. Although the total abundance of northern pike was unknown, this approach allowed for estimates of the relative change in predation on salmon by the northern pike population during the course of the suppression program during 2013–2016. All field sampling and laboratory analysis was conducted by CIAA.

Field Sampling and Laboratory Analysis

During the summers (May–September) of 2013–2016, pike were captured throughout the littoral zone of Shell Lake with gillnets (2.54 cm [1 in] bar mesh) following the protocol of (Glick, 2010). Initial sampling, primarily with angling gear was initiated in 2012, but given differences in approach and the lack of biological samples from harvested northern pike, this initial year is not included in the analyses. Water surface temperatures were recorded daily at 5:00 PM. Gillnets and hoop nets were checked daily. Each northern pike was sacrificed, measured (fork length) to nearest millimeter, weighed to the nearest 10 g, and sexed by presence of ovaries or gonads. Additionally, the left cleithrum and stomach were collected from a subset of northern pike for subsequent laboratory age and diet analyses. Cleithra were aged following the methods of (Euchner, 1988). Diet composition was quantified using two methods. In 2014 and 2015, the relative proportions of each prey type in the stomach contents were visually estimated. In 2016, individual prey items were weighed to the nearest 0.1 g. Additional details on the field sampling and laboratory analysis are provided by (Wizik, 2017).

Age and Growth

The mean initial and final weights of each northern pike age class were estimated using field data. The final weights were calculated directly as the mean weight of each age class during August. Preliminary analysis suggested possible inconsistencies in the ages assigned to pike captured during May and June (see Appendix 6), which resulted in initial weights exceeding final weights for some age classes. This was implausible, so instead it was assumed that the initial weight of each age class *N* was equal to the final weight of the previous age class *N* -1, based on the assumption that little growth occurred during winter (Sepulveda et al., 2015). Age 1 pike appeared to first recruit to the gillnets in July, and their initial length was estimated from a length-frequency histogram (Appendix 7). This initial length was converted to an initial weight using a length-weight relationship calculated using all pike captured in the study:

$$W = 9.330 \times 10^{-9} * FL^{2.975} \qquad (1)$$

where *W* is weight in kg and FL is fork length in mm ($r^2 = 0.94$; $p < 0.001$; Figure 7). Initial and final weights of each age class (Table 1) were used as inputs to the bioenergetics model.

Diet Composition

The diet compositions of northern pike were analyzed using a two-step process because data were collected using different methods in 2014–15 and 2016. First, the dietary patterns were compared graphically using data collected during all three years. The proportion of salmon in the stomach contents of individual northern pike vs. northern pike fork lengths were plotted (Figure 8). During all three years, the proportion of salmon in northern pike diets declined as northern pike grew larger. To account for this ontogenetic diet shift, northern pike were broken down into three size classes: small (< 325 mm FL), medium (325-500 mm), and large (> 500 mm) for use in the subsequent diet and CPUE analyses. Based on this plot, it was also concluded that after northern pike size was taken into account, salmon made up similar proportion of northern pike diets in 2016, when prey items were weighed, as in 2014 and 2015, when diet proportions were only estimated visually. Therefore, the focus was placed on the higher-quality 2016 diet data for the remainder of the analysis.

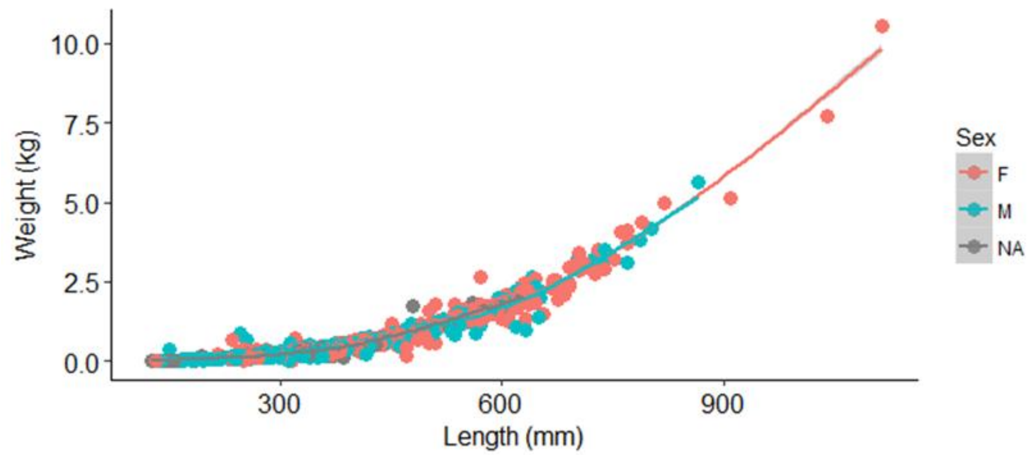


Figure 7: Length-weight relationship for all northern pike measured and weighed during the study.

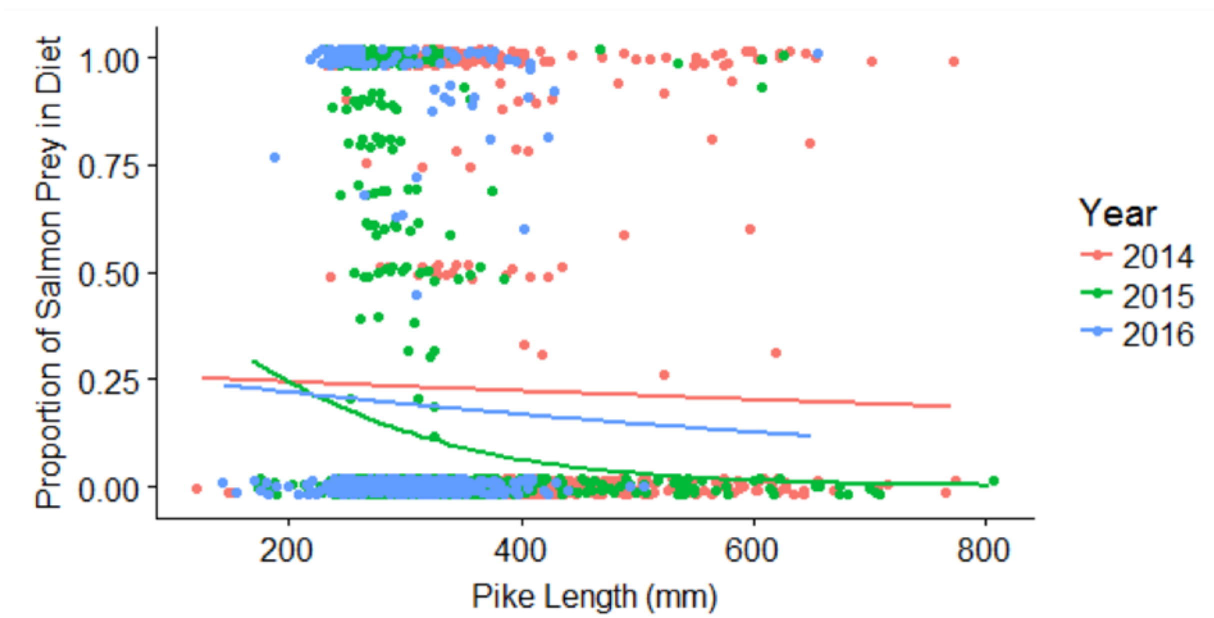


Figure 8: Proportions of salmon in the stomach contents of individual northern pike captured during 2014–2016. Diet proportions were estimated visually in 2014–2015 and calculated from the weights of individual diet items during 2016. Data points are jittered to improve visibility of overlapping symbols. Curves represent logistic regression fits to the data from each year, showing a decrease in the proportion of salmon in the diets of larger pike.

Second, diet proportions were calculated by weight using the prey weight data collected in 2016. For the small and medium size classes of northern pike, diet composition was calculated in terms of diet proportions by weight, the preferred metric for predation studies (Chipps and Garvey, 2007). Only two individual diet samples were available from the largest pike size class in 2016, so the diet composition of this size class was estimated using pooled data from all years of the study, calculated using the means of individual diet proportions. Preliminary analysis did not reveal meaningful seasonal changes in the consumption of salmon, so the diet proportions were calculated for the entire sampling period rather than breaking the data down seasonally.

Bioenergetics Modeling

The per-capita consumption rates of pike ages 1–5 were estimated using the Fish Bioenergetics 4.0 model (Deslauriers et al., 2017) using physiological parameters developed for northern pike (Bevelhimer et al., 1985). Previous research suggests these parameters may overestimate the consumption rates of northern pike in Alaska (Sepulveda et al., 2015); however this was unimportant for this study because the interest was in comparing relative consumption rates among years, not estimating the absolute consumption rates. Model inputs included the growth rates and diet composition values described above, as well as the water temperatures experienced by northern pike and the energy densities of each prey category. Age 1 northern pike were simulated for 37 days (July 15 to August 20) and ages 2–5 were simulated for 91 days (May 22 to August 20) based on the availability of field data.

The daily thermal experience of northern pike was specified as the daily mean surface water temperatures measured from 2012–2016. Energy density values from the literature were used (Table 1). Prey indigestibility values of 3% were specified for fishes and 17% for invertebrates (Beauchamp et al., 2007). There was no account made for the effects of spawning on northern pike consumption rates because all simulations began after the peak spawning period (Sepulveda et al., 2015). Due to the reliance on quantitative diet data from 2016, a single per-capita consumption rate was estimated for each northern pike age class and it was assumed that these consumption rates did not change appreciably during the four years of the study.

Table 1: Energy density values used in bioenergetics models.

Prey taxon	Energy Density (J / g)	Surrogate taxon
Salmonids	5,756	
Stickleback	5,000	
Sculpin	5,450	
Northern Pike	5,756	Salmonids
Trout + Burbot + Sucker	5,756	Salmonids
Insects + Leeches	4,995	
Unidentifiable	5,756	Salmonids

All values from Cartwright et al., 1998.

Population-Level Consumption Rates

The per-capita consumption rate of each northern pike age class was scaled up to the population level by multiplying them by the mean CPUE of the corresponding size class in each year. This assumed that CPUE was proportional to northern pike abundance (i.e., that catchability of pike in gillnets did not change over time). The results were expressed as the relative change in population-level consumption of salmon by northern pike from 2013–2016. The results were "relative" because the total abundance of northern pike was unknown, so that the total biomass of salmon consumed by northern pike could not be determined; however, the relative change in salmon consumption could be quantified.

RESULTS

Environmental Conditions and Limnological Sampling

2017

Environmental conditions were monitored on Shell Creek near the smolt trap site from May 24 through June 21, and at the adult weir near the lake from June 22 through September 26. The water level in the creek varied by ±1.1 feet from the first reading on May 24. Water temperatures ranged from 6.0 to 21.2ºC with an average temperature of 14.5ºC (Table 2). Air temperatures averaged 18.1ºC and ranged from 7.0 to 31.7ºC. Fifteen percent of the days were clear, 39% were partly cloudy and 46% of the days were completely overcast. Measureable rain was recorded for 34% of the days and a total of 283 mm of precipitation fell over this period.

Table 2: Summary of environmental conditions, Shell Lake, 2017.

	Precipitation Millimeters	Staff Gauge Feet	Water Temperature ºC	Air Temperature ºC
Total	282.8			
Average	2.2	1.0	14.5	18.1
Minimum	0.0	0.8	6.0	7.0
Maximum	20.3	1.9	21.2	31.7

Ice out = May 19

Summary of Cloud Cover - Percent of Days				
Number of Days	Measurable Rain	Overcast	Partly Cloudy	Clear
126	34%	46%	39%	15%

Zooplankton samples collected in May, June, July, and August indicate that there is an adequate food supply in Shell Lake for the rearing of juvenile salmon (tables 3–8). The assemblage of species noted in Shell Lake zooplankton samples has not changed drastically over the years with *cyclops, diaptomus, daphnia l.*, and *bosmina* being the top taxa present in the samples. However, the samples from 2016–2017 have shown lower overall densities of zooplankton when compared to samples from previous years. Water quality parameters provided by the ADF&G analysis share a similar chemical profile with samples collected in previous years with the exception of phosphorus, which has decreased when comparing samples from 2006–2009 with samples from 2010–2011 and 2016–2017 (Table 4).

Table 3: Summary of zooplankton biomass, Shell Lake, 2006–2012, 2016–2017.

Year	Density Seasonal Mean (No/m2)	Biomass Seasonal Weighted Mean (mg/m2)
2006	147,436	440
2007	281,941	791
2008	132,824	533
2009	231,291	621
2010	367,056	1,008
2011	243,464	707
2012	183,337	646
2016	75,885	291
2017	79,055	341

Table 4: Average water quality in Shell Lake 2006–2011, 2016–2017.

AVERAGE WATER QUALITY - 1 METER

Year	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)	EZD Sta	EZD (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)
2006	11.2	4.3	3.7	302.7	16.1	559.2	170 :1	4,202	749	1.39	0.46	A	6.0	32	5.6	10.1	0.4	22	4.3	0.5	85	A	4.0
2007	7.6	4.2	3.7	253.7	12.5	480.8	213 :1	4,205	484	0.99	0.36	A	7.5	37	6.7	15.3	0.5	11	4.8	0.7	44	A	5.1
2008	14.0	11.3	2.4	233.2	13.4	417.4	103 :1	3,875	220	0.79	0.50	A	8.3	31	6.7	13.1	0.6	20	3.9	0.8	62	A	4.1
2009	12.1	8.1	1.3	222.0	8.1	393.8	113 :1	3,778	241	1.03	0.45	A	7.8	35	6.5	12.8	0.6	15	4.4	1.0	51	A	4.3
2010	7.0	3.9	1.6	ND	10.7	422.7	ND :1	3,972	166	0.94	0.28	A	9.0	35	6.6	12.1	0.5	18	4.1	1.1	64	A	5.0
2011	6.3	3.0	2.5	ND	7.7	314.3	ND :1	3,670	223	1.35	0.44	A	7.9	34	7.1	13.9	0.5	20	4.3	1.1	71	A	4.4
2016	3.9	1.9	1.3	406.2	2.5	442.5	487 :1	4,032	252	2.42	0.77	A	5.9	31	7.1	14.2	0.6	16	4.0	0.2	37	A	4.0
2017	5.6	2.4	1.9	324.0	5.6	407.4	294 :1	3,780	212	ND	ND	A	6.6	27	6.9	15.0	0.3	16	4.7	0.1	44	A	5.1

AVERAGE WATER QUALITY - HYPOLIMNION

Year	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)	EZD Sta	EZD (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)
2006	7.6	4.2	3.7	253.7	12.5	480.8	213 :1	4,205	484	0.99	0.36	A	7.5	37	6.7	15.3	0.5	11	4.8	0.7	44	B	5.1
2007	11.2	4.3	3.7	302.7	16.1	559.2	170 :1	4,202	749	1.39	0.46	A	6.0	32	5.6	10.1	0.4	22	4.3	0.5	85	B	4.0
2008	8.7	6.2	2.3	210.1	10.2	467.1	172 :1	3,929	175	0.54	0.49	A	7.4	31	6.5	12.7	0.5	20	4.0	0.9	61	B	4.4
2009	9.4	5.9	1.6	204.6	9.6	480.4	162 :1	3,928	141	0.41	0.41	A	7.6	35	6.4	12.5	0.5	17	4.4	1.0	50	B	4.4
2010	7.6	4.7	1.7	ND	23.7	446.4	ND :1	4,159	170	0.50	0.39	A	ND	37	6.5	12.3	0.4	18	4.1	1.2	74	B	4.9
2011	6.7	3.3	2.3	ND	9.2	375.5	ND :1	3,837	176	0.64	0.36	A	ND	35	7.3	13.7	0.5	20	4.3	1.0	73	B	4.6
2016	6.5	3.1	1.4	338.3	7.4	522.5	319 :1	4,430	187	0.95	0.62	A	5.9	32	6.6	12.7	0.6	16	4.1	0.3	51	B	5.3
2017	6.9	2.66	1.8	295.0	13.1	457.9	241 :1	4,103	148	ND	ND	A	6.6	28	6.8	14.5	0.3	17	4.6	0.1	55	B	5.1

For 2017 TKN and TN averages were calculated only from the July and August samples due to an equipment failure
EZD and Secchi provided by CIAA.
Open water season only.
ND = No Data

Table 5: Zooplankton density, Site A, Shell Lake, 2017.

