Shell Lake
Sockeye Salmon
Progress Report
2019

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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 2019 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.

This report was prepared by CIAA with partial funding provided by the U.S. Fish and Wildlife Service, Habitat Restoration Program.

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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 Mat-Su Basin Salmon Habitat Partnership; the U.S. Fish and Wildlife Service, Habitat Restoration Program; 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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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ABSTRACT

This progress report summarizes the 2019 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. On May 22, 2019 approximately 15,000 sockeye salmon smolt (brood year 2017) resulting from the 2017 egg take at Shell Lake were flown from Trail Lakes Hatchery and placed into a net pen located at the northwest side of Shell Lake for imprinting. The net pen was towed to Shell Creek and the smolt were released on May 24. The smolt weir on Shell Creek could not be installed in 2019 due to high water. A sample of 100 sockeye smolt had length and weight measurements taken prior to their transport to Shell Lake. A weir was installed at Shell Lake on July 11 to enumerate adult salmon returning to the lake. From July 11–September 23, CIAA staff counted 16 sockeye salmon and 44 coho salmon entering Shell Lake. Due to the critically low level of escapement at Shell Lake, no fish were handled at the weir for sample collection.

Gillnets were deployed from May 22–September 24 capturing a total of 1,323 northern pike during that time period. Data were collected regarding age (1,247), sex (1,248), length, and weight (1,267). Thirty-five percent of the harvested northern pike with distinguishable sexual characteristics were females and 65% were males. Northern pike lengths ranged from 160 mm to 750 mm with an average length of 283 mm (±1.6 mm) for males and 286 mm (±3.4 mm) for females. Mean weight for the northern pike males was 0.22 kg (±0.06 kg) and 0.21 kg (±0.01 kg) for females. Stomach contents were analyzed for 1,248 of the harvested pike and contents of non-empty stomachs were identified. Of the stomach contents analyzed, 52.6% were empty and 47.4% had food items identified. Fish comprised 80.1% of all non-empty stomach content samples with the remaining 17.3% being invertebrates (including leeches and insects), and 2.6% were frogs. Juvenile salmon were identified in 67 of the pike stomachs representing 11.5% of all of the contents. The mean length and weight of harvested pike has decreased for most year classes from 2014–2016 before rising slightly in 2017 it fell again in 2018–2019. In 2019 the average lengths and weights of northern pike harvested in Shell Lake were the lowest since the project began at 285 mm and 0.22 kg respectively. The average of recorded ages of captured northern pike in Shell Lake has decreased from 2.32 years in 2014, to 0.24 years in 2019.

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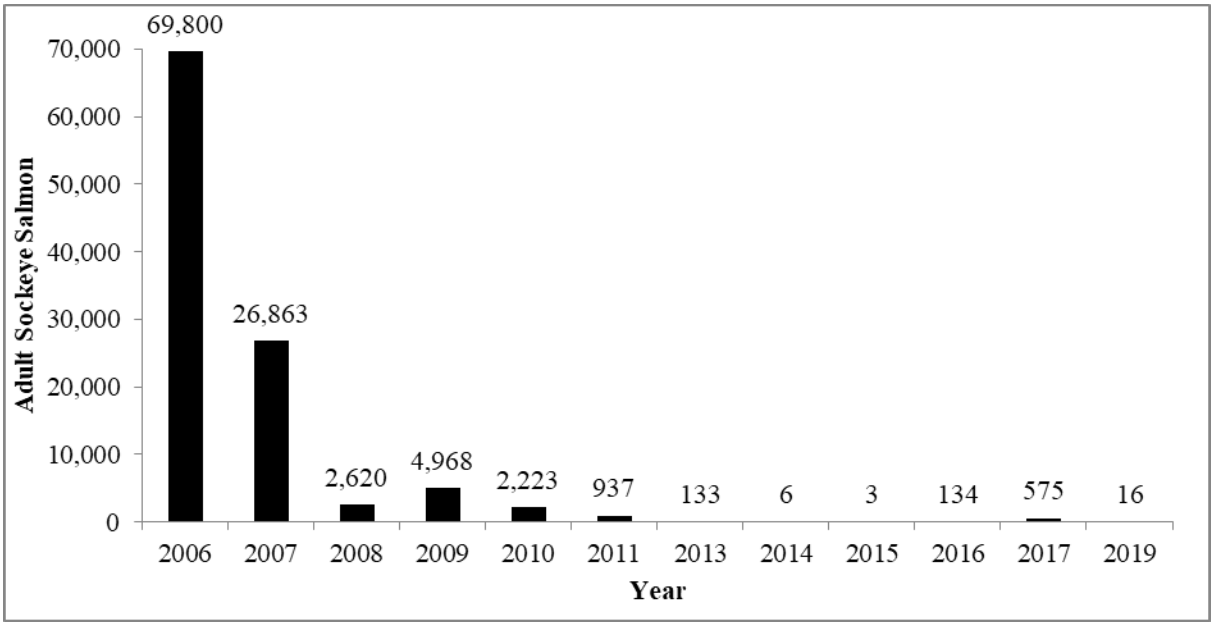
INTRODUCTION AND PURPOSE

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) has declined precipitously since 2007 (Figure 1).



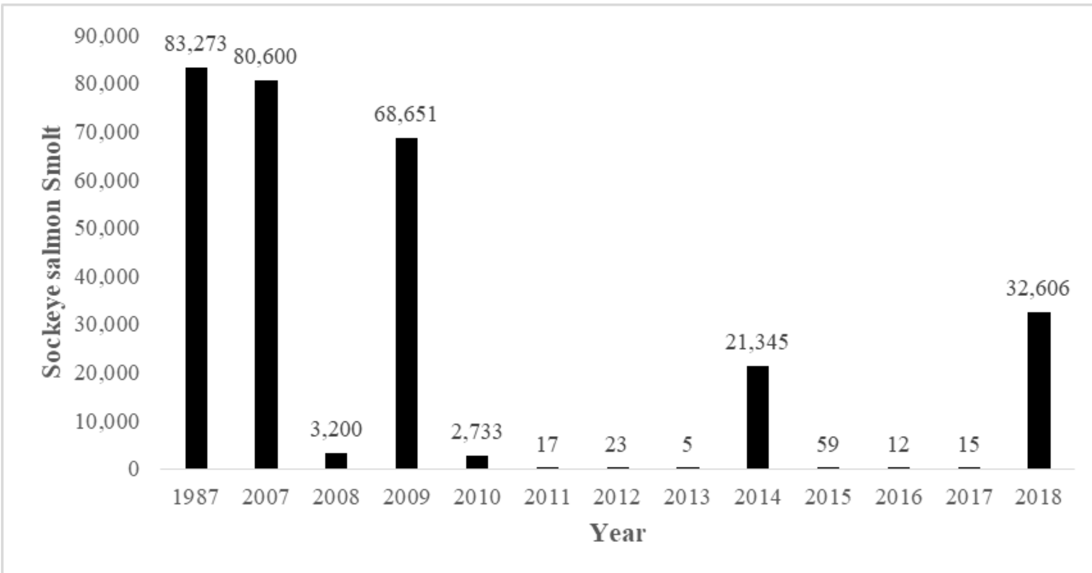
*No weir data available for 2012 and 2018

Figure 1: Weir counts at Shell Lake, 2006–2011, 2013–2017, 2019.

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 and 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 was 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 was 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. 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.



*Data for 2014 and 2018 include stocked smolt. No count available for 2019

Figure 2: Sockeye smolt counts 1987, 2007–2018.

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, 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 2019, 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.

Following the summer of 2016 CIAA staff noted a decline in mean lengths of the northern pike harvested in Shell Lake. Because observations from other studies in the region have indicated that smaller pike tend to consume more juvenile salmon (Rutz, 1999), CIAA enlisted the assistance of researchers at the University of Alaska Fairbanks (UAF) Institute of Arctic Biology and College of Fisheries and Ocean Sciences to model the effects that intensive netting may be having on the Shell Lake pike population. Using CIAA pike data obtained by from 2013–2016 UAF was able to build a bioenergetics model to estimate the per-capita consumption rates of northern pike ages 1–5 in Shell Lake (Deslauriers, 2017). Model inputs included pike growth rates (initial and final weights), diet composition, water temperatures from Shell Lake, and energy density estimates from the literature

(Chipps and Garvey, 2007). 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.

That analysis determined that 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 (Appendix 9). 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.

The catch per unit effort (CPUE) of northern pike in standardized gillnet sets declined by 75% overall from 2013–2016 in Shell Lake (Appendix 3). 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.

Larger northern pike consumed more salmon biomass per capita than smaller pike, according to the bioenergetics model. From mid- 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.

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 3). 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 3). Based on this model CIAA plans to continue the intensive harvest of northern pike in Shell Lake in 2019 and beyond in an attempt to determine if this reduced consumption can translate into positive natural sockeye salmon production in Shell Lake.

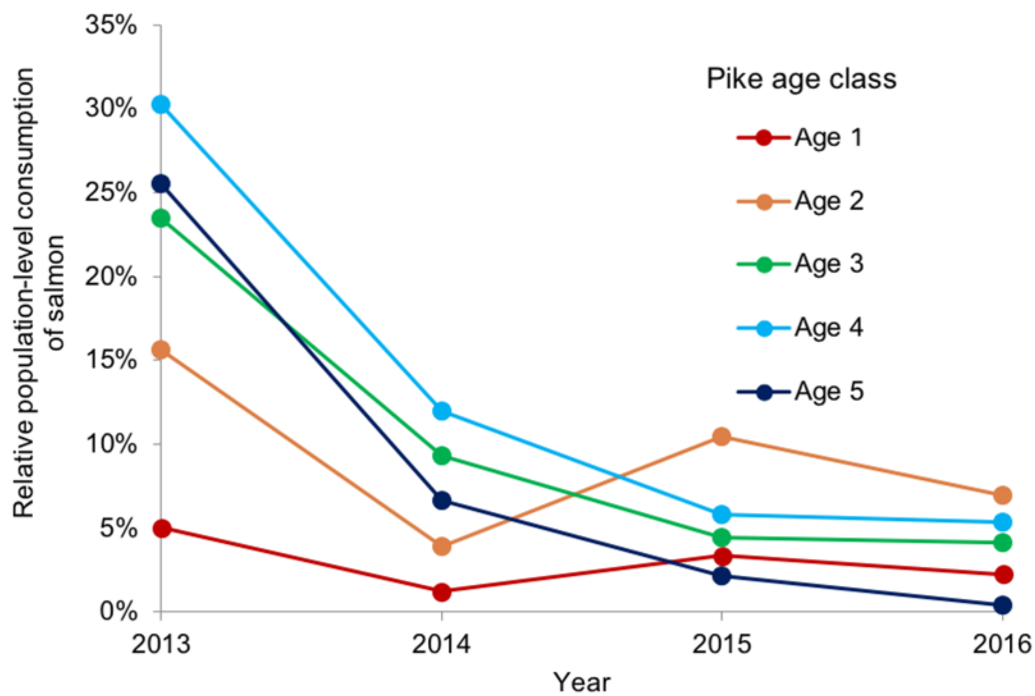


Figure 3: Relative total consumption of salmon by the northern pike population in Shell Lake, broken down by pike age class, 2013–2016.
Values were estimated as the per-capita consumption of salmon by an average pike in each age class, multiplied by the relative abundance of that pike age class in each year (estimated from CPUE). Relative consumption values are scaled so that total salmon consumption by all age classes of northern pike in 2013 = 100%.

In addition to salmon monitoring and northern pike harvest, CIAA performs beaver dam surveys on several streams important to salmon migration in the Susitna River drainage 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.

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).[1] The complete amended pathology report can be found in Appendix 10.

1. 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.

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 2019 monitoring of sockeye salmon smolt and adults at Shell Lake, gamete collection and the salmon stocking efforts from 2012–2019, the survey of beaver dams on Shell Creek, and data collected from the pike population via intensive harvesting. 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 4). 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 5) (Kyle, et al. 1993). Shell Lake has seven small tributaries and discharges southeast via Shell Creek which runs approximately six river miles to the Skwentna River.

