

Hewitt and Whiskey Lake Pike Suppression Final Completion Report (2018–2020)

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This project was made possible through an Alaska Sustainable Salmon Fund grant (Project Number 51003) 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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DISCLAIMER

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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 final report is a synopsis of the studies conducted as part of the Alaska Sustainable Salmon Fund grant entitled “Hewitt and Whiskey Lake Pike Suppression.” Field research was conducted by CIAA the Alaska Department of Fish and Game (ADF&G) Division of Commercial Fisheries at Whiskey and Hewitt lakes. The purpose of this report is to provide a vehicle to distribute the information produced by three years of pike suppression 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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Many individuals contributed to the success of the Hewitt and Whiskey Lake Pike Suppression Project. Cook Inlet Aquaculture Association recognizes Mark Willette from ADF&G who spent his career dedicated to the protection of salmonids in Alaska and was integral in the development and implementation of this project. Mark's passing in 2020 has left a hole in the Alaska fisheries community and he will be missed. Thanks goes to Robert DeCino for stepping in to complete the ADF&G portion of the work following Mark's departure. Gratitude is extended to the many Cook Inlet Aquaculture Association interns, seasonal assistants, and regular staff who invested many hours in planning and executing this project. Trail Ridge Air and Alaska West Aviation provided needed assistance with hauling gear and supplies. Many local residents of these lakes offered a great deal of help and were vital to the project, particularly Krista and Martin Wegscheider who were so gracious in hosting CIAA staff for dinner and hot showers, and providing lodging to ADF&G hydroacoustic survey staff. Gratitude is also extended to the staff at the Student Conservation Association (SCA) and the Alaska Sustainable Salmon Fund (AKSSD), in particular Zachary Bolick with SCA and Debbie Maas from AKSSF. Appreciation is extended to CIAA's Board of Directors; and to CIAA staff members, Lisa Ka'aihue, who provided oversight of the project, and Ronnie Minter who assisted with the ADF&G hydroacoustic surveys.

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TABLE OF CONTENTS

DISCLAIMER	ii
ACKNOWLEDGEMENTS	iv
ABSTRACT	1
INTRODUCTION AND PURPOSE	3
PROJECT AREA	5
METHODS	9
Objective 1: Reduce northern pike relative abundance in the Hewitt-Whiskey Lake system by 80% from 2018–2020	9
Objective 2: Estimate northern pike age, sex, and length composition and diet composition ..	10
Objective 3: Estimate the number of juvenile salmon rearing in Hewitt Lake	10
Age, weight, and length (AWL) surveys	12
RESULTS	15
Objective 1: Suppress northern pike in the Hewitt-Whiskey Lake system such that pike relative abundance is reduced by 80% from 2018 to 2020	15
Objective 2: Estimate northern pike age, sex, and length composition and diet composition ..	16
Objective 3: Estimate the abundance of juvenile sockeye salmon rearing in Hewitt Lake	21
2018	21
2019	22
2020	22
DISCUSSION	27
RECOMMENDATIONS	29
REFERENCES	31
APPENDICES	33

LIST OF FIGURES

Figure 1: Northern pike suppression project site in relation to Cook Inlet, Alaska	5
Figure 2: Bathymetric map of Whiskey Lake	6
Figure 3: Bathymetric map of Hewitt Lake	7
Figure 4: Whiskey and Hewitt lakes in relation to Yentna River	8
Figure 5: Catch per unit effort for Whiskey and Hewitt lakes northern pike suppression 2014, 2018–2020	15
Figure 6: Average lengths of captured pike from Whiskey and Hewitt lakes 2014, 2018–2020 ..	16
Figure 7: Average weights of captured pike from Whiskey and Hewitt lakes 2014, 2018–2020 ..	17
Figure 8: Length at age for Whiskey Lake, 2018	19
Figure 9: Length at age for Whiskey Lake, 2019	19
Figure 10: Length at age for Whiskey Lake, 2020	19
Figure 11: Length at age for Hewitt Lake, 2018	20
Figure 12: Length at age for Hewitt Lake, 2019	20
Figure 13: Length at age for Hewitt Lake, 2020	20

LIST OF TABLES

Table 1: Northern pike average age and female percentage of the pike population.....	17
Table 2: Northern pike average size at age for Hewitt and Whiskey lakes, 2018–2020	18
Table 3: Whiskey and Hewitt lakes northern pike stomach contents 2018–2020	21
Table 4: Target strength (TS) and the mean area backscattering coefficient, σ , used to echo integrate defined depth strata, 2018–2020.....	24
Table 5: Population estimates for total and sockeye salmon fry in Hewitt Lake, 2018–2020.	24
Table 6: Percentage of all species captured in mid water trawls in Hewitt lake townet studies, 2018–2020.....	25
Table 7: Population estimates of non-sockeye salmon targets based on midwater trawl apportionment, 2018–2020.	25
Table 8: Age, weight and length of sockeye salmon fry captured in midwater trawls, 2018–2020.	25
Table 9: Weight and lengths of stickleback from midwater trawl catches, 2018–2020.	25

LIST OF APPENDICES

Appendix 1: Environmental Conditions at Whiskey Lake 2018	34
Appendix 2: Environmental Conditions at Whiskey Lake 2019	35
Appendix 3: Environmental Conditions at Whiskey Lake 2020	36
Appendix 4: Acoustic data collection parameters for Hewitt lake surveys	37
Appendix 5: Hewitt Lake mean σ and target strength (TS) for each depth strata and year. . Error! Bookmark not defined.	

ABSTRACT

Cook Inlet Aquaculture Association conducted a 3-year northern pike (*Esox Lucius*) suppression project at Whiskey and Hewitt lakes removing pike from the lakes during each summer from 2018–2020 primarily with gillnets. During that time, 6,557 pike were removed from the system while deploying gillnets for 19,405 hours. Catch per unit effort calculated for 2020 showed decreases in the number of pike caught per hour at both lakes when compared to catch per unit effort from a study conducted in 2014. The number of northern pike per hour decreased by 54% at Whiskey Lake from 0.742 pike/hour in 2014 to 0.335 pike/hour in 2020 and at Hewitt by 58% from 0.799 pike/hour in 2014 to 0.335 pike/hour in 2020. The average age, length, and weight of northern pike decreased at both lakes from 2018–2020. Analysis of pike diets were conducted by removing, emptying, and weighing the stomachs of captured pike. Insects were the dominant prey item discovered comprising 31.9% of the mass collected from non-empty stomachs followed by sticklebacks (27.4%), and salmonids (11.1%). Cannibalism was detected in 8.1% of non-empty pike stomachs.

Hydroacoustic and midwater trawl surveys were conducted in September 2018–2020 to estimate the abundance of juvenile sockeye salmon (*Oncorhynchus nerka*) and other pelagic fishes in Hewitt Lake. The population estimates of juvenile sockeye salmon increased from approximately 368,000 to 551,000 in 2019 and then decreased to 441,000 by 2020. Threespine sticklebacks (*Gasterosteus aculeatus*) were the most predominant pelagic species present. Midwater trawl surveys were conducted to apportion the acoustic survey population estimates.

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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 (Marrow 1980), but were illegally introduced to the Matanuska-Susitna Valley in Southcentral Alaska in the 1950s (Rutz 1999). Pike have spread to more than 130 water bodies in the Matanuska-Susitna Valley, Anchorage, and the Kenai Peninsula (Alaska Department of Fish and Game 2015). The Susitna River watershed comprises 49,210 km² originating in the Alaska Range (Figure 1), 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 drainage (Alaska Department of Fish and Game 2015).

In response to the recorded low returns of sockeye salmon, the Cook Inlet Aquaculture Association (CIAA) and the Alaska Department of Fish and Game (ADF&G) began to monitor salmon populations at lakes throughout the Susitna drainage. Information was lacking about the health of salmon stocks returning to lakes that previously did not have the presence of northern pike. From 2009 to 2013, 15 lakes were monitored for numbers of salmon returning to spawn. Historically, all of these lakes had populations of salmon. Monitoring indicated that 8 of these lakes now had northern pike populations, 4 of which no longer had returning salmon, and 3 lakes were found to have salmon populations considered to be below historical averages including Whiskey and Hewitt lakes near Skwentna. After realizing the extent of the problem invasive northern pike have caused, CIAA developed a project entitled “Northern Pike Investigations.” It was a 3-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.

Since the conclusion of the “Northern Pike Investigations” project, CIAA continued maintenance gillnetting at Whiskey and Hewitt for approximately 1 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. Prior to the onset of this project CIAA had already removed over 2,700 northern pike from Whiskey and Hewitt lakes. The Hewitt and Whiskey Lake Pike Suppression Project was designed to build on prior pike suppression efforts. By continuing to remove pike from

this system 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. This project took place from May 2018 to September 2020. This report presents the results of the project.

PROJECT AREA

Whiskey and Hewitt lakes are located in the Susitna River drainage of the Cook Inlet watershed in Southcentral Alaska (Figure 1).