Macrozooplankton Density - Site A - Depth 10m - 12m
(No/m2)

	26-May	22-Jun	28-Jul	27-Aug	Mean (No/m2)	Seasonal Mean (No/m2)
Epischura	796	3,185	2,627	14,676	5,321	5,321
Ovig Epischura						
Diaptomus		36,359	36,067		36,213	18,107
Ovig Diaptomus			80	1,115	598	299
Cyclops		21,630	31,131	26,752	26,504	19,878
Ovig. Cyclops	478	531	398		469	352
Bosmina	2,389	133	1,115	51,645	13,821	13,821
Ovig. Bosmina	318	133	398	19,135	4,996	4,996
Daphnia l.	24,522		637	37,712	20,957	15,718
Ovig. Daphnia l.						
Heterocope		2,256			2,256	564
Holopedium						
Ovigerous Holopedium						
Total:	28,503	64,227			111,134	79,055
Ave:	5,701	9,175			12,348	8,784
STDEV:	10,554	14,237			12,897	8,066

Table 6: Zooplankton density, Site B, Shell Lake, 2017.

Macrozooplankton Density - Site B - Depth 12m - 16m (No/m2)

	28-Jul	27-Aug	Mean (No/m2)	Seasonal Mean (No/m2)
Epischura	1,354	4,220	2,787	1,394
Ovig Epischura				
Diaptomus	16,959	14,013	15,486	7,743
Ovig Diaptomus	159		159	40
Cyclops	11,863	50,637	31,250	15,625
Ovig. Cyclops	80	239	160	80
Bosmina	1,592	33,201	17,397	8,698
Ovig. Bosmina	557	6,529	3,543	1,772
Daphnia l.	159	80	120	60
Ovig. Daphnia l.				
Heterocope	239		239	60
Holopedium				
Ovigerous Holopedium				
Total:	32,962	108,919	71,140	35,470
Ave:	3,662	15,560	7,904	3,941
STDEV:	6,249	19,272	11,052	5,535

Table 7: Zooplankton biomass Site A, Shell Lake, 2017

	Body Size - Site A - Depth 12m - 16m (mm)				Seasonal Means				
	26-May	22-Jun	28-Jul	27-Aug	Mean Length (mm)	Weighted Length (mm)	Biomass (mg/m2)	Weighted Biomass (mg/m2)	% by Species
Epischura	1.02	0.77	1.43	1.15	1.09	1.12	31	33	9%
Ovig Epischura									
Diaptomus		1.04	1.20	1.20	1.15	1.12	115	107	28%
Ovig Diaptomus			1.39	1.38	1.39	1.38	3	3	1%
Cyclops		0.85	0.82	0.82	0.83	0.83	48	48	13%
Ovig. Cyclops	1.21	1.19	1.26		1.22	1.22	2	2	1%
Bosmina	0.54	0.48	0.40	0.50	0.48	0.50	8	33	9%
Ovig. Bosmina	0.66	0.48	0.41	0.66	0.55	0.65	4	21	5%
Daphnia l.	0.97		0.65		0.81	0.96	39	66	17%
Ovig. Daphnia l.									
Heterocope		2.94			2.94	2.94	69	69	18%
Holopedium									
Ovigerous Holopedium									
TOTAL:							319	382	100%

Table 8: Zooplankton biomass, Site B, Shell Lake, 2017.

	Body Size - Site B - Depth 12m - 16m (mm)		Seasonal Means				
	28-Jul	27-Aug	Mean Length (mm)	Weighted Length (mm)	Biomass (mg/m2)	Weighted Biomass (mg/m2)	% by Species
Epischura	1.48	1.20	1.34	1.27	29	25	8%
Ovig Epischura							
Diaptomus	1.20	1.27	1.24	1.23	121	120	40%
Ovig Diaptomus	1.28		1.28	1.28	1	1	0%
Cyclops	0.85	0.89	0.87	0.88	84	86	29%
Ovig. Cyclops	1.16	1.20	1.18	1.19	1	1	0%
Bosmina	0.44	0.48	0.46	0.48	9	37	13%
Ovig. Bosmina	0.45	0.62	0.54	0.61	3	13	4%
Daphnia l.	0.80	0.72	0.76	0.77	0	0	0%
Ovig. Daphnia l.							0%
Heterocope	3.04		3.04	3.04	16	16	5%
Holopedium							0%
Ovigerous Holopedium							0%
TOTAL:					262	299	100%

Smolt Enumeration

The ice out as reported by Shell Lake Lodge was May 19. The 2017 Shell Lake salmon smolt migration was monitored from May 23 through June 21. Staff counted 15 sockeye salmon smolt and 6 coho smolt leaving Shell Lake. None of the smolts emigrating from Shell Lake were sampled due to the low number of emigrants (Figure 9).

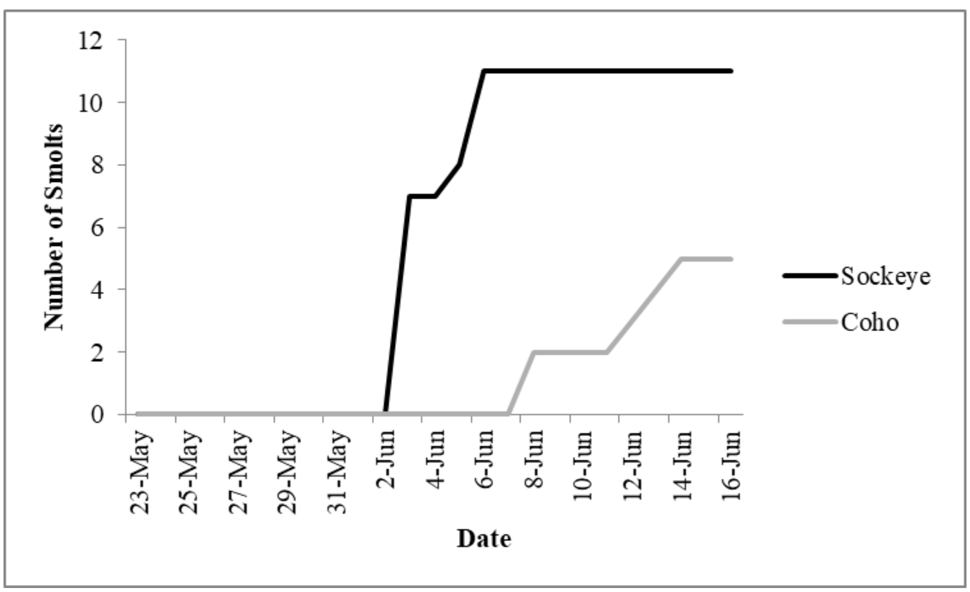


Figure 9: Sockeye and coho smolts migrations, Shell Lake, 2017.

Adult Enumeration, Broodstock Collection, and Beaver Dam Monitoring

In 2017, a video recording weir was installed on July 10 and the recording equipment ran continuously until September 23 except for a 12 hour period on July 20 when a blown fuse caused the system to go off-line. It is believed that no passing salmon were missed because none were seen in the creek or the lake until beaver dams had been notched in late August. Escapement of sockeye salmon into Shell Lake was 575 sockeye and 411 coho salmon and all of those fish entered the lake from September 1–23. Fourteen female and 25 male sockeye were used as broodstock with 11 females having their egg lots split to be spawned with 22 of the males. The remaining 3 females did not have their egg lots split and were spawned 1 to 1 with the remaining 3 males.

Otolith samples were taken from the 39 salmon used for broodstock and 12 sockeye salmon carcasses found in the lake that had succumbed to post-spawning mortality. All of the samples were readable and showed that 45 of the sockeye salmon were age 1.3 fish reared at the Trail Lakes Hatchery from broodstock collected in 2012 and 6 were naturally-produced fish. Of the naturally-produced fish, 4 were age 2.2 and the other two were ages 1.2 and 1.3 respectively. Samples of the kidneys, gills, and ovarian fluid were collected from fish used for broodstock. Samples were sent to the ADF&G Fish Pathology Laboratory in Anchorage for analysis. The laboratory analysis will be attached to this report as an amendment once it has been completed.

Several active beaver dams were noted on Shell Creek in 2017. On an August 25 aerial survey, the crew noted an undetermined number of salmon near the mouth of the creek that could not be identified to species because of the dark water and tree cover of the lower creek. Because salmon were present in the lower creek, the crew began assessing for dams to determine how many were present and if they were passable to fish. The crew flew the creek from the lake to the mouth noting 9 beaver dams. Eight of the dams were deemed impassible due to their height, and because shallow gravel bars below the dam had formed preventing salmon ascending the creek from jumping over them (Figure 10). All eight dams were notched and had coyote decoys placed atop them to prevent the beavers from quickly rebuilding them.

Figure 10: An impassible dam on Shell Creek, 2017

Northern Pike Harvest

A total of 780 northern pike were harvested from Shell Lake during the open water season in 2017 requiring 13,872 hours of gillnetting effort for a CPUE of 0.06 pike/hour. Staff collected data from the harvested fish regarding length (n=736), weight (n=736), age (n=736), stomach contents (n=127), and sex (n=737). Of the northern pike sampled, 51.4% were males (n=379), and 48.6% were females (n=358) and 5.5% (n=43) were of unknown sex (Table 9). Mean length of the males was 360 mm (±5.7mm) and mean weight of males was 0.39 kg (±0.02 kg). Female mean length and weight was 388 mm (±7.6 mm) and 0.53 kg (±0.08 kg) respectively.

Table 9: Northern pike male and female characteristics, Shell Lake, 2017.

Male Pike Length (mm)			
Minimum	150		
Maximum	520	Standard Deviation	95% Confidence
Average	360	57	6
Male Pike Weight (kg)			
Minimum	0.01		
Maximum	1.21	Standard Deviation	95% Confidence
Average	0.39	0.17	0.02
Female Pike Length (mm)			
Minimum	190		
Maximum	1090	Standard Deviation	95% Confidence
Average	388	74	8
Female Pike Weight (kg)			
Minimum	0.03		
Maximum	11.67	Standard Deviation	95% Confidence
Average	0.53	0.82	0.08
Pencentage Male/Female			
Male	51%		
Female	49%		

The stomach contents of 127 harvested pike were examined—37% (n=47) contained prey and 63% (n=80) were empty. Prey items were weighed to the nearest tenth of a gram and are presented as a percentage of the total wet weight of stomach contents—0.8% of the total wet weight of food items were invertebrates, 37.4% was salmonids, 54.2% of the mass was other non-salmonid fishes including sticklebacks *(Gasteroseidae* spp.*)*, burbot *(Lota lota)*, slimy sculpin *(Cottus cognatus)*, northern pike, or longnose sucker *(Catostomus catostomus)* (Figure 11). Cannibalism was detected in 2.3% of examined northern pike stomach contents.

There were an estimated 20–40 additional northern pike caught in gillnets set under the ice March 9 and pulled on May 19. The decomposition of those fish caused many to fall out of the net when it was pulled so an exact number of fish captured could not be made nor could any samples be taken from those fish.

Table 10: Percentage of pike stomachs containing prey items and percentage of total weights of items in northern pike stomach contents, Shell Lake, 2017.

		Non-Empty Stomachs			
	Empty	Other Fish	Invertebrates	Mammals	Salmonids
Samples	80	41	6	4	11
Percentage of Pike	63.0%	32.3%	4.7%	3.1%	8.7%
Percentage of total weight		54.2%	0.8%	7.2%	37.4%

Other fish includes burbot, stickleback,sculpin, northern pike, and suckers
Salmonids noted were sockeye, coho, and rainbow trout

Gamete Collection and Fish Stocking

The first gamete collection performed by CIAA on Shell Lake occurred on September 8, 2012 resulting in the successful release of 80,000 sockeye smolt back into Shell Lake in 2014. The first return of adult sockeye from the 2014 smolt release made it to Shell Lake in late August of 2016 and efforts were undertaken to perform another egg take. Eggs (88,000) were collected from 33 pairs of sockeye salmon over two days (September 14 and 28) and are being reared at the Trail Lakes Hatchery for release in 2018.

The second return from the 2012 egg take made it to Shell Lake in 2017. Of the 575 adult sockeye enumerated at the weir in 2017, only 14 females and 25 males were captured prior to spawning during the September 25 egg take. Eleven of the egg lots were split and each half was spawned with the milt of different males. The remaining 3 females did not have their egg lots split and were spawned 1 to 1 with the remaining 3 males for an effective population of 25 spawning pairs. Newly-fertilized eggs were water hardened in iodophor solution for 2 hours before being placed into Kitoi incubators. Once eggs reached the eyed stage, they were shocked, picked, and inventoried (n=30,000). Resulting live eggs were placed into Kitoi incubators for hatching and emergence. The sockeye salmon eggs collected in 2017 are currently being incubated at Trail Lakes Hatchery and are scheduled to be released back into Shell Lake as smolt in 2019.

University of Alaska Fairbanks Pike Data Analysis

Water Temperature

Daily mean water temperatures averaged 15.3˚ C (minimum = 7.0˚ C, maximum = 20.5˚ C) during the model simulation period (May 22 – August 20; Figure 11).

