Whiskey, Hewitt, Chelatna, and Shell Lakes Pike Suppression Final Completion Report (2021–2023)

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August 2024

This project was made possible through an Alaska Sustainable Salmon Fund grant (Project Number 54006) received from the Alaska Department of Fish and Game and through salmon enhancement taxes paid by the commercial fishermen in Area H, Cook Inlet and associated waters.

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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 final report is a synopsis of the studies conducted under an Alaska Sustainable Salmon Fund grant entitled "Mobile Northern Pike Suppression Crew." Field research was conducted by CIAA at Chelatna, Shell, Whiskey, and Hewitt lakes. The purpose of this report is to provide a vehicle to distribute the information produced by three years of pike supression and research. 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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ACKNOWLEDGEMENTS

Many individuals contributed to the success of the Mobile Northern Pike Suppression Crew Project. Cook Inlet Aquaculture Association recognizes interns, seasonal fisheries technicians, and regular staff who helped plan and execute this project. Andy Wizik, former CIAA staff member and Principal Investigator, is also recognized for his work to make this project a success. Trail Ridge Air and Alaska West Aviation provided needed assistance with hauling gear and supplies. Many local residents of Chelatna, Shell, Whiskey, and Hewitt lakes provided a great deal of help and were vital to the project, particularly Christa and Martin Wegscheider who were so gracious in hosting CIAA staff for dinner and hot showers. Gratitude is also extended to the staff at the Student Conservation Association (SCA) and the Alaska Sustainable Salmon Fund (AKSSF), in particular Debbie Maas from AKSSF. Appreciation is also extended to CIAA's Board of Directors.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ABSTRACT

Cook Inlet Aquaculture Association conducted a three-year northern pike (*Esox Lucius*) suppression project at Chelatna Lake (2021–2022), Shell Lake (2023), Whiskey Lake (2021–2023), and Hewitt Lake (2021–2023) removing pike during the summer season primarily with gillnets. During that time 3,729 pike were removed from these lakes while deploying gillnets for 28,385 hours. Catch per unit effort calculated for 2023 (2022 for Chelatna Lake) showed decreases in the number of pike caught per hour at all lakes when compared to catch per unit effort from a study conducted in 2012. The number of northern pike caught per hour decreased by 96% at Whiskey Lake from 2.666 pike/hour in 2012 to 0.105 pike/hour in 2023; at Hewitt Lake by 48% from 1.487 pike/hour in 2012 to 0.768 pike/hour in 2023; at Shell Lake by 99% from 0.388 pike/hour in 2012 to 0.003 pike/hour in 2023; and at Chelatna Lake by 77% from 0.473 pike/hour in 2012 to 0.109 pike/hour in 2022.

Surveys for the invasive waterweed Elodea were also conducted on Chelatna Lake (2021 and 2022), Shell Lake (2021 and 2023), Whiskey Lake (2021–2023) and Hewitt Lake (2021–2023) and no elodea was detected.

Smolt enumeration was conducted at Shell Lake in 2023. The target species moving through the weir was sockeye salmon (*Oncorhyncus nerka*). The weir operated from mid-May through June. Staff counted both sockeye and coho (*O. kisutch*) smolt. During 2023 CIAA staff at Shell Lake also collected juvenile lamprey (*Entosphenus tridentatus* and *Lampetra planeri*) samples for the Pacific Lamprey Conservation Initiative from the smolt trap on Shell Creek outside of the Alaska Sustainable Salmon Fund grant. Samples were transferred to Trent Sutton of the University of Alaska Fairbanks.

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INTRODUCTION AND PURPOSE

Nonnative species are altering aquatic communities worldwide, with opportunistic predators having particularly catastrophic effects (Sepulveda et al. 2013). The introduction of northern pike (*Esox lucius*) to freshwater systems outside their native range has resulted in negative impacts on resident fish populations (Lee 2001, Patankar et al. 2006, Sepulveda et al. 2013). Outside their native range, northern pike have the potential to interfere with ecosystem function and destroy economically important fisheries.

In Alaska, northern pike are native north of the Alaska Range (Morrow 1980), but were illegally introduced to the Matanuska-Susitna Valley in Southcentral Alaska in the 1950s (Rutz 1999). Pike have spread throughout the Matanuska-Susitna Valley, Anchorage, and the Kenai Peninsula (Alaska Department of Fish and Game 2015). The Cook Inlet drainage (Figure 1) encompasses the Susitna River watershed, which comprises 49,210 km^2 originating in the Alaska Range, and contains a myriad of shallow lakes, sloughs, and clear water tributaries, many of which provide prime northern pike spawning and rearing habitats.

Pike are voracious predators and it is hypothesized their expansion is responsible for the decline of salmonid species in many water bodies in the Susitna basin (Rutz 1999, Patankar et al. 2006, Sepulveda et al. 2013). Once established, northern pike can be devastating to juvenile salmonids and have impacted numerous coho (*Oncorhynchus kisutch*), Chinook (*O. tshawytscha*), and sockeye salmon (*O. nerka*) runs from the Susitna River watershed (Alaska Department of Fish and Game 2015).

The Yentna drainage contains one-half of the sockeye salmon producing lakes that flow into the Susitna River; among the most productive systems in the Yentna are Chelatna, Shell, Hewitt, and Judd lakes. The Susitna River sockeye salmon was designated as a stock of yield concern at the February 2008 Board of Fisheries (BOF) meeting and was attributed to low salmon numbers from predation by invasive northern pike. The BOF subsequently removed the stock of yield concern from the Susitna sockeye population but continued to restrict fishing opportunities stating that the there are multiple issues facing the sockeye populations including predation from invasive northern pike (Brehmer 2020).

Although Cook Inlet Aquaculture Association (CIAA) had been monitoring sockeye runs in various Susitna systems since the early 1990s, the invasive pike threat steered CIAA into a new direction. CIAA and the Alaska Department of Fish and Game (ADF&G) began to monitor salmon populations at lakes throughout the Susitna River watershed specifically related to invasive pike. Information was lacking about the health of salmon stocks returning to lakes that previously did not have the presence of northern pike. Under a joint CIAA-ADF&G project, several lakes—which included Chelatna, Shell, Hewitt and Whiskey lakes—were monitored for numbers of salmon

returning to spawn (Alaska Sustainable Salmon Fund 2013). Historically, all of these lakes had populations of salmon. Monitoring indicated that eight of these lakes now had northern pike populations, four of which no longer had returning salmon, and three lakes were found to have salmon populations considered to be below historical averages including Shell, Whiskey, and Hewitt lakes near Skwentna. Through this project it was determined that lake depth played a significant factor in pike predation and salmon survival. In shallow lakes (less than 20 meters mean depth), the number of juvenile salmon produced per spawner was significantly lower in lakes with northern pike versus lakes without northern pike. Overall, the mean number of juvenile sockeye salmon produced per spawner was significantly greater in deep lakes versus shallow lakes and it also found that juvenile salmon are more susceptible to predation by northern pike in shallow lakes (Diana et al. 1977, Glick and Willette 2013).

After realizing the extent of the problem invasive northern pike have caused, CIAA developed a project entitled Northern Pike Investigations. It was a three-year project intended to help meet CIAA's ultimate goal for the Susitna River watershed of increasing salmon production by removal of northern pike and rehabilitation of lakes throughout the system. The Northern Pike Investigations Project focused on Chelatna, Whiskey and Hewitt lakes.

Since the conclusion of the Northern Pike Investigations Project, CIAA continued maintenance gillnetting at Whiskey and Hewitt lakes for approximately one week per summer during 2016–2017 catching 251 and 365 northern pike respectively, as funding was sought to continue intensive pike harvests at the lakes. From 2018–2020 the Hewitt and Whiskey Lakes Pike Suppression Project (Alaska Sustainable Salmon Fund 2021) was implemented and designed to build on prior pike suppression efforts. By continuing to remove pike from these lakes while evaluating the fry population in Hewitt Lake, CIAA and ADF&G wanted to determine if measurable increased salmon production could be documented in light of pike suppression efforts. Although the goal of increasing salmon fry rearing in Hewitt Lake to a million was not reached, the Hewitt Lake sockeye fry population did increase by 20% over the course of the 2018–2020 project.

CIAA has funded suppression work and rehabilitation efforts at Shell Lake since 2012 using a combination of its own funding and various grants. Shell Lake was once a significant contributor to sockeye production in the Susitna River watershed (Wizik 2022). Shell Lake can potentially contribute 10% to the sockeye salmon return to the Susitna River watershed (Tarbox and Kyle 1989). Due to notable decline in the salmon population (smolt and adult) within Shell Lake CIAA initiated rehabilitation efforts. Starting in 2012, the project included smolt and adult enumeration, salmon stocking, disease screening, invasive northern pike suppression, beaver dam surveys and notching, and an evaluation of what effect the harvesting of northern pike prey may have on both northern pike and salmon populations.

In 2016 CIAA enlisted the help of researchers at the University of Alaska Fairbanks (UAF) Institute of Arctic Biology and College of Fisheries and Ocean Sciences to model effects that intensive netting may be having on the Shell Lake pike population. This was prompted when CIAA staff noticed a decline in mean length of northern pike harvested at Shell Lake. Observations from other studies within the region have indicated that smaller pike tend to consume more juvenile salmon (Rutz 1999).

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). 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 but larger northern pike consumed more salmon biomass per capita than smaller pike. 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. Overall, in comparison to 2013, the northern pike population consumed 67% less salmon in 2014, 74% less in 2015, and 81% less in 2016. Based on this model CIAA continued the intensive harvest of northern pike in Shell Lake from 2020 to 2023 in an attempt to determine if this reduced consumption can translate into positive natural sockeye salmon production in Shell Lake.

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 was 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. Sockeye salmon escapements to Shell Lake from 2020–2023 were expected to be comprised primarily of hatchery progeny from brood years 2016 and 2017. Because the State of Alaska salmon genetics policy recommends not taking eggs from hatchery-produced salmon, Shell Lake sockeye salmon returning to the lake during 2020–2023 needed to successfully reproduce naturally if this stock is able to survive extirpation.

Additional funding was received from the Alaska Sustainable Salmon Fund (AKSSF) to continue pike suppression work in Chelatna, Shell, Whiskey and Hewitt lakes from 2021–2023. The following report details those findings. Other historical data are provided for reference.