Whiskey and Hewitt lakes in relation to Cook Inlet

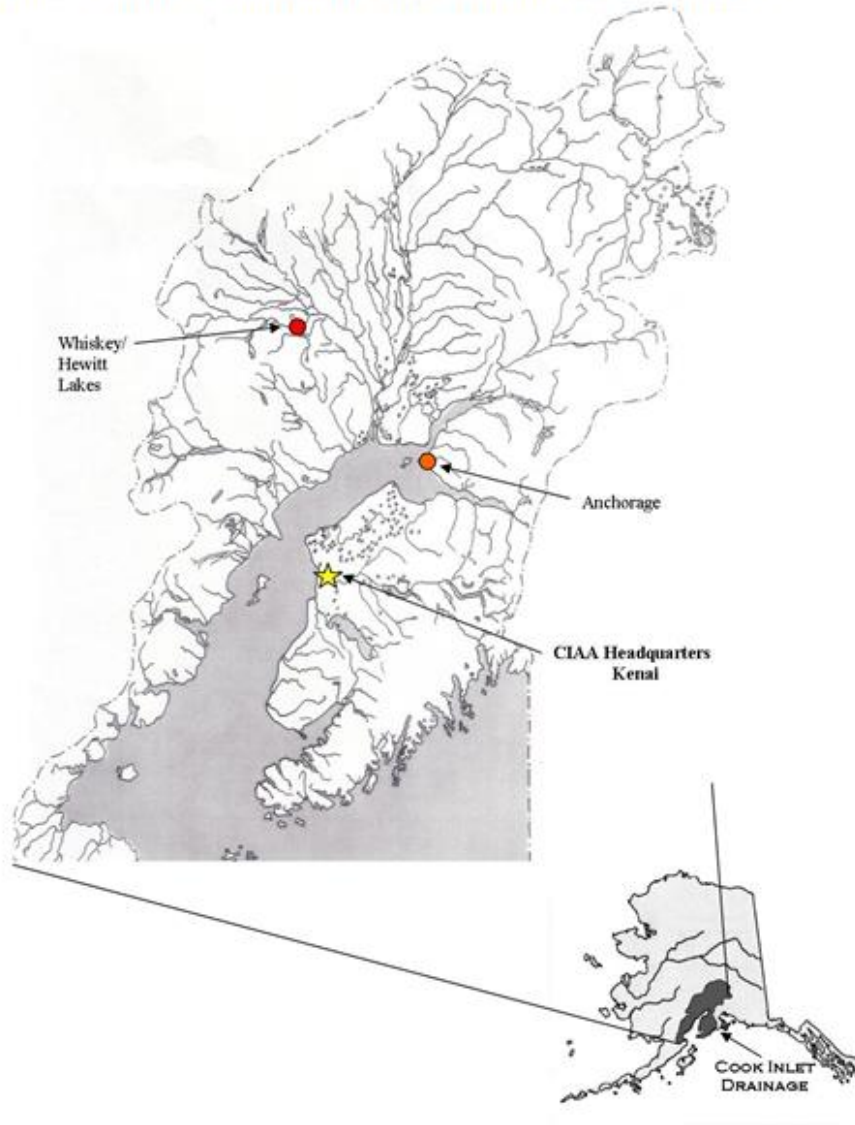


Figure 1: Northern pike suppression project site in relation to Cook Inlet, Alaska.

Whiskey Lake

Whiskey Lake is located at 61°59' W latitude and 151°24' N longitude at the base of the Shell Hills in the Susitna River drainage, approximately 118 kilometers northwest of Anchorage, Alaska (Figure 1). The lake has an elevation of 45 meters and a surface area of 110 hectares (Figure 2) (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.

Contours in meters.



Figure 2: Bathymetric map of Whiskey Lake.

Hewitt Lake

Hewitt Lake (Figure 3) is located approximately 0.5 km to the east of Whiskey Lake (Figure 4). 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).

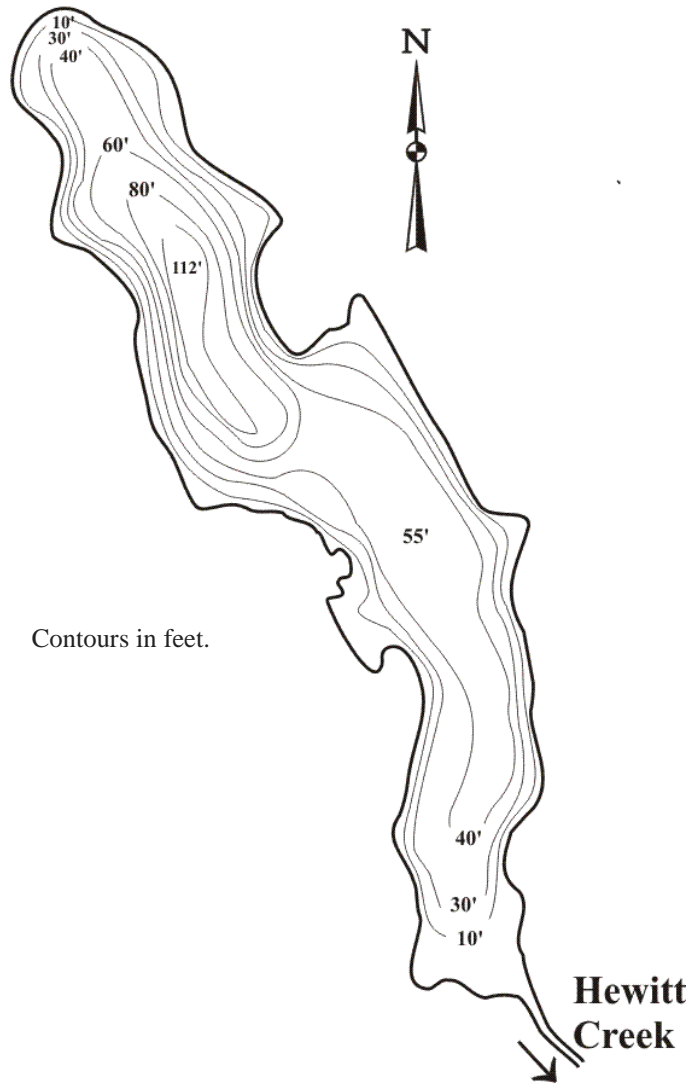


Figure 3: Bathymetric map of Hewitt Lake.



Figure 4: Whiskey and Hewitt lakes in relation to Yentna River.

METHODS

Objective 1: Reduce northern pike relative abundance in the Hewitt-Whiskey Lake system by 80% from 2018–2020

One inch bar mesh gillnets were used to capture and remove northern pike in Hewitt and Whiskey lakes and the Hewitt-Whiskey Creek outlet that connects these lakes to the Yentna River. Northern pike were removed from this system from May through late-August/early-September 2018, 2019 and 2020. Northern pike were also captured by hook-and-line fishing. Fish caught via hook-and-line were sampled for length, weight, sex, and stomach contents 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. An attempt was made to deploy a fyke net in 2018 but its use was discontinued due to river otters damaging the nets.

Each day, up to ten 1" bar mesh gillnets were deployed in different shallow and vegetated sites that typically provide optimal northern pike habitat. Nets were checked at least every 24 hours. The time of each net set and retrieval was recorded to the nearest minute. Gillnets were 15.2 m long x 2.4 m deep and constructed of monofilament line with a 1" bar mesh size. The top line was a floating core line and the bottom line was lead weighted to sink (CIAA 2018, CIAA 2019, and CIAA 2020).

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. Catch-per-unit effort figures were also calculated 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. CPUE figures were compared between the 3 years of the current project as well as those calculated from sampling in 2014 to determine what (if any) changes are occurring in this pike population as suppression continues.

The catch of species other than northern pike was recorded, and any bycatch still alive were removed and released immediately. Captured pike were removed from the nets and quickly dispatched using a small bat if they had not already expired. When possible, northern pike were donated to local residents. If no one was available to take the fish, then they were cut completely in half and disposed in the middle of the lake.

For each year of the project the, suppression crew recorded environmental data at the camp site at Whiskey Lake. Data collected included: percent cloud cover (visually estimated), and precipitation measured to the nearest millimeter, both recorded at 5:00 pm each day. Whiskey Lake water and air temperatures were recorded during the project using a data logger (Hobo®) that recorded water and air temperature every four hours. Recordings were then averaged over a 24-hour period to provide a daily average air and water temperatures.

Objective 2: Estimate northern pike age, sex, and length composition and diet composition

Age composition, sex ratio, and length at age was compared among years 2018–2020 and between 2014 and the current project to evaluate whether northern pike population characteristics are changing over time in response to the northern pike removal effort. All northern pike captured in Whiskey and Hewitt lakes from 2018–2020 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 and the left cleithrum was removed for later age determination at the CIAA lab (Laine et al. 1991).

Diet composition was evaluated by removing northern pike stomachs and sorting the contents into categories then weighing individual prey categories to the nearest 0.1 gram. Prey categories were salmon, trout, stickleback, pike, sucker, sculpin, burbot, unidentified fish, insects, leeches, birds, and mammals (CIAA 2018, CIAA 2019, and CIAA 2020).

The mass of juvenile salmon that would have been consumed by the northern pike removed from the lake in the year following the project was estimated using a simple gastric evacuation rate model and assuming pike would have continued to consume juvenile salmon over a 5-month period (150 days) following the project (Smukall 2015). Northern pike stomach contents are 50% digested after 20–24 hours at 16–23°C (Seaburg and Moyle 1964, Diana 1979). Assuming juvenile salmon that were more than 50% digested would not be identifiable, the mass of identifiable juvenile salmon found in stomachs roughly represents consumption over the previous day. The potential gross weight of juvenile salmon that would have been consumed during the summer following the project was estimated by multiplying the total mass of juvenile salmon found in all stomachs by 150 days and by multiplying that figure by the total number of pike removed from the lakes over the 3 years of the project. This method provided a minimum estimate of the biomass of juvenile salmon saved by removing the pike, because it did not account for predation over winter and it did not account for predation beyond the first year following the project.

