Fishery Data Series No. 22-17

Alexander Creek Northern Pike Suppression, 2019–2021

by

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and

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Alaska Department of Fish and Game

Divisions of Sport Fish and Commercial Fisheries

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	′
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	″
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA SERIES NO. 22-17

ALEXANDER CREEK NORTHERN PIKE SUPPRESSION, 2019–2021

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

To increase salmon production in the Alexander Creek drainage in Southcentral Alaska, invasive northern pike (*Esox lucius*) were suppressed annually in up to 71 side sloughs of Alexander Creek from 2019 through 2021. During that time, 6,192 invasive northern pike ranging in length from 158 to 890 mm were captured and removed. The relative abundance of prey was analyzed from the stomach contents of 6,024 northern pike captured during suppression efforts. Of those stomachs, 11% were empty and 89% contained at least 1 prey item. The most common prey items in order of abundance were macroinvertebrates (e.g., Odonata and Amphipoda), juvenile salmon (*Oncorhynchus* spp.), leeches (Hirudinea), lamprey (Petromyzontidae), wood frogs (*Lithobates sylvaticus*), threespine stickleback (*Gasterosteus aculeatus*), and slimy sculpin (*Cottus cognatus*). In addition, 1 minnow-trapping event was conducted in June 2019 to assess relative abundance and spatial distribution of juvenile salmon in Alexander Creek. Only 12 juvenile salmon were captured in minnow traps, of which 3 were Chinook salmon (*O. tshawytscha*) and 9 were coho salmon (*O. kisutch*). Due to low catches and low water conditions during this period, the minnow trapping effort was not continued after 2019. After 8 years of northern pike suppression efforts, 2019 Alexander Creek aerial escapement index counts of spawning Chinook salmon were the highest since 2005, but declined again in 2020 and 2021. However, low indexes in those years reflect a pattern that other Susitna River systems (without northern pike) also experienced. Suppression efforts will need to continue for several more years to fully assess how these efforts are influencing runs within Alexander Creek.

Keywords: Northern pike, *Esox lucius*, Alexander Creek, suppression, invasive species, Chinook salmon, *Oncorhynchus tshawytscha*, Susitna River, Deshka River, gillnets, minnow traps, juvenile salmon, stomach contents

INTRODUCTION

BACKGROUND

Invasive northern pike (*Esox lucius*) are a predatory fish that poses a significant threat to juvenile salmon (*Oncorhynchus* spp.) in Southcentral Alaska (Dunker et al. 2020). Northern pike are native throughout much of the state of Alaska but do not naturally occur south and east of the Alaska Range (Figure 1). It is thought that northern pike were first introduced by an air charter operator to the Yentna River drainage (Bulchitna Lake, Lake Creek drainage) in the late 1950s and subsequently spread throughout the Susitna River basin via natural migration and further illegal stockings. Based on reports from local residents, it is believed that northern pike were illegally introduced to Alexander Lake in the late 1960s, although there was no harvest record of them prior to 1985 (Mills 1986).

Anecdotal accounts from Alexander Creek area residents suggest that dispersal of northern pike from the lake to the lower river occurred slowly over a 30-year period. The first documented catch of northern pike in the lower Alexander Creek drainage (river kilometer [RKM] 0–1.6) was in the mid-1990s. Today, northern pike are widespread throughout the system. The majority of the drainage is shallow, low velocity, and meandering, with numerous side-slough channels, interconnecting shallow lakes and ponds, tens of thousands of acres of adjacent wetland areas, and dense aquatic instream vegetated areas, making it ideal northern pike habitat (Morrow 1980; Inskip 1982; Mecklenburg et al. 2002).

Prior to 2000, Alexander Creek was one of the most productive Chinook salmon (*O. tshawytscha*) systems in the entire Northern Cook Inlet (NCI) area. Alexander Creek fisheries historically generated an average of 13,700 angler-days for the 20-year period from 1980 to 1999 (Oslund et al. 2013). During that same period, an average of 2,880 Chinook salmon were harvested annually (Oslund et al. 2013). From 1977 to 2010, the peak of the sport fishery occurred in 1991 with a reported 26,235 angler-days of effort and a harvest of 6,548 Chinook salmon (Oslund et al. 2013). During the peak of the Chinook salmon fishery, 10 fishing lodges, 7 guide operations, 3 boat rental services, and numerous charter services (both float plane and boat) were in operation, primarily catering to the Chinook salmon fishery. A more recent average (2005–2015) for sport fishing effort on Alexander Creek was approximately 2,000 angler days (Oslund et al. 2017).