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PROJECT AREA

Chelatna, Shell, Whiskey and Hewitt lakes are located in the Cook Inlet drainage in Southcentral Alaska (Figure 1).

Figure 1: Northern pike suppression project sites in relation to Cook Inlet, Alaska.

Chelatna Lake

Chelatna Lake is located at 62°48’ N latitude and 151°45’ W longitude at the base of the Alaska Range approximately 68 kilometers northwest of Talkeetna, Alaska (Figure 2). The lake lies near Denali National Park between two 1,219 meter mountains and has a surface elevation of 422 meters. Chelatna Lake has a surface area of 1,581 hectares (Spafard and Edmundson 2000). Major tributaries to Chelatna Lake are Coffee and Snowslide creeks. Both creeks are glacier fed and produce Chelatna Lake’s semi-glacial characteristics. The lake’s discharge forms Lake Creek, which flows 71 kilometers to the Yentna River. Chelatna Lake is part of the Anadromous Waters Catalog, code 247-41-10200-2053-3170-0010 (Giefer and Graziano 2023).

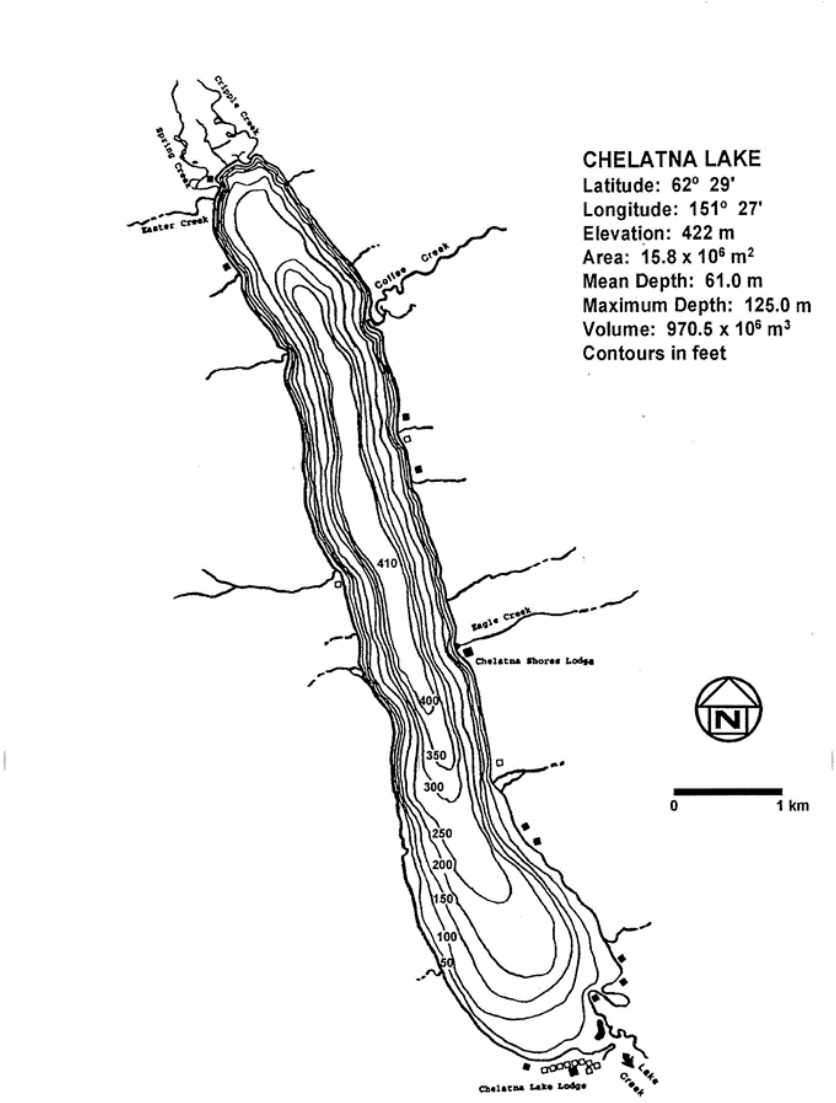

Figure 2: Bathymetric map of Chelatna Lake

Shell Lake

Shell Lake is located at 61º58’ N latitude and 151º33’ W longitude at the base of Shell Hills in the Susitna River drainage approximately 121 kilometers northwest of Anchorage, Alaska (Figure 3). The lake has a surface elevation of 123 meters. Shell Lake has a surface area of 523 hectares, has maximum depth of 29 m, a mean depth of 11.9 m and 16.6 km of shoreline (Kyle at al. 1994). Shell Lake has seven small tributaries and discharges southeast via Shell Creek, which runs approximately six river miles to the Skwentna River. Shell Lake is part of the Anadromous Waters Catalog, code 247-41-10200-2053-3205-4052-0010 (Giefer and Graziano 2023).

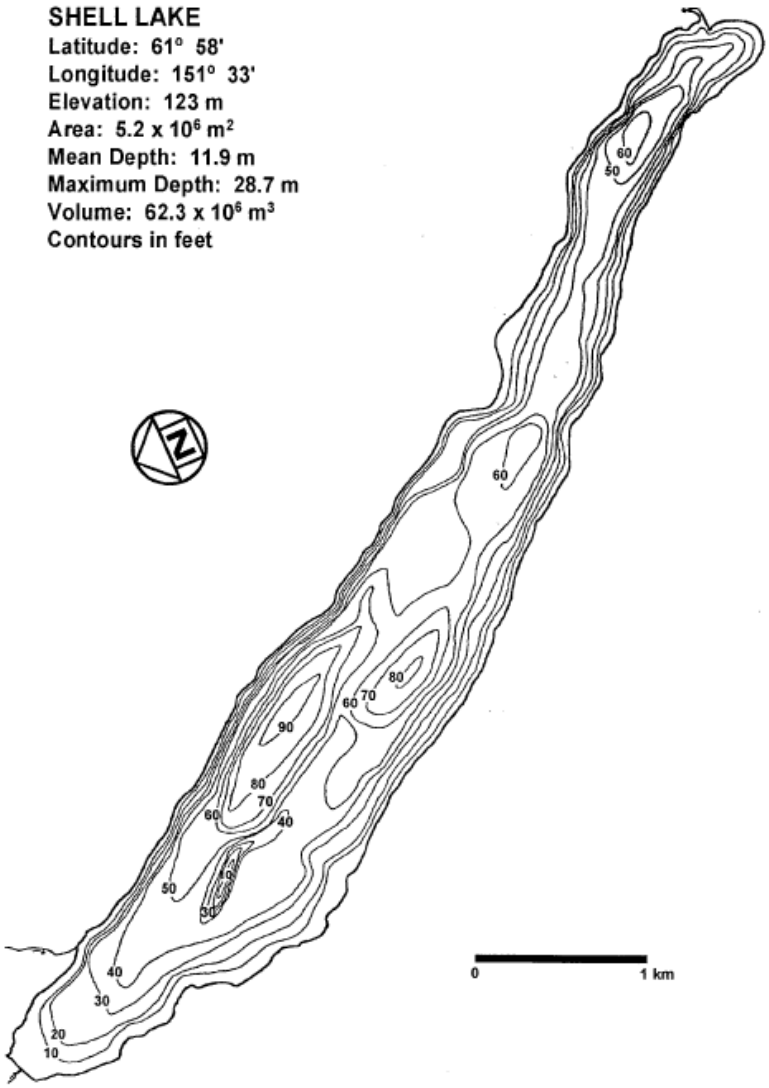

Figure 3: Bathymetric map of Shell Lake

Whiskey Lake

Whiskey Lake is located at 61º59’ N latitude and 151º24’ W longitude at the base of the Shell Hills in the Susitna River drainage, approximately 118 kilometers northwest of Anchorage, Alaska (Figure 4). The lake has an elevation of 45 meters and a surface area of 110 hectares (Spafard and Edmundson 2000). There is one small unnamed tributary of Whiskey Lake located on the north side of the lake. The lake’s discharge forms Whiskey Creek, which flows into Hewitt Creek and the Yentna River. Whiskey Lake is part of the Anadromous Waters Catalog, code 247-41-10200-2053-3213-4052-0010 (Giefer and Graziano 2023).

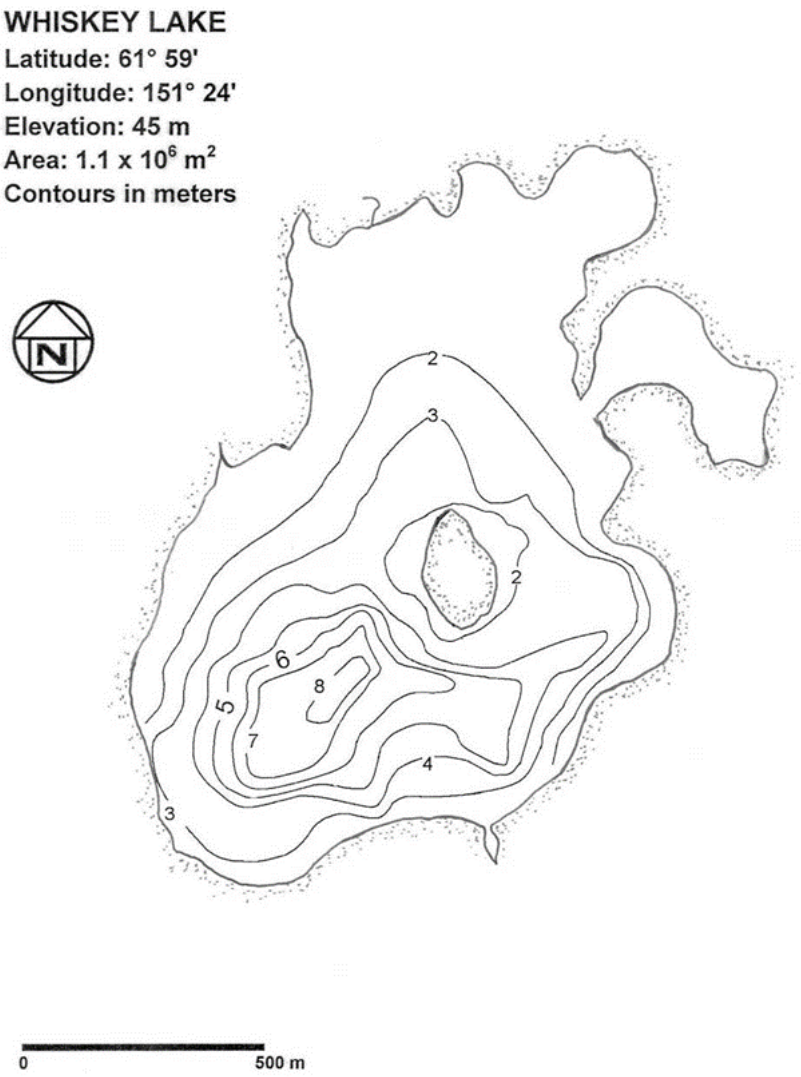

Figure 4: Bathymetric map of Whiskey Lake.