Objective 3: Estimate the number of juvenile salmon rearing in Hewitt Lake

In September 2018, 2019 and 2020, ADF&G conducted hydroacoustic and midwater trawling surveys on Hewitt Lake (Figure 3) to determine population abundance, age distribution, and size of juvenile sockeye salmon. Similar historical studies have been completed on Hewitt Lake (King and Walker 1997, DeCino and Willette 2014 and Glick and Willette 2014). A systematic parallel sampling design was for the hydroacoustic surveys (MacLennan and Simmonds 1992). Fourteen evenly spaced transects, based on previous studies (King and Walker 1997, DeCino and Willette 2014) were chosen and plotted on maps before traveling to the field during the first year of the

study. In the field, transect end points were affixed with a flashing strobe light prior to the night-time hydroacoustic survey. In addition, transect end points were saved as waypoints on a handheld GPS in order to replicate survey design in subsequent years. During the hydroacoustic survey, transects were traversed at approximately 2 m s⁻¹. The acoustic vessel (6.0 m long cataraft) was powered by one 50 hp 2-stroke outboard engine.

For all the hydroacoustic surveys, pelagic fish communities were sampled acoustically at night with a BioSonics¹ DTx-60001 split-beam echosounder. The down-looking transducer was mounted to a 1.5-m long aluminum tow body. The tow body was attached to a polypropylene rope connected to a boom and towed off the boat's starboard side approximately 1-m below the water surface. The transducer transmitted digital data via a direct connection data cable to the echosounder. The echosounder was connected to a laptop computer via ethernet data connection. For geo-referenced transect routes, a Lowrance global positioning system (GPS) was used. Acoustic digital data were collected and stored on a laptop computer hard drive. Configuration parameters (Appendix 4) were input into BioSonics¹ Visual Acquisition data collection software. Temperature was measured with a YSI¹ model-58 digital thermistor and input to the environmental variables of the program. A 12V battery powered the acoustic system and the laptop computer. Acoustic data were stored (hard drive) and transported to the area office where they were uploaded into the office network for access by analysis programs. The acoustic data were edited using SonarData Echoview¹ analysis software. Acoustic data were first bottom edited to remove bottom echoes. After bottom editing was complete, individual target information was processed and saved for estimation of in-situ target strength (TS) and sigma (σ), the area backscattering coefficient. TS and σ computations were performed using a macro built by Aquacoustics Inc.¹ This macro appended all transects and calculated in-situ TSs and σ s from each detected target. Targets were filtered to include only those echoes near the beam center (+3 to -3dB off axis) and the largest σ s were removed (> -40dB) to compute the average σ . Target number and average σ were calculated and assembled into 1 m depth strata (Appendix 5). The following rule was used to determine the in-situ σ to use for calculating target densities in any depth stratum. If the stratum σ differed by more than 20% of the mean σ computed for the entire lake and target density was greater than 5% of total targets used to compute average σ then the stratum σ was used to compute target densities in that stratum, otherwise a σ averaged over several similar depth strata was used (DeCino and Willette 2011). Typically, 2 to 3 σ s averaged over different depth strata were input to a spreadsheet to compute fish densities for each transect using echo integration.

A fish density estimate was computed for each transect and expanded for each lake from which they were collected. The echo integrator compiled data in one report along each transect and sent outputs to computer files for further reduction and analysis. The total number of fish (\hat{N}_{ij}) for a

¹ Use of specific vendor equipment or software does not constitute and endorsement by CIAA or ADF&G.

lake i based on transects j was estimated across depth stratum k . \hat{N}_{ij} consisted of an estimate of the number of fish detected by hydroacoustic gear in both the surface and mid-water depth intervals either to lake bottom or extent of deepest targets as described in DeCino and Degan (2000) and DeCino and Willette (2011). The population estimate of the lake based on the density of transect j component was estimated as

$$\hat{N}_{ij} = a_i \sum_{k=1}^K \hat{M}_{ijk} \quad (1)$$

where a_i represented the surface area (m^2) of the lake stratum i which was estimated using a planimeter and USGS maps of each Susitna drainage lake (King and Walker 1997), and \hat{M}_{ijk} (number/ m^2) was the estimated mean fish density in area i depth k across transect j . Using transects as the sampling unit (Burczynski and Johnson 1986), fish abundance in lake i (\hat{N}_i) was estimated from the mean abundance for all transects j in the lake, i.e.

$$\hat{N}_i = J^{-1} \sum_{j=1}^J \hat{N}_{ij} \quad (2)$$

and its variance was estimated as

$$v(\hat{N}_i) = \sum (\hat{N}_{ij} - \hat{N}_i)^2 (J-1)^{-1} J^{-1} \quad (3)$$

The abundance of juvenile sockeye salmon in each lake (\hat{N}_s) was estimated as

$$\hat{N}_s = \hat{N} \hat{P}_s \quad (4)$$

where \hat{P}_s was the estimated proportion of total fish targets that were juvenile sockeye salmon in the lake. Age-specific numbers of juvenile sockeye salmon, \hat{N}_{sa} , were estimated as

$$\hat{N}_{sa} = \hat{N}_s \hat{P}_a \quad (5)$$

where \hat{P}_a was the estimated proportion of age- a sockeye salmon in the fish population.

Variance estimates were calculated as described in DeCino and Willette (2011, 2014).

Age, weight, and length (AWL) surveys

A midwater trawl survey was conducted on Hewitt Lake after the acoustic survey was completed, to estimate the species composition of acoustic targets. Age composition (sockeye salmon only), mean wet weight (g), and mean fork length (mm) were estimated from a subsample of all pelagic fishes. The high-speed midwater rope trawl used to capture juvenile fish was proportionally modified after the Dotson and Griffith (1996) published trawl. Each trawl set consisted of towing the net from the cataraft at approximately 4 knots for 10 minutes. The trawl was held open by a weighted steel pipe attached to the foot rope and an aluminum pipe attached to the head rope. The depth of each net tow was set by attaching buoys on both ends of the head rope using various lengths of line. The areas to trawl were identified from hydroacoustic surveys to maximize catch using observed target information. Fish captured in each tow were identified and enumerated by species. If greater than 200 individuals of any non-salmonid species were captured in a tow, their numbers were counted and a minimum sub-sample of 100 fish were saved for length and weight

measurements while the remaining fish were returned to the lake. All juvenile sockeye salmon captured were sampled to estimate age, mean length, and weight.

All fish sampled in this study were preserved in a 10% formalin solution and transported to the laboratory. All sockeye salmon fry and sub-sampled non-salmonids were enumerated, measured to the nearest 1 mm and weighed to the nearest 0.1 g. Scales were removed from sockeye fry and their age determined from scale samples using criteria outlined by Mosher (1969).

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RESULTS

Objective 1: Suppress northern pike in the Hewitt-Whiskey Lake system such that pike relative abundance is reduced by 80% from 2018 to 2020

Gillnetting of northern pike from Whiskey and Hewitt lakes occurred from May 25–August 24, 2018, May 22–September 2, 2019, and June 2–August 26, 2020. Effort hours were recorded to the nearest minute for all gillnets set on both lakes. During 2018, gillnets fished Whiskey Lake for 5,703.82 hours, and Hewitt Lake for 2,646.97 hours. Effort hours for Whiskey Lake 2019 and 2020 were 3,101.39 and 4,062.73 hours respectively. Gillnet effort hours for Hewitt Lake for 2019 and 2020 were 786.76 and 3,103.55 hours respectively. During 2019, the crew gillnetted for shorter periods of time often setting nets in the morning and retrieving them the same day resulting in higher CPUE calculations and reduced effort hours.

The total number of pike removed from the system via gillnets and hook-and-line fishing from 2018–2020 was 6,557 with 4,344 captured in Whiskey Lake and 2,213 removed from Hewitt Lake. Catch per unit effort was calculated for both lakes and all efforts undertaken on Hewitt Creek were attributed to Hewitt Lake. From 2018–2020 CPUE in Whiskey Lake rose slightly from 0.316 pike/hour in 2018 to 0.335 pike/hour in 2020, and fell slightly at Hewitt Lake from 0.378 in 2018 to 0.335 in 2020. The 2020 northern pike CPUE at Whiskey and Hewitt lakes was 0.335 pike/hour at each and was significantly lower than the 2014 Whiskey Lake CPUE of 0.742 pike/hour ($p=0.0001$), and the 2014 Hewitt Lake CPUE of 0.799 pike/net-hour ($p=0.0005$)(Figure 5). When compared with the onset of the intensive harvest at Whiskey and Hewitt lakes in 2014, 2020 CPUE at both has been reduced, (55% at Whiskey Lake) and (58% at Hewitt).

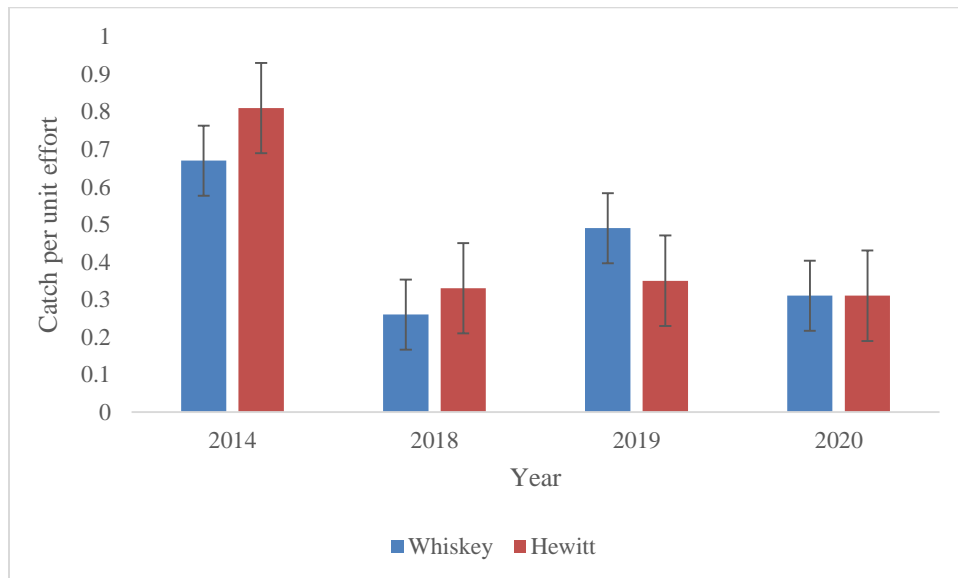


Figure 5: Catch per unit effort for Whiskey and Hewitt lakes northern pike suppression 2014, 2018–2020

Raw CPUE figures calculated for Whiskey and Hewitt lakes from 2018–2020 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 decreased from 0.371 kg/hour in 2018 to 0.217 in 2020 and from 0.217 to 0.121 kg/hour at Whiskey Lake. This represents a nearly 42% reduction in the biomass of pike at Hewitt and a reduction of over 44% of the pike biomass in Whiskey Lake over the 3 years of this project.