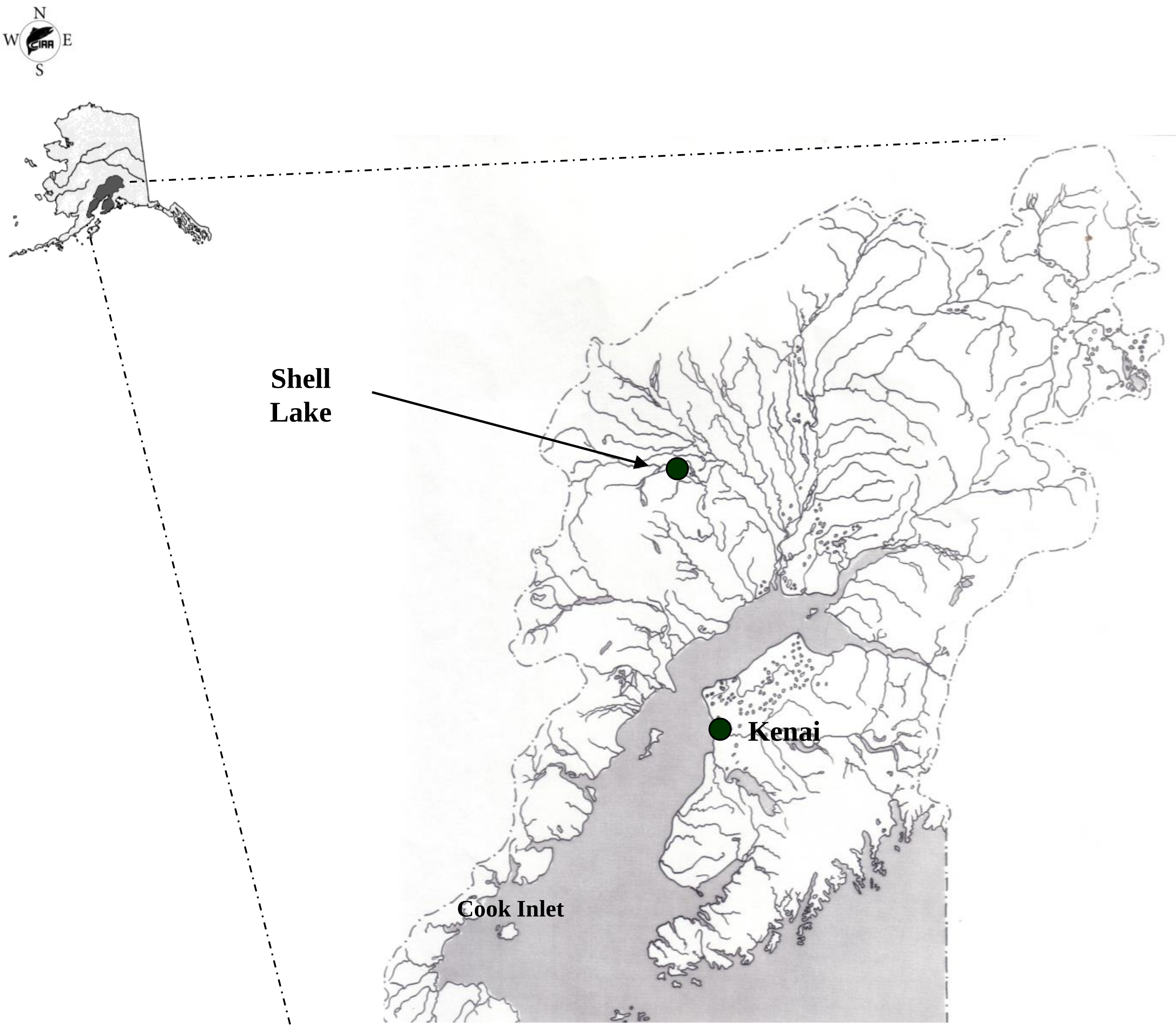
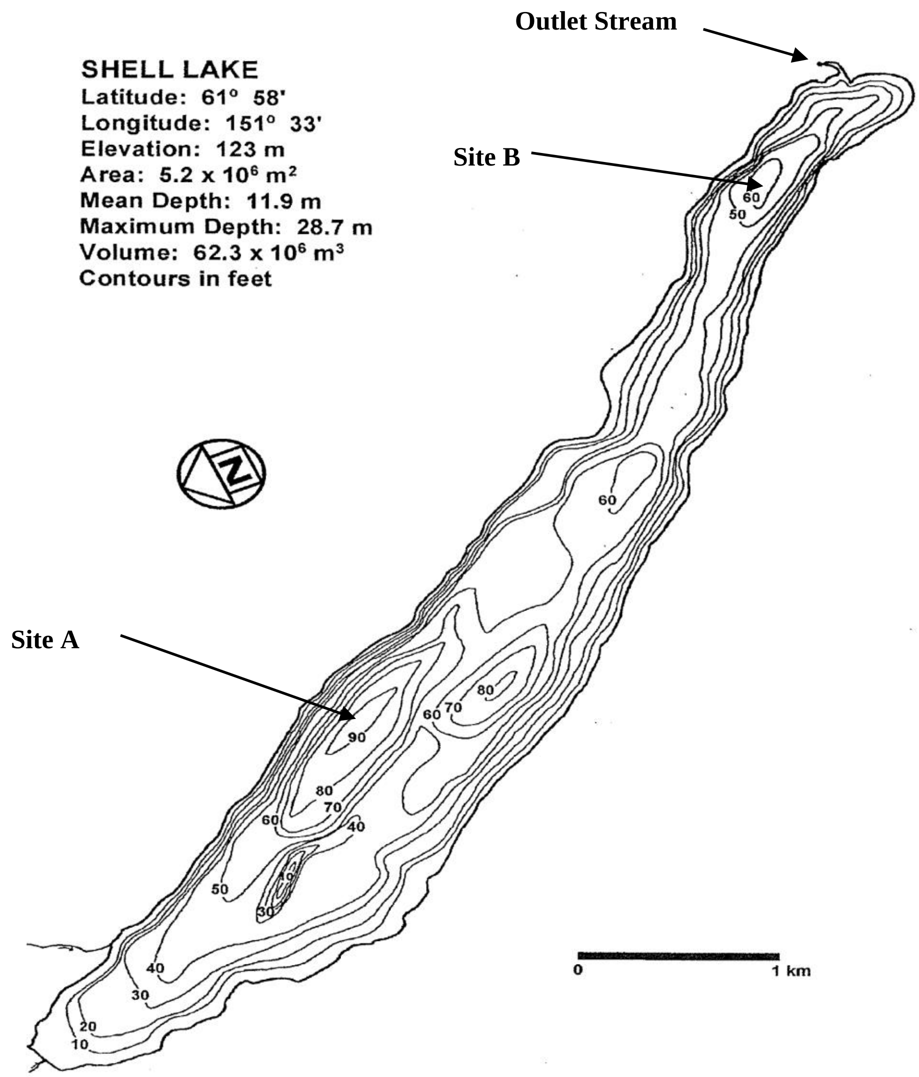


Figure 4: Shell Lake in relation to Cook Inlet and Alaska.



Source: (Sparfard and Edmundson, 2000)

Figure 5: Bathymetric map of Shell Lake.[2]

2. Site A and Site B refer to water quality collection sites from previous years, which are discussed in the appendix section of the report. Both the smolt and adult weirs are located on the outlet stream of Shell Lake.

METHODS

Environmental Conditions

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. All measurements were recorded at 5:00 PM each day (CIAA, 2019a). Shell Creek water temperatures were recorded using a (Hobo®) data logger that recorded water and air temperature every hour. Recordings were then averaged over a 24-hour period to provide a daily average water temperature. Due to a sharp drop in the level of water in Shell Creek the data logger was left dry from June 9–July 11, 2019 so there were no water temperatures taken until July 12 when the logger was placed back into Shell Creek. Air temperatures were taken using an analog thermometer at 5:00 pm daily. Previous to 2016, water and air temperatures were measured using a thermometer at 5:00 pm each day, and therefore water temperature results prior to this date may not be comparable to subsequent years.

Smolt Enumeration

Prior to 2019, the smolt migration from Shell Lake was monitored by placing a smolt trap 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.

In late May–early June of 2019, the water level in Shell Creek was deemed too high to install the smolt trap. Because of the high water level, concerns were raised regarding the ability of the crew to enumerate the smolt population without causing smolt mortality due to the intense flow of water at the trap site. Additionally, in late May it was also unsafe for the crew to enter the creek to perform enumeration and trap maintenance so smolt enumeration did not occur in 2019.

Smolt Characteristics

A sample of 100 sockeye salmon smolt were weighed to the nearest gram and measured to the nearest millimeter prior to being transported to Shell Lake.

To distinguish naturally-spawned individuals from hatchery stock, CIAA staff at Trail Lakes Hatchery clipped the adipose fins of all smolt released into Shell Lake in 2019 so they can be externally identified upon their return as adults.

Adult Enumeration and Beaver Dam Monitoring

To enumerate adult salmon, staff installed a fixed picket weir fitted with video recording equipment during the 2019 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 6). 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 2019b). Because of power failures during previous years, the Shell lake field crew was instructed to closely monitor the battery bank powering the video equipment. For any days the camera system could not operate, the crew was on-site to enumerate all passing salmon.

Figure 6: Video weir camera box and passage chute.

During the summer of 2019, beaver dams were monitored in Shell Creek for blockage to fish passage during the adult migration. An aerial survey was conducted twice on August 9, and September 13, beginning at the confluence of Shell Creek and Skwentna River and continuing upstream approximately 3.8 miles "as the crow flies." If beaver dams were found to be blocking the upstream movements of salmon, the crew would make a notch approximately 3–5-ft wide in the dam to allow them to pass.

Adult Characteristics

For field season 2019, no adult sockeye salmon were handled by CIAA staff therefore no physical data such as sex and standard fork length were collected.

Northern Pike Harvest

Northern pike harvesting and sampling procedures were based on the "Susitna Lakes Pike Sampling Procedures Manual" (Glick, 2010). The only method used to capture Shell Lake northern pike in 2019 was the use of 1-in bar mesh gillnets.

During the open water season, from May 23–September 24, up to ten 1-inch bar mesh gillnets 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 and weighed. 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 following the field season. Stomach contents were weighed to the nearest tenth of a gram for individual prey items. Approximately 56 northern pike had one or no measurements taken due to river otters (*Lontra Canadensis*) partially eating the netted fish and scale malfunctions. 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

No eggs were taken from Shell Lake sockeye salmon in 2019 due to low numbers of returning adults.

Approximately 15,000 Shell Lake smolt reared at the Trail Lakes Hatchery were placed in transport tanks and flown to Shell Lake on May 22. Upon arrival, the smolt were temporarily placed into a net pen for imprinting. The smolt were imprinted on the traditional sockeye salmon spawning grounds on the northwest side of Shell Lake, towed down the lake to Shell Creek and were released into the creek on May 24, 2019.

RESULTS

Environmental Conditions

2019

Environmental conditions were monitored on Shell Creek near the outflow from Shell Lake from May 23 through September 24. The water level in the creek varied by ±1.9 feet from the first reading on May 23. Water temperatures ranged from 6.3 to 23.8ºC with an average temperature of 16.5ºC (Table 1). Air temperatures averaged 20.8ºC and ranged from 7.0 to 32.0ºC. Forty-one percent of the days were clear, 30% were partly cloudy and 28% of the days were completely overcast. Measureable rain was recorded for 17% of the days and a total of 8.4 mm of precipitation fell over this period.

Table 1: Summary of environmental conditions, Shell Lake, 2019.