Hewitt Lake

Hewitt Lake (Figure 5) is located approximately 0.5 km to the east of Whiskey Lake. Hewitt Creek is a common outlet for both lakes, and flows 6.4 meandering kilometers to the Yentna River. Hewitt Lake covers 226 hectares, has a maximum depth of 34 m, a mean depth of 13.5 m, a 10.6 km shoreline, and is located at an elevation of 40 m above sea level (Spafard and Edmundson 2000). Hewitt Lake is part of the Anadromous Waters Catalog, code 247-41-10200-2053-3213-4050-0010 (Giefer and Graziano 2023).

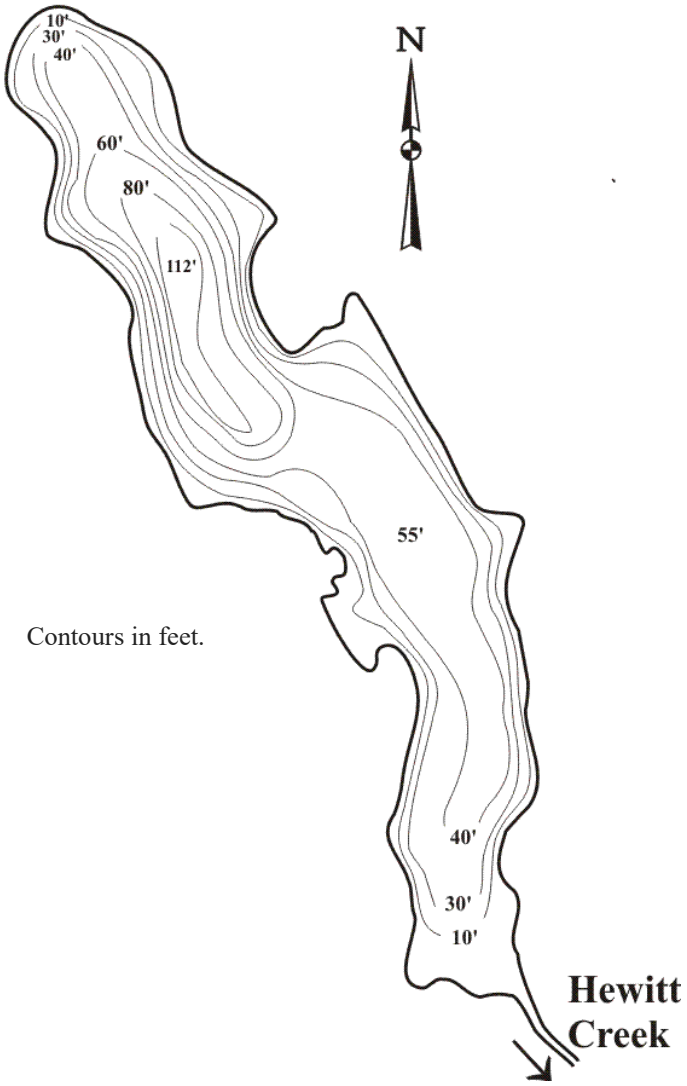

Figure 5: Bathymetric map of Hewitt Lake.

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METHODS

Invasive Northern Pike Suppression

Staff from CIAA used one inch bar mesh gillnets to capture and remove northern pike in Chelatna, Shell, Whiskey, and Hewitt lakes and the Hewitt-Whiskey Creek outlet that connects these two lakes to the Yentna River. Staff removed northern pike at Chelatna Lake from May to early-July 2021 and 2022; Shell Lake from May to late June 2023; Whiskey and Hewitt lakes system from July through late-August/early-September 2021, 2022 and 2023. Staff also used hook-and-line fishing. Fish caught via hook-and-line were sampled for age, length, weight, and sex but no attempt to calculate catch per unit effort (CPUE) was made for angled fish due to the differences in techniques and skill of anglers.

Each day, staff deployed up to 10 one inch bar mesh gillnets at 10 different shallow and vegetated sites that typically provide optimal northern pike habitat. Nets were checked at least every 24 hours. Staff recorded the time of each net set and retrieval to the nearest minute. Gillnets were 15.2 m long x 2.4 m deep and constructed of monofilament line with a one inch bar mesh size. The top line was a floating core line and the bottom line was lead weighted to sink (CIAA 2021, CIAA 2022, and CIAA 2023a).

Northern pike CPUE was recorded after each net set by dividing the number of northern pike caught by the number of hours the net was in the water. Staff also calculated CPUE figures to factor in the mass of pike by multiplying the CPUE figure by the average weight of pike caught during each year of the project to give the biomass of pike caught per effort hour in addition to the number of fish per hour. The CPUE figures were compared between the three years of the current project (2021–2023) as well as those calculated from sampling in 2012 and 2018–2020 to determine if any changes are occurring in this pike population as suppression continues. The results from this analyses was specifically used to evaluate whether northern pike CPUE was reduced by 80%.

Staff recorded any catch of species other than northern pike, and any bycatch still alive was removed and released immediately. Staff removed captured pike from the nets and quickly dispatched any living pike using a small bat. When possible, northern pike were donated to local residents. If no one was available to take the fish, then the fish were cut completely in half and disposed in the middle of the lake in which they were caught.

Age composition, sex ratio, and length at age was compared among years 2014, 2018–2020 and the current project to evaluate whether northern pike population characteristics were changing over time in response to the northern pike removal effort. All northern pike captured during the project

from 2021–2023 that had not been partially eaten by wildlife were measured from the fork of the tail to the tip of the snout, to the nearest mm; and were weighed to the nearest 0.01 kg. Sex was determined for all whole pike by examining the gonads of the fish. The left cleithrum was removed for later age determination at the CIAA lab (Laine et al. 1991).

The original intent of the project was to focus suppression efforts on Chelatna, Whiskey and Hewitt lakes but a change was made prior to the 2023 field season allowing CIAA to swap out Chelatna Lake for Shell Lake under the AKSSF grant agreement. At the time, the CIAA Board of Directors had made financial decisions to cut back on habitat projects such as Shell Lake efforts to focus more on their salmon hatchery operations.

At Shell, there has been a near collapse of the pike population through pike suppression and a spawning failure in 2019. In a normal population, such a failure would generally be recovered because the population would not be so dependent on spawning. This suppressed population at Shell is primarily comprised of age 1 pike from the year prior, so a spawning failure in combination with intense suppression efforts allows for the chance to nearly or completely extirpate them from a system.

Since 2019, CIAA have recorded low numbers of pike but there is a chance that the few pike remaining in the lake could have a good spawning year. Without a suppression crew on site the possibility that this population spirals out of control is a real threat to the effort that has been put into the lake.

Though the suppression efforts at Chelatna Lake are important, there was a general agreement within the Alaska pike community that: Chelatna Lake has marginal pike habitat; most of the lake provides refuge to juvenile salmonids; the pike captures do save salmon but CPUE has not changed significantly despite netting efforts; and, since ADF&G discontinued the weir counts at Chelatna Lake, it was more difficult to assess the suppression effort's effects on salmon abundance. It is highly unlikely that the sockeye salmon population at Chelatna Lake would ever be extirpated; unlike the situation at Shell Lake, making Shell Lake more of a priority for funding.

Environmental Conditions

For each year of the project the suppression crew recorded environmental data at their respective camp site; one site for Shell Lake; one site for Chelatna Lake and one site on Whiskey Lake, which encompassed time at both Whiskey and Hewitt lakes. Data collected included: percent cloud cover (visually estimated) and precipitation measured to the nearest millimeter, both recorded at 5:00 pm each day. Water and air temperatures were recorded during the project using data loggers (Hobo®) that recorded water and air temperature every hour. Recordings were then averaged over a 24-hour period to provide a daily average air and water temperatures.

Elodea Surveys

The CIAA suppression crew conducted full shoreline surveys for the presence of elodea. These surveys followed a combination of the U.S. Fish and Wildlife Service Aquatic Invasive Species Survey Protocol (2012) and the Survey Design and Methodology for Elodea Detection in Alaska Lakes (Fulkerson 2021). To better inform the surveyors about the lakes they were provided with lake maps and size information, depth and contour information, shoreline length, and adjoining land usage information when available.

Staff conducted full shoreline surveys on Whiskey and Hewitt lakes in 2021–2023, Shell Lake in 2021 and 2023, and Chelatna Lake in 2021 and 2022. The crew worked as a team with one person steering the boat and the other doing a visual shoreline survey. At each designated point one crew member threw a vegetation rake to identify all vegetation at the site. When vegetation could not be identified it was collected in a zip-lock bag and labelled with the site number, lake name, and date for later identification with the aid of a field guide; or it would be sent back to the CIAA Kenai office for identification by the biologist. At high risk areas like boat launches, docks, outlets and inlets, more thorough visual surveys were completed and additional rake throws were conducted if visual identification of vegetation was not possible. Information was recorded in a weatherproof notebook and shared with Alaska Exotic Plants Information Clearinghouse (AKEPIC) by November of each survey season.

Smolt Enumeration

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 one of the two live-box compartments where they were enumerated. A total count was made during smolt migrations (CIAA 2023b).

During the 2023 smolt enumeration staff analyzed age, weight, and length characteristics of emigrating sockeye and coho salmon smolts. Staff collected smolt scale samples in proportion to the emigration. This was accomplished by attempting to collect every 100^{th} sockeye and coho salmon smolt that was counted and passed through the smolt trap. The numbering sequence began when the first fish passed through the trap and continued consecutively until the smolt migration was complete. Smolt lengths and weights were recorded for all sampled fish and the mean values of those measurements are presented in this report.