Objective 2: Estimate northern pike age, sex, and length composition and diet composition

Of the 2,117 northern pike captured via gillnets in Hewitt Lake, 2,091 had lengths taken and 2,045 were weighed. Of the 4,264 northern pike captured via gillnets in Whiskey Lake, 1,251 had lengths taken and 1,243 were weighed. For both lakes, average lengths and weights of captured pike decreased from 2018–2020 (figures 6 and 7). In Hewitt Lake, the average age of captured pike decreased from an average of 3.3 years in 2018 to 1.9 years in 2020 (Table 1). Whiskey Lake average pike ages fell from 3.2 years in 2018 to 1.4 years in 2020. At both lakes, the proportion of female pike in the captured population grew over the course of the project from 46% at Whiskey Lake and 44% at Hewitt Lake in 2018 to 59% and 64% in 2020 respectively (Table 1).

Environmental data taken at Whiskey Lake including air and water temperature for each year of the project are presented in appendices 1–3.

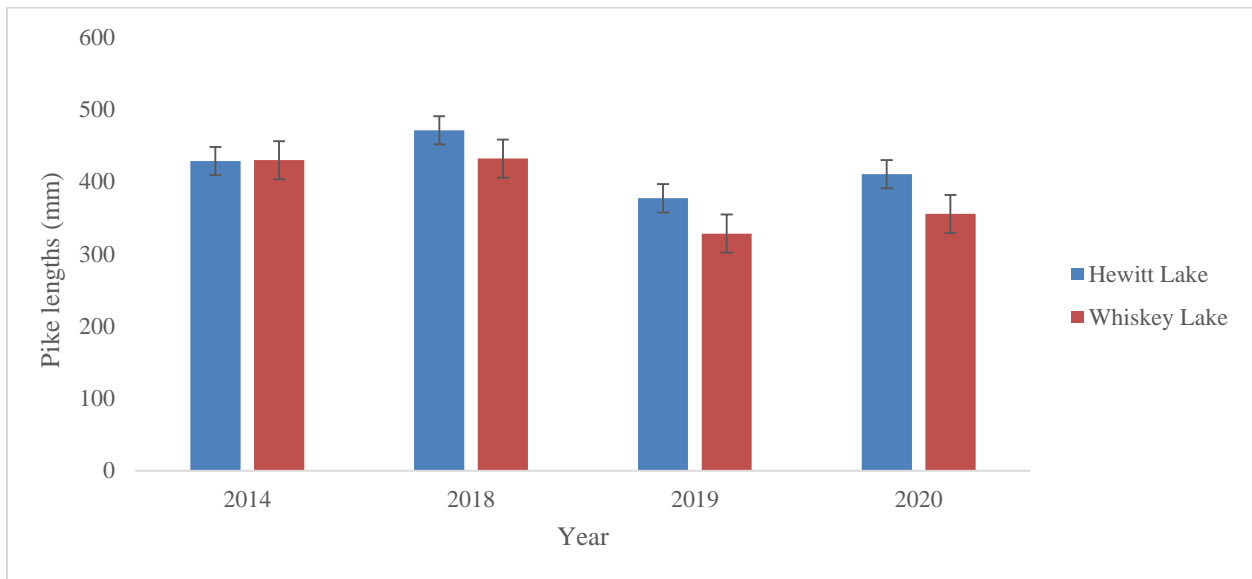


Figure 6: Average lengths of captured pike from Whiskey and Hewitt lakes 2014, 2018–2020

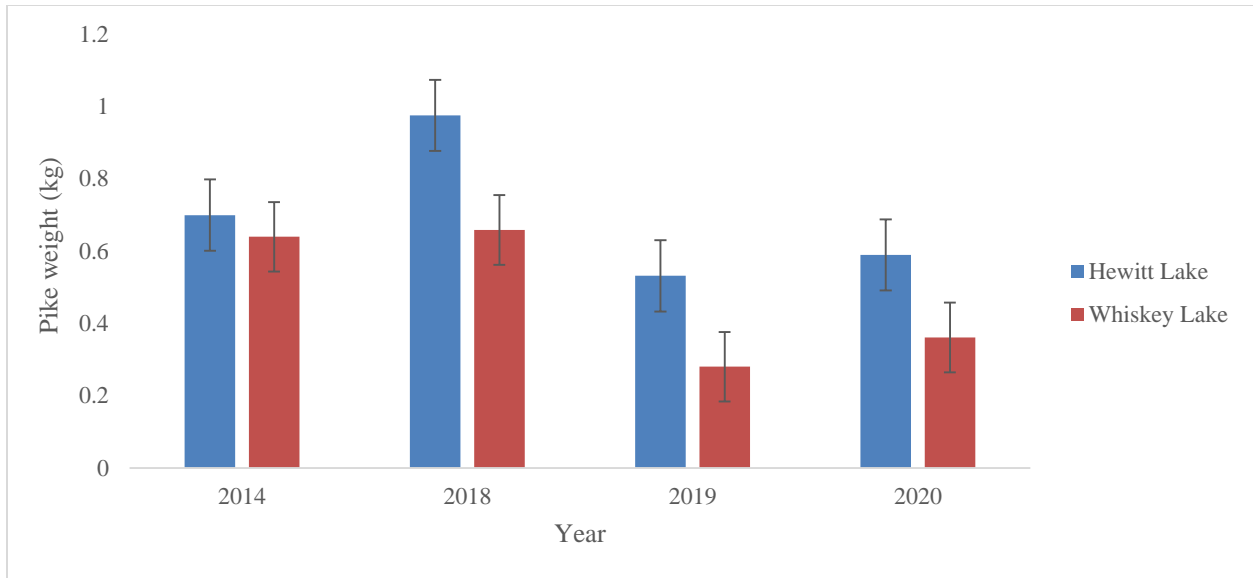


Figure 7: Average weights of captured pike from Whiskey and Hewitt lakes 2014, 2018–2020

Table 1: Northern pike average age and female percentage of the pike population

	Whiskey Lake			Hewitt Lake		
	% Female	Avg. Age	Age Range	% Female	Avg. Age	Age Range
2018	46%	3.2	0-10	44%	3.3	1-8
2019	49%	1.1	1-6	59%	1.5	1-6
2020	59%	1.4	1-11	64%	1.9	1-8

From 2018–2020, 4,171 pike cleithra were removed from captured pike in Whiskey and 2,040 from Hewitt Lake and analyzed. Over the 3 years of the project the number of year classes of northern pike detected in Whiskey Lake decreased from 10 in 2018 to 5 in 2020 (tables 1 and 2). As the number of year classes decreased in Whiskey Lake, the size at age of the remaining year classes increased likely due to decreased competition for resources from conspecifics (figures 8–10). From 2018–2019 the number of year classes detected in captured pike decreased from 8–6 at Hewitt Lake but 8 year classes were sampled again in 2020. Size at age however increased at Hewitt Lake over the course of the project similarly to that of the Whiskey Lake pike population (figures 11-13).

Table 2: Northern pike average size at age for Hewitt and Whiskey lakes, 2018–2020

Hewitt Lake Pike Length (mm) at Age (years)				Whiskey Lake Pike Length (mm) at Age (years)			
Age+	2018	2019	2020	Age+	2018	2019	2020
0	NS	NS	NS	0	193	NS	NS
1	311	319	334	1	304	317	327
2	386	441	425	2	360	393	400
3	468	576	489	3	424	498	445
4	534	649	577	4	484	561	527
5	579	671	637	5	520	663	NS
6	612	740	697	6	576	850	NS
7	659	NS	678	7	593	NS	NS
8	685	NS	714	8	657	NS	NS
9	NS	NS	NS	9	674	NS	NS
10	NS	NS	NS	10	NS	NS	NS
11	NS	NS	NS	11	655	NS	955

Shaded areas represented by only one sample. NS = No Sample

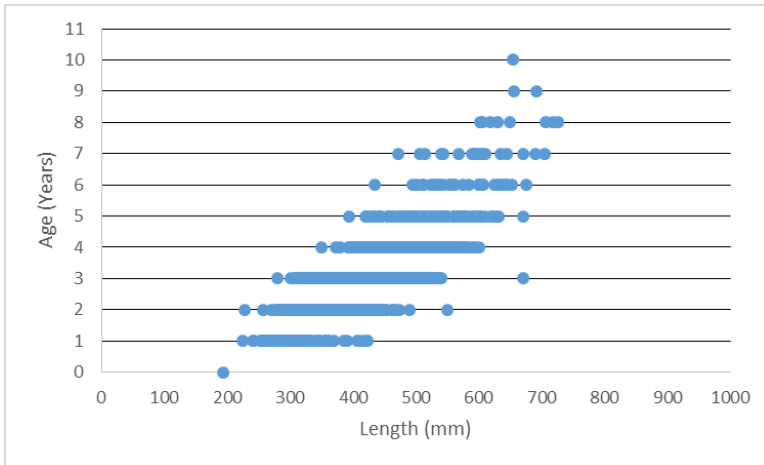


Figure 8: Length at age for Whiskey Lake, 2018.