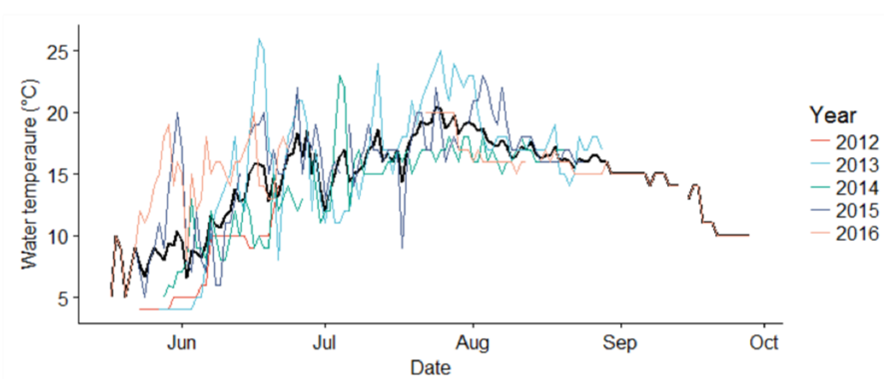


Figure 11: Daily water temperatures measured at the surface of Shell Lake during 2012–2016. Black line represents daily mean water temperature.

Growth Rates

On average, northern pike grew from roughly 200 mm FL (65.4 g) at age-1 when they first recruited to the gillnets in mid-July to 616 mm FL (1.8 kg) at age 5 by the end of the sampling period in August (Table 11).

Table 11: Growth inputs (initial and final mean weight at age) used for bioenergetics model simulations of pike. Initial and final fork lengths (FL; mm) provided for reference. Simulations ran from July 15 to August 20 for age 1, and from May 22 to August 20 for ages 2–5 pike.

Age	Simulation length (days)	Size class for diet (mm FL)	Initial Length (mm)	Initial Weight (g)	Final Length (mm)	Final weight (g)
1	37	< 325	200	65.4	271	180.1
2	91	< 325	271	180.1	383	483.7
3	91	325–500	383	483.7	470	871.6
4	91	325–500	470	871.6	545	1307.4
5	91	> 500	545	1307.4	616	1810.0

Diet Composition

Northern pike of all sizes consumed salmon, but on average salmon made up a smaller fraction of the diets of larger northern pike. Salmon made up 34.5% of the diet of the smallest size class (< 325 mm FL), 28.5% of the diet of the medium size class (325-500 mm), and 22.7% of the diet of the largest size class of pike (Figure 12). The remainder of the diet was mostly composed of other fish species, including sticklebacks (*Gasterosteus aculeatus*), sculpins (*Cottus* spp.), trout (*Oncorhynchus* spp.), burbot (*Lota lota*), and suckers (*Castomus* spp.). Little cannibalism was documented, with northern pike representing only 1.8% of the diet of the smallest size class of pike, 6.7% of the diet of the medium size class, and 9.9% of the diet of the largest size class.

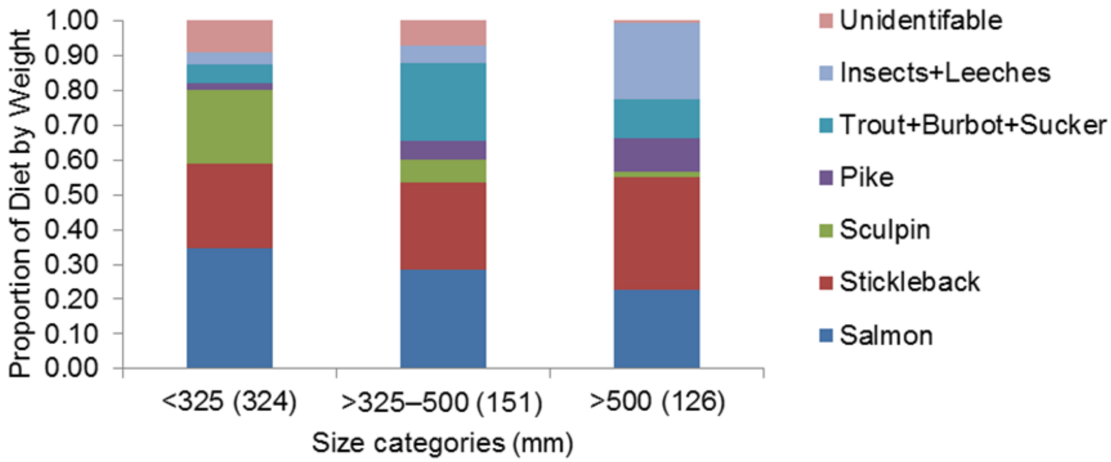


Figure 12: Diet composition of pike in three size categories (fork length, mm).
Numbers in parentheses in the x-axis labels indicate sample sizes.

Catch Per Unit Effort

The catch per unit effort (CPUE) of northern pike in standardized gillnet sets declined by 75% overall from 2013–2016 in Shell Lake (Figure 13). The reduction in catch rates was greatest for the larger size classes. Catch rates declined by 55% for small size class (< 325 mm FL), 82% for medium size class (325–500 mm), and 98% for large size class (> 500 mm) of northern pike.

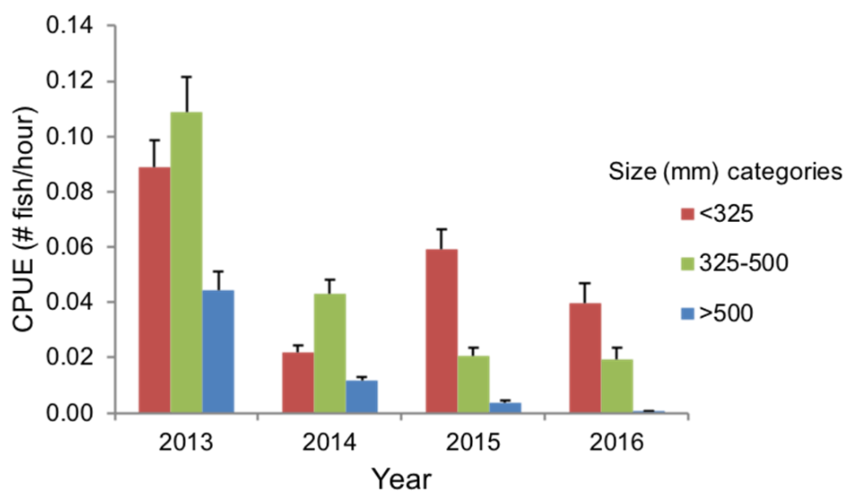


Figure 13: Mean (± SE) catch per unit effort (CPUE) of pike in three size categories (fork length, mm) captured in standardized gillnet sets during 2013–2016.

Per-Capita Consumption of Salmon by Northern Pike

Larger northern pike consumed more salmon biomass per capita than smaller pike, according to the bioenergetics model. From mid-summer to late summer, an age-1 northern pike consumed 91.0 g of salmon on average (modeled for 37 days from July15–August 20). During the full sampling period (91 days from May 22–August 20), the average salmon consumption by an individual northern pike in each age class was 283.1 g for age 2, 346.2 g for age 3, 446.2 g for age 4, and 459.8 g for age 5 (Figure 14).

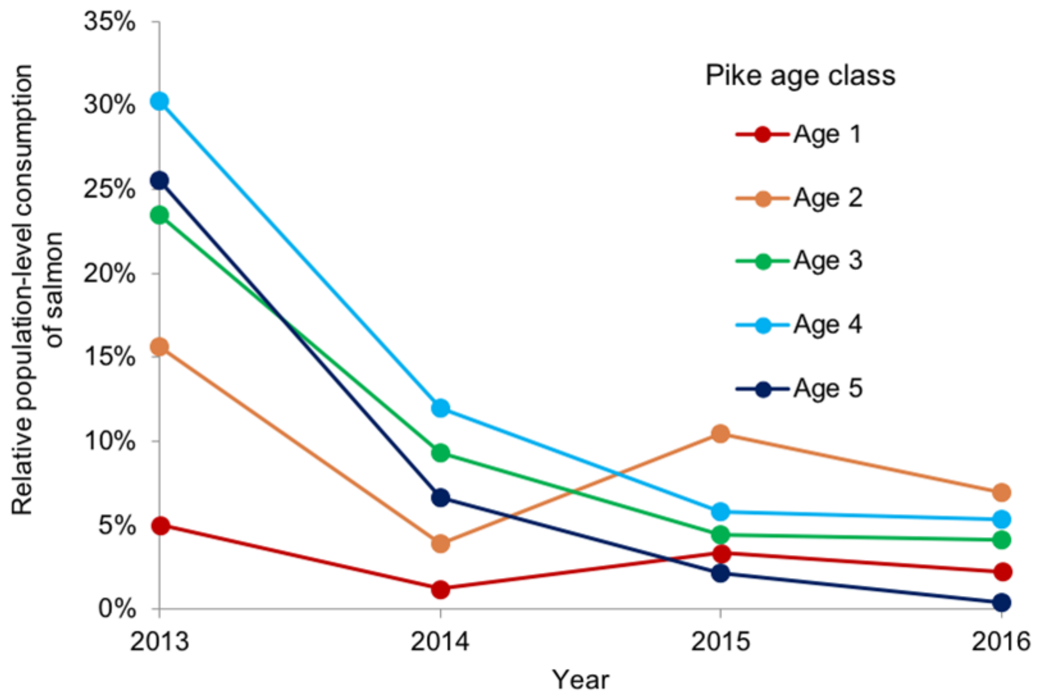


Figure 14: Relative total consumption of salmon by the northern pike population in Shell Lake, broken down by pike age class.
Values were estimated as the per-capita consumption of salmon by an average pike in each age class, multiplied by the relative abundance of that pike age class in each year (estimated from CPUE). Relative consumption values are scaled so that total salmon consumption by all age classes of northern pike in 2013 = 100%.

Consumption of Salmon by the Northern Pike Population

Total consumption of salmon by all age classes of northern pike decreased substantially from 2013–2016. All five age classes of northern pike consumed less salmon at the population level in 2016 than in 2013 (Figure 14). Overall, in comparison to 2013, the northern pike population consumed 67% less salmon in 2014, 74% less in 2015, and 81% less in 2016 (Figure 15).

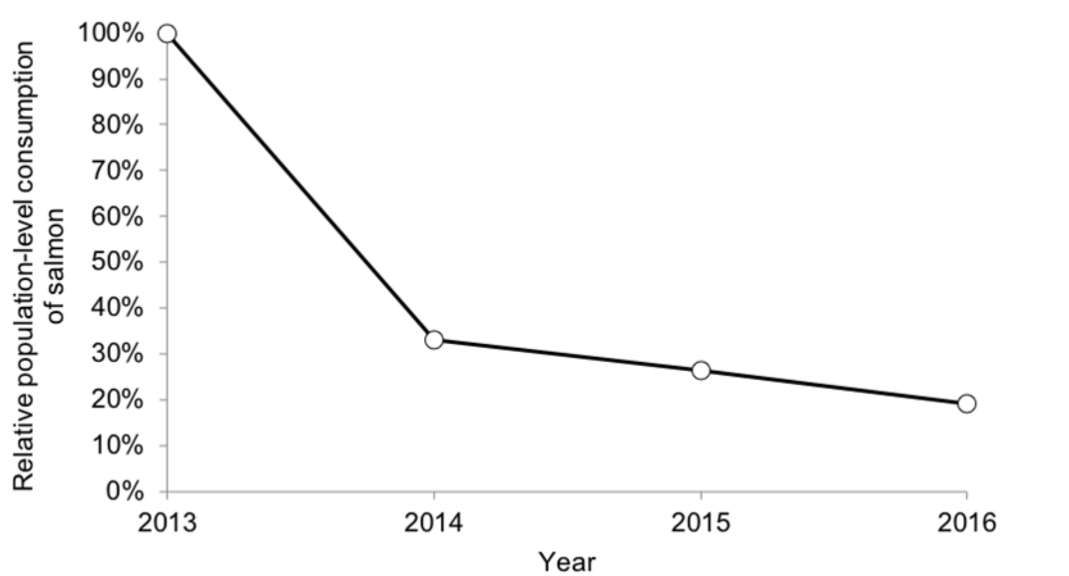


Figure 15: Relative total consumption of salmon by the pike population in Shell Lake during the pike suppression program from 2013–2016.
Values are scaled so that total salmon consumption by the pike population in 2013 = 100%.

DISCUSSION

CIAA Shell Lake Salmon Monitoring, Northern Pike Harvesting, and Stocking

Since 2012, CIAA has harvested 5,152 northern pike from Shell Lake. Although aggressive northern pike netting has taken many potential salmon predators out of the lake, changes in the size and age structure of the northern pike population over the course of the project caused concern because the literature and the observations of pike stomach contents have showed that smaller northern pike tend to consume more juvenile salmon (Sepulveda et al., 2013) (Figure 16).

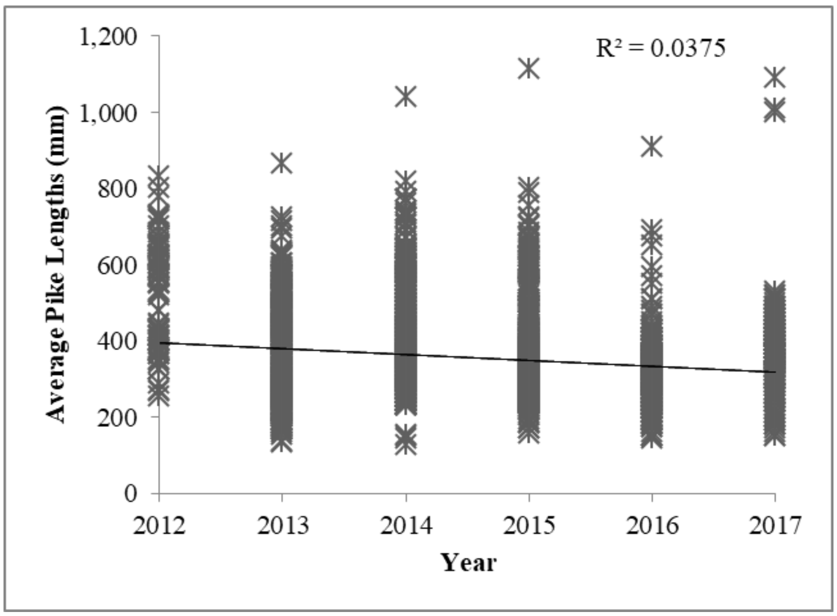


Figure 16: Average northern pike length, Shell Lake, 2012–2017.

With this in mind, CIAA included a request for funding a modeling study of the impacts that northern pike netting is having on Shell Lake along with a grant application to the Mat-Su Borough to continue monitoring the salmon population. The resulting model has shown that despite reductions in the size structure of the northern pike population in Shell Lake, overall potential consumption of salmonids has decreased because the population of pike has been reduced (see the next section).

The egg collection activities at Shell Lake in 2016–2017 involved input from the ADF&G Gene Conservation Laboratory staff to assist in the development of methods to increase the effective population size of Shell Lake sockeye salmon and ensure that genetic diversity was made a priority of the sockeye population recovery at Shell Lake. Beginning in 2020, when the second generation of hatchery-produced sockeye salmon is expected to return to Shell Lake, CIAA will need to begin family tracking for all fish used as broodstock to ensure that domestication is not occurring by back stocking resulting progeny whose parents were determined to be from wild stock. Because approximately 70 of the sockeye salmon returning to the lake in 2016 and 500 in 2017 were not used for egg take, it can be assumed that some natural production may have occurred.