The fish collected for sampling were placed in a plastic container filled with a diluted solution of 99.5% pure Tricaine Methanesulfonate Finquel® MS-222® and water to anesthetize the fish during the sampling event. Sockeye and coho salmon smolts were first measured to the nearest millimeter for fork length and then weighed to the nearest 0.1 gram. Up to 10 scales were removed from the primary growth area and mounted on a glass slide for subsequent age determination for all sampled smolts. All salmon smolts were allowed to recover in a bucket of fresh water and released unharmed after biological data were recorded.

Pacific Lamprey Collection

Staff at Shell Lake also collected juvenile lamprey (*Entosphenus tridentatus* and *Lampetra planeri*) samples for the Pacific Lamprey Conservation Initiative from the smolt trap on Shell Creek. When lamprey were present in the smolt trap the crew would collect them and transfer them to a bucket with MS-222®. Once dispatched the crew bagged and transported them to a local resident's cabin where the samples were frozen until they were able to be transported back to Kenai and then transferred to Trent Sutton of the University of Alaska Fairbanks.

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RESULTS

Invasive Northern Pike Suppression

Gillnetting of northern pike from Chelatna Lake occurred from May 31–June 30, 2021, and May 9–June 21, 2022. Gillnetting of northern pike from Shell Lake occurred from May 25–June 28, 2023. Gillnetting of northern pike from Whiskey and Hewitt lakes occurred from July 9–August 25, 2021, July 6–August 30, 2022, and July 12–August 22, 2023.

Effort hours were recorded to the nearest minute for all gillnets set on all lakes. During 2021, gillnets fished Whiskey Lake for 6,017.25 hours, Hewitt Lake for 3,212.63 hours, and Chelatna Lake for 4,628.31 hours. In 2022 the effort hours were 6,359.13 at Whiskey Lake, 231.30 at Hewitt Lake, and 1,718.87 at Chelatna Lake. In 2023 the effort hours were 3,744.80 at Whiskey Lake, 259.08 at Hewitt Lake, and 795.38 at Shell Lake.

The total number of pike removed from the lakes via gillnets and hook-and-line fishing from 2021–2023 was 3,729 with 1,853 captured in Whiskey Lake, 1,171 removed from Hewitt Lake, 693 removed from Chelatna Lake and 12 from Shell Lake. Bycatch caught in each lake per year is reported in appendix 1.

Catch per unit effort was calculated for all lakes and all efforts undertaken on Hewitt-Whiskey Creek were attributed to Hewitt Lake. From 2021–2023 CPUE in Whiskey Lake fell slightly from 0.134 pike/hour in 2021 to 0.105 pike/hour in 2023; and rose at Hewitt Lake from 0.167 in 2021 to 0.768 in 2023. The CPUE at Chelatna Lake remained similar in 2021 and 2022 with 0.100 and 0.109 pike/hour respectively. The CPUE at Shell Lake in 2023 was 0.003 pike/hour, which was down from netting efforts in 2019 and comparable to efforts from 2020 through 2022.

The latest CPUE data for each lake (2023 for Whiskey, Hewitt and Shell and 2022 for Chelatna) has decreased since initial netting efforts in 2012 (Figure 6). When compared with the intensive harvest at Whiskey, Hewitt, Shell and Chelatna lakes in 2012, 2023 CPUE at all lakes has been reduced: 96% at Whiskey, 48% at Hewitt, 99% at Shell, and 77% at Chelatna.

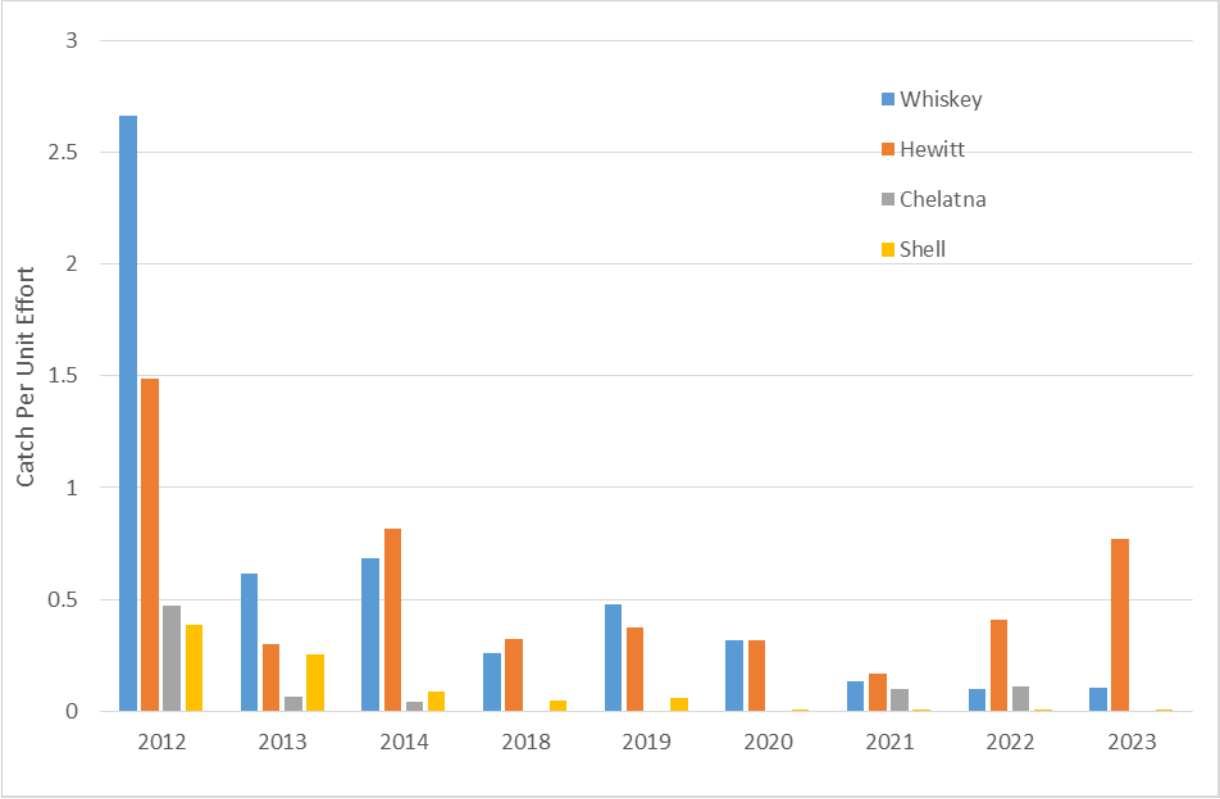

Figure 6: Catch per unit effort for Whiskey, Hewitt, Chelatna, and Shell lakes northern pike suppression 2012–2023. Suppression work did not occur at Chelatna from 2018–2020 and 2023.

Raw CPUE figures calculated for the project lakes from 2021–2023 were multiplied by the average weights of pike captured during each year to determine the biomass of northern pike caught per hour for each year of the project. Biomass-per-hour calculations from Hewitt Lake increased from 0.14 kg/hour in 2021 to 0.76 in 2023, likely due to a more targeted netting effort. Whiskey Lake biomass decreased from 0.134 to 0.050 kg/hour; Shell Lake biomass was 0.00069 kg/hour; and Chelatna Lake biomass increased from 0.020 kg/hour in 2021 to 0.070 kg/hour in 2022.

For all lakes, average lengths and weights of captured pike are provided in figures 7 and 8. There is fluctuation throughout the years but in general from the start of suppression work in 2012 pike size has been reduced in most of the lakes, besides Chelatna. Table 1 depicts the changes within the pike populations in each lake from 2021–2023. The average age of pike caught increased within all the lakes while the percentage of females within the population decreased in all lakes except Chelatna Lake, which may be due to the amount of pike with gonads that could be identified.

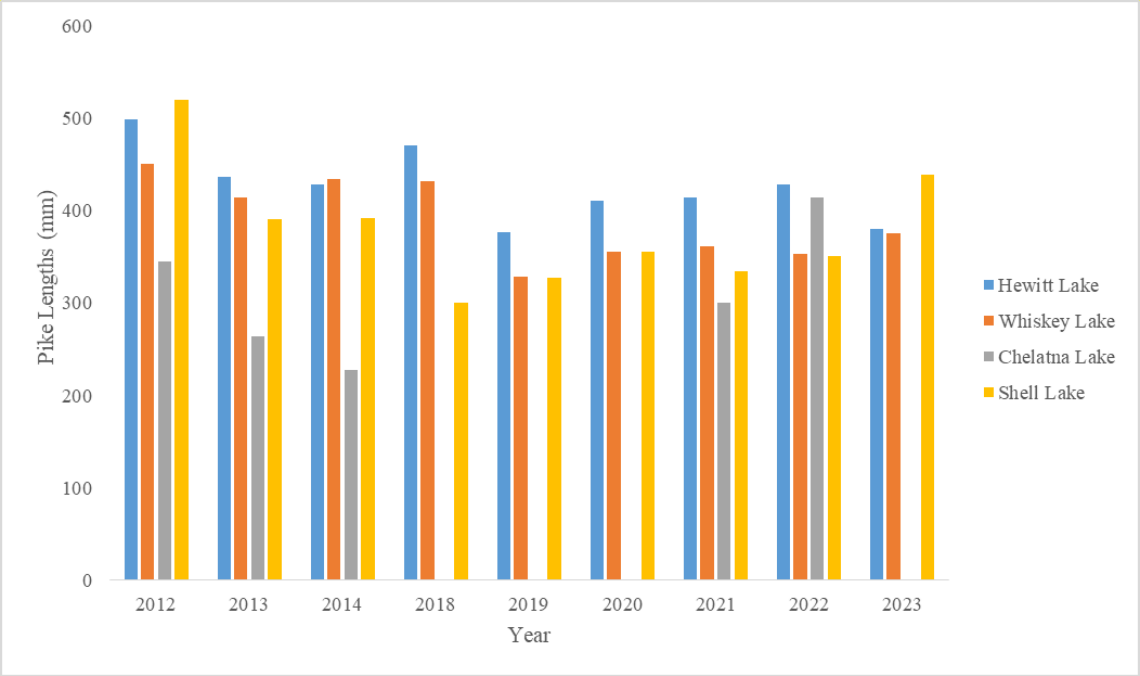

Figure 7: Average lengths of captured pike for Whiskey, Hewitt, Chelatnana, and Shell lakes, 2012–2023. Suppression work did not occur at Chelatna Lake from 2018–2020 and 2023.