	Precipitation Millimeters	Staff Gauge Feet	Water Temperature ºC	Air Temperature ºC
Total	8.4			
Average	0.1	0.6	16.5	20.8
Minimum	0.0	0.0	7.0	7.0
Maximum	1.7	1.9	23.8	32.0

Ice out = May 16

Summary of Cloud Cover - Percent of Days				
Number of Days	Measurable Rain	Days Overcast	Partly Cloudy	Clear
116	17%	28%	30%	41%

Smolt Enumeration

The ice-out as reported by Shell Lake Lodge was May 16. The crew was unable to monitor 2019 Shell Lake salmon smolt migration due to high water conditions. A sub-sample of 100 hatchery produced sockeye smolt from Shell Lake brood year 2017 reared at Trail Lakes Hatchery were weighed and measured prior to transport to Shell Lake. Those smolt averaged 110 mm (±1.3 mm) in length and 13.0 g (±0.53 g) weight.

Adult Enumeration, and Beaver Dam Monitoring

In 2019, a fixed picket weir fitted with video recording equipment was installed in Shell Creek on July 9. Two batteries from the video weir battery bank died in late July and the system was not able to consistently capture video for most of the remainder of the summer. Because of the battery issues, CIAA staff physically monitored the weir until September 23. During this time 16 adult sockeye salmon and 44 coho salmon were enumerated as they passed into Shell Creek.

Beaver dam surveys were conducted on Shell Creek twice in 2019. On Friday August 9, CIAA staff flew the length of Shell Creek looking for the presence of salmon impounded behind beaver dams. The creek was experiencing low flows due to the lack of precipitation and approximately 80 pink salmon were spotted near the creek's confluence with the Skwentna River. Though the crew had spotted five beaver dams that had the potential to block salmon migration, no salmon were impounded directly behind those dams. Because pink salmon typically do not migrate all the way to Shell Lake, and low water would have likely prevented the fish from ascending the chute below the lake, no action was taken to modify the dams on this trip. On Friday, September 13 CIAA staff flew another beaver dam survey on Shell Creek. The water level had risen since the previous survey and the crew noted approximately 40 coho salmon located below the furthest downstream dam on Shell Creek. The crew notched this dam and began working up the creek towards Shell Lake. Eight dams were noted with six being deemed impassible and thusly modified to allow for upstream fish passage. During the week following the notching of all six dams, 44 coho salmon and 16 sockeye were able to ascend Shell Creek passing the weir between September 17 and 23 when adult counting was discontinued. Prior to dam modification, no salmon had been counted at the weir.

Northern Pike Harvest

A total of 1,323 northern pike were harvested from Shell Lake during the open water season in 2019 requiring 21,933 hours of gillnetting effort for a CPUE of 0.06 pike/hour. Staff collected data from the harvested fish regarding length (n=1,267), weight (n=1,267), age (n=1,247), stomach contents (n=1,240), and sex (n=1,248). Of the northern pike sampled, 61.7% were males (n=815), and 32.7% were females (n=433) and 5.7% (n=75) were of unknown sex. Mean length of the males was 283 mm (±1.6mm) and mean weight of males was 0.22 kg (±0.06 kg). Female mean length and weight was 286 mm (±3.4 mm) and 0.21 kg (±0.01 kg) respectively (Table 2).

Table 2: Northern pike male and female characteristics, Shell Lake, 2019.

Male Pike Length (mm)			
Minimum	180		
Maximum	390	Standard Deviation	95% Confidence
Average	283	22.7	1.6
Male Pike Weight (kg)			
Minimum	0.08		
Maximum	26.00	Standard Deviation	95% Confidence
Average	0.22	0.91	0.06
Female Pike Length (mm)			
Minimum	160		
Maximum	750	Standard Deviation	95% Confidence
Average	286	35.6	3.4
Female Pike Weight (kg)			
Minimum	0.05		
Maximum	3.10	Standard Deviation	95% Confidence
Average	0.21	0.15	0.01
Percentage Male/Female			
Male	61.6%		
Female	32.7%		
Unknown	5.7%		

The stomach contents of 1,240 harvested pike were examined—47.4% (n=583) contained prey and 52.6% (n=657) were empty. Prey items were identified and are presented as an estimated percentage of the total stomach contents—17.3% of food items were invertebrates, 11.5% were salmonids, 50.2% of the contents were other non-salmonid fishes including sticklebacks *(Gasteroseidae* spp.*)*, burbot *(Lota lota)*, slimy sculpin *(Cottus cognatus)*, northern pike, or longnose sucker *(Catostomus catostomus)* (Table 3). Cannibalism was detected in 18.4% of examined northern pike stomach contents.

Table 3: Percentage of pike stomachs containing prey items and estimated percentage of total prey items in northern pike stomach contents, Shell Lake, 2019.

		Non-Empty Stomachs				
	Empty	Pike	Salmonids	Other Fish	Invertebrates	Frogs
Samples	657	107	67	293	101	15
Percentage of Pike	52.6%	18.4%	11.5%	50.2%	17.3%	2.6%

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

Gamete Collection and Fish Stocking

No gamete collection was performed by CIAA on Shell Lake during 2019 because escapement was insufficient to allow for the collection of broodstock.

Approximately 15,000 sockeye salmon smolt from BY2017 were released back into Shell Lake on May 22.

DISCUSSION

Since 2012, CIAA has harvested over 7,457 northern pike from Shell Lake. Based on a model of the Shell Lake pike population developed by University of Alaska Fairbanks researchers it is estimated that this pike harvest has reduced the potential predation on juvenile salmonids by as much as 81% from the time netting began in 2012 until the end of field season 2016. It is assumed that the consumption of salmonids by northern pike is equal to or lower than the 2016 total estimated by that model following three additional years of intensive pike harvest in 2017–2019.

In 2018 CIAA released an estimated 46,000 smolt reared from eggs collected in 2016 from Shell Lake sockeye salmon. In 2020, CIAA expects to see the first adult sockeye salmon return of age 1.2 fish resulting from the 2016 egg take. It will be important to maximize the netting pressure early during 2020 to achieve the highest level of pike suppression possible prior to the adult salmon return when the gillnets will need to be pulled from the lake. According to recommendations from the ADF&G Gene Conservation Lab in Anchorage, CIAA will not be allowed to take eggs from the returning sockeye salmon reared in the hatchery so natural spawning and rearing of sockeye salmon in Shell Lake will have to be successful to save this stock from extirpation.

Because most of the pike harvest at Shell Lake occurred following the 2014 smolt migration, the hope is that this reduced pike population and inferred reduced consumption rates will result in improved survival rates of Shell Lake's juvenile salmonids going forward. This will be especially important during brood years 2020–2023 when returns from 2018–2019 are expected to be realized.

Few adult sockeye salmon made it to Shell Lake during 2019. In 2020 CIAA staff expect the first return resulting from the 2016 egg take and subsequent release in 2018. During field season 2018, CIAA staff enumerated over 32,000 sockeye smolt as they emigrated from Shell Lake. The majority are expected to return as age 1.2 sockeye next year. If the ocean survival rate of those smolt achieves 10%, CIAA estimates the adult return for 2020 to exceed 3,000 fish.

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RECOMMENDATIONS

The first return of adult sockeye salmon to Shell Lake resulting from the 2018 smolt release is expected in 2020. In order to ensure maximum spawning success at Shell Lake, all gillnets should be removed from the water once salmon have entered the lake.

While two of the main goals of this project are to return Shell Lake to positive natural sockeye production and preserve this genetically distinct stock, there is a chance that the resulting juvenile salmon produced by hatchery progeny in 2020–2023 will fail to be sufficient to accomplish either goal. In light of the significant time and resources spent attempting to suppress the pike population and recover the Shell Lake sockeye salmon population, if it is determined through smolt counts in 2021–2023 that smolt production resulting from these sockeye returns is not apparent, CIAA should reevaluate the strategies regarding pike in the area. Conversely, should sockeye production improve at Shell Lake, CIAA should continue pike control and salmon monitoring and seek out additional systems to which this model can be applied.

Because few smolt are expected to migrate in 2020 CIAA should not install the smolt counting weir in 2020. Effort at Shell Lake should instead be focused on early season northern pike harvest in order to further reduce the pike population and increase the likelihood of successful sockeye salmon spawning in 2020.