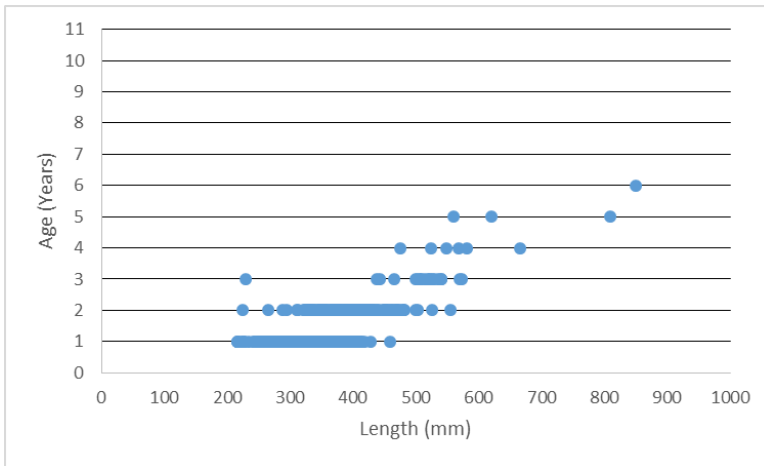


Figure 9: Length at age for Whiskey Lake, 2019.

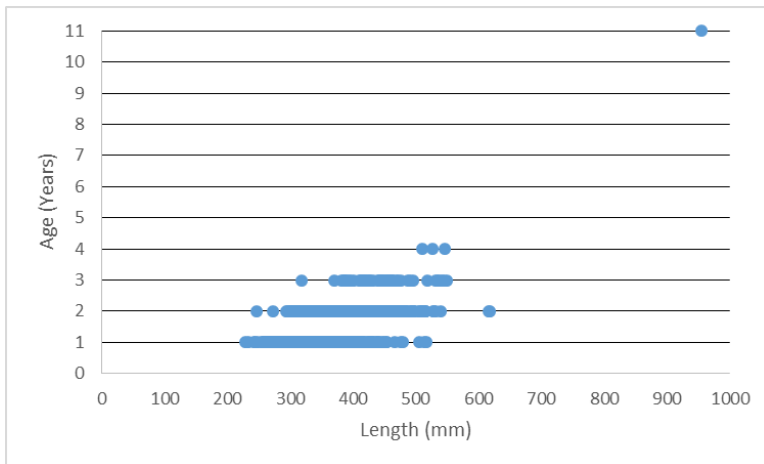


Figure 10: Length at age for Whiskey Lake, 2020.

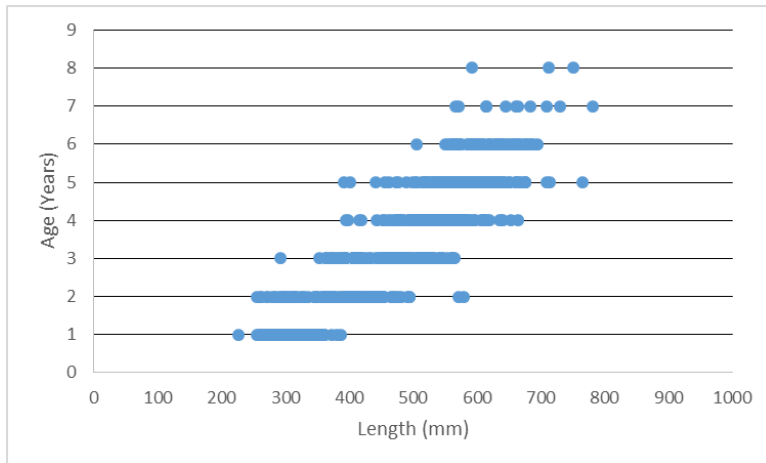


Figure 11: Length at age for Hewitt Lake, 2018.

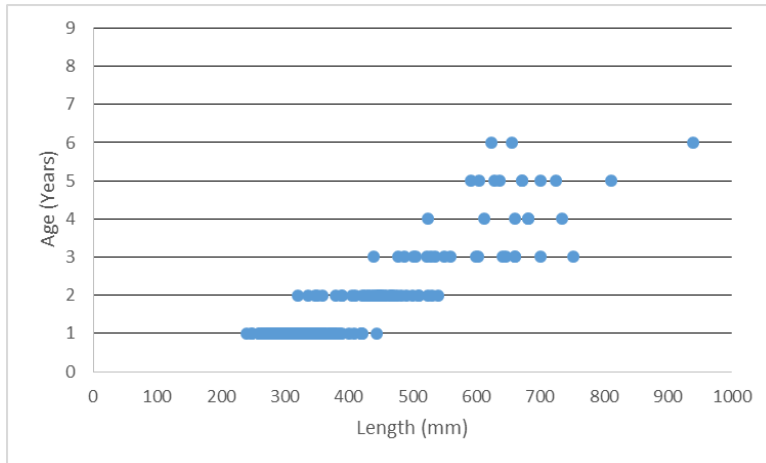


Figure 12: Length at age for Hewitt Lake, 2019.

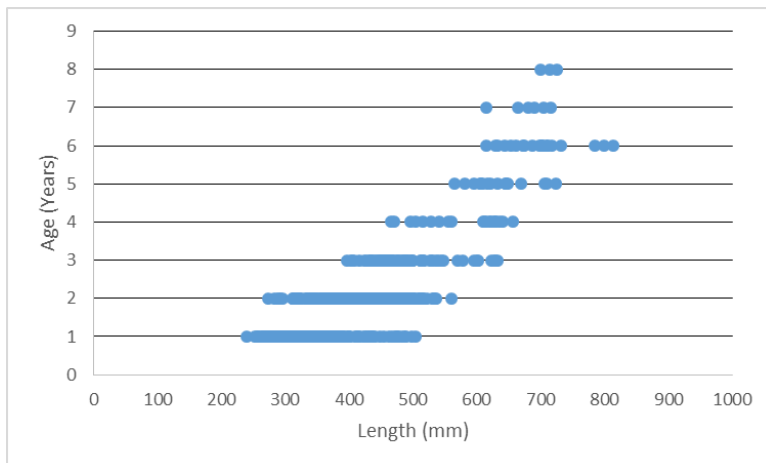


Figure 13: Length at age for Hewitt Lake, 2020.

The stomach contents of 6,431 pike were analyzed and contents were sorted into categories and weighed to the nearest 0.1 gram. Of the stomachs analyzed, 37.7% were empty. Prey items were detected and weighed in 3,869 pike stomachs. Over the 3 years of the project, over 33,500 grams of northern pike prey were weighed by CIAA staff. Insects (not identified to species) were the dominant prey item in the pike diets averaging 31.9% of the total volume of prey with sticklebacks and non-trout salmonids being the second and third most dominant item at 27.4% and 11.1% respectively (Table 3).

Table 3: Whiskey and Hewitt lakes northern pike stomach contents 2018–2020

Year	Weight Inverts		Weight Fish								Weight Other			Empty
	Leach	Insects	Salmon	Trout	Burbot	Stickleback	Sculpin	Pike	Sucker	Unidentifiable	Birds	Frog	Mammal	
2018	4.5%	16.7%	9.5%	0.0%	0.4%	56.0%	0.2%	4.8%	0.0%	6.6%	0.6%	0.2%	0.7%	30.1%
2019	0.0%	38.0%	13.1%	14.6%	0.0%	8.4%	0.6%	10.8%	0.3%	9.9%	0.2%	0.0%	4.2%	37.9%
2020	7.3%	41.0%	10.6%	0.0%	0.0%	17.7%	0.1%	8.6%	4.5%	4.5%	0.7%	0.1%	4.9%	45.1%
Average	3.9%	31.9%	11.1%	4.9%	0.1%	27.4%	0.3%	8.1%	1.6%	7.0%	0.5%	0.1%	3.2%	37.7%

Salmonids were detected in the stomach contents of 377 pike or 9.7% of the stomachs sampled making up between 9.5–13.1% of the wet weight of prey items averaging 11.1% of the total wet weight of prey sampled. A total of 3,483 grams of salmon were weighed during the analysis of 6,431 pike stomach contents or 0.54 grams per pike per day. From 2018–2020, 6,557 pike were removed from the two lakes, assuming those pike would have kept eating salmon for a minimum of 150 days, approximately 531,117 grams of salmon biomass was preserved. Assuming the average age-0 sockeye fry weight is 1.0 grams, it is likely that at least 0.5 million juvenile salmon have been preserved due to this suppression project.

Objective 3: Estimate the abundance of juvenile sockeye salmon rearing in Hewitt Lake

2018

For each year acoustic studies, the target data was collected at a -65 dB threshold (Appendix 4). Our TS data collected with the -65 dB threshold were comparable to previous studies (DeCino and Willette 2014). For Hewitt Lake the overall TS of -54.6 dB with a corresponding whole water column σ of 5.21×10^{-6} was used to echo integrate the juvenile fish density (Table 4).

A total of approximately 7.3 million fish were estimated in Hewitt Lake. The juvenile sockeye salmon population estimate was about 368,000 fish (Table 5), which accounted for 5% of the total fish target estimate (Table 6). Sticklebacks were the most abundant non-salmonid at 95% or about 6.9 million fish (Table 7).