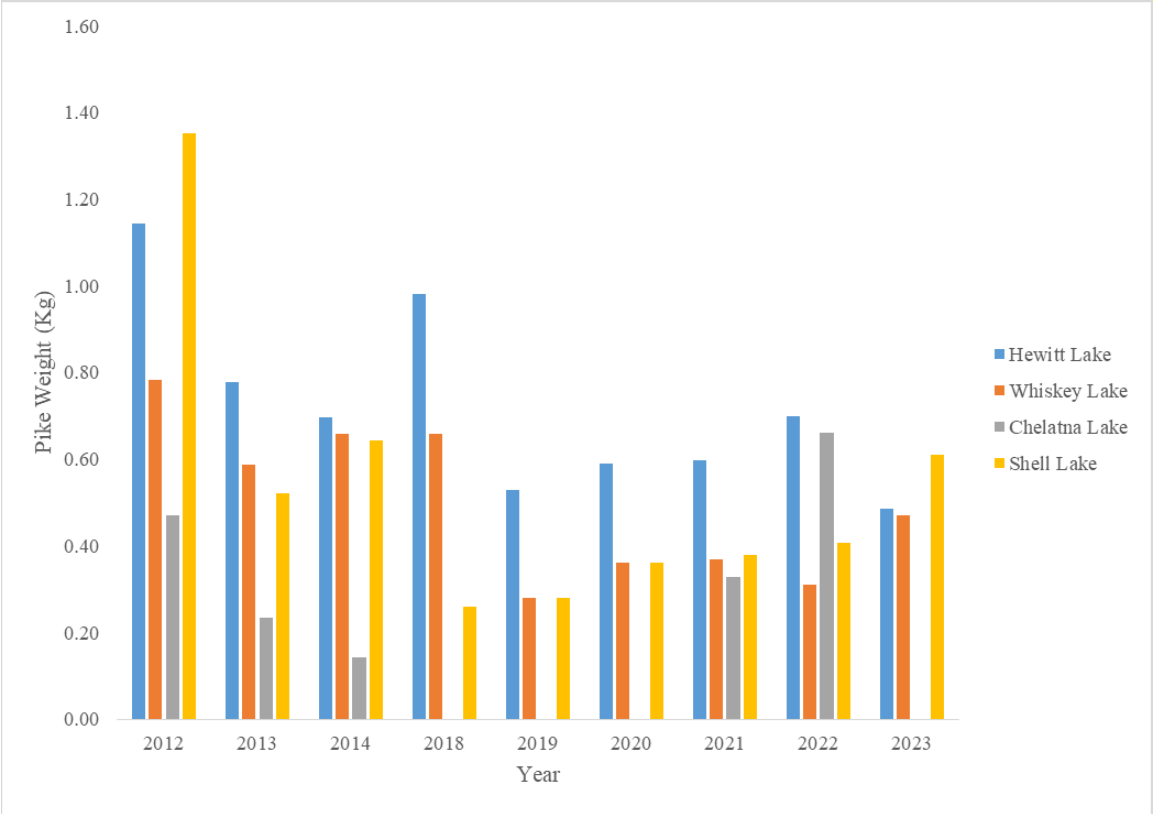

Figure 8: Average weights of captured pike for Whiskey, Hewitt, Chelatnana, and Shell lakes, 2012–2023. Suppression work did not occur at Chelatna Lake from 2018–2020 and 2023.

Table 1: Northern pike average age and female percentage of the pike population, Whiskey, Hewitt, Shell, and Chelatna lakes, 2021–2023.

	Whiskey Lake			Hewitt Lake		
	% Female	Avg. Age	Age Range	% Female	Avg. Age	Age Range
2021	53%	1.9	0–9	50%	2.2	0–12
2022	17%	1.6	0–6	56%	2.0	0–5
2023	37%	2.1	0–5	37%	2.1	1–8
	Shell Lake			**Chelatna Lake**		
	% Female	Avg. Age	Age Range	% Female	Avg. Age	Age Range
2021	57%	2.0	1–3	9%	1.5	0–6
2022	56%	2.8	2–4	42%	2.9	0–7
2023	25%	2.3	2–3	ND	ND	ND

Shaded cells indicated a significant portion of gonads could not be sexed

Over the three years of the project the number of year classes of northern pike detected in all the lakes decreased (tables 1 and 2). As the number of year classes decreased in Chelatna and Hewitt lakes the size at age of the remaining year classes increased. This is likely due to decreased competition for resources from conspecifics. In Whiskey and Shell lakes the size at age did not increase with continued suppression effort (figures 9–12).

Table 2: Northern pike average size at age, Hewitt, Whiskey, Chelatna, and Shell lakes, 2021–2023.

Hewitt Lake Pike Length (mm) at Age (years)				Whiskey Lake Pike Length (mm) at Age (years)				Chelatna Lake Pike Length (mm) at Age (years)			Shell Lake Pike Length (mm) at Age (years)			
Age+	2021	2022	2023	Age+	2021	2022	2023	Age+	2021	2022	Age+	2021	2022	2023
0	247	275	NS	0	275	285	263	0	248	205	0	NS	NS	NS
1	312	349	300	1	303	321	319	1	269	256	1	315	NS	NS
2	427	413	390	2	371	369	355	2	290	364	2	346	309	426
3	480	511	436	3	417	437	442	3	453	415	3	485	520	464
4	529	644	506	4	482	526	490	4	540	470	4	NS	NS	NS
5	601	679	608	5	487	585	511	5	630	596	5	NS	NS	NS
6	581	NS	638	6	NS	ND	NS	6	692	695	6	NS	NS	NS
7	717	NS	NS	7	NS	NS	NS	7	720	NS	7	NS	NS	NS
8	NS	NS	800	8	NS	NS	NS	8	NS	NS	8	NS	NS	NS
9	NS	NS	NS	9	896	NS	NS	9	NS	NS	9	NS	NS	NS
10	NS	NS	NS	10	NS	NS	NS	10	NS	NS	10	NS	NS	NS
11	NS	NS	NS	11	NS	NS	NS	11	NS	NS	11	NS	NS	NS
12	898	NS	NS	12	NS	NS	NS	12	NS	NS	12	NS	NS	NS

Shaded areas represented by only one sample. NS = No Sample. ND = No Data due to otter predation on the carcasses leaving the cleithra but no pike for length/weight data collection.

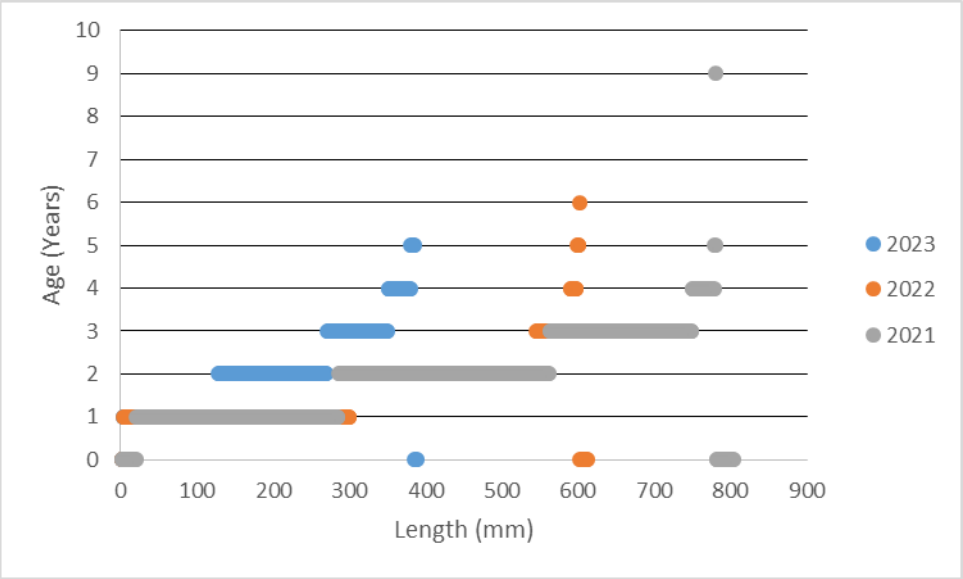

Figure 9: Northern pike length at age, Whiskey Lake, 2021–2023.

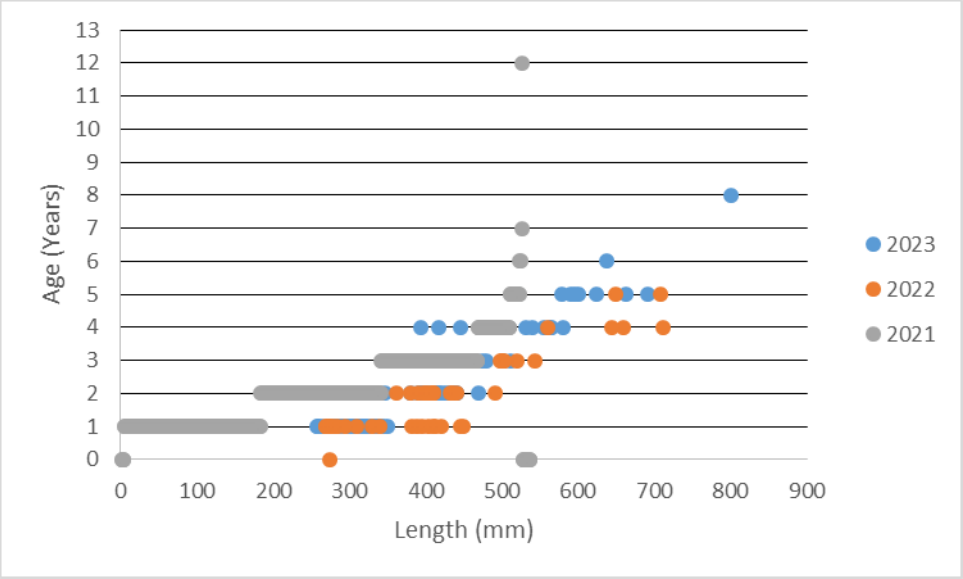

Figure 10: Northern pike length at age, Hewitt Lake, 2021–2023.