University of Alaska Fairbanks Pike Data Analysis

The pike suppression program in Shell Lake reduced salmon consumption by the pike population by 81% over four years. This reduction in consumption rates was driven by a 75% reduction in the relative abundance of northern pike in the lake, estimated from CPUE. Although the pike suppression program did appear to shift the age structure of the pike population to be more dominated by small pike (which had been shown to consume more juvenile salmon), the analysis showed that this did not cause an increase in salmon consumption, in part because all age classes of pike were reduced in numbers (i.e., removals of large pike did not lead to increased catch rates of small pike). Based on this analysis, it is concluded that the pike suppression program was highly effective at reducing pike consumption of salmon in Shell Lake.

This analysis relied on several simplifying assumptions. First, pike growth rates and diet composition could not be calculated separately for each study year, due to the nature of the dataset, and therefore it was assumed that these values were unchanged from 2013–2016. It is possible that growth rates or diet composition actually did change, which could have caused the model to over- or under-estimate the overall change in salmon consumption by the pike population during the suppression program. However, it is believed any such errors would have been minor. UAF examined the raw data visually (e.g., Figure 8) and did not detect any substantial changes in growth or the fraction of salmon in the diet of pike among years. Further, the effects of modest changes in growth rates or diet would likely be small in comparison with the huge (55–98% by size class) reduction in pike CPUE, which drove the reductions in estimated salmon consumption in our analysis. Second, UAF assumed that catchability of pike in gillnets was stable from year to year. It is possible that catchability could decline if certain pike were more susceptible to being caught in gillnets, and they were preferentially removed from the population, but it seems implausible that this could account for the huge reduction in CPUE observed during the suppression program. Thus, UAF is confident that these caveats do not affect the conclusions of the study.

The goal of the analysis was to estimate the relative change in salmon consumption by the pike population over time, and the results do not provide an absolute estimate of how many salmon were consumed by pike in any given year. To estimate the population-level consumption rate in absolute terms, it would be necessary to estimate the abundance of northern pike in Shell Lake, potentially using a mark-recapture approach. Even if northern pike abundance could be estimated, the physiological parameters for pike that we used in the bioenergetics model (Bevelheimer et al., 1985; the only published parameters currently available), are believed to overestimate the consumption rates of Alaskan pike (Sepulveda et al., 2015), so the model outputs might overestimate the consumption benefit from suppression. This was not a problem for this study as UAF was interested in the scaled relative effect of suppression, but this would be an important consideration for any research project attempting to estimate absolute consumption rates or predation impacts on the salmon population.

The UAF results contrast with a widely-held view that smaller pike consume more salmon than larger pike in Southcentral Alaskan waters (Rutz 1999, Sepulveda et al., 2013). Although UAF did find that salmon made up a larger percentage of the stomach contents of smaller pike than larger pike, this did not translate into greater salmon consumption in terms of biomass. Larger fish consume more total biomass than smaller fish on a per-capita basis, and the bioenergetics model predicted that the largest size class (>500 mm) of northern pike in this study actually consumed the greatest biomass of salmon, per capita. The results differed slightly from those of a similar study estimating consumption of salmonids by pike in Alexander Creek, another tributary of the Susitna River (Sepulveda et al. 2015). That study found that age 3 and age 4 pike consumed more salmon on a per-capita basis than either age 2 or age 5+ pike. However, both studies found that all pike size classes, including the largest, consumed a large biomass of salmonids and that cannibalism of small pike was rare. In some cases, managers have used protective slot limits in an attempt to reduce the abundance of smaller pike while maintaining the abundance of larger pike, in part because smaller pike were believed to eat more salmon than larger pike (see Sepulveda et al. 2013). However, our results and those of Sepulveda et al. (2015) show that large pike are in fact important salmon predators. Reducing the abundance of age 5 pike to near zero was an important element contributing to the reduction in total salmon consumption by northern pike in Shell Lake (see figures 13 and 14). UAF concludes that suppression strategies targeting all size classes of pike are more likely to be effective at reducing consumption of salmon.

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RECOMMENDATIONS

With the sharp reductions in the northern pike population and the inferred effects on the consumption rates of salmonids, the focus of the Shell Lake project should be the continuation of gillnetting efforts to keep the pike population at the current reduced level. Effort should be made to estimate the current population of Shell Lake northern pike and identify what level of netting effort would be required to maintain this lower population.

Monitoring of Shell Lake smolt emigration and adult returns should continue at least through 2023 when CIAA expects the last return from hatchery progeny currently being reared at Trail Lakes Hatchery or possibly longer if naturally produced broodstock can provide eggs during the upcoming seasons. Due to the advanced decomposition of the fish captured using under-ice gillnets causing uncertainty about the catch and degradation of any potential samples, it is recommended that under-ice netting be discontinued.

In order to aid in the recovery of Shell Lake sockeye salmon CIAA should ensure that it is maximizing natural and hatchery production of the Shell Lake sockeye salmon stock. One factor that will be critical to maximizing Shell Lake sockeye production and rescuing this stock from extirpation will be the ability to externally distinguish naturally-spawned sockeye salmon from those produced in the hatchery because hatchery stock will not be allowed to serve as broodstock beyond 2019. Currently, these two groups can only be distinguished by pulling the otolith from each fish and reading it in the lab. Those otoliths are collected at the time of the egg take and any eggs collected found to be of hatchery origin would need to be destroyed going forward. To maximize the potential of sockeye recovery in Shell Lake, it is recommended that salmon stocked from the 2016–2017 egg collections that are expected to return in 2020–2023 be allowed to naturally spawn. Because this population is at a critical stage and northern pike are still in Shell Lake, CIAA should also be using as many naturally-spawned salmon returning in those years for an egg take. Hatchery rearing of those eggs will increase their survival and provide for a faster recovery of the population than natural spawning alone.

To distinguish naturally-spawned individuals from hatchery stock, CIAA staff at Trail Lakes Hatchery will clip the adipose fins of all smolt before they are released into Shell Lake for brood years 2016 and 2017 so they can be externally identified upon return. During the subsequent returns, eggs will then only be taken from Shell Lake from adults with adipose fins allowing all returning hatchery fish to spawn in the lake effectively maximizing the number of potential spawners.

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LITERATURE CITED

Anderson, J.L., Hetrick, N.J.,Spencer, D.,Larson, J.P., Santos, M. 2006. Design and performance of a digital video monitoring station incorporated in a V-shaped resistance board weir. Alaska Fisheries Technical Report Number 91. U.S. Fish and Wildlife Service.

Bentz, C., and Jayde Ferguson. 2013. Amended report of laboratory examination. Alaska Department of Fish and Game, Division of Commercial Fisheries-Fish Pathology Section, Accession No. 2013-0027, 333 Raspberry Road, Anchorage, AK 99518-1599, page 11.

Bevelhimer, M.S., Stein, R.A., and Carline, R.F. 1985. Assessing Significance of Physiological Differences among Three Esocids with a Bioenergetics Model. Can. J. Fish. Aquat. Sci **42**(1): 57-69.

Chipps, S.R., and Garvey, J.E. 2007. Quantitative assessment of food habits and feeding patterns. *In* Analysis and Interpretation of Freshwater Fisheries Data. *Edited by* C.S. Guy and M.L. Brown. American Fisheries Society, Bethesda, Maryland. pp. 473-514.

Cook Inlet Aquaculture Association. 2016a. Larval pike procedures manual. Cook Inlet Aquaculture Association. 40610 Kalifornsky Beach Road, Kenai, AK 99611.

Cook Inlet Aquaculture Association. 2016b. Shell Lake procedures manual. Cook Inlet Aquaculture Association. 40610 Kalifornsky Beach Road, Kenai, AK 99611.

Cook Inlet Aquaculture Association. 2016c. Video weir set-up and operations manual. Cook Inlet Aquaculture Association. 40610 Kalifornsky Beach Road, Kenai, AK 99611.

Cooper, John, E. 2016. Development, growth, and food of early life stages of Northern Pike *(Esox Lucius)* and Muskellunge *(Esox masquinongy)* in the Upper St. Lawrence River. Cooper Environmental Research. 1444 County Route 23 Constantia, NY 13044.

Deslauriers, D., Chipps, S.R., Breck, J.E., Rice, J.A., and Madenjian, C.P. 2017. Fish Bioenergetics 4.0: An R-Based Modeling Application. Fisheries **42**(11): 586-596.

Euchner, R.B.1988. Collection, preparation and use of northern pike (*Esox lucius*) cleithra for age determination. Ministry of Environment and Parks Recreational Fisheries Branch. 10142- 101st Ave St. John, B.C. Report No. PCE.20.

Giles, N. Wright, R.M. Nord, M.E. 2006. Cannibalism in pike fry, *Esox lucius L*.:some experiments with fry densities. Journal of Fish Biology29(1):107–113.

Glick, W. 2010. Susitna lakes pike sampling procedures. Alaska Department of Fish and Game. 43961 Kalifornsky Beach Road Suite B, Kenai, AK 99611.

King, B.E., Walker, S.C. 1997. Susitna River sockeye salmon fry studies, 1994 and 1995. Regional Information Report. Alaska Department of Fish and Game Commercial Fisheries Management and Development Division. Report No. 2A97-26.

Koenings, J.P., Edmundson, J.A., Kyle, G.B., Edmundson, J.M. 1987. Limnology field and laboratory manual: methods for assessing aquatic production. Alaska Department of Fish and Game Division of Fisheries Rehabilitation, Enhancement, and Development. Juneau, AK. Number 71.

Kyle, G.B., King, B.E., Peltz, L.R., and Edmundson, J.A. 1993. Susitna drainage sockeye salmon investigations: 1993 annual report on fish and limnological surveys. Alaska Department of Fish and Game. Division of Commercial Fisheries Management and Development. Juneau, AK, page 40.

Johnson, J. and P. Blanche. 2010. Catalog of waters important for spawning, rearing, or migration of anadromous fishes – Southcentral Region, Effective June 1, 2010. Alaska Department of Fish and Game, Special Publication No. 10-06, Anchorage, AK pages 323–324.

Margenau, T.L., Rassmussen, P.W. Kampa, J.M.1998. Factors affecting growth of northern pike in small northern Wisconsin lakes. North American Journal of Fisheries Management 18:625-39.

McDaniel, T.R., Pratt, K.M., Meyers, T.R., Ellison, T.D. Follett, J.E., Burke, J.A. (1994). Alaska sockeye salmon culture manual. Special Publication Number 6. Alaska Department of Fish & Game: Commercial Fisheries Management and Development Division.

Rutz, D. 1999. Movements, food availability and stomach contents of northern pike in selected Susitna River drainages, 1996–1997. Fishery Data Series No. 99-5. Alaska Department of Fish and Game, Anchorage.

Sepulveda, A., Rutz, D., Ivey, S. Dunker, K., Gross, J. 2013. Introduced northern pike predation on salmonids in Southcentral Alaska. Ecology of Freshwater Fish. Vol. 22 issue 2, pages 268–279.

Sepulveda, A.J., Rutz, D.S., Dupuis, A.W., Shields, P.A., and Dunker, K.J. 2015. Introduced northern pike consumption of salmonids in Southcentral Alaska. Ecol. Freshw. Fish 24(4): 519-531.

Spafard, M. A. and J. A. Edmundson. 2000. A morphometric atlas of Alaskan lakes: Cook Inlet, Prince William Sound, and Bristol Bay areas. Alaska Department of Fish and Game, Commercial Fisheries Division, Regional Information Report No. 2A00-23, page 75.

Tarbox, K. E. and G. B. Kyle. 1989. An estimation of adult sockeye salmon (*Oncorhynchus nerka*) production, based on euphotic volume, for the Susitna River Drainage, Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries, Division of Fisheries Rehabilitation, Enhancement, and Development, Regional Information Report No. 1S89-01. 1989.

Willette, T.M., R.D. DeCino, A.W. Barclay and X. Zhang. 2016. An evaluation of the selectivity of fish wheels used to apportion sonar counts to species on the Yentna River, Alaska. Alaska Department of Fish and Game, Fishery Manuscript Series No. 16-02. Anchorage.

Wizik, A. 2016. Shell Lake Sockeye Salmon Progress Report 2015. Cook Inlet Aquaculture Association. 36pp.

Wizik, A. 2017. Shell Lake Sockeye Salmon Progress Report 2016. Cook Inlet Aquaculture Association. 36pp.

Yanusz, R., R. Merizon, D. Evans, M. Willette, T. Spencer, and S. Raborn. 2007. Inriver abundance and distribution of spawning Susitna River sockeye salmon *Oncorhynchus nerka*, 2006. Alaska Department of Fish and Game, Fishery Data Series No. 07-83, Anchorage.

Yanusz, R., R. Merizon, T.M. Willette, D. Evans, and T.R. Spencer. 2011a. Inriver abundance and distribution of spawning Susitna River sockeye salmon *Oncorhynchus nerka*, 2007. Alaska Department of Fish and Game, Fishery Data Series No. 11-19, Anchorage.

Yanusz, R., R. Merizon, T.M. Willette, D. Evans, and T.R. Spencer. 2011b. Inriver abundance and distribution of spawning Susitna River sockeye salmon *Oncorhynchus nerka*, 2008. Alaska Department of Fish and Game, Fishery Data Series No. 11-12, Anchorage.