Six midwater trawls were conducted in 2018 which totaled 103 minutes of fishing time. A total of 2,602 fish were captured with stickleback as the most predominant species (Table 6) at 95% followed by juvenile sockeye salmon at 5% (Table 5). The juvenile sockeye salmon were predominately age-0 fry at 94%. The mean length of age-0 fry was 37.8 mm (SE = 0.78mm)

(Table 8). The mean weight of age-0 sockeye fry totaled 0.7 g with a SE = 0.05 g (Table 8). Age-1 fry made up the remaining 6% of the midwater trawls. The mean length and weight for the age-1 juvenile sockeye was 61.1 mm (SE = 1.35 mm), and 2.8 g (SE = 0.41 g), respectively. For the non-salmonid sticklebacks captured, their mean length and weight totaled 34.6 mm (SE = 0.30) and 0.4 g (SE = 0.01) (Table 9).

2019

Hewitt Lake's overall TS was -57.3 dB (Table 4). Two σ s was used to integrate fish targets in 2019. The 0 – 5 m and 10 m – bottom stratum $\sigma = 3.49 \times 10^{-6}$ and the 5 m – 10 m strata $\sigma = 1.61 \times 10^{-6}$ (Table 4).

The total population estimate for 2019 was 7.4 million fish detected by the acoustic gear. The juvenile salmon population increased to approximately 568,000 fish (Table 5), which accounted for about 7.7% of the total pelagic fish estimate (Table 6). Sticklebacks were the most abundant non-salmonid at 92.3% (Table 6) or about 6.8 million fish (Table 7).

Seven midwater trawls were conducted in 2019 which totaled 70 minutes fishing time. A total of 5,020 fish were captured of which sticklebacks were the predominant species followed by juvenile sockeye salmon (Table 6). Scale samples to age juvenile sockeye salmon were not retained in 2019 because of communication error between staff. The average length and weight of the juvenile sockeye salmon was 43.3 mm (SE = 0.47 mm) and 1.0 g (SE=0.04 g; Table 8). The mean length and weight for non-salmonid sticklebacks captured were 32.3 mm (SE = .31 mm) and 0.4 g (SE = 0.01 g; Table 9).

2020

Hewitt lake's overall TS was -58.0 dB (Table 4) and was the smallest of the three years. Two σ s were used to integrate fish targets in 2020. The 0 – 5 m and 10 m – bottom stratum $\sigma = 2.59 \times 10^{-6}$ and the 5 m – 10 m strata $\sigma = 1.56 \times 10^{-6}$ (Table 4).

The total population estimate for 2020 increased to 12.5 million fish detected by the acoustic gear. The juvenile salmon population decreased from the 2019 estimate to 440,000 fish (Table 5), which accounted for about 3.5% of the total juvenile fish estimate (Table 6). Sticklebacks were the most abundant non-salmonid at 96.5% (Table 6) or about 12.0 million fish (Table 7).

Eight mid water trawls were conducted in 2020 which totaled 76 minutes fishing time. A total of 3,990 fish were captured of which sticklebacks were the predominant species followed by juvenile sockeye salmon (Table 6). Of the juvenile sockeye salmon captured approximately 99% were age-0 and less than 1% were age-2 fish. The average length and weight of the age-0 juvenile sockeye salmon was 40.1 mm (SE = 0.64 mm) and 0.8 g (SE = 0.04 g; Table 8). Only one age-2 sockeye fry was captured in the trawl in 2020 and was 76 mm and 5.8 g (Table 8). The sticklebacks

captured had a mean length and weight of 33.2 mm (SE = 0.66 mm) and 0.3 g (SE = 0.02 g; Table 9).

Table 4: Target strength (TS) and the mean area backscattering coefficient, σ , used to echo integrate defined depth strata, 2018–2020.

Lake	2018			2019			2020		
	Depth strata	σ	TS	Depth strata	σ	TS	Depth strata	σ	TS
Hewitt				0 to 5m	3.49×10^{-6}	-56.3	0 to 5 m	2.59×10^{-6}	-57.4
				5 to 10 m	1.61×10^{-6}	-59.2	5 to 10 m	1.56×10^{-6}	-59.3
				10 m to bottom	3.49×10^{-6}	-56.3	10 m to bottom	2.59×10^{-6}	-57.4
	whole water column	5.21×10^{-6}	-54.6	whole water column	2.86×10^{-6}	-57.3	whole water column	2.26×10^{-6}	-58.0

Table 5: Population estimates for total and sockeye salmon fry in Hewitt Lake, 2018–2020.

Lake	Year	Total estimated targets				Estimated number of juvenile sockeye fry						
		Surface	Midwater	Total	SE	Surface	Midwater	Total	95 % CI	Age 0	Age 1	Age 2
Hewitt	2018	496,510	6,805,988	7,302,499	1,467,154	24,997	342,654	367,652	34,191	347,388	20,264	
Hewitt	2019	227,651	7,183,914	7,411,565	1,200,977	17,459	550,934	568,393	92,103			
Hewitt	2020	345,515	12,120,257	12,465,772	1,167,593	12,210	428,310	440,520	41,261	437,436		3,083

Table 6: Percentage of all species captured in mid water trawls in Hewitt lake tow net studies, 2018–2020.

Lake	Year	Sockeye	Stickleback	Other	Total fish	Total min fished	Number of tows
Hewitt	2018	5.0	95.0		2602	103	6
Hewitt	2019	7.7	92.3	>1	5020	70	7
Hewitt	2020	3.5	96.5		3990	76	8

Table 7: Population estimates of non-sockeye salmon targets based on midwater trawl apportionment, 2018–2020.

Lake	Year	Stickleback	SE	other	95% CI
Hewitt	2018	6,934,847	1,393,289		
Hewitt	2019	6,841,667	2,172,876	74	12
Hewitt	2020	12,025,252	2,207,571		

Table 8: Age, weight and length of sockeye salmon fry captured in midwater trawls, 2018–2020.

Lake	Year	Sockeye age-0					Sockeye age-1					Sockeye age-2				
		N	L (mm)	SE	W (g)	SE	N	L (mm)	SE	W (g)	SE	N	L (mm)	SE	W (g)	se
Hewitt	2018	120	37.8	0.78	0.7	0.05	7	61.1	1.35	2.8	0.41					
Hewitt	2019 ^a	375	43.3	0.47	1.0	0.04										
Hewitt	2020	140	40.1	0.64	0.8	0.04						1	76		5.8	

Table 9: Weight and lengths of stickleback from midwater trawl catches, 2018–2020.

Lake	Year	N	Stickleback			
			L (mm)	SE	W (g)	SE
Hewitt	2018	269	34.6	0.30	0.4	0.01
Hewitt	2019	669	32.3	0.31	0.4	0.01
Hewitt	2020	111	33.2	0.66	0.3	0.02

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DISSCUSSION

From the onset of intensive pike suppression at Whiskey and Hewitt lakes in 2014 to the end of the current project in 2020, the relative abundance of northern pike has been decreased at Whiskey and Hewitt lakes by 54% and 58% respectively. From 2018–2020, pike suppression has further reduced the biomass of northern pike in both lakes by decreasing the number of year classes of northern pike thus reducing the average size of pike. In addition to reducing the number and size 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 Whiskey-Hewitt sockeye salmon populations. If the pike population can be driven to this lower population status it is likely that netting efforts can be reduced in the future and a minimum effort may suffice to maintain this reduced state. However, if netting operations were to cease, it is likely that these pike populations would recover within a few years.

The smaller than expected increase in the number of sockeye fry sampled during hydroacoustic surveys at Hewitt Lake is likely a function of the lack available spawning salmon and not an indication that suppression is not aiding their survival. During 2018–2019, few sockeye salmon were seen in Hewitt Lake so there was no source of eggs to spark a recovery of the fry population. Though no official count of adult salmon returning to Hewitt Lake was conducted during the 3 years of this project, anecdotal reports from lake residents indicate that the 2020 sockeye return was the largest that they had seen in over a decade. If those salmon were able to spawn successfully, their progeny will be emerging in the spring of 2021. Despite not meeting the goal of increasing the number of sockeye fry rearing in Hewitt Lake to one million, the Hewitt sockeye fry population did increase by nearly 20% over the course of this project.

Sockeye salmon originating from Whiskey and Hewitt lakes are a genetically distinct population that are one part 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 increase 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 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 Hewitt and Whisky lakes should continue especially because of the potential for increased sockeye salmon production resulting from the reported increase in adult sockeye returning to the system in 2020. In order to ensure that the removal of northern pike is the primary priority of the project, data collection should be curtailed to exclude stomach content analysis. By foregoing stomach analysis the suppression crew will be able to better focus their efforts on removing pike. The CPUE of gillnets should still serve as a measurement of relative pike abundance and ASL data should still be collected to enable the demographic description of the pike population.

Pelagic population estimates of fish with hydroacoustic and midwater trawl surveys should continue to attempt to measure the response of the sockeye population recovery to the reduced consumption of salmonids that is assumed by removing northern pike. If no measurable increase is seen in this population within the next few generations, a new plan of action should be considered for the recovery of sockeye production in these lakes.