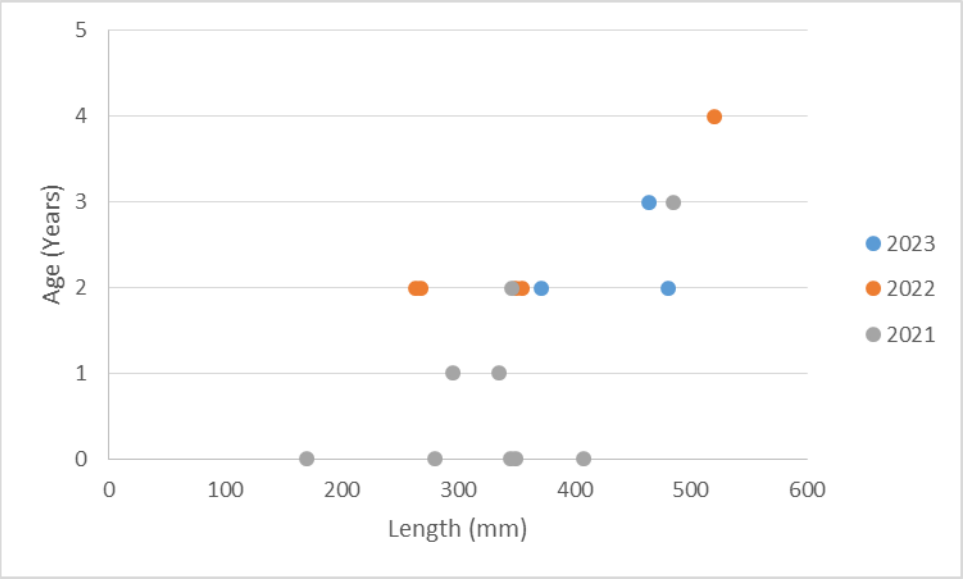

Figure 11: Northern pike length at age, Shell Lake, 2021–2023.

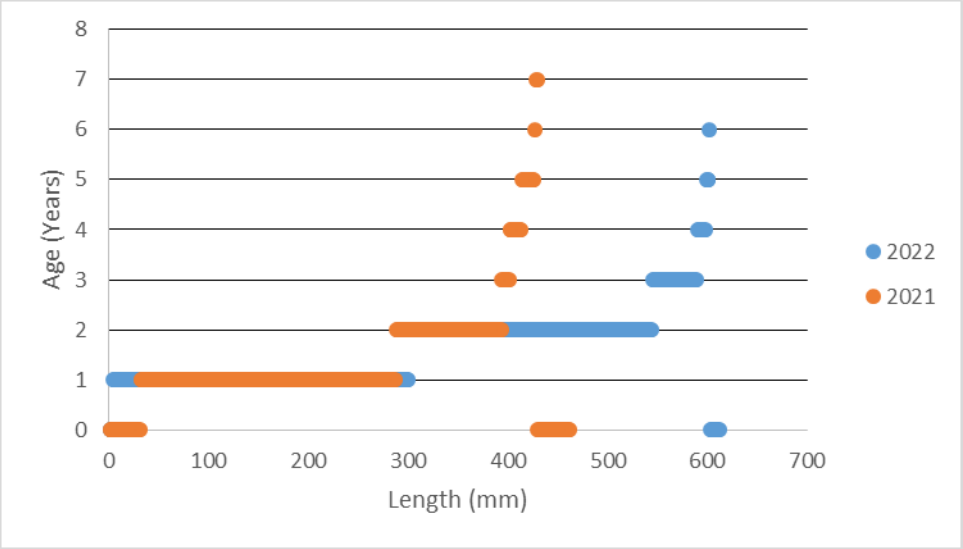

Figure 12: Northern pike length at age, Chelatna Lake, 2021–2022.

Environmental Conditions

Environmental data taken at Chelatna, Shell, Whiskey, and Hewitt lakes including air and water temperature for each year of the project are presented in appendices 2–4.

Elodea Surveys

Surveys for elodea were conducted when time and weather allowed at each lake. Surveys varied each year depending on the surveyors but the sample points on the lakes remained consistent from year-to-year: 146 points on Whiskey; 357 points on Shell; 244 points on Hewitt; and 239 points on Chelatna. Shell Lake was not surveyed in 2022 and Chelatna Lake was not surveyed in 2023. In general it took the crew roughly two days to survey each lake. No elodea was detected in any of the surveys. All survey data was submitted to the AKEPIC by November of each year the data were collected. Tables 3–5 depict the native vegetation that was found at each of the lakes during the surveys.

Table 3: Elodea survey data, Whiskey, Hewitt, Shell, and Chelatna lakes, 2021.

		Lakes Surveyed			
Common Name	**Scientific Name**	Whiskey	Hewitt	Shell	Chelatna
Horsetail	*Equisetum fluviatile*	x	x	x	ND
Mare's Tail	*Hippuris vulgaris*	x	x		ND
Bur-reed	*Sparganium* sp.	x	x	x	ND
Lillies	*Nuphar lutea*	x	x	x	ND
Pygmy Waterlilly	*Nymphaea tetragona*	x	x		ND
floating-leaved pondweed	*Potamogeton natans*			x	ND
two-headed water starwort	*Callitriche heterophylla*		x		ND
vernal water starwort	*Callitriche palustris*				ND
Coon's Tail	*Ceratophyllum demersum*		x		ND
quillworts	*Isoetes* sp.	x	x	x	ND
star duckweed	*Lemna trisulca*	x			ND
Siberian watermilfoil	*Myriophyllum sibiricum*	x	x		ND
nodding waternymph	*Najas flexilis*	x	x		ND
Frie's pondweed	*Potamogeton obtusifolius*	x	x		ND
long-stalked pondweed	*Potamogeton praelongus*	x	x		ND
Richardson's pondweed	*Potamogeton richardsonii*	x	x	x	ND
fern-leaf pondweed	*Potamogeton robbinsii*		x	x	ND
fineleaf pondweed	*Stuckenia filiformis*	x	x		ND
water buttercup	*Ranunculus aquatilis*			x	ND
spiral ditch-grass	*Ruppia cirrhosa*	x	x		ND
swaying bulrush	*Schoenoplectus subterminali*	x	x		ND
waterawlwort	*Subularia aquatica*	x			ND
common bladderwort	*Utricularia macrorhiza*		x		ND
muskwort	*Chara* sp.			x	ND
common watermoss	*Fontinalis antipyretica*		x		ND

ND = Chelatna Lake was also surveyed but only for the presence/absence of elodea, no native vegetation was identified during the survey.

Table 4: Elodea survey data, Whiskey, Hewitt, and Chelatna lakes, 2022.

		Lakes Surveyed		
Common Name	**Scientific Name**	Whiskey	Hewitt	Chelatna
Horsetail	*Equisetum fluviatile*	x	x	ND
Mare's Tail	*Hippuris vulgaris*	x		ND
Bur-reed	*Sparganium* sp.	x		ND
Lillies	*Nuphar lutea*	x	x	ND
Siberian watermilfoil	*Myriophyllum sibiricum*		x	ND
nodding waternymph	*Najas flexilis*	x		ND
small pondweed	*Potamogeton pusillus*		x	ND
Richardson's pondweed	*Potamogeton richardsonii*	x	x	ND
fern-leaf pondweed	*Potamogeton robbinsii*	x	x	ND
swaying bulrush	*Schoenoplectus subterminali*	x	x	ND
common watermoss	*Fontinalis antipyretica*	x	x	ND

ND = Chelatna Lake was also surveyed but only for the presence/absence of elodea, no native vegetation was identified during the survey.

Table 5: Elodea survey data, Whiskey, Hewitt, and Shell lakes, 2023.

		Lakes Surveyed		
Common Name	**Scientific Name**	Whiskey	Hewitt	Shell
Horsetail	*Equisetum fluviatile*	x	x	ND
Mare's Tail	*Hippuris vulgaris*	x		ND
Lillies	*Nuphar lutea*	x	x	ND
Siberian watermilfoil	*Myriophyllum sibiricum*	x		ND
Richardson's pondweed	*Potamogeton richardsonii*	x	x	ND
muskwort	*Chara spp.*	x		ND
common watermoss	*Fontinalis antipyretica*	x	x	ND
quillworts	*Isoetes spp.*		x	ND
fern-leaf pondweed	*Potamogeton robbinsii*	x	x	ND
Siberian watermilfoil	*Myriophyllum sibiricum*		x	ND
nodding waternymph	*Najas flexilis*	x	x	ND
Coon's Tail	*Ceratophyllum demersum*		x	ND

ND = Shell Lake was also surveyed but only for the presence/absence of elodea, no native vegetation was identified during the survey.

Smolt Enumeration

Staff monitored Shell Lake salmon smolt migration from May 25 through June 28, 2023 and counted 466 sockeye salmon smolt and 2,926 coho salmon (Appendix 5). Samples were collected from four of the migrating sockeye smolt and 29 of the coho smolt. Seven of the coho smolt

samples were unreadable. Because of the low numbers of emigrating smolt, no statistical analysis of demographic data was performed in 2023. The four sockeye smolt sampled were age-1 smolt from brood year 2021.

Pacific Lamprey Collection

Staff at Shell Lake also collected juvenile lamprey samples for the Pacific Lamprey Conservation Initiative from the smolt trap on Shell Creek. Twenty-eight Arctic lamprey (*Lethenteron* spp.) were collected on Shell Creek.

DISSCUSSION

From the onset of intensive pike suppression at the project lakes in 2012 to the end of the current project in 2023, the relative abundance of northern pike has decreased at Shell, Whiskey, Hewitt, and Chelatna lakes by 99%, 96%, 48% and 76% respectively. From 2021–2023, pike suppression has further reduced the biomass of northern pike in all lakes by decreasing the number of year classes of northern pike. In addition to reducing the number of pike and their inferred consumption on juvenile salmonids, changing the demographics of these pike populations to that of younger/smaller fish reduces the number of northern pike eggs available for spawning each spring. Reducing these populations and transforming the demographics to a population dominated by small one-year-old fish will reduce consumption of juvenile salmonids by pike and may enable the recovery of the important sockeye salmon populations. If netting operations were to cease, it is likely that these pike populations would recover within a few years.