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APPENDICES

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Appendix 1: Shell Lake – Daily Historical Adult Cumulative Sockeye Salmon Escapement

Date	1986	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
10-Jul	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
11-Jul	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
12-Jul	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
13-Jul	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
14-Jul	0	ND	ND	0	ND	ND	ND	ND	ND	ND	ND	ND	0
15-Jul	0	0	ND	0	0	0	ND	ND	ND	ND	ND	ND	0
16-Jul	0	0	0	0	0	0	ND	ND	ND	ND	ND	ND	0
17-Jul	0	0	0	0	0	0	0	ND	ND	ND	0	ND	0
18-Jul	0	0	0	0	0	0	0	ND	ND	ND	0	ND	0
19-Jul	0	0	0	0	0	0	0	ND	ND	ND	0	ND	0
20-Jul	0	0	0	0	0	0	0	ND	ND	ND	0	ND	0
21-Jul	0	0	0	0	0	0	0	ND	ND	ND	0	ND	0
22-Jul	0	0	0	0	0	0	0	ND	ND	0	0	ND	0
23-Jul	0	10	0	0	0	0	0	ND	ND	0	0	ND	0
24-Jul	0	1,140	0	0	0	0	0	ND	ND	1	0	ND	0
25-Jul	0	3,474	0	1	0	0	0	ND	ND	0	0	ND	0
26-Jul	0	3,481	0	1	0	0	0	ND	ND	0	0	ND	0
27-Jul	0	5,806	0	3	0	389	0	ND	ND	0	0	ND	0
28-Jul	0	6,510	0	8	0	389	0	ND	ND	0	0	ND	0
29-Jul	0	6,533	0	1,236	475	395	0	ND	ND	0	0	ND	0
30-Jul	0	7,650	0	1,251	589	395	0	ND	ND	0	0	ND	0
31-Jul	0	9,518	0	1,253	621	728	0	ND	ND	0	0	ND	0
01-Aug	0	10,422	0	1,269	642	1,395	0	ND	ND	2	0	ND	0
02-Aug	0	11,099	0	1,269	642	1,677	0	ND	ND	3	0	ND	0
03-Aug	0	11,099	0	1,269	644	1,686	0	ND	ND	0	0	ND	0
04-Aug	0	25,251	0	1,270	835	1,895	0	ND	ND	0	0	ND	0
05-Aug	0	36,337	7,911	1,271	876	1,947	219	ND	ND	4	0	ND	0
06-Aug	1,578	37,761	11,203	1,273	876	1,947	235	ND	ND	0	0	ND	0
07-Aug	2,370	42,772	11,962	1,273	879	1,950	265	ND	ND	0	0	ND	0
08-Aug	3,041	45,385	12,755	1,273	890	1,951	323	ND	ND	0	0	ND	0
09-Aug	3,216	53,663	13,555	1,275	894	1,954	385	ND	11	0	0	ND	0
10-Aug	3,296	60,786	14,476	1,532	903	1,955	400	ND	18	0	0	ND	0
11-Aug	3,346	60,786	14,552	1,689	903	1,962	416	ND	18	0	0	ND	0
12-Aug	3,461	63,682	15,992	1,689	903	1,983	459	ND	87	0	0	ND	0
13-Aug	3,478	64,133	17,434	1,726	903	2,023	492	ND	102	0	0	ND	0
14-Aug	3,489	64,314	17,939	1,749	2,017	2,107	492	ND	115	0	0	ND	0
15-Aug	3,565	67,566	18,729	1,764	4,053	2,107	492	ND	117	0	0	ND	0
16-Aug	3,597	69,133	18,907	2,508	4,554	2,128	492	ND	119	0	0	ND	0
17-Aug	3,623	69,133	18,911	2,508	4,564	2,143	492	ND	123	0	0	ND	0
18-Aug	3,726	69,138	19,846	2,508	4,564	2,204	492	ND	123	0	0	ND	0
19-Aug	3,820	69,800	21,336	2,510	4,573	2,204	492	ND	123	0	0	ND	0
20-Aug	3,857	ND	21,999	2,510	4,590	2,220	588	ND	123	5	0	ND	0
21-Aug	3,883	ND	22,491	2,530	4,673	2,223	588	ND	123	0	0	ND	0
22-Aug	3,909	ND	23,719	2,559	4,684	2,223	593	ND	128	6	0	ND	0
23-Aug	3,909	ND	24,157	2,572	4,688	2,223	874	ND	130	0	0	ND	0
24-Aug	3,909	ND	24,379	2,572	4,688	2,223	909	ND	130	0	0	ND	0
25-Aug	3,909	ND	24,554	2,580	4,697	2,223	933	ND	130	0	0	ND	0
26-Aug	4,159	ND	24,677	2,580	4,697	2,223	937	ND	130	0	0	ND	0
27-Aug	4,176	ND	25,052	2,601	4,809	2,223	937	ND	132	ND	0	ND	0
28-Aug	4,200	ND	25,765	2,602	4,856	2,223	937	ND	132	ND	0	ND	3
29-Aug	4,200	ND	25,963	2,607	4,896	2,223	937	ND	133	ND	0	ND	0
30-Aug	4,200	ND	26,094	2,607	4,918	2,223	937	ND	ND	ND	0	ND	0
31-Aug	4,221	ND	26,252	2,607	4,931	2,223	937	ND	ND	ND	0	ND	0
01-Sep	4,231	ND	26,423	2,613	4,931	2,223	937	ND	ND	ND	0	ND	53
02-Sep	4,231	ND	26,780	2,620	4,940	2,223	937	ND	ND	ND	0	ND	186
03-Sep	ND	ND	26,784	2,620	4,940	ND	937	ND	ND	ND	0	ND	196
04-Sep	ND	ND	26,844	ND	4,940	ND	937	ND	ND	ND	0	ND	202
05-Sep	ND	ND	26,846	ND	4,952	ND	ND	ND	ND	ND	0	ND	211
06-Sep	ND	ND	26,851	ND	4,962	ND	ND	ND	ND	ND	0	ND	238
07-Sep	ND	ND	26,862	ND	4,968	ND	ND	ND	ND	ND	0	ND	271
08-Sep	ND	ND	26,863	ND	ND	ND	ND	ND	ND	ND	0	ND	288
09-Sep	ND	ND	26,863	ND	ND	ND	ND	ND	ND	ND	0	ND	307
10-Sep	ND	ND	26,863	ND	ND	ND	ND	ND	ND	ND	0	ND	336
11-Sep	ND	ND	26,863	ND	ND	ND	ND	ND	ND	ND	0	ND	348
12-Sep	ND	ND	26,863	ND	ND	ND	ND	ND	ND	ND	0	ND	355
13-Sep	ND	ND	26,863	ND	ND	ND	ND	ND	ND	ND	0	ND	363
14-Sep	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0	ND	383
15-Sep	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3	ND	403
16-Sep	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2	ND	430
17-Sep	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	448
18-Sep	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	465
19-Sep	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5	ND	505
20-Sep	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3	ND	514
21-Sep	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3	ND	539
22-Sep	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3	ND	557
23-Sep	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3	ND	575
Total	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133*	6*	3*	134**	575

* Counts are estimates due to partial video loss. ND means no data was gathered for that time period

* Salmon could not be identified to the species level

** Weir was damaged and counts are an estimate based on aerial and foot surveys

Appendix 2: Shell Lake – Daily Historical Sockeye Salmon Cumulative Smolt Migration

Date	1987	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
9-May	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
10-May	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11-May	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
12-May	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
13-May	11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-May	14	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
15-May	19	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
16-May	52	ND	ND	47	ND	ND	ND	ND	ND	ND	ND	ND
17-May	61	ND	ND	92	ND	0	ND	ND	ND	ND	0	ND
18-May	81	ND	ND	113	ND	0	0	ND	ND	ND	0	ND
19-May	94	ND	ND	190	ND	0	0	ND	ND	ND	0	ND
20-May	126	ND	ND	342	ND	0	0	ND	ND	ND	4	ND
21-May	295	ND	ND	355	ND	0	0	ND	ND	ND	5	ND
22-May	415	ND	ND	395	ND	0	0	ND	ND	0	12	ND
23-May	563	ND	ND	466	ND	0	0	ND	ND	0	12	0
24-May	11,172	ND	ND	8,254	217	0	0	0	ND	7	12	0
25-May	11,742	ND	ND	9,729	288	0	0	0	ND	9	12	0
26-May	17,027	ND	ND	12,494	546	0	0	0	ND	9	12	0
27-May	24,127	ND	ND	12,494	555	0	0	0	ND	9	12	0
28-May	32,984	0	ND	12,498	1,679	0	0	0	ND	14	12	0
29-May	36,198	0	ND	14,133	1,995	0	0	0	ND	14	12	0
30-May	42,974	1	ND	14,137	2,075	5	0	0	ND	18	12	0
31-May	42,989	13	ND	14,138	2,412	6	5	0	ND	20	12	0
1-Jun	43,151	18	ND	14,275	2,520	6	6	0	ND	20	12	0
2-Jun	43,941	18	ND	15,854	2,524	7	6	0	134	20	12	0
3-Jun	46,632	27	ND	42,223	2,549	7	7	0	151	20	12	7
4-Jun	46,857	71	392	44,430	2,549	7	7	0	3,540	21	12	7
5-Jun	47,726	1,157	482	45,542	2,549	7	7	0	4,307	50	12	8
6-Jun	52,782	1,308	636	65,367	2,565	14	7	0	4,913	55	12	11
7-Jun	54,172	1,563	681	66,261	2,651	15	14	0	6,237	55	12	11
8-Jun	57,923	1,678	1,323	66,508	2,660	15	15	0	6,999	56	12	11
9-Jun	59,167	3,780	2,088	66,830	2,662	15	15	0	7,648	57	12	11
10-Jun	59,570	3,792	2,286	67,095	2,700	15	15	0	9,969	57	12	11
11-Jun	59,809	9,804	2,294	67,440	2,715	15	15	0	13,186	58	12	11
12-Jun	62,623	10,595	2,296	67,478	2,716	15	15	1	16,480	59	12	11
13-Jun	62,981	10,613	2,296	67,507	2,732	15	15	1	18,501	59	12	11
14-Jun	64,383	50,914	2,783	68,413	2,733	16	15	3	19,916	59	12	11
15-Jun	64,796	64,854	2,915	68,469	2,733	16	16	3	20,574	59	12	11
16-Jun	65,685	76,045	2,918	68,637	2,733	17	23	3	20,872	ND	12	11
17-Jun	67,793	78,512	3,063	68,638	2,733	17	23	3	21,126	ND	12	11
18-Jun	68,939	79,482	3,130	68,639	2,733	17	23	3	21,253	ND	12	15
19-Jun	69,621	79,488	3,134	68,648	2,733	17	23	3	21,288	ND	12	15
20-Jun	71,995	79,758	3,143	68,648	2,733	17	23	4	21,299	ND	ND	15
21-Jun	72,160	79,758	3,181	68,651	2,733	17	23	4	21,302	ND	ND	15
22-Jun	74,794	79,758	3,183	68,651	2,733	17	ND	5	21,320	ND	ND	ND
23-Jun	75,674	79,798	3,185	68,651	ND	17	ND	5	21,329	ND	ND	ND
24-Jun	76,663	79,798	3,185	68,651	ND	17	ND	5	21,342	ND	ND	ND
25-Jun	77,335	79,948	3,197	ND	ND	17	ND	5	21,342	ND	ND	ND
26-Jun	77,781	80,600	3,200	ND	ND	17	ND	5	21,342	ND	ND	ND
27-Jun	78,343	ND	ND	ND	ND	17	ND	5	21,342	ND	ND	ND
28-Jun	78,465	ND	ND	ND	ND	ND	ND	5	21,343	ND	ND	ND
29-Jun	78,575	ND	ND	ND	ND	ND	ND	5	21,343	ND	ND	ND
30-Jun	80,403	ND	ND	ND	ND	ND	ND	5	21,345	ND	ND	ND
1-Jul	81,290	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Jul	81,772	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3-Jul	82,527	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Jul	82,785	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
5-Jul	83,114	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6-Jul	83,198	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7-Jul	83,273	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total	83,273	80,600	3,200	68,651	2,733	17	23	5	21,345	59	12	15
ND means no data was collected for that time period												

Appendix 3: Shell Lake Gillnet CPUE 2012–2017

Shell Lake Gillnet CPUE 2012-2017

Year	Pike caught	Net hours	CPUE
2012	87	224	0.39
2013	467	1,838	0.25
2014	1,356	15,072	0.09
2015	1,729	19,728	0.09
2016	729	13,032	0.06
2017	784	13,872	0.06

Shaded areas may not be comparable to other years due to differences in netting between years

Appendix 4: Shell Lake 2017 – Update

Misc. Activities	
Ice-out:	19-May
Crew On-site:	23-May
Crew Off-site:	28-Sep

Smolt Migration				
Dates:		23-May	to	21-Jun
Coho:	11			
Sockeyes:	15			
Mortalities:	0			
Rainbow Trout:	0			
Dolly Varden:	0			

Adult Migration			
Dates:	10-Jul	to	23-Sep
Coho Salmon	411		
*Sockeye Salmon :	575		
Mortalities:	0%		

Northern Pike Harvest (All Gear)		
Dates:		5/31-9/3
Effort (Hours):		13,872
No. Harvest:		780
	Male	379*
	Female	358*

* Some samples not sexed due to otter predation

Appendix 5: Shell Lake 2017 – Daily Environmental Log

Date	Sky	Precip. (mm)	Staff Gauge (ft)	Water Temp. (°C)	Air Temp. (°C)
24-May	5	19.3	1.1	6	7
25-May	2	0.0	1.1	6	8
26-May	4	0.0	1.1	6	8
27-May	3	0.0	1.1	7	9
28-May	4	8.9	1.1	7	8
29-May	3	5.8	1.2	7	9
30-May	2	0.0	1.2	8	19
31-May	1	0.0	1.2	11	24
1-Jun	1	0.0	1.2	12	23
2-Jun	2	0.0	1.1	12	21
3-Jun	1	0.0	1.1	10	23
4-Jun	1	0.0	1.1	9	23
5-Jun	5	1.8	1.1	8	10
6-Jun	2	0.0	1.1	11	23
7-Jun	2	0.0	1.1	13	23
8-Jun	3	0.0	1.0	11	21
9-Jun	3	0.0	1.0	14	23
10-Jun	4	2.5	1.0	12	14
11-Jun	3	0.0	1.0	11	23
12-Jun	3	0.0	1.0	11	18
13-Jun	4	0.0	1.0	11	18
14-Jun	2	0.0	1.0	12	17
15-Jun	2	0.0	1.0	14	20
16-Jun	3	0.0	0.9	15	22
17-Jun	3	0.0	0.9	12	21
18-Jun	3	0.0	0.9	13	20
19-Jun	2	0.0	0.9	14	25
20-Jun	4	0.0	0.9	13	21
21-Jun	2	0.0	0.9	14	21
22-Jun	4	0.0	0.9	13	17
23-Jun	4	0.0	0.9	13	17
24-Jun	1	0.0	0.9	16	27
25-Jun	1	0.0	0.9	18	27
26-Jun	4	0.3	0.9	14	13
27-Jun	5	2.8	0.9	14	13
28-Jun	3	0.0	0.9	15	19
29-Jun	4	0.0	0.9	16	18
30-Jun	3	0.0	0.9	16	18
1-Jul	2	0.0	0.9	18	27
2-Jul	4	0.0	1.0	15	16
3-Jul	3	2.8	1.0	15	20
4-Jul	2	0.0	1.0	16	24
5-Jul	1	0.0	1.0	16	25
6-Jul	1	0.0	1.0	17	29
7-Jul	2	0.0	1.0	17	25
8-Jul	5	8.4	1.0	18	16
9-Jul	3	0.0	1.0	16	18
10-Jul	3	0.0	1.0	17	20
11-Jul	2	0.0	1.0	17	23
12-Jul	1	0.0	1.0	19	32
13-Jul	1	0.0	1.0	21	32
14-Jul	4	0.0	1.0	19	20
15-Jul	3	0.0	1.0	17	24
16-Jul	3	0.0	1.0	17	26
17-Jul	4	0.0	1.0	17	17
18-Jul	5	14.7	1.0	17	13
19-Jul	3	0.0	1.0	17	19
20-Jul	2	0.0	1.0	18	24
21-Jul	1	0.0	1.0	18	26
22-Jul	1	0.0	1.0	20	30
23-Jul	1	0.0	1.0	19	27
24-Jul	4	0.0	1.0	17	17
25-Jul	5	1.5	1.0	18	14
26-Jul	4	6.1	1.0	18	19
27-Jul	1	0.0	1.0	18	26