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APPENDICES

Appendix 1: Environmental Conditions at Whiskey Lake 2018

2018 Environmental Conditions									
Date	Sky	Precip. (mm)	Water Temp. (°C)	Air Temp. (°C)	Date	Sky	Precip. (mm)	Water Temp. (°C)	Air Temp. (°C)
26-May	2	0.0	10.0	18.5	24-Jul	4	ND	21.0	21.0
27-May	2	0.0	11.0	26.0	25-Jul	5	ND	20.0	20.0
28-May	3	0.0	11.0	23.0	26-Jul	3	4.3	20.0	17.0
29-May	3	16.0	12.0	21.0	27-Jul	3	3.0	19.0	19.0
30-May	3	23.0	12.0	17.0	28-Jul	4	0.4	21.0	21.0
31-May	2	24.0	12.5	20.0	29-Jul	4	0.0	20.0	21.0
1-Jun	ND	ND	ND	ND	30-Jul	4	0.0	21.0	21.0
2-Jun	2	0.0	15.0	27.0	31-Jul	4	0.0	20.0	20.0
3-Jun	2	7.0	17.0	23.0	1-Aug	4	0.5	21.0	16.0
4-Jun	4	0.0	16.0	22.0	2-Aug	5	17.7	17.0	12.0
5-Jun	2	0.0	16.0	25.0	3-Aug	4	6.0	18.0	20.0
6-Jun	4	0.0	16.0	21.0	4-Aug	1	0.5	19.0	20.0
7-Jun	3	0.0	16.0	21.0	5-Aug	4	0.6	18.0	15.0
8-Jun	3	0.0	18.0	21.0	6-Aug	4	1.8	17.0	17.0
9-Jun	2	1.0	18.0	22.0	7-Aug	1	3.0	18.0	15.0
10-Jun	5	4.0	18.0	22.0	8-Aug	4	0.5	17.0	16.0
11-Jun	3	0.2	16.0	18.0	9-Aug	1	0.2	17.0	18.0
12-Jun	3	0.0	16.0	20.0	10-Aug	4	0.0	18.0	18.0
13-Jun	3	0.0	18.0	25.0	11-Aug	1	0.0	18.0	19.0
14-Jun	3	0.0	18.0	27.0	12-Aug	5	7.0	16.0	12.0
15-Jun	5	7.2	16.0	14.0	13-Aug	4	27.0	16.0	14.0
16-Jun	5	17.5	15.0	18.0	14-Aug	4	4.4	15.0	14.0
17-Jun	5	17.6	14.0	20.0	15-Aug	1	6.1	16.0	16.0
18-Jun	4	39.0	14.0	22.0	16-Aug	1	0.5	16.0	16.0
19-Jun	3	0.5	15.0	21.0	17-Aug	1	0.0	16.0	15.0
20-Jun	3	0.4	18.0	24.0	18-Aug	4	0.0	15.0	15.0
21-Jun	5	0.1	17.0	20.0	19-Aug	4	6.0	16.0	12.0
22-Jun	3	2.1	16.0	21.0	20-Aug	5	9.5	15.0	14.0
23-Jun	3	0.2	17.0	23.0	21-Aug	4	22.0	16.0	15.0
24-Jun	3	0.7	17.0	20.0	22-Aug	ND	ND	ND	ND
25-Jun	4	0.5	18.0	21.0	23-Aug	5	7.5	15.0	11.0
26-Jun	3	0.2	17.0	22.0	24-Aug	4	6.0	ND	13.0
27-Jun	3	0.0	17.0	22.0	Total		304	Water	Air
28-Jun	3	0.0	18.0	23.0	Avg.		4.3	17.0	19.3
29-Jun	2	0.0	19.0	24.0	Min.		0.0	9.0	11.0
30-Jun	2	0.0	18.0	24.0	Max.		39.0	23.0	27.0
1-Jul	2	0.0	20.0	26.0	Ice out = 21-May				
11-Jul	3	ND	16.0	16.0	Summary of Cloud Cover - Percent of Days				
12-Jul	2	ND	18.0	18.0	No.	Meas.	Partly		
13-Jul	4	0.4	17.0	15.0	Days	Rain	Cloudy	Clear	
14-Jul	3	1.2	18.0	16.0	81	57%	44%	14%	
15-Jul	3	4.0	18.0	17.0	1 = Clear				
16-Jul	5	1.8	18.0	15.0	2 = Cloud Cover <50%				
17-Jul	2	0.5	18.0	22.0	3 = Cloud Cover >50%				
18-Jul	2	ND	20.0	21.0	4 = Overcast				
19-Jul	1	ND	20.0	22.0	5 = Rain				
20-Jul	1	ND	20.0	21.0	ND = No Data				
21-Jul	1	ND	23.0	23.0					
22-Jul	1	ND	20.0	25.0					

*Crew Break From July 2-10

Appendix 2: Environmental Conditions at Whiskey Lake 2019

2019 Environmental Conditions																																													
Date	Sky	Precip. (mm)	Water Temp. (°C)	Air Temp. (°C)	Date	Sky	Precip. (mm)	Water Temp. (°C)	Air Temp. (°C)																																				
										22-May	4	ND	12.0	17.0	26-Jul	3	0.0	22.0	18.0																										
23-May	4	ND	ND	ND	27-Jul	3	0.0	23.0	18.0																																				
24-May	2	ND	11.0	16.0	28-Jul	2	0.0	23.0	19.0																																				
25-May	5	ND	10.0	15.0	29-Jul	2	0.0	23.0	20.0																																				
26-May	5	ND	11.0	13.0	30-Jul	2	0.0	23.0	19.0																																				
27-May	2	ND	11.0	16.0	31-Jul	4	0.0	22.0	18.0																																				
28-May	2	ND	12.0	17.0	1-Aug	4	2.0	21.0	21.0																																				
29-May	3	ND	13.0	16.0	2-Aug	3	0.0	19.0	20.0																																				
30-May	5	ND	13.0	18.0	3-Aug	3	0.0	19.0	17.0																																				
31-May	2	ND	14.0	16.0	4-Aug	4	7.0	19.0	19.0																																				
1-Jun	3	ND	13.0	19.0	5-Aug	5	7.0	20.0	18.0																																				
2-Jun	2	ND	16.0	26.0	6-Aug	1	0.0	19.0	19.0																																				
3-Jun	5	ND	15.0	19.0	7-Aug	2	0.0	20.0	20.0																																				
4-Jun	2	ND	15.0	21.0	8-Aug	1	0.0	20.0	20.0																																				
5-Jun	2	ND	17.0	20.0	9-Aug	2	0.0	20.0	20.0																																				
6-Jun	2	ND	16.0	21.0	10-Aug	2	0.0	20.0	19.0																																				
7-Jun	2	ND	17.0	23.0	11-Aug	2	0.0	21.0	26.0																																				
8-Jun	2	5.5	16.0	20.0	12-Aug	2	0.0	21.0	23.0																																				
9-Jun	3	0.0	15.0	17.0	13-Aug	2	0.0	20.0	21.0																																				
10-Jun	1	0.0	19.0	22.0	14-Aug	2	0.0	20.0	21.0																																				
11-Jun	2	0.0	19.0	22.0	15-Aug	2	0.0	20.0	20.0																																				
12-Jun	2	0.0	18.0	21.0	16-Aug	2	0.0	19.0	20.0																																				
13-Jun	3	0.0	19.0	22.0	17-Aug	1	0.0	18.0	18.0																																				
14-Jun	3	0.0	18.0	18.0	18-Aug	1	0.0	17.0	16.0																																				
15-Jun	4	0.0	17.0	18.0	19-Aug	1	0.0	17.0	15.0																																				
16-Jun	4	0.5	17.0	17.0	20-Aug	1	0.0	17.0	17.0																																				
17-Jun	4	0.0	18.0	21.0	21-Aug	2	0.0	18.0	18.0																																				
18-Jun	2	0.0	18.0	20.0	22-Aug	1	0.0	17.0	17.0																																				
19-Jun	2	0.0	17.0	19.0	23-Aug	2	0.0	18.0	18.0																																				
20-Jun	2	0.0	19.0	22.0	24-Aug	1	0.0	16.0	22.0																																				
21-Jun	2	0.0	20.0	24.0	25-Aug	3	0.0	17.0	17.0																																				
22-Jun	2	0.0	20.0	24.0	26-Aug	2	0.0	17.0	17.0																																				
23-Jun	2	0.0	20.0	25.0	27-Aug	2	0.0	18.0	18.0																																				
24-Jun	2	0.0	21.0	ND	28-Aug	2	0.0	17.0	18.0																																				
25-Jun	3	0.0	22.0	ND	29-Aug	3	0.0	16.0	18.0																																				
26-Jun	1	6.5	22.0	ND	30-Aug	3	0.0	16.0	17.0																																				
27-Jun	1	0.0	22.0	ND	31-Aug	4	3.0	17.0	16.0																																				
28-Jun	1	0.0	22.0	ND	1-Sep	5	4.0	16.0	15.0																																				
29-Jun	1	0.0	22.0	ND	2-Sep	5	4.0	16.0	16.0																																				
30-Jun	2	0.0	22.0	ND	Total		64	Water	Air																																				
9-Jul	2	0.0	25.0	31.0	Avg.		0.8	18.8	19.8																																				
10-Jul	4	0.0	24.0	20.0	Min.		0.0	10.0	13.0																																				
11-Jul	4	0.0	23.0	19.0	Max.		11.5	25.0	31.0																																				
12-Jul	4	0.0	21.0	19.0	Ice out = 21-May																																								
13-Jul	4	0.0	21.0	21.0	Summary of Cloud Cover - Percent of Days																																								
14-Jul	4	0.0	19.0	20.0																																									
15-Jul	3	0.0	22.0	18.0																																									
16-Jul	2	5.0	21.0	21.0																																									
17-Jul	2	0.0	21.0	25.0																																									
18-Jul	2	0.0	23.0	26.0																																									
19-Jul	2	0.0	23.0	25.0																																									
20-Jul	3	0.0	23.0	26.0																																									
21-Jul	2	0.0	23.0	26.0																																									
22-Jul	4	0.0	23.0	22.0																																									
23-Jul	5	5.0	20.0	17.0																																									
24-Jul	5	3.0	21.0	16.0																																									
25-Jul	5	11.5	22.0	17.0																																									
<table border="1"> <tr> <td>No.</td> <td>Meas.</td> <td>Partly</td> <td></td> </tr> <tr> <td>Days</td> <td>Rain</td> <td>Cloudy</td> <td>Clear</td> </tr> <tr> <td>91</td> <td>11%</td> <td>62%</td> <td>14%</td> </tr> <tr> <td colspan="4">1 = Clear</td> </tr> <tr> <td colspan="4">2 = Cloud Cover <50%</td> </tr> <tr> <td colspan="4">3 = Cloud Cover >50%</td> </tr> <tr> <td colspan="4">4 = Overcast</td> </tr> <tr> <td colspan="4">5 = Rain</td> </tr> <tr> <td colspan="4">ND = No Data</td> </tr> </table>										No.	Meas.	Partly		Days	Rain	Cloudy	Clear	91	11%	62%	14%	1 = Clear				2 = Cloud Cover <50%				3 = Cloud Cover >50%				4 = Overcast				5 = Rain				ND = No Data			
No.	Meas.	Partly																																											
Days	Rain	Cloudy	Clear																																										
91	11%	62%	14%																																										
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5 = Rain																																													
ND = No Data																																													
Crew break from July 1-8																																													