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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	2018	2019
10-Jul	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0	ND	ND
11-Jul	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0	ND	ND
12-Jul	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0	ND	0
13-Jul	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0	ND	0
14-Jul	0	ND	ND	0	ND	ND	ND	ND	ND	ND	ND	ND	0	ND	0
15-Jul	0	0	ND	0	0	0	ND	ND	ND	ND	ND	ND	0	ND	0
16-Jul	0	0	0	0	0	0	ND	ND	ND	ND	ND	ND	0	ND	0
17-Jul	0	0	0	0	0	0	0	ND	ND	ND	0	ND	0	ND	0
18-Jul	0	0	0	0	0	0	0	ND	ND	ND	0	ND	0	ND	0
19-Jul	0	0	0	0	0	0	0	ND	ND	ND	0	ND	0	ND	0
20-Jul	0	0	0	0	0	0	0	ND	ND	ND	0	ND	0	ND	0
21-Jul	0	0	0	0	0	0	0	ND	ND	ND	0	ND	0	ND	0
22-Jul	0	0	0	0	0	0	0	ND	ND	0	0	ND	0	ND	0
23-Jul	0	10	0	0	0	0	0	ND	ND	0	0	ND	0	ND	0
24-Jul	0	1,140	0	0	0	0	0	ND	ND	1	0	ND	0	ND	0
25-Jul	0	3,474	0	1	0	0	0	ND	ND	1	0	ND	0	ND	0
26-Jul	0	3,481	0	1	0	0	0	ND	ND	1	0	ND	0	ND	0
27-Jul	0	5,806	0	3	0	389	0	ND	ND	1	0	ND	0	ND	0
28-Jul	0	6,510	0	8	0	389	0	ND	ND	1	0	ND	0	ND	0
29-Jul	0	6,533	0	1,236	475	395	0	ND	ND	1	0	ND	0	ND	0
30-Jul	0	7,650	0	1,251	589	395	0	ND	ND	1	0	ND	0	ND	0
31-Jul	0	9,518	0	1,253	621	728	0	ND	ND	1	0	ND	0	ND	0
01-Aug	0	10,422	0	1,269	642	1,395	0	ND	ND	2	0	ND	0	ND	0
02-Aug	0	11,099	0	1,269	642	1,677	0	ND	ND	3	0	ND	0	ND	0
03-Aug	0	11,099	0	1,269	644	1,686	0	ND	ND	3	0	ND	0	ND	0
04-Aug	0	25,251	0	1,270	835	1,895	0	ND	ND	3	0	ND	0	ND	0
05-Aug	0	36,337	7,911	1,271	876	1,947	219	ND	ND	4	0	ND	0	ND	0
06-Aug	1,578	37,761	11,203	1,273	876	1,947	235	ND	ND	4	0	ND	0	ND	0
07-Aug	2,370	42,772	11,962	1,273	879	1,950	265	ND	ND	4	0	ND	0	ND	0
08-Aug	3,041	45,385	12,755	1,273	890	1,951	323	ND	ND	4	0	ND	0	ND	0
09-Aug	3,216	53,663	13,555	1,275	894	1,954	385	ND	11	4	0	ND	0	ND	0
10-Aug	3,296	60,786	14,476	1,532	903	1,955	400	ND	18	4	0	ND	0	ND	0
11-Aug	3,346	60,786	14,552	1,689	903	1,962	416	ND	18	4	0	ND	0	ND	0
12-Aug	3,461	63,682	15,992	1,689	903	1,983	459	ND	87	4	0	ND	0	ND	0
13-Aug	3,478	64,133	17,434	1,726	903	2,023	492	ND	102	4	0	ND	0	ND	0
14-Aug	3,489	64,314	17,939	1,749	2,017	2,107	492	ND	115	4	0	ND	0	ND	0
15-Aug	3,565	67,566	18,729	1,764	4,053	2,107	492	ND	117	4	0	ND	0	ND	0
16-Aug	3,597	69,133	18,907	2,508	4,554	2,128	492	ND	119	4	0	ND	0	ND	0
17-Aug	3,623	69,133	18,911	2,508	4,564	2,143	492	ND	123	4	0	ND	0	ND	0
18-Aug	3,726	69,138	19,846	2,508	4,564	2,204	492	ND	123	4	0	ND	0	ND	0
19-Aug	3,820	69,800	21,336	2,510	4,573	2,204	492	ND	123	4	0	ND	0	ND	0
20-Aug	3,857	69,800	21,999	2,510	4,590	2,220	588	ND	123	5	0	ND	0	ND	0
21-Aug	3,883	69,800	22,491	2,530	4,673	2,223	588	ND	123	5	0	ND	0	ND	0
22-Aug	3,909	69,800	23,719	2,559	4,684	2,223	593	ND	128	6	0	ND	0	ND	0
23-Aug	3,909	69,800	24,157	2,572	4,688	2,223	874	ND	130	6	0	ND	0	ND	0
24-Aug	3,909	69,800	24,379	2,572	4,688	2,223	909	ND	130	6	0	ND	0	ND	0
25-Aug	3,909	69,800	24,554	2,580	4,697	2,223	933	ND	130	6	0	ND	0	ND	0
26-Aug	4,159	69,800	24,677	2,580	4,697	2,223	937	ND	130	6	0	ND	0	ND	0
27-Aug	4,176	69,800	25,052	2,601	4,809	2,223	937	ND	132	6	0	ND	0	ND	0
28-Aug	4,200	69,800	25,765	2,602	4,856	2,223	937	ND	132	6	0	ND	3	ND	0
29-Aug	4,200	69,800	25,963	2,607	4,896	2,223	937	ND	133	6	0	ND	0	ND	0
30-Aug	4,200	69,800	26,094	2,607	4,918	2,223	937	ND	133	6	0	ND	0	ND	0
31-Aug	4,221	69,800	26,252	2,607	4,931	2,223	937	ND	133	6	0	ND	0	ND	0
01-Sep	4,231	69,800	26,423	2,613	4,931	2,223	937	ND	133	6	0	ND	53	ND	0
02-Sep	4,231	69,800	26,780	2,620	4,940	2,223	937	ND	133	6	0	ND	186	ND	0
03-Sep	4,231	69,800	26,784	2,620	4,940	2,223	937	ND	133	6	0	ND	196	ND	0
04-Sep	4,231	69,800	26,844	2,620	4,940	2,223	937	ND	133	6	0	ND	202	ND	0
05-Sep	4,231	69,800	26,846	2,620	4,952	2,223	937	ND	133	6	0	ND	211	ND	0
06-Sep	4,231	69,800	26,851	2,620	4,962	2,223	937	ND	133	6	0	ND	238	ND	0
07-Sep	4,231	69,800	26,862	2,620	4,968	2,223	937	ND	133	6	0	ND	271	ND	0
08-Sep	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133	6	0	ND	288	ND	0
09-Sep	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133	6	0	ND	307	ND	0
10-Sep	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133	6	0	ND	336	ND	0
11-Sep	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133	6	0	ND	348	ND	0
12-Sep	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133	6	0	ND	355	ND	0
13-Sep	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133	6	0	ND	363	ND	0
14-Sep	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133	6	0	ND	383	ND	0
15-Sep	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133	6	3	ND	403	ND	0
16-Sep	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133	6	2	ND	430	ND	0
17-Sep	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133	6	1	ND	448	ND	0
18-Sep	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133	6	1	ND	465	ND	0
19-Sep	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133	6	5	ND	505	ND	2
20-Sep	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133	6	3	ND	514	ND	2
21-Sep	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133	6	3	ND	539	ND	8
22-Sep	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133	6	3	ND	557	ND	16
23-Sep	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133	6	3	ND	575	ND	16
Total	4,231	69,800	26,863	2,620	4,968	2,223	937	ND	133*	6*	3*	134**	575		16

* 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

Gray shading indicates that no counts were made on that date

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

Shell Lake Sockeye Smolt Migration Comparison

Date	1987	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
9-May	0	ND	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	ND
11-May	3	ND	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	ND
13-May	11	ND	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	ND
15-May	19	ND	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	ND
17-May	61	ND	ND	92	ND	0	ND	ND	ND	ND	0	ND	ND
18-May	81	ND	ND	113	ND	0	0	ND	ND	ND	0	ND	ND
19-May	94	ND	ND	190	ND	0	0	ND	ND	ND	0	ND	ND
20-May	126	ND	ND	342	ND	0	0	ND	ND	ND	4	ND	ND
21-May	295	ND	ND	355	ND	0	0	ND	ND	ND	5	ND	ND
22-May	415	ND	ND	395	ND	0	0	ND	ND	0	12	ND	ND
23-May	563	ND	ND	466	ND	0	0	ND	ND	0	12	0	ND
24-May	11,172	ND	ND	8,254	217	0	0	0	ND	7	12	0	ND
25-May	11,742	ND	ND	9,729	288	0	0	0	ND	9	12	0	ND
26-May	17,027	ND	ND	12,494	546	0	0	0	ND	9	12	0	ND
27-May	24,127	ND	ND	12,494	555	0	0	0	ND	9	12	0	ND
28-May	32,984	0	ND	12,498	1,679	0	0	0	ND	14	12	0	ND
29-May	36,198	0	ND	14,133	1,995	0	0	0	ND	14	12	0	ND
30-May	42,974	1	ND	14,137	2,075	5	0	0	ND	18	12	0	ND
31-May	42,989	13	ND	14,138	2,412	6	5	0	ND	20	12	0	ND
1-Jun	43,151	18	ND	14,275	2,520	6	6	0	ND	20	12	0	6,804
2-Jun	43,941	18	ND	15,854	2,524	7	6	0	134	20	12	0	25,413
3-Jun	46,632	27	ND	42,223	2,549	7	7	0	151	20	12	7	27,634
4-Jun	46,857	71	392	44,430	2,549	7	7	0	3,540	21	12	7	28,802
5-Jun	47,726	1,157	482	45,542	2,549	7	7	0	4,307	50	12	8	31,244
6-Jun	52,782	1,308	636	65,367	2,565	14	7	0	4,913	55	12	11	31,725
7-Jun	54,172	1,563	681	66,261	2,651	15	14	0	6,237	55	12	11	31,925
8-Jun	57,923	1,678	1,323	66,508	2,660	15	15	0	6,999	56	12	11	31,948
9-Jun	59,167	3,780	2,088	66,830	2,662	15	15	0	7,648	57	12	11	32,290
10-Jun	59,570	3,792	2,286	67,095	2,700	15	15	0	9,969	57	12	11	32,345
11-Jun	59,809	9,804	2,294	67,440	2,715	15	15	0	13,186	58	12	11	32,528
12-Jun	62,623	10,595	2,296	67,478	2,716	15	15	1	16,480	59	12	11	32,588
13-Jun	62,981	10,613	2,296	67,507	2,732	15	15	1	18,501	59	12	11	32,593
14-Jun	64,383	50,914	2,783	68,413	2,733	16	15	3	19,916	59	12	11	32,600
15-Jun	64,796	64,854	2,915	68,469	2,733	16	16	3	20,574	59	12	11	32,606
16-Jun	65,685	76,045	2,918	68,637	2,733	17	23	3	20,872	59	12	11	32,606
17-Jun	67,793	78,512	3,063	68,638	2,733	17	23	3	21,126	59	12	11	32,606
18-Jun	68,939	79,482	3,130	68,639	2,733	17	23	3	21,253	59	12	15	32,606
19-Jun	69,621	79,488	3,134	68,648	2,733	17	23	3	21,288	59	12	15	32,606
20-Jun	71,995	79,758	3,143	68,648	2,733	17	23	4	21,299	59	12	15	32,606
21-Jun	72,160	79,758	3,181	68,651	2,733	17	23	4	21,302	59	12	15	32,606
22-Jun	74,794	79,758	3,183	68,651	2,733	17	23	5	21,320	59	12	15	32,606
23-Jun	75,674	79,798	3,185	68,651	2,733	17	23	5	21,329	59	12	15	32,606
24-Jun	76,663	79,798	3,185	68,651	2,733	17	23	5	21,342	59	12	15	32,606
25-Jun	77,335	79,948	3,197	68,651	2,733	17	23	5	21,342	59	12	15	32,606
26-Jun	77,781	80,600	3,200	68,651	2,733	17	23	5	21,342	59	12	15	32,606
27-Jun	78,343	80,600	3,200	68,651	2,733	17	23	5	21,342	59	12	15	32,606
28-Jun	78,465	80,600	3,200	68,651	2,733	17	23	5	21,343	59	12	15	32,606
29-Jun	78,575	80,600	3,200	68,651	2,733	17	23	5	21,343	59	12	15	32,606
30-Jun	80,403	80,600	3,200	68,651	2,733	17	23	5	21,345	59	12	15	32,606
1-Jul	81,290	80,600	3,200	68,651	2,733	17	23	5	21,345	59	12	15	32,606
2-Jul	81,772	80,600	3,200	68,651	2,733	17	23	5	21,345	59	12	15	32,606
3-Jul	82,527	80,600	3,200	68,651	2,733	17	23	5	21,345	59	12	15	32,606
4-Jul	82,785	80,600	3,200	68,651	2,733	17	23	5	21,345	59	12	15	32,606
5-Jul	83,114	80,600	3,200	68,651	2,733	17	23	5	21,345	59	12	15	32,606
6-Jul	83,198	80,600	3,200	68,651	2,733	17	23	5	21,345	59	12	15	32,606
7-Jul	83,273	80,600	3,200	68,651	2,733	17	23	5	21,345	59	12	15	32,606
Total	83,273	80,600	3,200	68,651	2,733	17	23	5	21,345	59	12	15	32,606

Blue shading indicates smolt enumeration operations were discontinued for the year

ND means no data was collected for that time period

Appendix 3: Shell Lake Gillnet CPUE 2012–2019

Shell Lake Gillnet CPUE 2012-2019

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
2018	575	12,654	0.05
2019	1,323	21,933	0.06

Shaded cells may not be comparable to other years due to differences in netting methods

Appendix 4: Shell Lake 2019 – Update

Misc. Activities	
Ice-out	16-May
Crew On-site:	21-May
Crew Off-site:	24-Sep

Smolt Migration				
Dates:		NA	to	NA
Coho:	NA			
Sockeye:	NA			
Mortalities:	NA	The 2019 Shell Lake smolt count did not occur due to high water during the spring.		
Rainbow Trout:	NA			
Dolly Varden:	NA			

Adult Migration			
Dates:	9-Jul	to	23-Sep
Coho Salmon:	44		
Sockeye Salmon:	16		
Mortalities:			

Northern Pike Harvest			
Dates:	22-May	to	24-Sep
Effort (hours):			21,933
Harvest total:			1,323
		Male:	815
		Female:	433