Date	Sky	Precip. (mm)	Staff Gauge (ft)	Water Temp. (°C)	Air Temp. (°C)
28-Jul	3	0.0	1.0	17	18
29-Jul	2	0.0	1.0	18	26
30-Jul	2	0.0	1.0	19	26
31-Jul	2	0.0	1.0	17	22
1-Aug	3	0.0	1.0	17	20
2-Aug	5	3.1	1.0	17	14
3-Aug	5	4.6	1.0	16	14
4-Aug	4	0.0	1.0	17	19
5-Aug	2	0.0	1.0	18	29
6-Aug	1	0.0	0.9	19	27
7-Aug	3	0.0	0.9	17	21
8-Aug	4	0.0	0.9	17	22
9-Aug	4	0.0	0.9	18	22
10-Aug	3	1.3	0.9	18	22
11-Aug	4	1.0	0.9	17	18
12-Aug	5	1.3	0.9	18	15
13-Aug	4	1.5	0.9	17	17
14-Aug	3	0.0	0.9	17	18
15-Aug	4	0.0	0.9	17	17
16-Aug	4	2.8	0.8	16	15
17-Aug	5	6.9	0.8	16	14
18-Aug	5	0.3	0.8	15	15
19-Aug	4	0.0	0.8	16	18
20-Aug	5	13.5	0.9	15	10
21-Aug	4	0.0	0.9	15	21
22-Aug	2	0.0	0.9	16	19
23-Aug	4	1.3	0.9	16	14
24-Aug	5	13.7	0.9	15	12
25-Aug	3	0.0	0.9	15	18
26-Aug	2	0.0	0.9	16	23
27-Aug	2	0.0	0.9	15	18
28-Aug	3	0.0	0.9	16	22
29-Aug	4	4.6	0.9	16	18
30-Aug	4	3.3	0.9	16	16
31-Aug	5	11.2	1.0	15	11
1-Sep	4	15.5	1.0	15	13
2-Sep	4	2.0	1.0	14	12
3-Sep	4	0.3	1.0	14	13
4-Sep	4	0.0	1.0	14	14
5-Sep	5	20.3	1.2	14	10
6-Sep	5	10.2	1.2	14	11
7-Sep	4	0.3	1.2	13	12
8-Sep	1	0.0	1.2	14	19
9-Sep	1	0.0	1.2	14	19
10-Sep	4	4.1	1.3	14	13
11-Sep	3	0.0	1.3	14	17
12-Sep	5	0.8	1.3	13	9
13-Sep	5	3.3	1.3	13	11
14-Sep	5	7	1.3	13	10
15-Sep	5	2.8	1.3	12	12
16-Sep	5	0.0	1.3	12	12
17-Sep	2	0.0	1.3	12	21
18-Sep	5	17.8	1.4	12	11
19-Sep	2	0.0	1.4	12	17
20-Sep	1	0.0	1.4	12	16
21-Sep	5	9.1	1.4	12	7
22-Sep	5	18.5	1.5	12	8
23-Sep	5	17.3	1.7	12	10
24-Sep	4	8.4	1.8	12	10
25-Sep	3	0.0	1.9	12	11
26-Sep	1	0.0	1.9	11	10
Total		283	Staff	Water	Air
Avg.		2.2	1.0	14.5	18.1
Min.		0	0.8	6	7
Max.		20.3	1.9	21	32

Appendix 6: Age Data Explanation for UAF Analysis

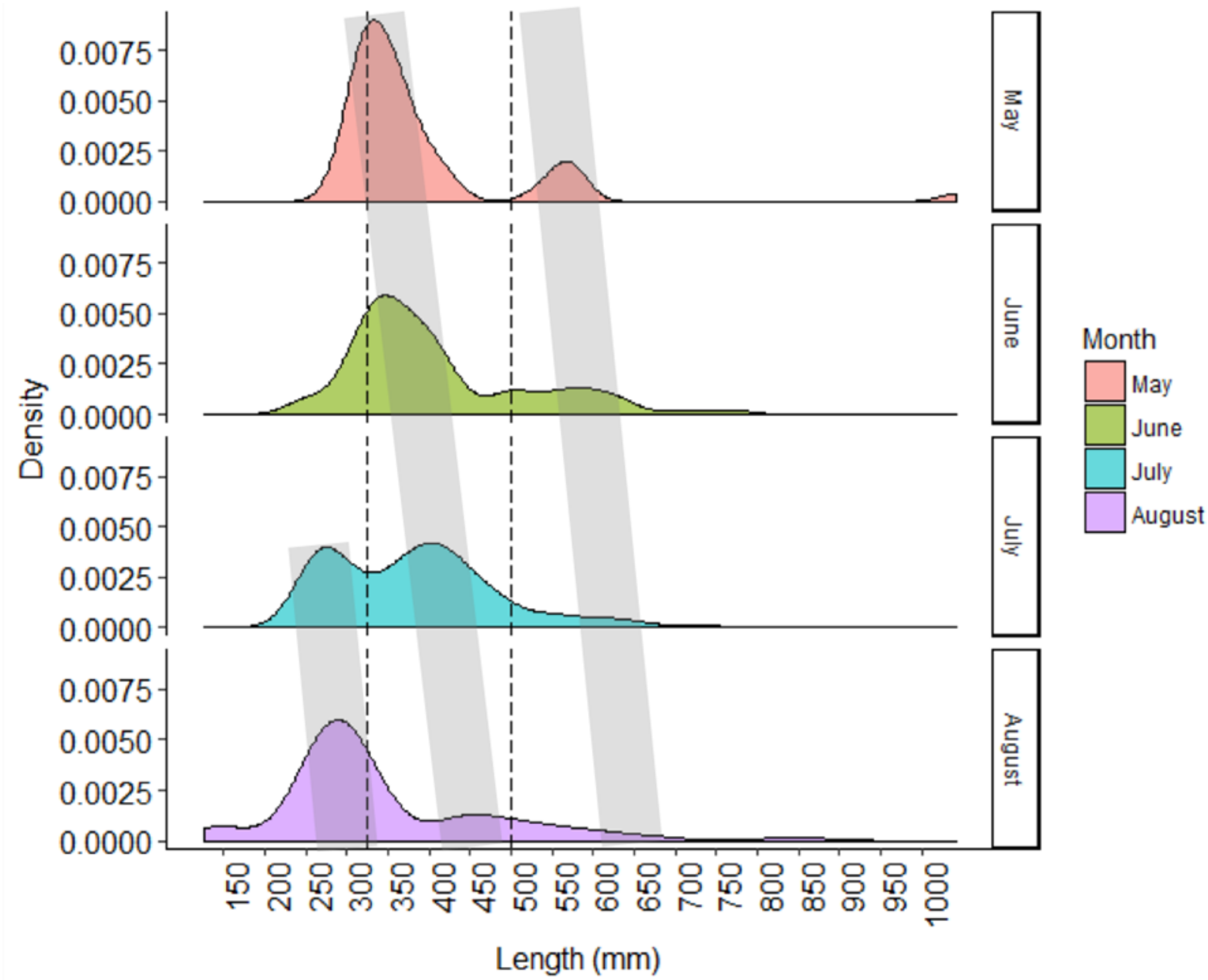
We initially attempted to calculate initial and final weights directly using the age data provided by CIAA, but this approach was unsuccessful. Using the cleithrum ages, we calculated the monthly mean weight-at-age of pike captured in each year to estimate the initial and final weights of an average pike in each year. However, several age groups appeared to lose weight during the summer growing season, which was unlikely. Many of these age groups also appeared to lose length during the season, which was implausible.

Further examination of the size-at-age data suggested that pike ages may have been underestimated during early summer in many cases, causing some cohorts to appear larger during early summer than during late summer. For pike captured during May and June, the annular mark from the previous winter could have been difficult to distinguish if it was adjacent to the margin of the cleithrum, with little or no additional “plus growth” providing separation. This was a plausible explanation for the apparent negative growth rates, but we could not be sure this was the case, nor could we adequately correct for it. Therefore, we used a length-frequency method for the remainder of the analysis. This approach had the advantage of not depending on the cleithrum age data, but the disadvantage that growth and consumption was modeled for pike size classes, which could have included a mixture of ages, rather than modeling each age cohort separately. In particular, the largest size class likely included pike ranging from ages 3-7, and their consumption rates were modeled using a single growth rate, based largely on the sizes of the more numerous age-3 pike. The older cohorts were much more abundant at the start of the suppression program than at the end, so the effect of estimating their consumption rates based on the growth of the age-3 cohort was to make our estimates of the reduction in predation rates more conservative. In our judgment, the conservatism of these estimates did not affect the conclusions of the study.

We identified pike size classes and estimated their growth rates using the length-frequency method (Isely and Grabowski 2007). We plotted monthly length-frequency histograms for pike captured in each year of the study. The histogram for pike captured in 2014 (Appendix 7) provided the clearest separation between cohorts, so we used this histogram for the analysis. We identified three primary size classes and inferred their growth rates based on changes in their modal lengths from month to month (represented by shaded bands in Appendix 7). The youngest cohort did not fully recruit to the sampling gear until July, so we estimated its growth from July to August. Histograms were less clear for other individual years and for all years combined, so by necessity, we assumed that pike grew at similar rates during the other years of the study as during 2014.

Appendix 7: Length frequency histograms of pike captured during 2014, broken down by month.

Shaded bands denote inferred seasonal growth of the three primary cohorts. The smallest cohort appeared to recruit to the sampling gear in July. Dashed lines represent breaks between size classes used for subsequent analyses.



Appendix 8: Amended ADF&G Pathology Report

ACCESSION NO: 2013-0027

ALASKA DEPARTMENT OF FISH AND GAME
DIVISION OF COMMERCIAL FISHERIES - FISH PATHOLOGY SECTION
333 RASPBERRY ROAD, ANCHORAGE, AK 99518-1599 - Phone (907) 267-2244/Fax 267-2194

REPORT OF LABORATORY EXAMINATION

LOT (YEAR, STOCK, SPECIES): Shell Lake sockeye salmon, *Oncorhynchus nerka*

FACILITY: Cook Inlet Aquaculture Association

CONTACT PERSON/ADDRESS: Nathan Weber, CIAA, 40610 Kalifornsky Rd, Kenai, AK 99611

SAMPLE DATE: 8/15/12 (1 fish) and 8/28/12 (7 fish)

DATE SAMPLE RECEIVED: 8/16/12 (1 fish) and 8/29/12 (7 fish)

LIFE STAGE: Adult **SPECIMEN TYPE**: Whole fish

STATE: Chilled

WILD: Yes **NUMBER OF SAMPLES**: 8

HISTORY/SIGNS: Over the last 3 years, sockeye salmon from Shell Lake (near Skwentna) have experienced dramatic population declines. Concurrently large numbers of pre-spawning adult mortalities have been detected. These fish appeared healthy, as they had no external lesions or signs of stress. Last year, two frozen fish were examined by the Fish Pathology Laboratory (Acc. No. 2012-0034) and no viral or bacterial pathogens were detected, suggesting that the cause may have been environmental. However, water quality data gathered over several months did not indicate any obvious problems. The only potential pathogen detected in the two submitted fish was a nematode (*Philonema* sp.), which occurred in high numbers in the peritoneal cavity and were associated with visceral adhesions.

This year the weir on Shell Creek was replaced with a video monitoring system due to concerns of local residents about handling stress during fish enumeration. Unfortunately this video system suffered a power failure on 5/24/12-5/28/12 so lake population estimates are biased. However, visual assessment of fish numbers on the sample collection day of 8/28/12 indicated that 43/100 adult fish died prior to spawning in the creek. Only 7 of these fish were in good enough condition for pathological evaluation. These fish appeared severely lethargic, in fact one fish did not move when approached nor try to escape when caught by hand. This fish subsequently expired several minutes later. There were 2 pre-spawn mortalities detected during the earlier sample collection this year (8/15/12) out of an estimated 200 fish that had immigrated into the lake. Only 1 of these fish was suitable for sample submission. Average lake temperature is about 13-16°C (16°C at 1m and 7.5°C at 15m). Northern Pike, *Esox lucius*, have also been introduced into the lake, which have exploited and affected approximately 25% of the spawning habitat.

REASON FOR SUBMISSION: Determine cause of pre-spawning mortality

FINAL REPORT DATE: 11/6/12; amended report 11/15/13

CLINICAL FINDINGS

NECROPSY:

MORTALITIES: 6 females and 2 males; Approximate fork length of 59.7 cm (n = 1)

8/8 fish appeared normal externally
5/6 females had no or partial egg skeins; 1/6 females ripe with eggs spilling from vent

4/8 moderately degraded gills
8/8 gills with extensive petechiae, with some possible post-mortem congestion
8/8 gills had excessive mucus and appeared inflamed and irritated
8/8 gills had grossly visible large white cysts (Figure 1)
3/8 gills had one to a few parasitic copepods (*Salmincola* sp.)
7/8 hearts pale; 1/7 pale hearts with petechiae and vessels appeared hypertrophied
2/8 livers pale; 1/8 mottled liver with multifocal green pigment (bilirubin)
4/8 with high intensities of larval and adult nematode infestations (*Philonema* sp.) in the peritoneal cavity, airbladder and viscera associated with visceral adhesions
4/4 fresh gills had moderate epithelial hyperplasia and few telangiectasia in wet mounts
1/8 gills had few non-motile bacilli, likely representing post-mortem spoilage organisms
8/8 gill wet mounts of grossly visible white cysts contained erythrocytes and leukocytes intermixed in encapsulating cyst-like structure
2/8 gills with few digenean metacercariae (*Neascus* sp.) in wet mounts;
1/8 gills with nematode eggs in wet mounts
8/8 gills with few to myriad numbers of microsporidian xenomas (*Loma salmonae*) in wet mounts; some xenomas were stacked on top of each other, whereas other xenomas had ruptured and released microspores (Figure 2)

FAT: FAT for all three Gram-negative pathogens was performed on the first fish that arrived on 8/15/12. However, only *Renibacterium salmoninarum* was tested in the subsequent 7 submitted fish due to the lack of clinical signs of an acute Gram-negative septicemia (BKD is typically chronic) and negative test results in the first submitted fish.

0/1 positive for *Aeromonas salmonicida*
0/8 positive for *Renibacterium salmoninarum*
0/1 positive for *Yersinia ruckeri* Type I
0/1 positive for *Yersinia ruckeri* Type II

BACTERIOLOGY: 0/1 kidneys struck on TSA at 15°C for 12 days had bacterial growth. Only the first fish was tested for systemic bacterial infections, as these results were negative and *Loma salmonae* was found to be the primary pathogen of concern (see below).

HISTOPATHOLOGY: 6µ sections, hematoxylin and eosin stains.

MORTALITIES: Some post-mortem changes were present, such as autolysis in several fish.