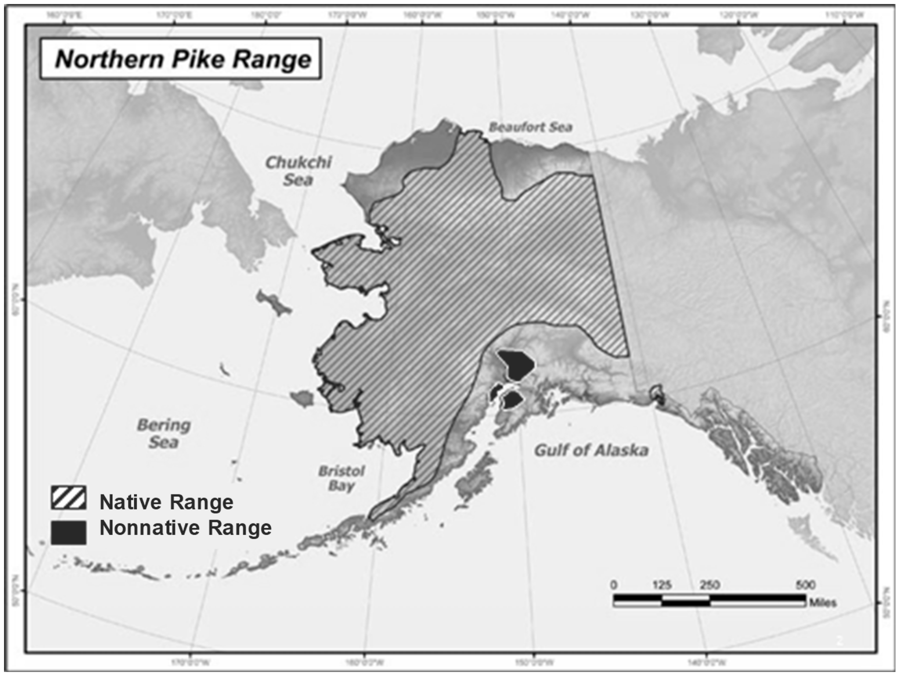

Figure 1.–Distribution of native and nonnative northern pike in Alaska.

Since the late 1990s, the presence of northern pike has coincided with reduced populations of multiple fish species in the Alexander Creek drainage. The sustainable escapement goal (SEG) established by the Alaska Board of Fisheries (BOF) for Chinook salmon on Alexander Creek has a range of 2,100–6,000 fish. The lower end of this goal has not been achieved since 2005 (Figure 2). Prior to that, from 2000 through 2004, the goal was either barely met or not achieved. The greatest index counts since 2005 occurred in 2019, when 1,297 Chinook salmon were observed during an arial escapement survey.

Due to these poor runs, the Chinook salmon sport fishery was severely restricted beginning in 2001 and then closed to harvest since 2008. Alexander Creek has been designated a "stock of concern" by the BOF since 2011. Aerial surveys have been flown on Alexander Creek annually since 1979. These surveys have shown a distinct change in Chinook salmon spawner distribution patterns. Since 1992, Chinook salmon spawning has completely disappeared from the tributaries upstream of Alexander Lake. Since 1998, Chinook salmon spawning abundance has declined sharply in the mainstem of Alexander Creek. From 2007 through 2013, less than 10% of the Alexander Creek drainage Chinook salmon were observed spawning in the mainstem of the creek whereas the majority spawned in other lower tributaries such as Sucker Creek, Granite Creek, and Pierce Creek (David Rutz, Alaska Department of Fish and Game [ADF&G], Division of Sport Fish, Anchorage, personal observation).

Like Chinook salmon, harvest of coho salmon (*O. kisutch*) in Alexander Creek has been below the historical average of 1,683 since 2004, ranging from 757 fish in 2005 to only 10 fish reported in 2008 (Oslund et al. 2020). The once popular and abundant rainbow trout (*O. mykiss*) and Arctic grayling (*Thymallus arcticus*) fisheries were also closed to harvest in 1996 (Whitmore and Sweet

1998). Despite these fisheries becoming catch-and-release, catch rates have declined over the past 20 years for both species (Oslund et al. 2020).