Appendix 5: Shell Lake 2019 – Daily Environmental Log

2019 Environmental Conditions

Date	Sky	Precip. (mm)	Staff Gauge (ft)	Water Temp. (oC)	Air Temp. (oC)
23-May	3	0.0	1.9	6.3	15
24-May	2	0.0	1.9	6.7	21
25-May	5	0.1	1.8	7.9	13
26-May	5	0.2	1.8	7.0	9
27-May	2	0.0	1.9	7.9	17
28-May	2	0.0	1.9	7.1	16
29-May	3	0.0	1.9	8.5	16
30-May	2	0.0	1.8	7.2	17
31-May	3	0.0	1.8	9.5	18
1-Jun	2	0.0	1.7	7.6	18
2-Jun	2	0.0	1.7	8.3	19
3-Jun	2	0.0	1.7	12.0	24
4-Jun	2	0.0	1.6	11.4	26
5-Jun	1	0.0	1.6	14.7	25
6-Jun	2	0.0	1.6	15.3	25
7-Jun	2	0.0	1.5	16.7	27
8-Jun	3	0.1	1.4	15.1	15
9-Jun	2	0.0	1.3		19
10-Jun	1	0.0	1.3		26
11-Jun	1	0.0	1.2		27
12-Jun	2	0.0	1.2		21
13-Jun	1	0.0	1.1		24
14-Jun	1	0.0	1.1		25
15-Jun	1	0.0	1.1		19
16-Jun	1	0.0	1.0		20
17-Jun	3	0.0	1.0		21
18-Jun	2	0.0	1.0		20
19-Jun	1	0.0	1.0		26
20-Jun	1	0.0	1.0		24
21-Jun	1	0.0	1.0		27
22-Jun	1	0.0	1.0		27
23-Jun	1	0.0	1.0		31
24-Jun	1	0.0	0.9		28
25-Jun	1	0.0	0.8		29
26-Jun	1	0.0	0.8		28
27-Jun	1	0.0	0.8		29
28-Jun	1	0.0	0.8		27
29-Jun	1	0.0	0.8		32
30-Jun	1	0.0	0.7		32
1-Jul					
2-Jul					
3-Jul					
4-Jul					
5-Jul					
6-Jul					
7-Jul					
8-Jul					
9-Jul	1	0.0	0.5		31
10-Jul	4	0.0	0.5		24
11-Jul	4	0.0	0.5		18
12-Jul	4	0.0	0.5	20.9	18
13-Jul	4	0.0	0.5	20.6	23
14-Jul	4	0.0	0.4	20.1	18
15-Jul	2	0.0	0.4	20.2	25
16-Jul	2	0.0	0.4	20.9	24
17-Jul	2	0.0	0.4	22.7	28
18-Jul	2	0.0	0.4	23.5	32
19-Jul	1	0.0	0.4	23.2	28
20-Jul	1	0.0	0.4	21.3	24
21-Jul	1	0.0	0.4	21.7	29
22-Jul	1	1.3	0.4	23.8	28
23-Jul	1	0.0	0.4	22.2	28
24-Jul	4	0.0	0.4	18.0	17
25-Jul	4	0.0	0.4	18.0	21
26-Jul	5	0.3	0.4	17.8	13
27-Jul	4	0.3	0.4	18.0	17
28-Jul	4	0.1	0.4	18.6	18
29-Jul	4	0.1	0.4	19.1	18
30-Jul	1	0.0	0.4	19.9	26
31-Jul	2	0.0	0.4	19.3	22
1-Aug	3	0.0	0.3	17.1	18

Date	Sky	Precip. (mm)	Staff Gauge (ft)	Water Temp. (oC)	Air Temp. (oC)
2-Aug	2	0.0	0.3	17.6	18
3-Aug	4	0.0	0.3	18.4	16
4-Aug	4	0.0	0.3	18.3	18
5-Aug	4	0.0	0.3	18.6	22
6-Aug	3	0.0	0.3	19.8	20
7-Aug	1	0.0	0.3	20.5	26
8-Aug	1	0.0	0.3	20.5	28
9-Aug	1	0.0	0.3	20.9	29
10-Aug	1	0.0	0.3	21.2	27
11-Aug	1	0.0	0.3	21.1	28
12-Aug	1	0.0	0.3	20.4	28
13-Aug	4	0.0	0.3	19.0	19
14-Aug				19.9	
15-Aug	2	0.0	0.3	21.0	26
16-Aug	2	0.0	0.3	21.3	28
17-Aug	1	0.0	0.3	19.8	24
18-Aug	1	0.0	0.3	19.1	24
19-Aug	1	0.0	0.3	18.5	21
20-Aug	1	0.0	0.3	17.8	21
21-Aug	1	0.0	0.3	17.2	19
22-Aug	1	0.0	0.2	17.0	23
23-Aug	1	0.0	0.1	16.9	21
24-Aug	1	0.0	0.1	16.9	23
25-Aug	1	0.0	0.1	16.6	21
26-Aug	4	0.0	0.1	16.6	11
27-Aug	1	0.0	0.1	17.0	21
28-Aug	1	0.0	0.1	17.5	21
29-Aug	1	0.0	0.0	16.4	19
30-Aug	1	0.0	0.0	15.9	19
31-Aug	1	0.0	0.0	16.1	22
1-Sep	5	0.1	0.0	15.5	11
2-Sep	5	0.1	0.0	15.5	11
3-Sep	5	0.3	0.0	15.8	12
4-Sep	4	0.0	0.0	15.7	13
5-Sep	4	0.0	0.0	14.9	16
6-Sep	3	0.0	0.0	14.7	14
7-Sep	5	0.1	0.0	14.3	12
8-Sep	3	0.0	0.0	14.9	17
9-Sep	2	0.0	0.0	14.9	16
10-Sep	5	0.3	0.0	14.9	10
11-Sep	4	0.4	0.0	14.8	16
12-Sep	5	0.5	0.0	14.4	9
13-Sep	5	0.6	0.1	14.3	9
14-Sep	1	0.0	0.1	14.4	19
15-Sep	5	1.2	0.1	13.9	8
16-Sep	1	0.0	0.2	14.1	17
17-Sep	3	0.0	0.2	14.0	13
18-Sep	5	1.7	0.5	13.5	7
19-Sep	5	0.1	0.6	13.6	10
20-Sep	4	0.4	0.6	13.4	11
21-Sep	4	0.0	0.6	12.5	12
22-Sep	3	0.0	0.6	12.3	11
23-Sep	2	0.0	0.6	12.1	13
24-Sep	3	0.0	0.7	11.7	10

Total	Total	8.4	Staff	Water	Air
Avg.	Avg	0.1	0.6	16.2	20.8
Min.	Min	0.0	0.0	6.3	7
Max.		1.7	1.9	23.8	32

Ice out = 16-May

Summary of Cloud Cover - Percent of Days

No. Days	Meas. Rain	Overcast	Partly Cloudy	Clear
111	22.5%	35.1%	39.6%	25.2%

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

Gray Shading Indicates that no data is available for that category

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:

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

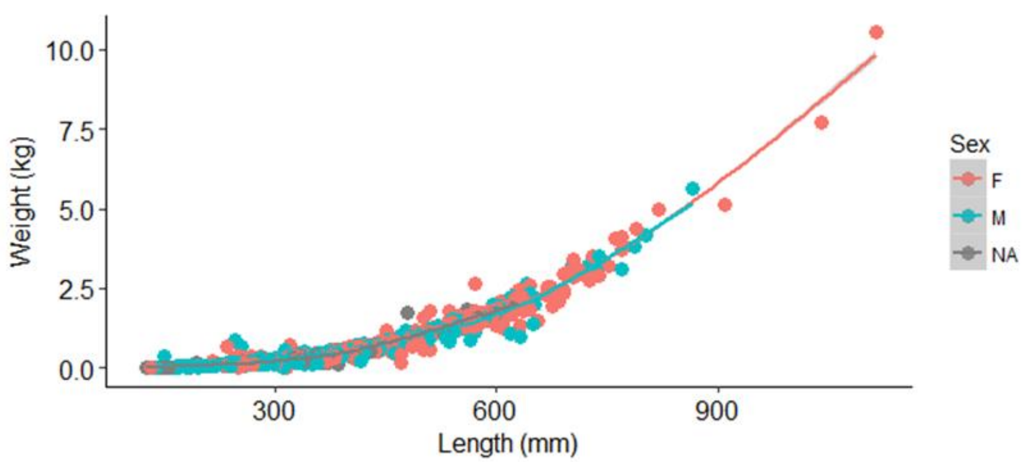


Figure 1: Length-weight relationship for all northern pike measured and weighed during the study.

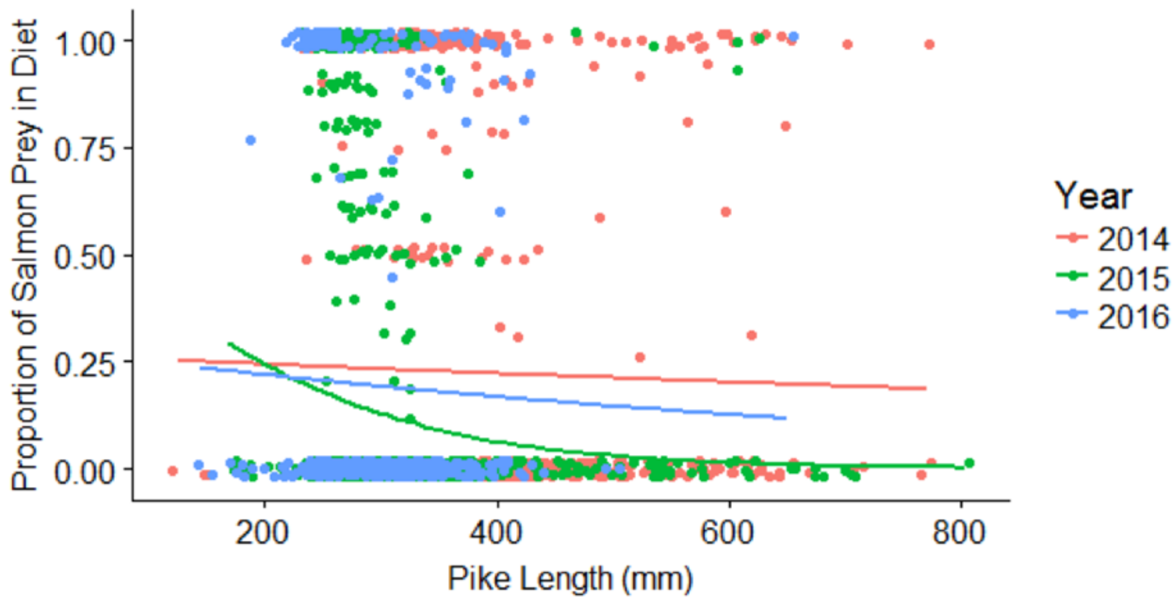


Figure 2: Proportions of salmon in the stomach contents of individual northern pike captured during 2014–2016. Diet proportions were estimated visually in 2014–2015 and calculated from the weights of individual diet items during 2016. Data points are jittered to improve visibility of overlapping symbols. 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.