Xenomas (hypertrophied host cells filled with spores) of *Loma salmonae* were found in 4/8 fish. Gill infections were most common, where xenomas occurred in the vasculature of primary and secondary lamellae and were associated with hemorrhage, inflammation, necrosis and fibrosis (Figures 3-5). Lamellar fusion was suggestive, but post-mortem changes made the interpretation of this lesion difficult. Less common sites of infection included heart (2 fish), spleen (1 fish) and kidney (1 fish). In the heart, xenomas infected the endothelial lining of the spongy ventricular myocardium and were associated with mild myocarditis and necrosis (Figure 6). Xenomas also occurred in the lumen of the bulbus arteriosus. A xenoma was located in the red pulp of the spleen, but no host response was observed. Likewise, no tissue changes were associated with xenomas in the parenchymal tissue of the renal interstitium or transmural infections of renal arterioles.

Other important parasite infections were detected in the kidneys of 8/8 fish. Sporogonic stages of a myxozoan parasite resembling a *Sphaerospora* sp. were found in the lumen of renal tubules (Figure 7). Extrasporogonic stages of what appeared to be a different myxozoan, possibly *Chloromyxum* sp., were in various developmental stages within the renal tubule epithelium that caused necrosis and complete replacement of affected renal tubules (Figure 8). Apparently uninfected renal tubules also displayed degenerative changes and necrotic tissue was associated with a frank nephritis (Figure 8).

A third parasite that was less commonly detected in histologic sections was a nematode, one in spleen and one in heart. These probably represent sections of *Philonema* sp. that was observed grossly at necropsy.

VIROLOGY: 0/1 (1 X fish/pool) positive for virus. Kidney and spleen processed by quantal assay on EPC cell lines at 14°C for 14 days and blindpassaged for an additional 14 days. Minimum level of detection = 50 infectious particles/g of pooled sample. Only the first fish was tested for systemic viral infections, as these results were negative and *Loma salmonae* was found to be the primary pathogen of concern (see below).

DIAGNOSIS: Systemic microsporidiosis; renal myxosporidiosis; heavy nematode burden

COMMENTS/RECOMMENDATIONS:

Necropsy revealed that *Loma salmonae* was the main pathogen associated with pre-spawning mortality based on gill lesions and a multitude of microsporidian-containing xenomas observed in wet mounts of every fish. This parasite causes disease in salmonids, usually adults, in the aquaculture and hatchery setting. The life-cycle of this parasite is direct and it is capable of undergoing autoinfection. Emergent fry likely become infected by feeding on spore infected adult carcasses. Infections are persistent, but it is possible for fish to become reinfected as they migrate back to freshwater. In Alaska, *Loma* caused up to 12% mortality of Chinook salmon rearing in earthen ponds at Fort Richardson Hatchery and mass mortality at post-release of survivors (Hauck, 1984). *Loma* has not been proven to be a major cause of mortality in wild fish populations, although mortality of spawning sockeye in British Columbia have been associated with high infections (cited in Shaw et al., 2000 as M. Higgens, Fisheries and Oceans, per comm.). This parasite elicits an intense inflammatory response to mature spores that have been released from ruptured or degraded xenomas and then necrosis ensues (Hauck, 1984). High infections can also lead to occluded blood vessels, gill hyperplasia and lamellar fusion, which results in respiratory distress. The clinical signs, gross lesions of gills and histopathology were all consistent with the major cause of mortality in these fish being attributable to the systemic infections by *Loma salmonae*.

Histopathology also demonstrated that these fish were co-infected with one or more renal myxozoan parasites. The life-cycle of these parasites is indirect and involves a freshwater invertebrate as a definitive host. Infections are persistent and fish can become reinfected as they migrate back to freshwater. These were tentatively identified as *Sphaerospora* sp. (possibly *S. oncorhynchi*) and *Chloromyxum* sp. (Dr. M. Kent, Oregon State Univ., per communication). The histopathologic changes in the kidney suggested that the renal disease may have been an important contributing factor to mortality in these fish.

The third parasite that was detected was the nematode *Philonema* sp., which is also a pathogen of propagated salmonids. This parasite has an indirect life-cycle. These nematodes cause visceral adhesion and was thought to be a contributory factor in the pre-spawning mortality of Shell Lake sockeye in samples submitted last year (Acc. No. 2012-0034).

From a management standpoint, there is little that can be done to mitigate mortality due to these parasites. There are no approved chemotherapeutics for treating these infections and a habitat restoration project is not practical nor would it necessarily help reduce infection levels. Clearly, the most significant direct source of population decline for this sockeye stock is pike predation that reduces recruitment resulting in fewer sockeye that can potentially survive parasite epizootics. In addition to pike eradication, CIAA is interested in an enhancement project to increase recruitment by releasing fed-fry. This may also enhance survival from *Loma* infections because it would reduce exposure levels to fry that would have normally been feeding on infected carcasses. One major consideration for this project is strict biosecurity when performing eggtake at Shell Lake because *Loma salmonae* can be directly transmitted to fish and spores are extremely resistant to environmental conditions and disinfectants, such as iodophors (Shaw et al., 1999). Therefore, transport equipment and water should be adequately disinfected, as should the eggs themselves, in efforts to prevent *Loma* exposure to other fish in the hatchery. Shell Lake fish, utensils used to rear them and their effluent water should not come in contact with other fish at the hatchery.

FISH HEALTH INVESTIGATOR: Bentz, Ferguson

TECHNICAL ASSISTANCE: Dickson

COPIES TO: FY2013, Misc., Davis, Rozen, Rabung, Otis, Hollowell, Ivey, Willette, Cherry (CIAA), Meyers

REFERENCES:

Hauck, A. K (1984) A mortality and associated tissue reactions of Chinook salmon, *Oncorhynchus tsharvytscha* (Walbaum), caused by the microsporidan *Loma* sp. Journal of Fish Diseases. 7: 217-229.

Shaw, R. W., Kent, M. L., and Adamson M.L., (1999) Iodophor treatment is not completely efficacious in preventing *Loma salmonae* (Microsporidia) transmission in experimentally challenged Chinook salmon, *Onocorhynchus tshawytscha* (Walbaum). Journal of Fish Diseases 22: 311-313.

Shaw, R.W., Kent, M.L., Brown, A.M., Whipps, C.M., and Adamson, M.L. (2000). Experimental and natural host specificity of *Loma salmonae* (Microsporidia). Diseases of Aquatic Organisms 40: 131–136.

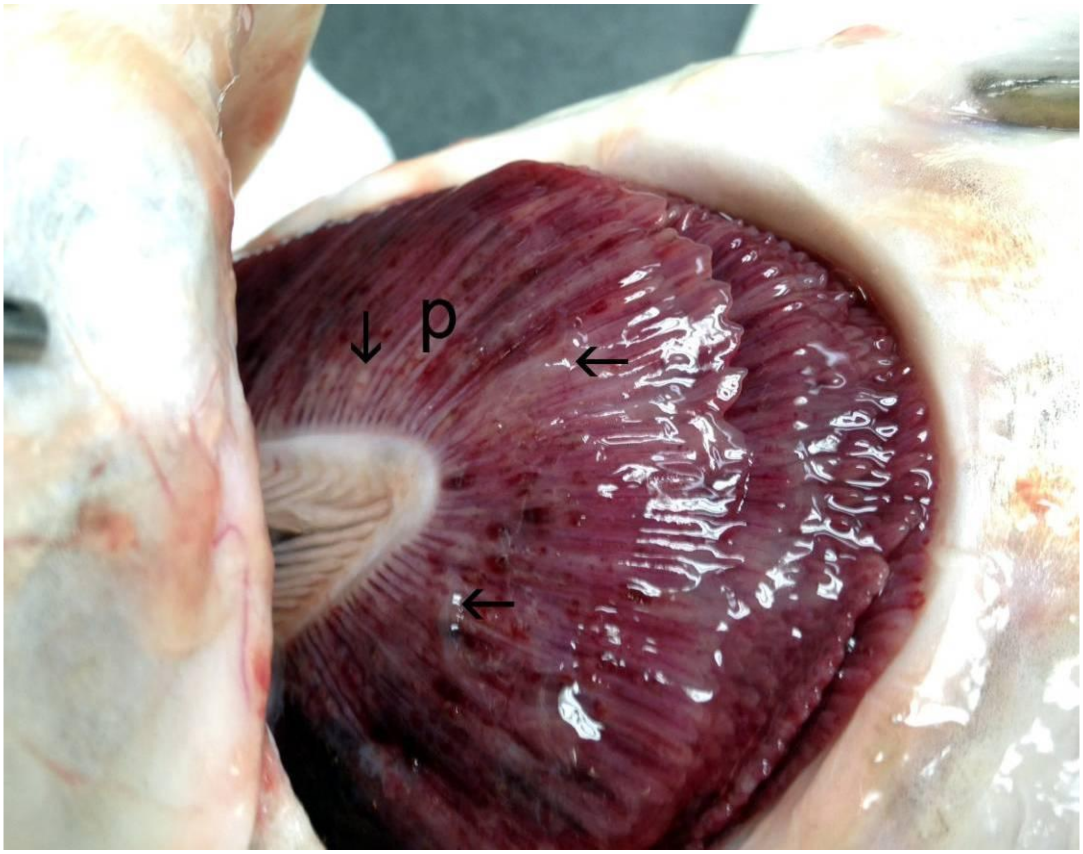


Figure 1. Gross pathology of gills from pre-spawn mortality in present case. Note the large, raised white cysts (arrows) and petechiae (p).

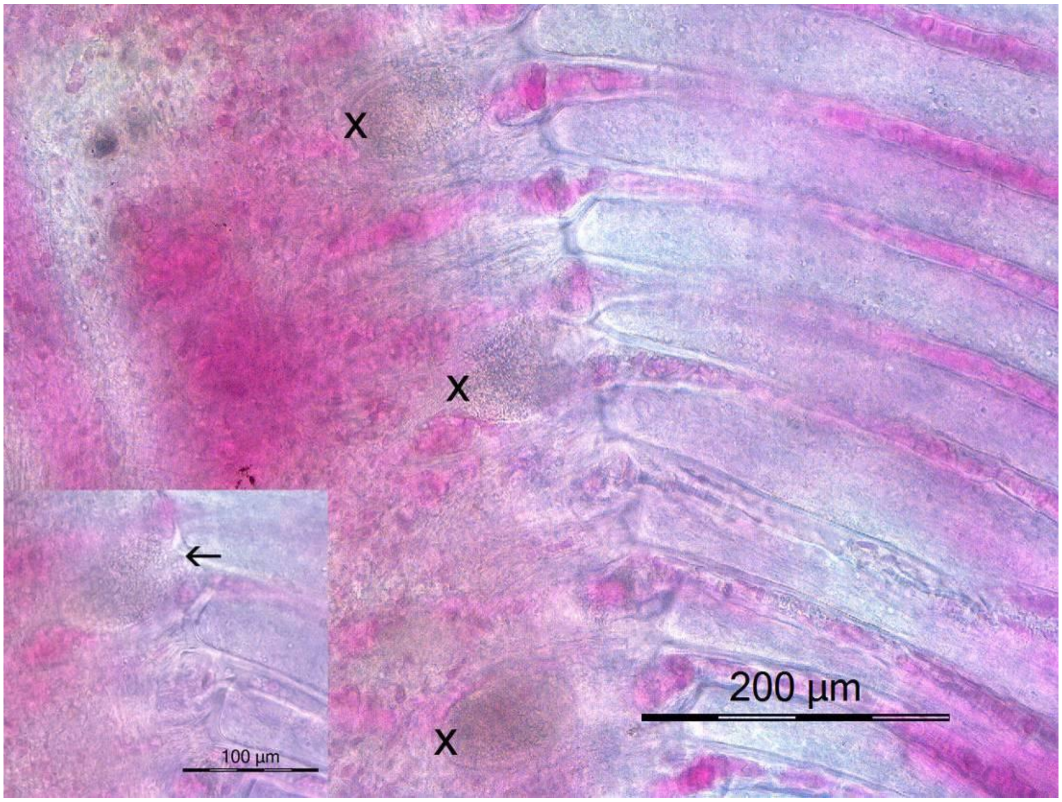


Figure 2. Wet mount of gills from pre-spawning mortality in present case. There are three xenomas (x) at the base of the primary lamellae. Inset shows ruptured xenoma releasing microspores (arrow).

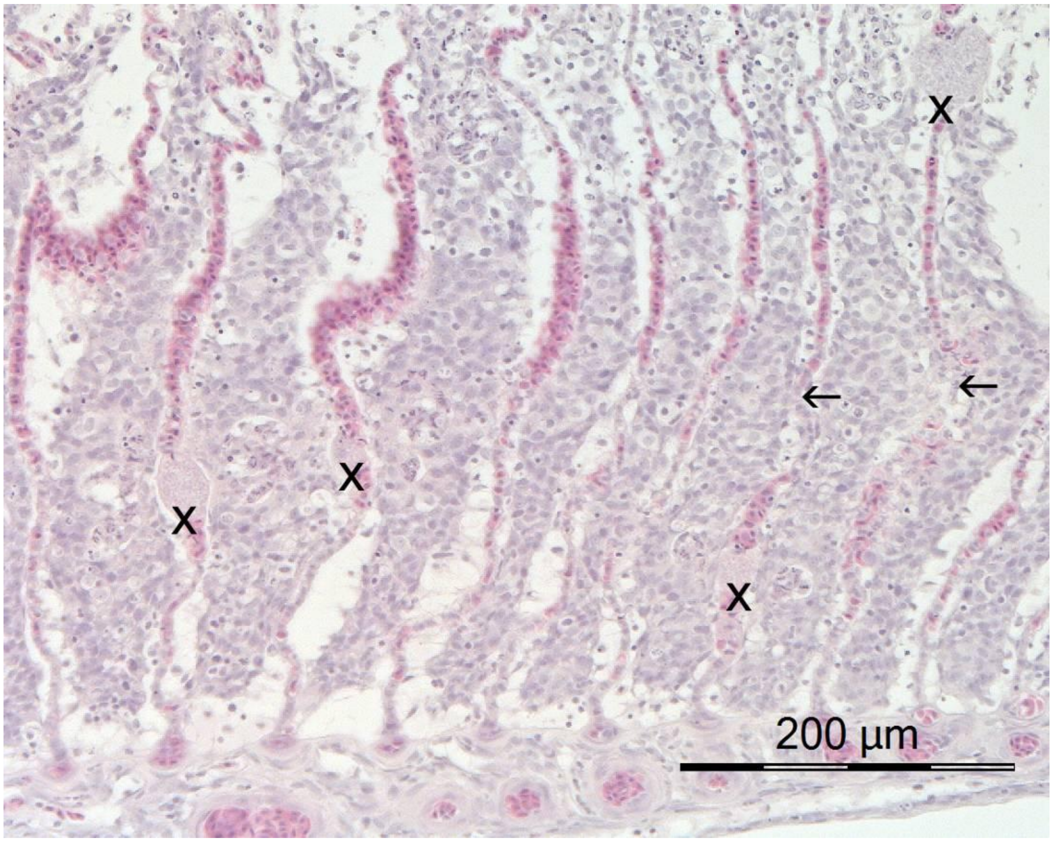


Figure 3. Histopathology of gills from pre-spawning mortality in present case. There are four xenomas (x) in the photograph and a fifth xenoma was located just beyond this field of view. Possible lamellar fusion (arrows).