Sockeye salmon originating from these lakes are genetically distinct populations that are pieces of a larger mosaic of genetic diversity making up the Susitna sockeye population. Genetic diversity provides this larger Susitna population with resilience by increasing phenotypic variety and increases the likelihood that a stock will be able to withstand weather anomalies, a disease outbreak, or a variety of other factors detrimental to salmon survival. While working to restore the positive production of Susitna River sockeye salmon is a noble goal, it will be the act of preserving unique genetic stocks within the larger population of Susitna River sockeye that will ensure that any potential recovery can be sustained long term. The loss of any of these stocks will weaken the recovery and future potential of sockeye salmon in this watershed.

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RECOMMENDATIONS

Suppression of northern pike in Chelatna, Shell, Whiskey, and Hewitt lakes should continue as CIAA or other organizations are able. The CPUE of gillnets should still serve as a measurement of relative pike abundance and age, sex, weight, and length data should still be collected to enable the demographic description of the pike population. Although stomach content analysis was not done under this project it was data we collected in the past. Moving forward crews should continue to collect stomach content analysis to get a better picture of the pike diet as preferred prey species (i.e., salmon) appear to be rebounding in some of these lakes.

The AKSSF has awarded CIAA funding to continue pike netting at Shell, Whiskey, and Hewitt lakes through the 2026 field season. CIAA did not propose to continue pike harvesting at Chelatna Lake. There appears to be enough habitat separation between salmon and pike habitats in Chelatna Lake so that the pike predation on juvenile salmon is not having as detrimental of an impact on the adult returns as in the other lakes therefore efforts will be focused on lakes that have already been heavily invested in.

If the adult sockeye population at Shell Lake is adequate another egg take may be warranted to increase the salmon production within the lake. If the adult sockeye population remains too small for an egg take and smolt migration is also small for natural recolonization, CIAA should work with ADF&G to in order to identify a genetically similar stock that could be used for future enhancement of the sockeye population within the lake.

Beaver dam surveys have been conducted annually by CIAA—when funding allows—during the late summer and fall when adult salmon are migrating to their natal lakes to spawn. These surveys are conducted to aid in the salmon migration by identifying barriers that salmon would not be able to bypass without intervention such as notching or heavy rain and increased water flows. Beaver dam surveys should continue to aid with the natural migration of adult salmon into Shell Lake. Shell Creek has had many dams in the recent past so it is a system in great need of beaver dam monitoring in addition to the other significant efforts and resources that have already put into rehabilitating the salmon population in the lake.

Alternative methods such as a flow control to keep northern pike population from rebounding in Shell Lake should also be investigated. The spawning failure in 2019 is attributed to a significant water level drop in the lake, which likely caused pike eggs to go dry before they emerged. Could that water level drop be recreated in subsequent years and paired with intensive suppression efforts to eradicate pike from Shell Lake? CIAA has applied for funding to conduct a feasibility study for a flow control structure at the outlet of Shell Lake with the goal of possible eradication of pike from the lake. The flow control structure could also aid in salmon monitoring by ensuring a weir could function within it; it could also aid in salmon migration by releasing water at critical times

for adult salmon to overcome obstacles within the creek system, which has seen a lot of beaver activity in the last few years.

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APPENDICES

Appendix 1: Bycatch across all lakes, 2021–2023

		Longnose Sucker		**Rainbow Trout**		**Sockeye Salmon**		**Lake Trout**		**Coho Salmon**		**Burbot**		**Bird**		**Whitefish**		**Pink Salmon**	
		Castostomus catostomus		*Oncorhynchus mykiss*		*Oncorhynchus nerka*		*Salvelinus namaycush*		*Oncorhynchus kisutch*		*Lota lota*		*Aves* species		*Coregonus clupeaformis*		*Oncorhynchus gorbuscha*	
		Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead
Shell Lake	2021	953	193	6	8	16	11	7	7	1	8	9	4	7	-	-	-	-	-
	2022	49	29	2	3	-	-	10	2	-	2	1	1	-	-	-	-	-	-
	2023	14	1	2	5	-	-	3	-	1	-	-	-	-	-	-	-	-	-
Whiskey Lake	2021	7	-	-	-	31	13	-	-	-	-	-	-	3	2	-	-	-	-
	2022	8	2	-	-	8	6	-	-	-	-	-	-	-	-	-	1	-	1
	2023	18	5	-	1	10	2	-	-	-	-	-	-	-	-	-	-	-	-
Hewitt Lake	2021	1	-	-	-	46	15	-	-	-	1	-	-	2	1	-	-	-	-
	2022	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2023	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-
Chelatna Lake	2021	30	14	-	1	-	-	-	-	-	-	-	-	2	-	5	2	-	-
	2022	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-

Coho salmon caught in Shell Lake were smolt. Other salmon bycatch caught in lakes were all adults.

Dashes (-) represent zero fish cuaght.

Appendix 2: Environmental Conditions 2021

Chelatna Lake

Date	Sky	Precip. (mm)	Water Temp. (°C)	Air Temp. (°C)
31-May	3	0.0	8.9	13.5
1-Jun	5	26.0	7.1	9.0
2-Jun	3	0.0	7.5	10.8
3-Jun	3	1.0	8.1	10.4
4-Jun	2	0.0	8.9	14.1
5-Jun	5	0.0	9.6	13.8
6-Jun	5	6.0	10.3	13.6
7-Jun	3	1.0	10.3	13.0
8-Jun	5	6.0	7.3	8.6
9-Jun	5	9.0	6.5	8.5
10-Jun	3	2.0	8.3	10.1
11-Jun	3	0.0	9.7	12.3
12-Jun	3	2.0	11.0	15.1
13-Jun	2	0.0	11.1	15.8
14-Jun	2	0.0	11.9	16.7
15-Jun	2	0.0	11.6	17.5
16-Jun	5	0.0	11.5	12.5
17-Jun	3	10.0	9.2	11.8
18-Jun	3	0.0	12.0	14.2
19-Jun	5	6.0	12.5	13.2
20-Jun	4	1.0	10.7	13.5
21-Jun	3	1.0	12.1	14.3
22-Jun	4	0.0	11.6	13.9
23-Jun	5	1.0	11.1	14.4
24-Jun	5	9.0	11.2	12.0
25-Jun	5	7.0	11.4	11.2
26-Jun	3	5.0	10.7	11.7
27-Jun	3	0.0	11.5	13.1
28-Jun	3	0.0	12.3	13.2
29-Jun	3	0.0	13.4	14.8
30-Jun	3	0.0	13.9	16.2

Chelatna Lake

		Water	Air
Total	93		
Avg.	3.0	10.4	13.0
Min.	0.0	6.5	8.5
Max.	26.0	13.9	17.5

Whiskey Lake

		Water	Air
Total	129		
Avg.	3.0	15.0	18.6
Min.	0.0	9.7	15.9
Max.	23.0	22.4	22.8

Whiskey Lake

Date	Sky	Precip. (mm)	Water Temp. (°C)	Air Temp. (°C)
12-Jul	3	0.0	15.6	17.9
13-Jul	2	1.0	14.9	17.9
14-Jul	2	1.0	16.4	18.3
15-Jul	2	0.0	17.8	19.6
16-Jul	1	0.0	20.2	20.6
17-Jul	2	0.0	20.8	22.0
18-Jul	2	0.0	22.4	22.6
19-Jul	3	0.0	20.3	22.8
20-Jul	5	6.0	16.1	21.1
21-Jul	5	23.0	14.4	19.8
22-Jul	3	1.0	16.0	19.9
23-Jul	4	0.0	16.7	20.2
24-Jul	3	8.0	15.4	19.8
25-Jul	3	2.0	14.4	19.1
26-Jul	4	0.0	15.7	19.0
27-Jul	4	0.0	15.2	19.0
28-Jul	4	3.0	13.3	18.3
29-Jul	4	0.0	13.4	17.7
30-Jul	4	0.0	14.1	17.6
31-Jul	2	0.0	14.2	17.4
1-Aug	3	0.0	16.9	18.0
2-Aug	1	0.0	18.0	19.0
3-Aug	1	0.0	17.7	19.7
4-Aug	2	0.0	16.4	19.9
5-Aug	2	0.0	17.7	20.4
6-Aug	3	0.0	18.2	20.6
7-Aug	4	0.0	16.1	20.1
8-Aug	5	13.0	12.7	19.0
9-Aug	4	6.0	12.4	18.3
10-Aug	3	9.0	13.2	18.0
11-Aug	5	1.0	12.1	17.4
12-Aug	4	20.0	12.1	17.0
13-Aug	2	13.0	12.6	17.0
14-Aug	4	0.0	12.9	17.2
15-Aug	3	0.0	12.7	17.1
16-Aug	4	0.0	12.4	16.8
17-Aug	4	5.0	12.8	16.6
18-Aug	2	0.0	13.8	17.0
19-Aug	5	1.0	12.6	16.9
20-Aug	1	2.0	12.6	16.7
21-Aug	2	0.0	10.8	16.7
22-Aug	5	2.0	9.7	16.2
23-Aug	5	12.0	11.7	15.9

Appendix 3: Environmental Conditions 2022

Chelatna Lake

Date	Sky	Precip. (mm)	Water Temp. (°C)	Air Temp. (°C)
9-Jun	3	0.0	10.0	23.0
10-Jun	3	0.0	10.0	16.0
11-Jun	3	0.0	9.0	16.0
12-Jun	3	0.0	10.0	18.0
13-Jun	3	0.0	9.0	22.0
14-Jun	3	0.0	10.0	21.0
15-Jun	3	0.5	12.0	21.0
16-Jun	3	0.0	13.0	23.0
17-Jun	3	0.0	13.0	17.0
18-Jun	3	0.0	11.0	17.0
19-Jun	3	0.0	12.0	23.0
20-Jun	2	0.0	13.0	25.0

Chelatna Lake			
Total	0.5	Water	Air
Avg.	0.0	11.0	20.2
Min.	0.0	9.0	16.0
Max.	0.5	13.0	25.0

Whiskey Lake			
Total	237	Water	Air
Avg.	4.3	17.0	13.7
Min.	0.0	14.6	10.7
Max.	30.0	20.8	17.8