Appendix 7: Age Data Explanation for UAF Analysis

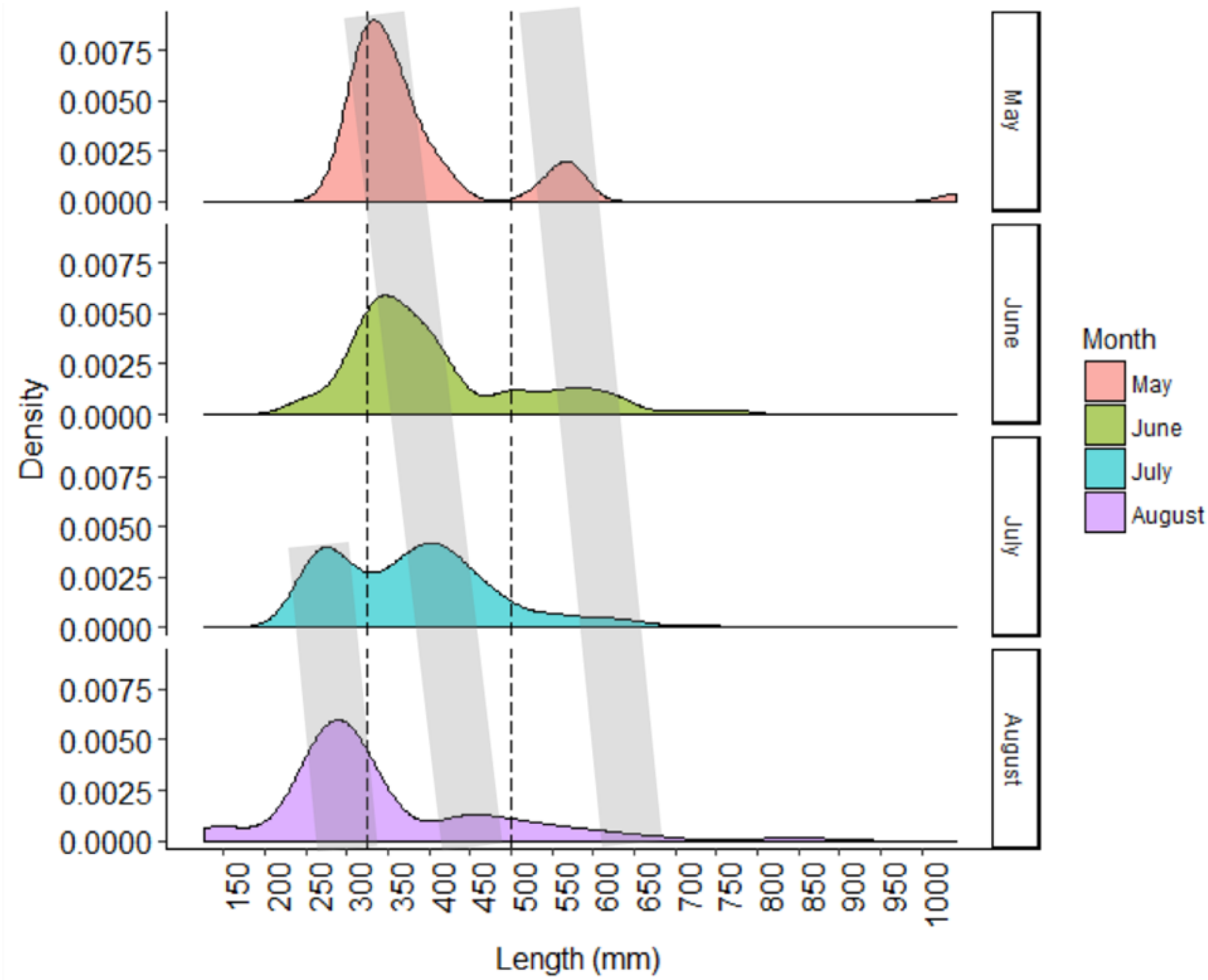
We initially attempted to calculate initial and final weights directly using the age data provided by CIAA, but this approach was unsuccessful. Using the cleithrum ages, we calculated the monthly mean weight-at-age of pike captured in each year to estimate the initial and final weights of an average 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 8: 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.



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 1).

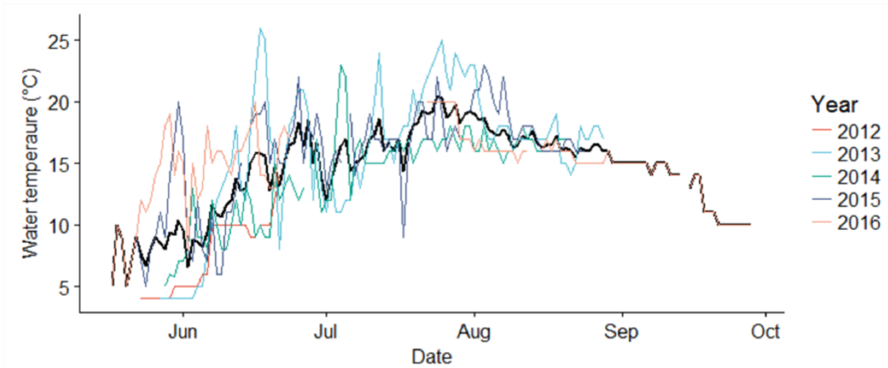


Figure 3: Daily water temperatures measured at the surface of Shell Lake during 2012–2016. Black line represents daily mean water temperature.

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 1).

Table 1: 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 2). 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.

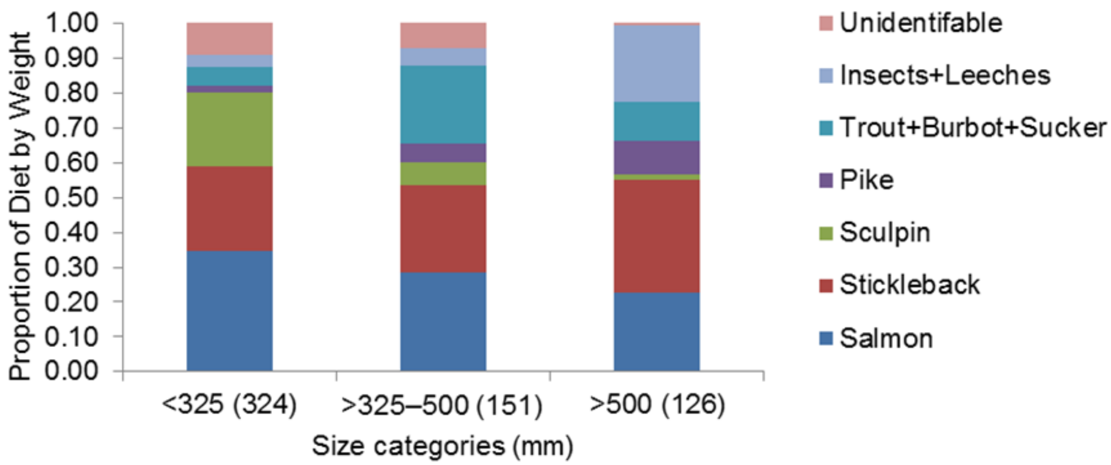


Figure 7: Diet composition of pike in three size categories (fork length, mm).
Numbers in parentheses in the x-axis labels indicate sample sizes.

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 3). 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.

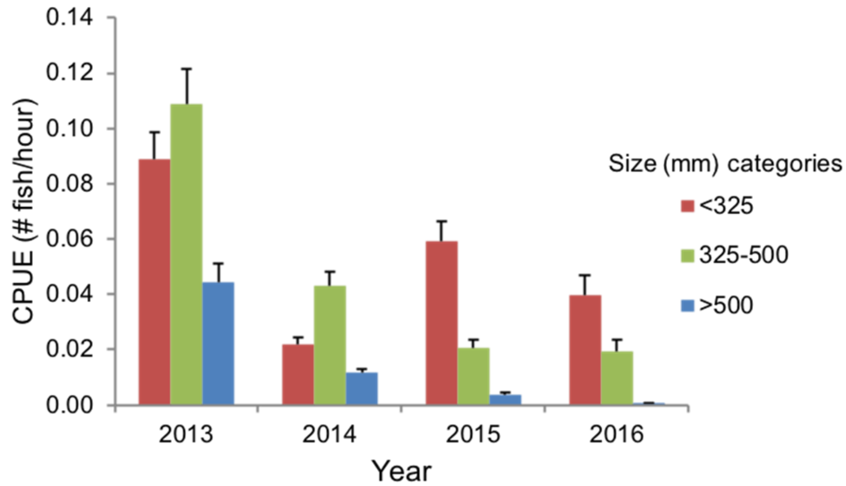


Figure 5: Mean (± SE) catch per unit effort (CPUE) of pike in three size categories (fork length, mm) captured in standardized gillnet sets during 2013–2016.

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 4).

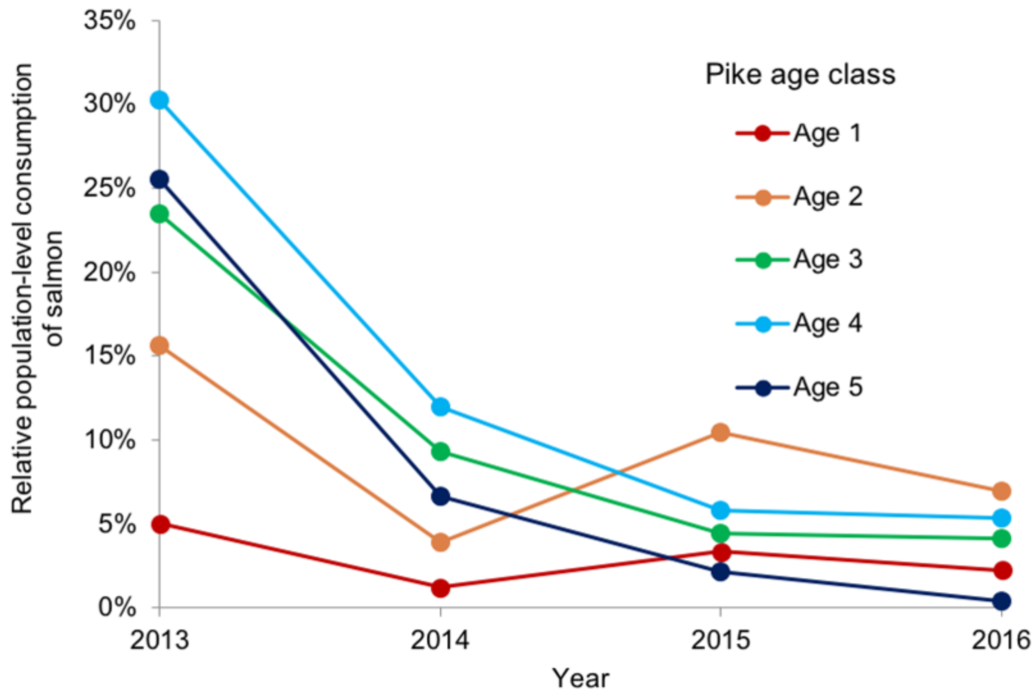


Figure 6: Relative total consumption of salmon by the northern pike population in Shell Lake, broken down by pike age class.
Values were estimated as the per-capita consumption of salmon by an average pike in each age class, multiplied by the relative abundance of that pike age class in each year (estimated 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 5).

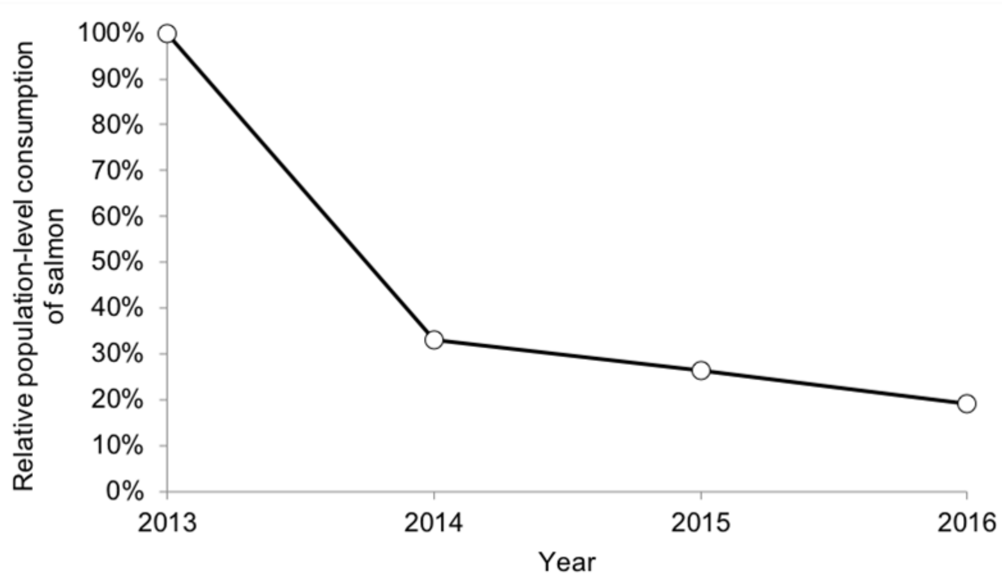


Figure 8: Relative total consumption of salmon by the pike population in Shell Lake during the pike suppression program from 2013–2016.
Values are scaled so that total salmon consumption by the pike population in 2013 = 100%.

ACCESSION NO: 2013-0027

ALASKA DEPARTMENT OF FISH AND GAME
DIVISION OF COMMERCIAL FISHERIES - FISH PATHOLOGY SECTION
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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

<u>CLINICAL FINDINGS</u>

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),

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.