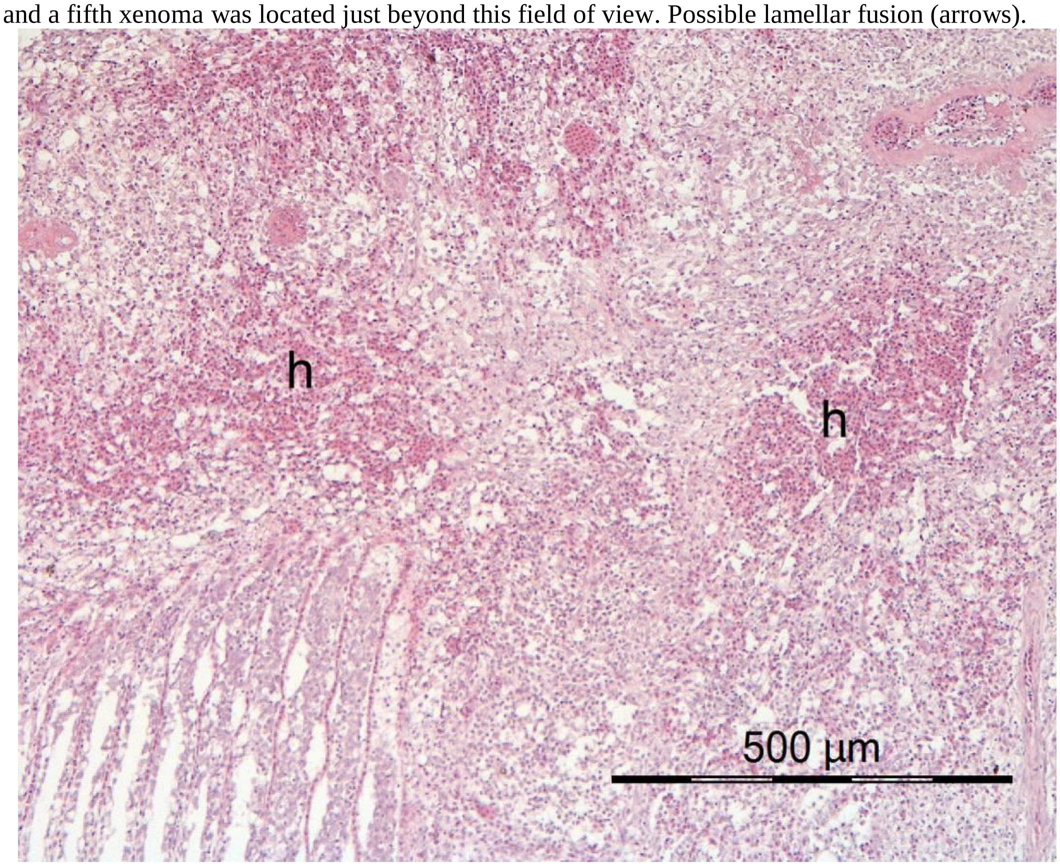


Figure 4. Histopathology of gills from pre-spawning mortality in present case. Extensive hemorrhage (h) was associated with nearby xenomas.

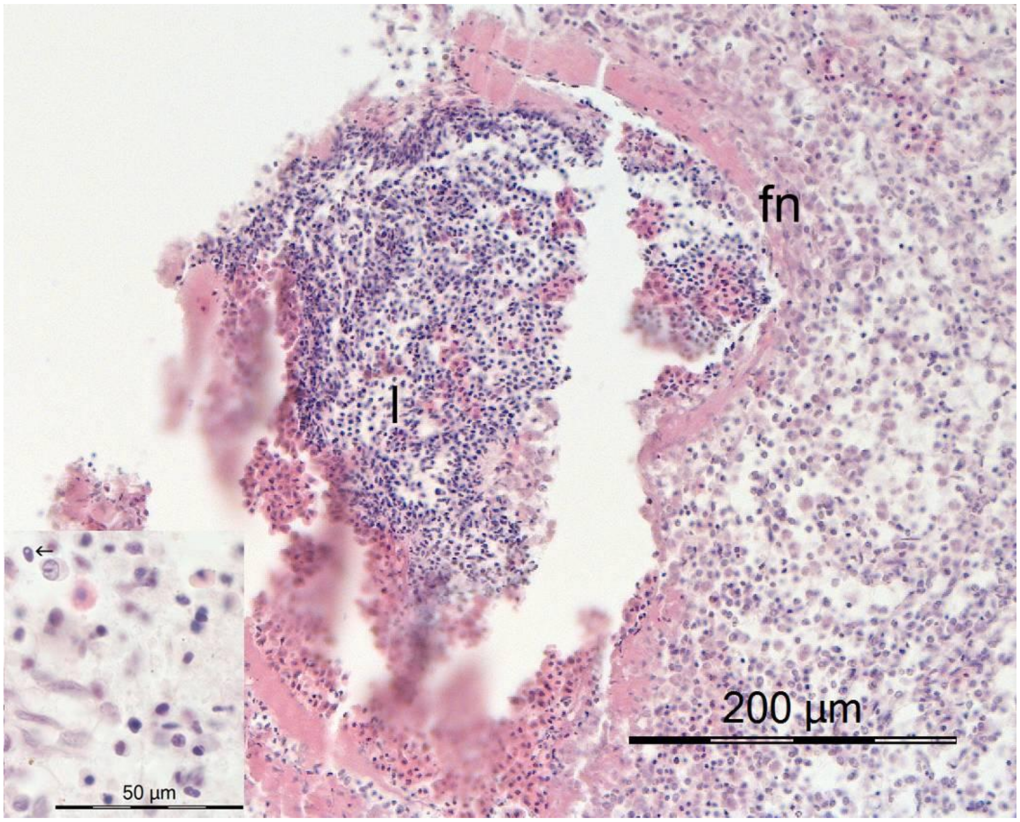


Figure 5. Histopathology of gills from pre-spawning mortality in present case. Marked fibronecrotic tissue (fn) surrounds an intense inflammatory focus comprised of leukocyte infiltrates (l), incited by microspores (arrow).

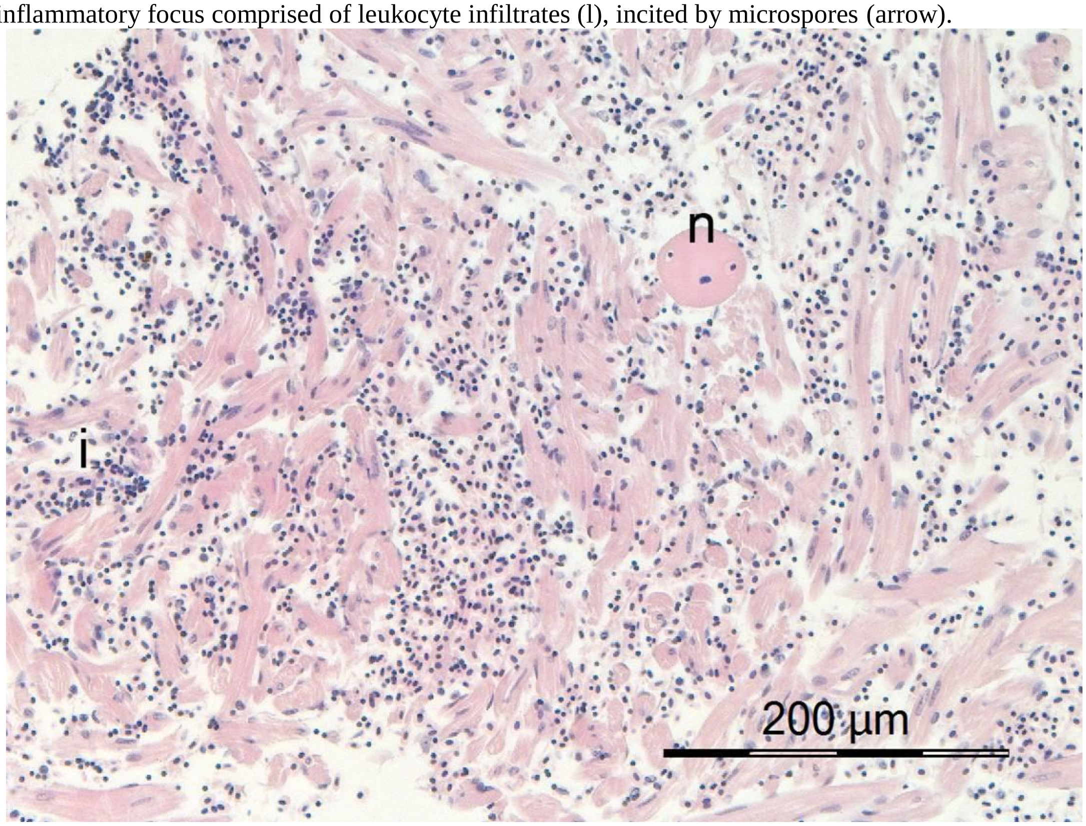


Figure 6. Histopathology of heart from pre-spawning mortality in present case. Multifocal myocarditis (i), cells with pyknotic nuclei and early coagulative necrosis (n) is evident in the spongy ventricular myocardium.

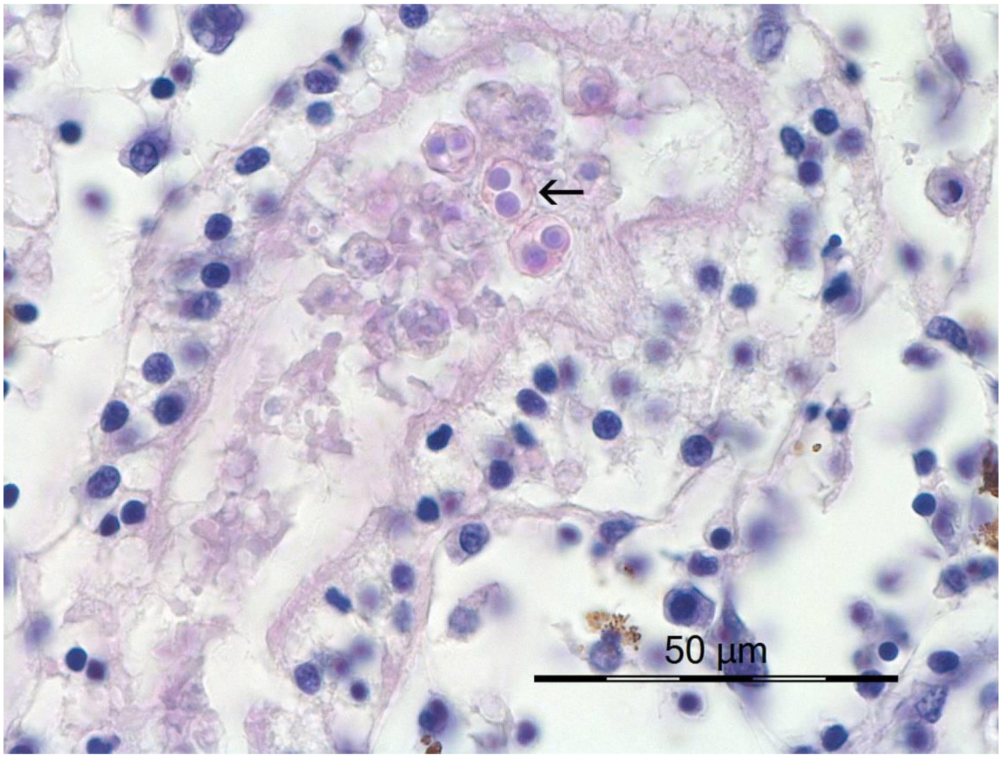


Figure 7. High magnification of presporogonic and sporogonic stages of a myxozoan parasite, possibly *Sphaerospora oncorhynchi* (arrow), tubular necrosis and pyknotic nuclei are also present in the kidney.

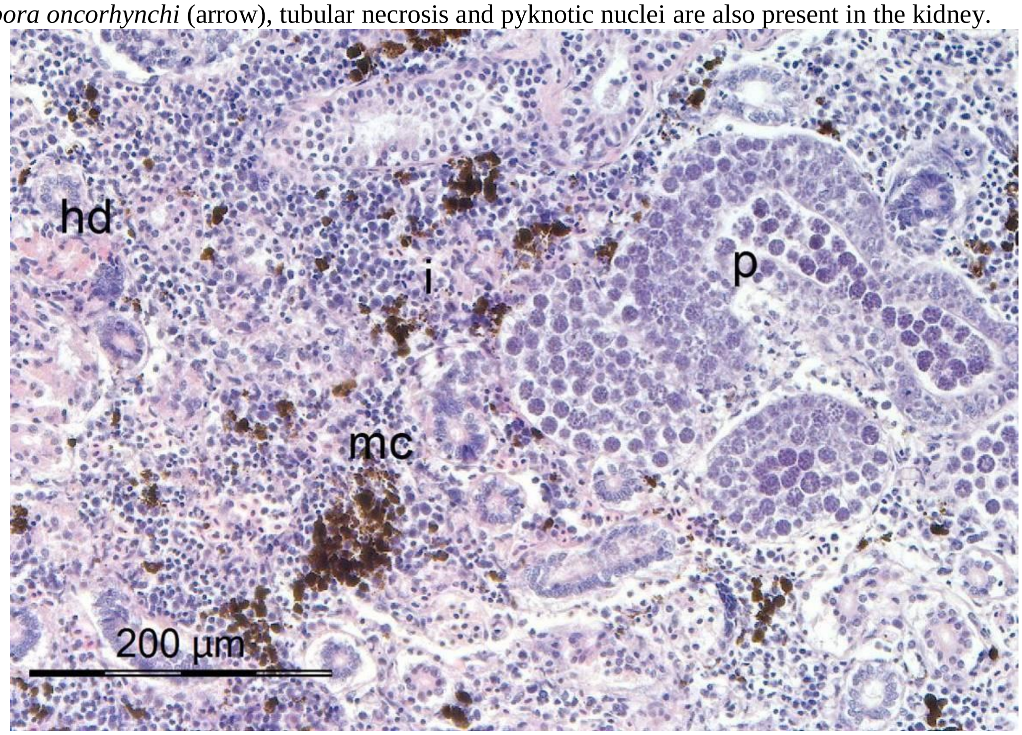


Figure 8. Histopathology of kidney from pre-spawning mortality in present case. The extrasporogonic stage of a myxozoan parasite (p), possibly representing *Chloromyxum* sp., has completely destroyed and replaced renal tubules. Nearby renal tubules are undergoing hyaline droplet degeneration (hd). Renal interstitium has numerous melanomacrophage centers (mc) and areas of nephritis (i).