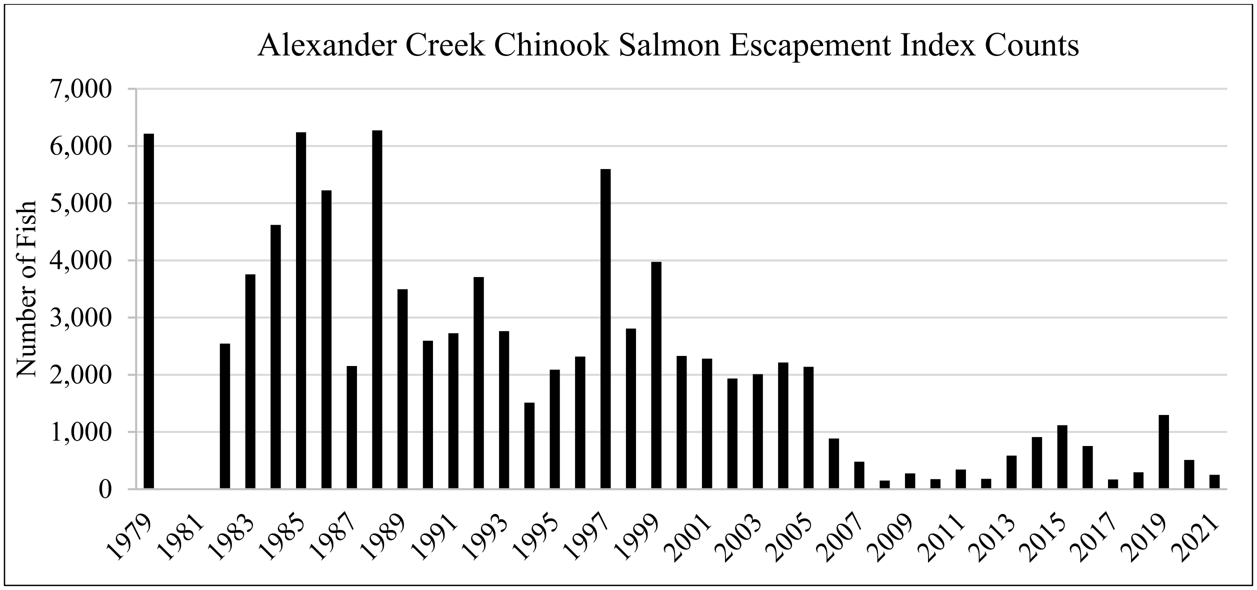

Figure 2.–Adult Chinook salmon escapement into Alexander Creek, 1979 and 1982–2021.

Source: Oslund et al. (2020). Data for 2019–2021 is unpublished, ADF&G, Division of Sport Fish, Palmer.

OVERVIEW OF NORTHERN PIKE SUPPRESSION PROJECT

A central objective of the ADF&G Division of Sport Fish (SF) strategic plan[1] is to "minimize impacts of invasive species on sport fish stocks and habitat." Removing northern pike from vital salmon rearing habitat directly relates to this objective. ADF&G has had an aquatic nuisance species management plan since 2002 (Fay 2002) and an invasive northern pike management plan since 2007 (ADF&G 2007). A new management plan is currently in draft form. Goals and objectives in these plans address the need to remove invasive northern pike where possible and improve salmon populations that have been impacted by northern pike. Alexander Creek is recognized by SF as the highest invasive northern pike control priority (ADF&G 2010, unpublished memorandum, Region II Invasive Northern Pike Priorities). The activities conducted under this project align with several plans and initiatives, and ADF&G believes this project will result in the eventual natural reestablishment of Chinook and other salmon species as well as Arctic grayling, rainbow trout, and other resident fishes in Alexander Creek.

The primary goal of annual northern pike suppression in Alexander Creek is to increase salmonid productivity and restore fisheries in the drainage by suppressing the invasive northern pike population. Given the size and complexity of the Alexander Creek system, complete eradication of northern pike is not feasible given cost and logistics. However, reducing northern pike predation on juvenile salmon may increase salmon populations by contributing to greater survival (Muhlfeld et al. 2008; Sepulveda et al. 2013). Eventually, ADF&G's goal is to restore salmon and resident fish production to levels observed during the mid- to late 1990s when viable fisheries coexisted with a much smaller northern pike population (Whitmore and Sweet 1998).

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[1] https://www.adfg.alaska.gov/static/fishing/PDFs/sport/StrategicPlan2015Final.pdf (accessed April 2022).

With this goal in mind, a spring northern pike gillnetting program was initiated in 2011 after feasibility studies were conducted in 2009 and 2010. This suppression program has been conducted annually in up to 71 side-channel sloughs adjacent to the mainstem of Alexander Creek (Figure 3). Operations commence in early to mid-May (ice-out) and continue through early June during the spring spawning period when northern pike are the most mobile and concentrated in the side channels of Alexander Creek (Diana et al. 1977; Rutz 1996). The goal of the suppression efforts is to achieve a significant reduction in northern pike catch in the targeted sloughs.