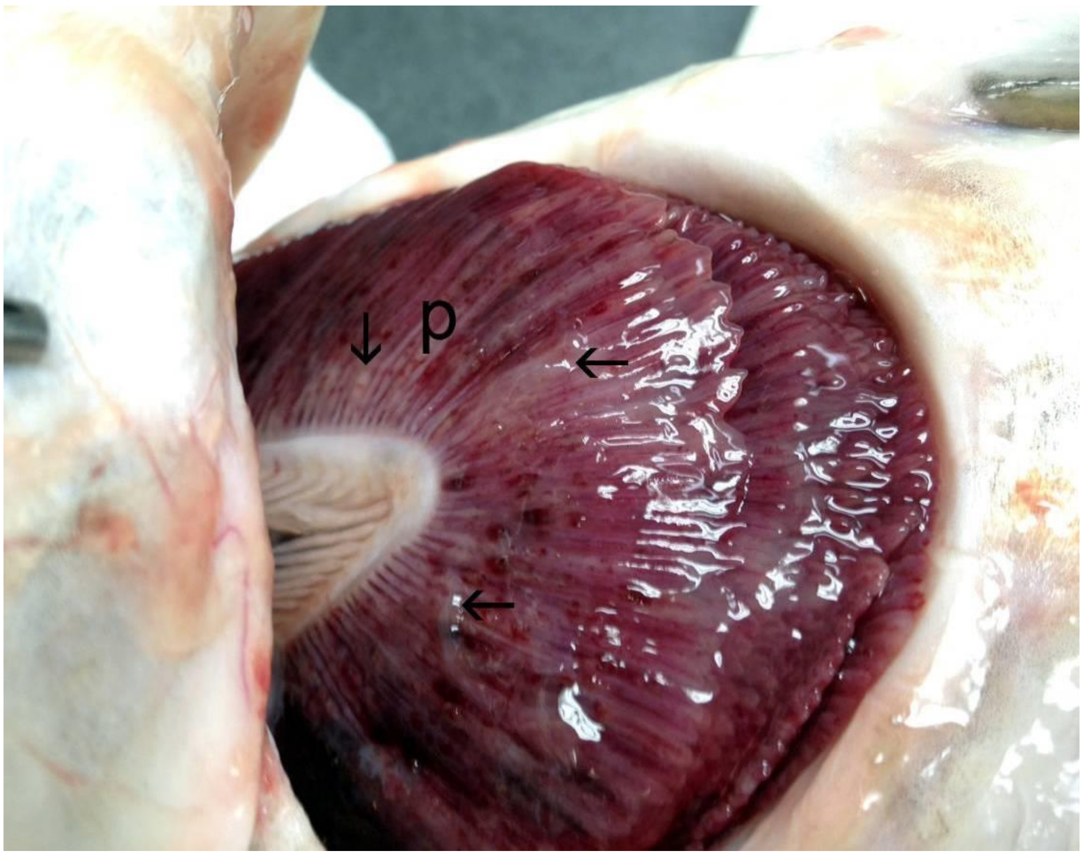

Figure 8. Gross pathology of gills from pre-spawn mortality in present case. Note the large, raised white cysts (arrows) and petechiae (p).

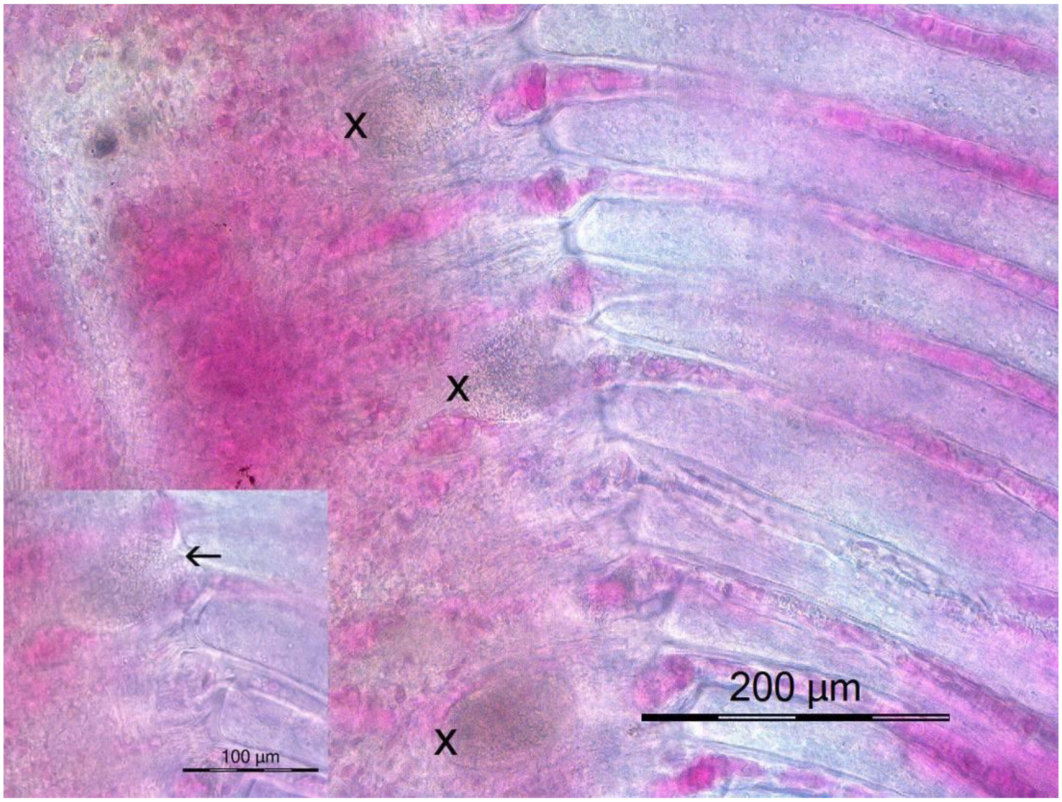

Figure 9. Wet mount of gills from pre-spawning mortality in present case. There are three xenomas (x) at the base of the primary lamellae. Inset shows ruptured xenoma releasing microspores (arrow).

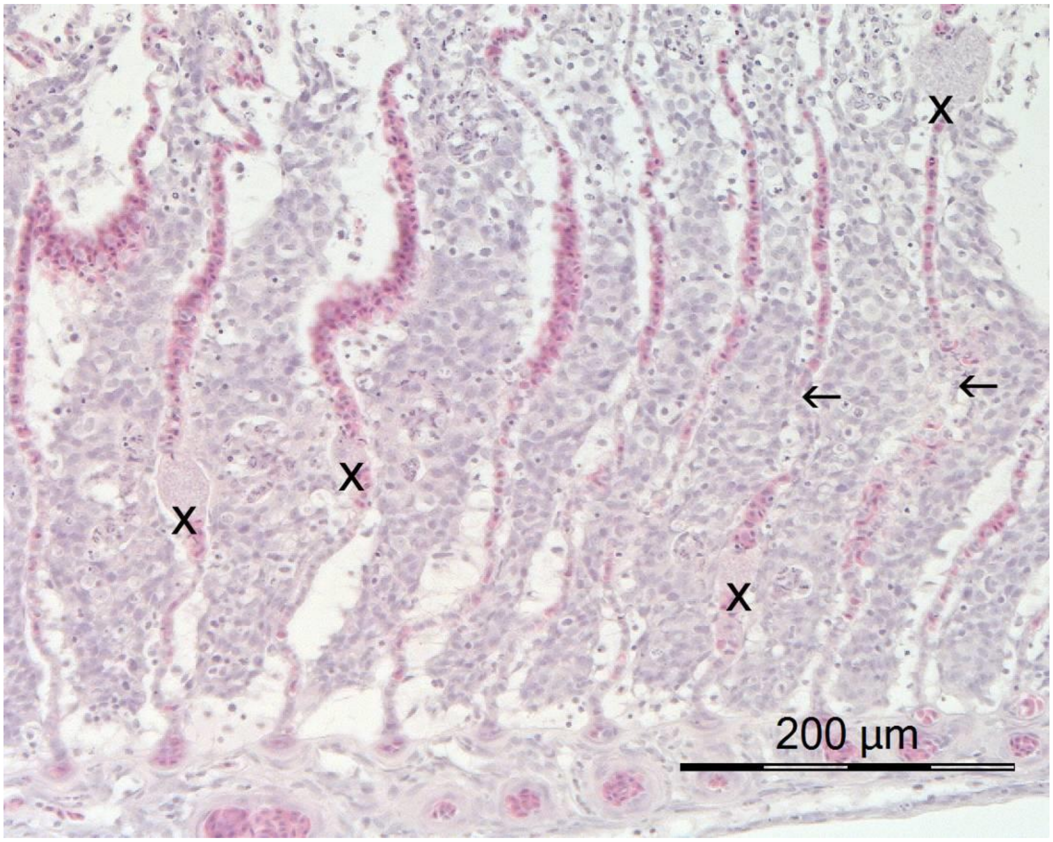

Figure 10. Histopathology of gills from pre-spawning mortality in present case. There are four xenomas (x) in the photograph and a fifth xenoma was located just beyond this field of view. Possible lamellar fusion (arrows).

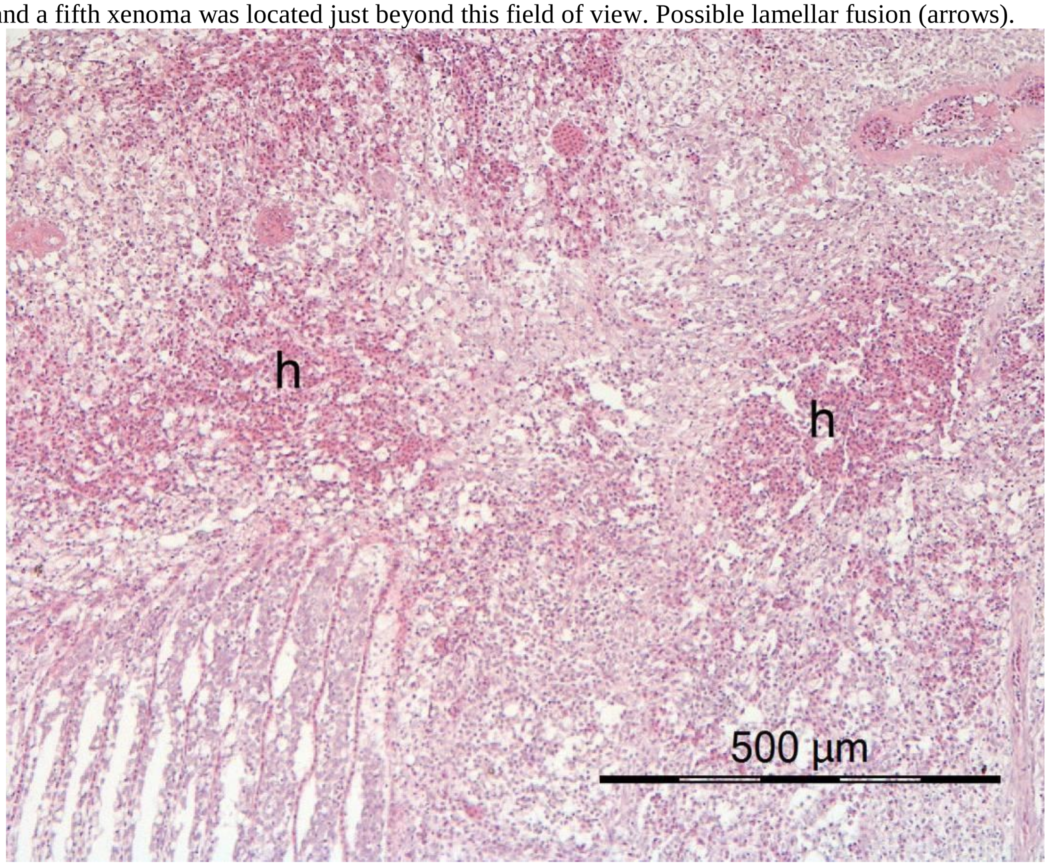

Figure 11. Histopathology of gills from pre-spawning mortality in present case. Extensive hemorrhage (h) was associated with nearby xenomas.