Appendix 3: Environmental Conditions at Whiskey Lake 2020

2020 Environmental Conditions									
Date	Sky	Precip. (mm)	Water Temp. (°C)	Air Temp. (°C)	Date	Sky	Precip. (mm)	Water Temp. (°C)	Air Temp. (°C)
3-Jun	2	0.0	15.0	15.7	29-Jul	2	0.0	19.5	18.1
4-Jun	3	0.0	15.5	15.6	30-Jul	3	0.0	19.3	18.0
5-Jun	2	0.0	16.7	15.0	31-Jul	3	0.0	19.5	17.6
6-Jun	1	0.0	17.2	14.6	1-Aug	4	10.4	19.2	15.0
7-Jun	4	1.2	17.6	15.1	2-Aug	4	23.8	18.9	14.5
8-Jun	1	0.0	16.7	12.7	3-Aug	3	0.0	18.8	15.7
9-Jun	1	0.0	16.5	13.2	4-Aug	2	0.0	19.2	15.9
10-Jun	2	0.0	16.3	15.6	5-Aug	2	0.0	19.6	18.0
11-Jun	3	0.0	17.7	16.8	6-Aug	5	0.0	18.8	14.3
12-Jun	5	9.8	17.7	16.8	7-Aug	2	0.0	18.9	14.9
13-Jun	3	0.0	18.7	16.2	8-Aug	2	0.0	18.5	13.9
14-Jun	3	0.0	19.2	17.4	9-Aug	3	0.0	18.3	15.7
15-Jun	3	0.0	19.6	17.7	10-Aug	2	0.0	18.4	16.1
16-Jun	4	2.4	19.2	16.2	11-Aug	2	22.4	18.2	12.9
17-Jun	4	0.8	18.9	16.3	12-Aug	2	0.0	18.4	14.2
18-Jun	3	0.0	19.1	16.3	13-Aug	3	0.0	18.9	16.2
19-Jun	5	6.7	18.1	12.0	14-Aug	1	0.0	19.0	16.5
20-Jun	3	0.6	17.3	12.0	15-Aug	3	0.0	18.8	18.6
21-Jun	2	0.0	17.0	15.3	16-Aug	1	0.0	18.8	19.1
22-Jun	5	1.0	16.7	12.0	17-Aug	1	0.0	18.9	16.9
23-Jun	4	0.0	16.2	12.8	18-Aug	3	0.0	18.7	15.6
24-Jun	2	0.0	16.2	11.9	19-Aug	2	0.0	19.1	16.9
25-Jun	3	0.0	17.0	14.2	20-Aug	2	0.0	19.3	17.9
26-Jun	5	0.0	16.7	13.6	21-Aug	2	0.0	19.2	19.3
27-Jun	2	0.0	16.7	15.5	22-Aug	2	0.0	19.3	17.5
28-Jun	5	0.0	16.4	11.1	23-Aug	5	0.5	19.2	14.6
29-Jun	3	1.3	16.0	11.5	24-Aug	2	0.0	18.9	14.4
30-Jun	2	0.4	16.6	15.0	25-Aug	2	0.0	18.5	13.5
1-Jul	1	0.0	17.9	16.7	26-Aug	3	0.0	18.2	10.7
2-Jul	3	2.4	18.4	16.2	Total		141	Water	Air
3-Jul	1	0.0	19.6	19.7	Avg.		1.8	18.4	15.7
4-Jul	2	0.0	20.6	22.1	Min.		0.0	15.0	10.7
5-Jul	1	0.0	20.3	20.1	Max.		23.8	20.7	22.1
6-Jul	3	10.2	20.7	16.6	Ice out = 21-May				
7-Jul	2	0.0	20.7	18.2	Summary of Cloud Cover - Percent of Days				
8-Jul	5	3.8	19.7	13.0		No.	Meas.	Partly	
9-Jul	1	1.4	19.3	18.0		Days	Rain	Cloudy	Clear
10-Jul	2	2.4	19.8	18.8		78	28%	64%	14%
11-Jul	4	21.3	19.9	15.8	1 = Clear 2 = Cloud Cover <50% 3 = Cloud Cover >50% 4 = Overcast 5 = Rain ND = No Data				
20-Jul	3	0.0	20.2	18.1	Crew break from July 12-19				
21-Jul	3	4.2	20.2	17.8					
22-Jul	2	0.0	19.8	16.7					
23-Jul	1	0.0	19.7	17.4					
24-Jul	5	6.8	19.2	12.9					
25-Jul	5	7.2	18.3	13.1					
26-Jul	2	0.0	18.7	15.3					
27-Jul	2	0.0	18.4	16.4					

Appendix 4: Acoustic data collection parameters for
Hewitt lake surveys

Parameter	Year	Hewitt
Frequency (kHz)	2018	208
Beam size (degree)		6.6
Mode		Circular
Pulse duration (ms)		Split
Sample range (m)		0.2
Water temperature (°C)		1 to 35
Transducer depth (m)		11
Threshold (dB)		1
Ping rate (pps)		-65
		4
Frequency (kHz)	2019	208
Beam size (degree)		6.6
Mode		Circular
Pulse duration (ms)		Split
Sample range (m)		0.2
Water temperature (°C)		1 to 35
Transducer depth (m)		15.3
Threshold (dB)		1
Ping rate (pps)		-65
		4
Frequency (kHz)	2020	208
Beam size (degree)		6.6
Mode		Circular
Pulse duration (ms)		Split
Sample range (m)		0.2
Water temperature (°C)		1 to 35
Transducer depth (m)		14
Threshold (dB)		1
Ping rate (pps)		-65
		4

Appendix 5: Hewitt Lake mean σ and target strength (TS) for each depth strata and year.

Depth (m)	2018			2019			2020		
	Number of targets	σ	TS	Number of targets	σ	TS	Number of targets	σ	TS
1	10	2.22×10^{-6}	-58.8	20	1.79×10^{-5}	-60.1	10	5.48×10^{-7}	-62.7
2	85	2.09×10^{-6}	-57.9	64	1.19×10^{-6}	-60.0	95	8.51×10^{-7}	-61.0
3	201	2.79×10^{-6}	-56.9	301	1.01×10^{-6}	-60.6	416	9.19×10^{-7}	-60.8
4	542	3.26×10^{-6}	-56.7	658	1.14×10^{-6}	-60.2	708	9.98×10^{-7}	-60.6
5	1,642	3.94×10^{-6}	-55.8	1,300	1.30×10^{-6}	-59.7	897	1.17×10^{-6}	-60.1
6	1,239	4.60×10^{-6}	-55.1	1,543	1.61×10^{-6}	-59.1	1,642	1.45×10^{-6}	-59.3
7	1,137	4.20×10^{-6}	-55.3	880	2.65×10^{-6}	-57.7	3,346	1.92×10^{-6}	-58.5
8	917	4.62×10^{-6}	-55.0	1,000	3.57×10^{-6}	-56.6	2,701	2.14×10^{-6}	-58.0
9	788	5.47×10^{-6}	-54.5	1,148	3.68×10^{-6}	-56.1	2,504	2.39×10^{-6}	-57.7
10	991	5.42×10^{-6}	-54.4	1,954	3.53×10^{-6}	-56.2	2,907	2.59×10^{-6}	-57.3
11	1,316	5.24×10^{-6}	-54.5	2,806	3.49×10^{-6}	-56.1	3,223	2.68×10^{-6}	-57.0
12	1,633	5.73×10^{-6}	-53.9	1,730	3.35×10^{-6}	-56.3	2,176	3.11×10^{-6}	-56.7
13	1,573	7.09×10^{-6}	-53.6	432	2.92×10^{-6}	-56.4	1,106	2.89×10^{-6}	-57.1
14	1,015	6.02×10^{-6}	-54.0	29	1.96×10^{-6}	-58.2	379	2.51×10^{-6}	-57.2
15	727	6.09×10^{-6}	-53.9	2	4.04×10^{-6}	-56.5	92	2.29×10^{-6}	-57.6
16	634	6.07×10^{-6}	-53.8				25	1.89×10^{-6}	-58.0
17	559	5.79×10^{-6}	-54.3						
18	333	4.59×10^{-6}	-54.6	1	4.21×10^{-7}	-63.7			
19	84	4.19×10^{-6}	-54.7						
22	9	6.35×10^{-6}	-52.5						
Grand Total	15,435	5.21×10^{-6}	-54.6	13,868	2.86×10^{-6}	-57.3	22,227	2.26×10^{-6}	-58.0