Figure 3.–Side channels and sloughs along Alexander Creek

Coincident with and following suppression, data on the catch per unit effort (CPUE) and relative abundance of juvenile salmonids in Alexander Creek have historically been collected annually via minnow trap surveys, first to establish a baseline dataset, and then to evaluate the long-term success of the northern pike suppression efforts in increasing salmon productivity. However, due to low catches and hazardously low water conditions that can occur in June, this activity was discontinued after 2019.

Adult Chinook salmon runs to Alexander Creek have been indexed by ADF&G via aerial surveys since 1979 (Oslund et al. 2020). Indices after 2011, when this project started, remained extremely low except for a small increase from 2014 to 2016 and in 2019, which coincided with an increase in Chinook salmon runs throughout the Susitna River drainage (Figure 2). However, minimum escapement has not been met since 2005. Because of the multigenerational composition of Chinook salmon runs and, to a lesser degree, coho salmon runs, it is not anticipated that any broad-scale increases in adult salmon abundance due to suppression of northern pike will be observed for several years, particularly during reduced statewide Chinook salmon production. Extraneous factors like low marine survival and increasing stream temperatures may be complicating recovery despite the likely success that suppression efforts are having on reducing juvenile mortality and preventing the extirpation of Chinook salmon in Alexander Creek.

This project lays the foundation for long-term salmon restoration in the Alexander Creek drainage.

OBJECTIVES

The purpose of this project was twofold: first, restore productivity of anadromous and resident fish populations; and second, restore sport fishing opportunities on a sustainable yield basis. To accomplish these, this project had 4 primary and 5 secondary objectives meant to reduce the number of northern pike and to measure the successes of that reduction in terms of resident and anadromous fish populations. Specific objectives for this project follow.

Primary Objectives

1) Annually set gillnets in up to 69 side sloughs for 3 days in each between May 1 and June 30 to target northern pike.
2) Calculate the CPUE of juvenile salmonids from minnow trap surveys in Alexander Creek after the netting season each year (June).
3) Annually tag 200 northern pike in Alexander Lake in late summer with passive integrated transponder (PIT) tags.
4) Annually remove northern pike in Alexander Lake in the winter through an incentivized angler harvest program.

Secondary Objectives

1) Calculate the mean and range of fork lengths measured for northern pike caught in gillnets.
2) Document stomach contents, sex, spawning condition, and maturity information from northern pike caught in gillnets.
3) Monitor gillnet catches for northern pike tagged with a PIT tag that originated from Alexander Lake.
4) Calculate the mean and range of fork lengths measured for each species of salmonid caught in minnow traps.
5) Document the species composition of juvenile salmonids caught in minnow traps in Alexander Creek.

METHODS

STUDY AREA

Alexander Creek is a remote river system that flows into the west side of the Susitna River approximately 19 RKM upstream from where the Susitna River drains into Cook Inlet (Figure 4).