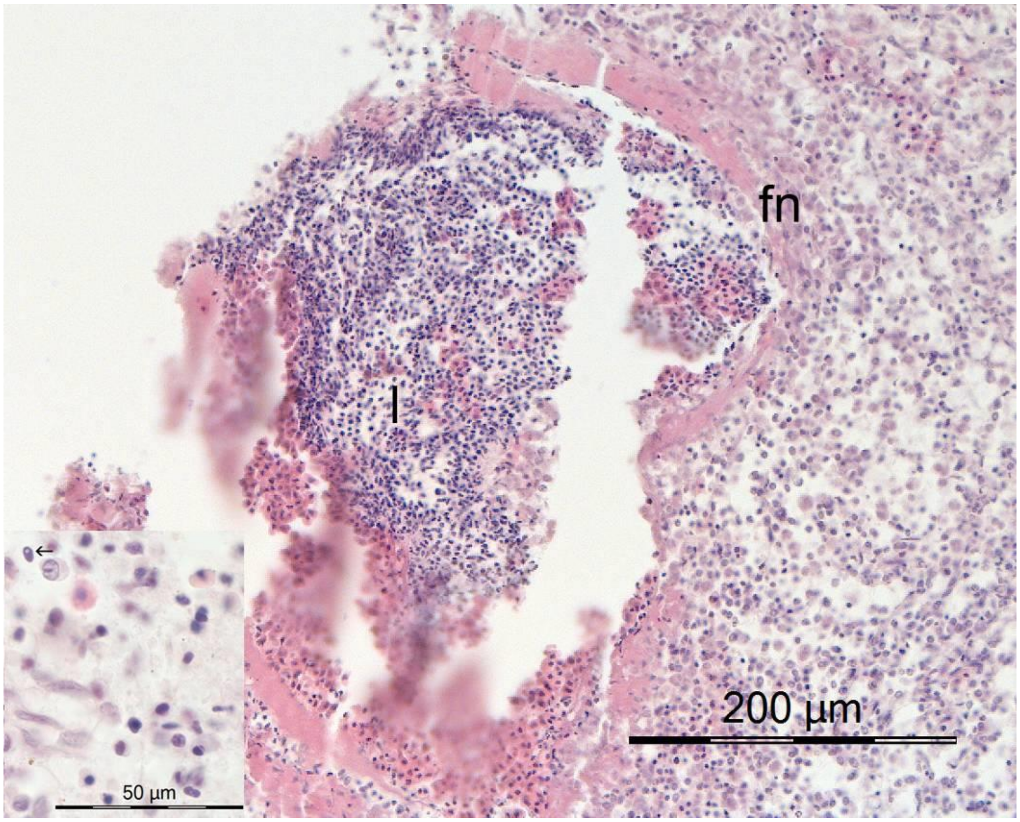

Figure 12. Histopathology of gills from pre-spawning mortality in present case. Marked fibronecrotic tissue (fn) surrounds an intense inflammatory focus comprised of leukocyte infiltrates (l), incited by microspores (arrow).

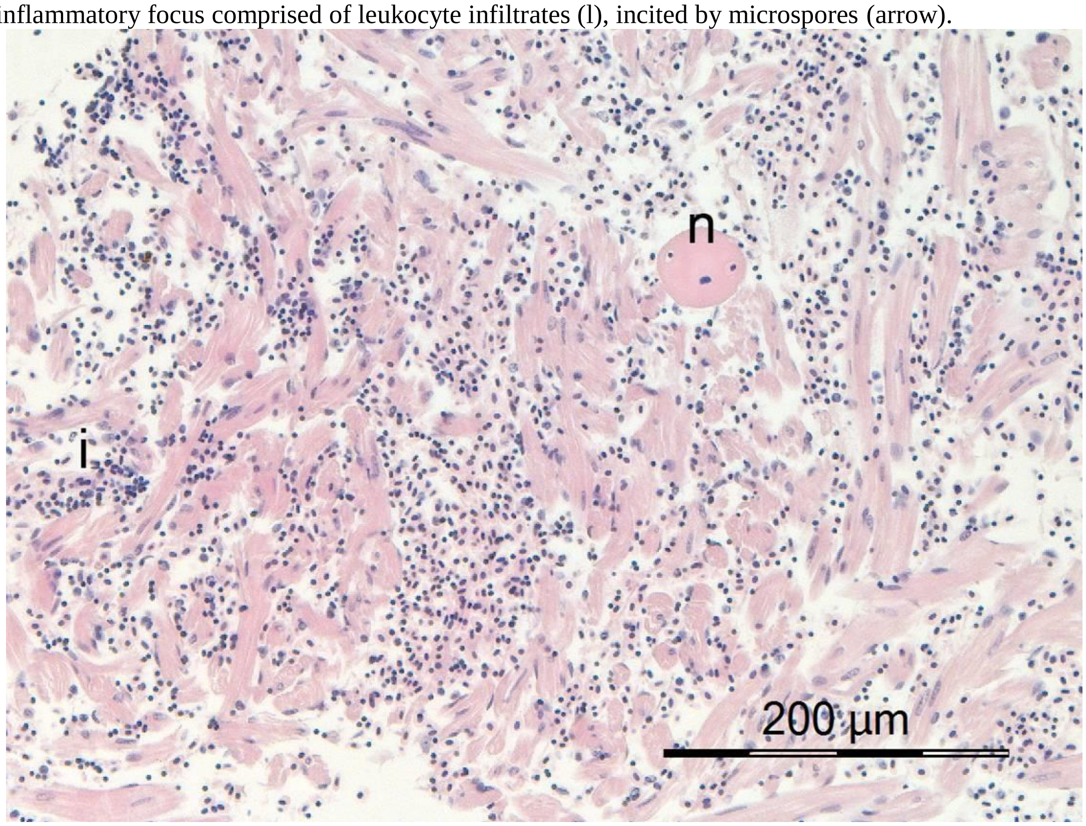

Figure 13. Histopathology of heart from pre-spawning mortality in present case. Multifocal myocarditis (i), cells with pyknotic nuclei and early coagulative necrosis (n) is evident in the spongy ventricular myocardium.

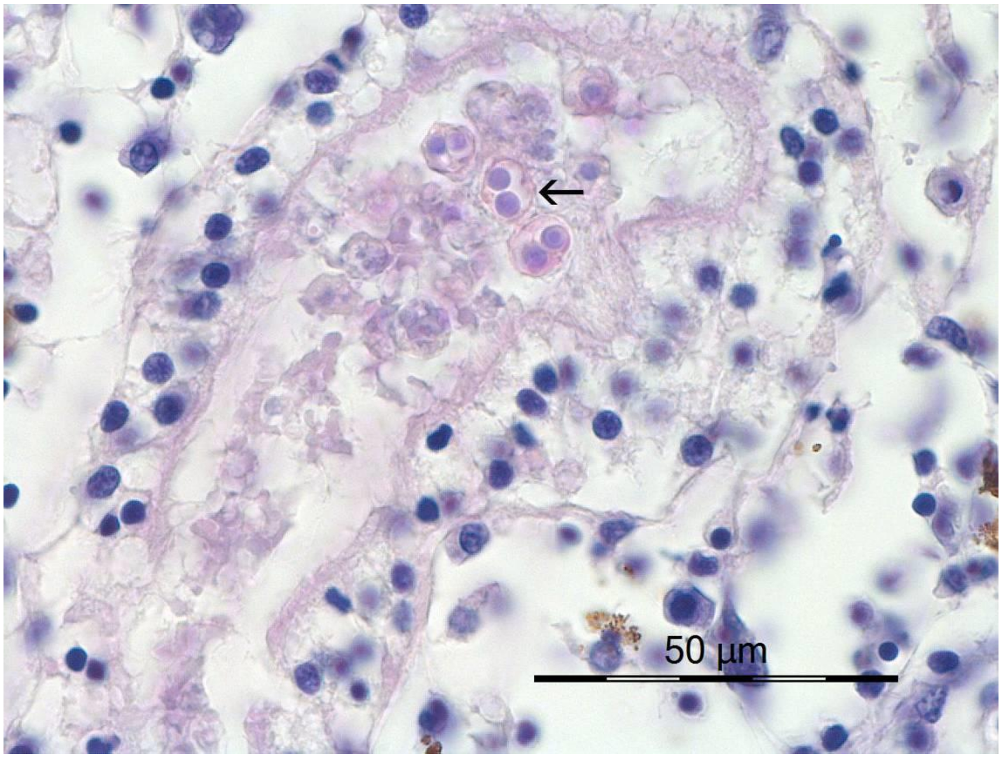

Figure 14. High magnification of presporogonic and sporogonic stages of a myxozoan parasite, possibly *Sphaerospora oncorhynchi* (arrow), tubular necrosis and pyknotic nuclei are also present in the kidney.

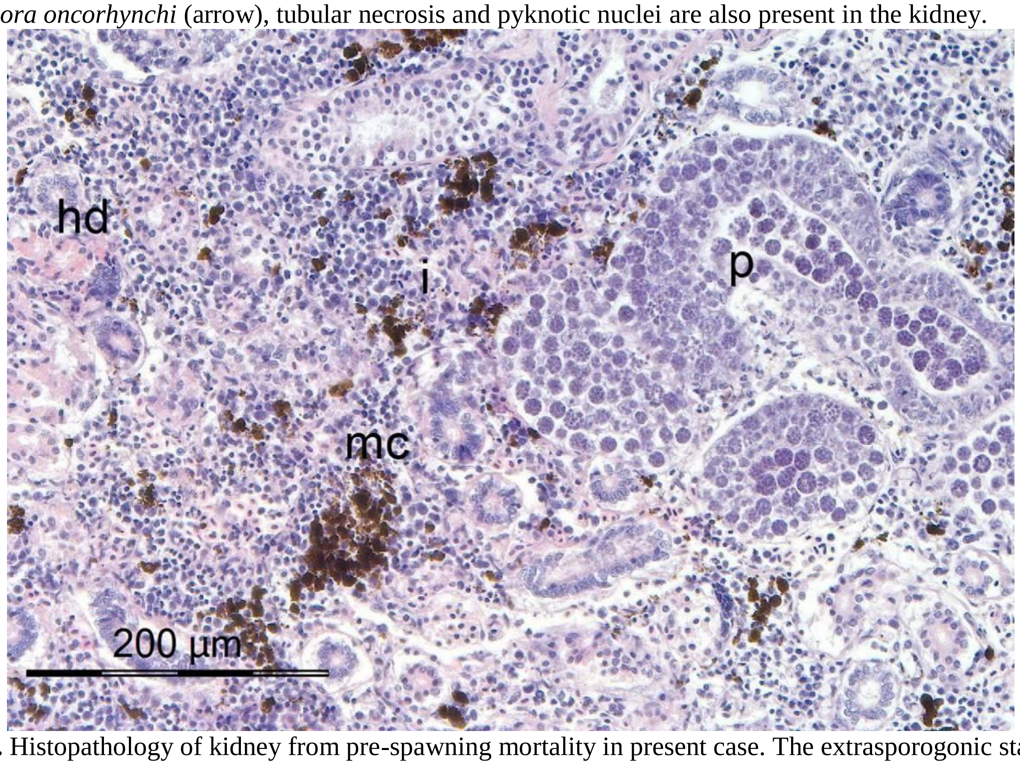

Figure 15. Histopathology of kidney from pre-spawning mortality in present case. The extrasporogonic stage of a myxozoan parasite (p), possibly representing *Chloromyxum* sp., has completely destroyed and replaced renal tubules. Nearby renal tubules are undergoing hyaline droplet degeneration (hd). Renal interstitium has numerous melanomacrophage centers (mc) and areas of nephritis (i).

Appendix 11: 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

Appendix 12: 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)	NH_3+NH_4 (ug/l)	NO_2+NO_3 (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)	NH_3+NH_4 (ug/l)	NO_2+NO_3 (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