Whiskey Lake

Date	Sky	Precip. (mm)	Water Temp. (°C)	Air Temp. (°C)
7-Jul	4	0.0	17.9	15.9
8-Jul	2	0.0	20.8	17.8
9-Jul	3	0.0	20.8	17.2
10-Jul	4	2.0	20.2	14.5
11-Jul	2	0.0	20.0	17.4
12-Jul	4	1.0	19.9	15.4
13-Jul	4	0.5	19.4	15.6
14-Jul	3	0.0	19.1	16.0
15-Jul	4	5.0	18.9	14.0
16-Jul	4	30.0	17.7	13.2
17-Jul	4	20.0	17.2	13.1
18-Jul	4	3.0	16.8	13.5
19-Jul	4	1.0	16.4	12.5
20-Jul	4	2.0	15.9	12.0
21-Jul	4	1.0	15.2	11.9
22-Jul	3	2.0	15.0	11.6
23-Jul	3	1.0	15.3	12.1
24-Jul	3	0.5	16.0	14.6
25-Jul	3	7.0	16.4	14.8
26-Jul	3	0.0	16.3	13.6
27-Jul	2	0.0	17.1	13.2
28-Jul	1	0.0	17.3	15.2
29-Jul	2	0.0	18.2	15.6
30-Jul	2	0.0	19.1	15.6
31-Jul	3	2.0	18.9	16.3
1-Aug	4	8.0	18.6	14.0
2-Aug	2	0.3	18.3	14.4
3-Aug	2	0.0	18.6	16.5
4-Aug	4	0.0	19.1	15.2
5-Aug	1	0.0	18.3	13.9
6-Aug	3	0.0	17.7	12.8
7-Aug	4	1.0	17.3	11.6
8-Aug	4	1.0	16.6	12.2
9-Aug	3	0.0	16.3	12.4
10-Aug	1	0.0	16.7	12.3
11-Aug	4	0.0	17.2	13.2
12-Aug	4	9.0	16.8	14.8
13-Aug	4	20.0	16.8	14.4
14-Aug	4	4.0	16.7	13.7
15-Aug	3	0.0	16.7	13.6
16-Aug	4	9.0	16.6	12.2
17-Aug	4	28.0	16.1	12.0
18-Aug	4	12.0	15.4	11.2
19-Aug	4	6.0	15.0	10.7
20-Aug	4	15.0	14.8	11.8
21-Aug	4	2.0	14.9	13.1
22-Aug	4	2.0	15.0	13.3
23-Aug	3	8.0	15.1	13.7
24-Aug	3	6.0	15.3	13.3
25-Aug	4	0.0	15.3	12.8
26-Aug	3	20.0	14.6	12.1
27-Aug	2	0.0	14.7	12.8
28-Aug	2	0.0	15.5	13.2
29-Aug	2	4.0	15.8	13.1
30-Aug	3	4.0	16.1	13.2

Appendix 4: Environmental Conditions 2023

Shell Lake

Date	Sky	Precip. (mm)	Water Temp. (°C)	Air Temp. (°C)	Staff Guage (ft)
26-May	4	0.0	6.52	8.82	1.42
27-May	4	0.0	5.62	8.29	1.37
28-May	3	1.0	5.89	9.49	1.28
29-May	2	0.0	5.65	9.88	1.25
30-May	4	0.0	5.40	7.64	1.18
31-May	4	8.0	5.65	8.05	1.12
1-Jun	4	0.0	5.72	7.03	1.1
2-Jun	2	0.0	5.88	8.69	1.05
3-Jun	4	0.0	5.99	8.88	0.99
4-Jun	3	0.0	6.26	9.84	0.96
5-Jun	1	0.0	7.81	12.71	0.92
6-Jun	4	0.0	7.42	11.90	0.84
7-Jun	4	0.0	7.66	11.17	0.86
8-Jun	3	11.0	9.67	11.30	0.9
9-Jun	2	7.0	10.23	11.89	0.9
10-Jun	3	2.0	7.61	10.90	0.88
11-Jun	5	2.0	7.34	8.58	0.88
12-Jun	4	4.0	8.30	8.85	0.88
13-Jun	4	5.0	7.78	8.50	0.82
14-Jun	3	0.5	8.04	9.69	0.82
15-Jun	4	0.0	8.59	10.04	0.82
16-Jun	4	0.0	9.22	11.52	0.8
17-Jun	1	1.0	10.02	13.52	0.78
18-Jun	2	0.0	11.93	15.64	0.78
19-Jun	4	0.0	14.00	15.69	0.74
20-Jun	4	0.0	13.18	14.99	0.71
21-Jun	4	0.0	12.91	14.81	0.7
22-Jun	4	5.0	11.14	14.90	0.68
23-Jun	4	1.0	11.72	15.32	0.67
24-Jun	2	1.0	13.28	16.36	0.66
25-Jun	4	2.0	11.89	13.31	0.68
26-Jun	4	11.0	10.11	12.18	0.67
27-Jun	5	5.0	11.86	11.64	0.67
28-Jun	4	3.0	12.74	12.50	0.6

Shell Lake

		Water	Air
Total	70		
Avg.	2.0	8.9	11.3
Min.	0.0	5.4	7.0
Max.	11.0	14.0	16.4

Whiskey Lake

		Water	Air
Total	119		
Avg.	3.1	19.2	16.1
Min.	0.0	16.4	12.8
Max.	47.0	22.2	20.2

Whiskey Lake

Date	Sky	Precip. (mm)	Water Temp. (°C)	Air Temp. (°C)
14-Jul	4	0.0	18.43	17.31
15-Jul	5	44.0	17.21	13.10
16-Jul	4	47.0	16.44	13.48
17-Jul	3	0.0	16.78	15.44
18-Jul	3	0.0	17.96	17.73
19-Jul	3	0.0	19.01	17.44
20-Jul	3	1.0	18.15	15.30
21-Jul	2	0.0	18.73	17.34
22-Jul	2	0.0	20.46	20.25
23-Jul	1	0.0	21.65	19.65
24-Jul	1	0.0	21.54	18.96
25-Jul	1	0.0	21.18	17.85
26-Jul	2	0.0	20.70	17.33
27-Jul	3	0.0	20.49	17.72
28-Jul	3	0.0	19.71	15.50
29-Jul	3	1.0	19.33	16.66
30-Jul	1	0.0	19.39	17.82
31-Jul	1	0.0	20.35	18.66
1-Aug	1	0.0	21.39	18.86
2-Aug	1	0.0	22.23	19.75
3-Aug	1	0.0	21.42	16.86
4-Aug	4	0.0	20.25	15.86
5-Aug	2	0.0	20.26	16.47
6-Aug	4	1.0	20.24	16.95
7-Aug	4	6.0	19.72	16.13
8-Aug	4	0.0	19.19	15.13
9-Aug	4	0.0	19.06	16.06
10-Aug	2	1.0	19.19	16.33
11-Aug	2	2.0	19.56	15.87
12-Aug	4	1.0	19.02	14.51
13-Aug	4	3.0	18.50	14.95
14-Aug	2	4.0	18.13	14.44
15-Aug	4	0.0	17.70	12.78
16-Aug	5	8.0	17.32	13.07
17-Aug	4	0.0	17.24	12.96
18-Aug	4	0.0	17.38	13.06
19-Aug	4	0.0	17.54	14.96
20-Aug	4	0.0	17.11	13.59
21-Aug	4	0.0	16.97	13.74

Appendix 5: Shell Lake 2023 Daily Smolt Migration

Shell Lake 2023 Smolt Migration											
	Sockeye			Coho		Rainbow		Dolly Varden		Pink	
Date	Daily	Mortality	Total	Daily	Total	Daily	Total	Daily	Total	Daily	Total
25-May	0	0	0	0	0	0	0	0	0	0	0
26-May	1	0	1	2	2	0	0	0	0	0	0
27-May	2	0	3	0	2	0	0	0	0	0	0
28-May	3	0	6	2	4	0	0	0	0	0	0
29-May	0	0	6	5	9	0	0	0	0	0	0
30-May	5	0	11	4	13	0	0	0	0	0	0
31-May	21	0	32	12	25	0	0	0	0	0	0
1-Jun	4	0	36	1	26	0	0	0	0	0	0
2-Jun	0	0	36	2	28	0	0	0	0	0	0
3-Jun	9	0	45	1	29	0	0	0	0	0	0
4-Jun	2	0	47	0	29	0	0	0	0	0	0
5-Jun	16	0	63	1	30	0	0	0	0	0	0
6-Jun	12	0	75	1	31	0	0	0	0	0	0
7-Jun	12	0	87	1	32	0	0	0	0	0	0
8-Jun	20	0	107	1	33	0	0	0	0	0	0
9-Jun	136	0	243	117	150	0	0	0	0	0	0
10-Jun	101	0	344	456	606	0	0	0	0	0	0
11-Jun	10	0	354	49	655	0	0	0	0	0	0
12-Jun	4	0	358	39	694	0	0	0	0	0	0
13-Jun	10	0	368	171	865	0	0	0	0	0	0
14-Jun	25	0	393	173	1,038	0	0	0	0	0	0
15-Jun	6	0	399	68	1,106	0	0	0	0	0	0
16-Jun	1	0	400	164	1,270	0	0	0	0	0	0
17-Jun	39	0	439	821	2,091	0	0	0	0	0	0
18-Jun	0	0	439	256	2,347	0	0	0	0	0	0
19-Jun	8	0	447	213	2,560	0	0	0	0	0	0
20-Jun	0	0	447	2	2,562	0	0	0	0	0	0
21-Jun	1	0	448	29	2,591	0	0	0	0	0	0
22-Jun	2	0	450	60	2,651	0	0	0	0	0	0
23-Jun	10	0	460	78	2,729	0	0	0	0	0	0
24-Jun	0	0	460	1	2,730	0	0	0	0	0	0
25-Jun	0	0	460	28	2,758	0	0	0	0	0	0
26-Jun	4	0	464	126	2,884	0	0	0	0	0	0
27-Jun	1	0	465	29	2,913	0	0	0	0	0	0
28-Jun	1	0	466	13	2,926	0	0	0	0	0	0
Total	**466**			**2,926**		**0**		**0**		**0**	