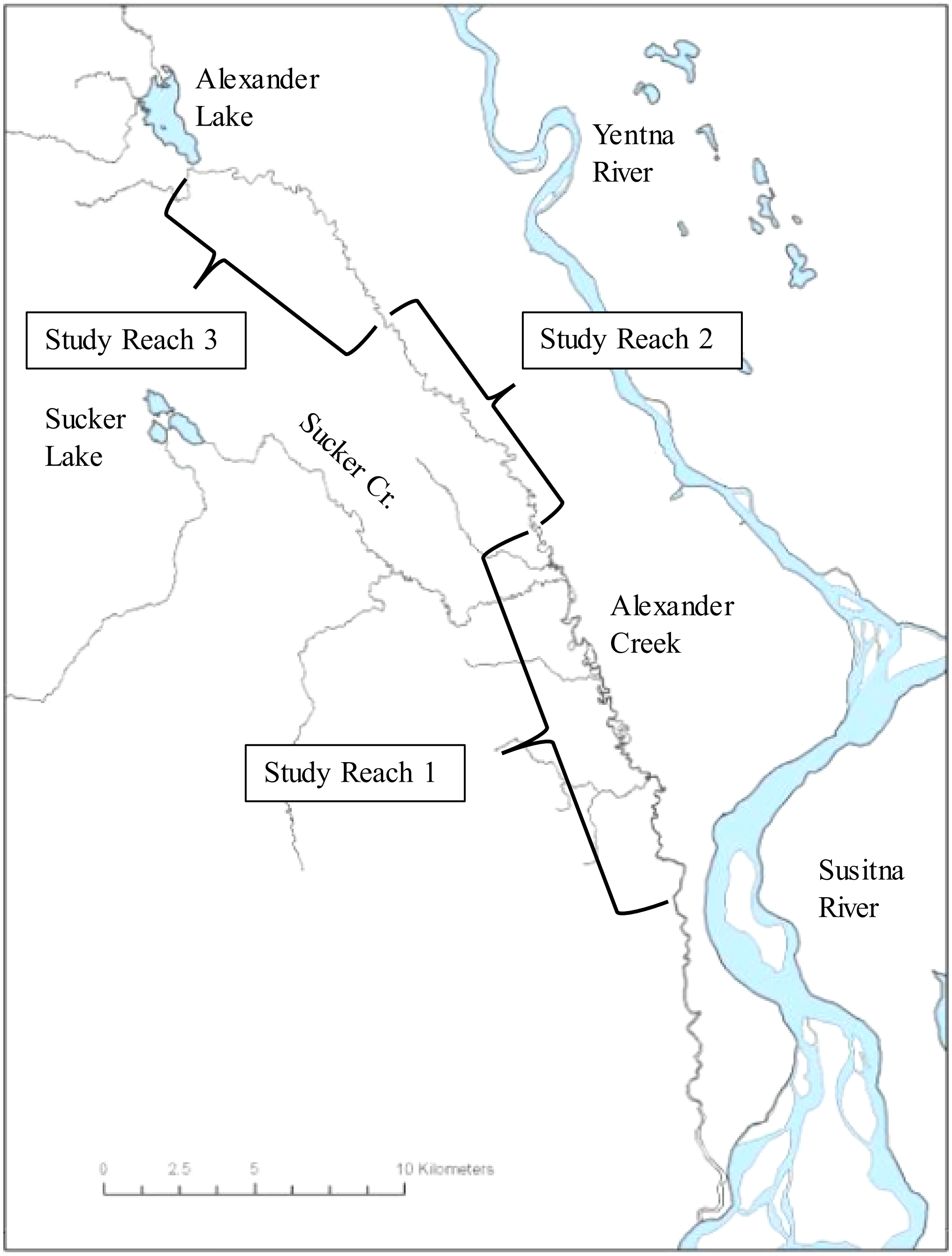

Figure 4.–Map of the Alexander Creek drainage, tributaries, and study reaches.

Aside from Alexander Lake and adjacent wetlands, several clearwater tributaries draining Mount Susitna and the Beluga Mountains contribute to the mainstem flow of Alexander Creek. Sucker Creek, the most prominent tributary, enters the mainstem at approximately RKM 34 and currently provides the majority of spawning and rearing habitat for Chinook and coho salmon. Alexander Creek is a densely vegetated, tannic, low gradient, meandering channel flowing approximately 68 km (42 miles) from Alexander Lake to its confluence with the Susitna River. This drainage encompasses hundreds of square miles and is composed of interconnecting shallow lakes and ponds, vast expanses of adjacent wetlands and numerous backwater side sloughs and oxbow channels that support ideal northern pike habitat. Northern pike are well suited to this type of system (Threinen et al. 1966; Inskip 1982; Rutz 1996), and to date, they have expanded throughout its entirety.

STUDY DESIGN

Primary Objective 1: Northern Pike Suppression

In the spring of each study year (2019–2021), gillnetting was conducted in the side sloughs of Alexander Creek. From approximately mid- to late May, northern pike were targeted in up to 71 side sloughs of Alexander Creek with variable mesh gillnets. This effort was conducted from 2 primary field camps and an additional third short-term field camp located between the 2 primary camps. The first primary camp was located in the lower river near Trail Creek at RKM 20 and was used as a base to sample Study Reach 1; the short-term camp was located upstream of the confluence with Sucker Creek at RKM 38 and was used to sample Study Reach 2; and the second primary camp was at the outlet of Alexander Lake (RKM 68) and was used to sample Study Reach 3 (Figure 4). Two staff were assigned to each field camp and were responsible for gillnetting sloughs along their corresponding study reach. Each study reach had between 13 and 31 side-channel sloughs that were targeted. The number and frequency of unique sloughs sampled from year to year varied depending upon water levels during that given year. Many of the sloughs dry out completely or become hydrologically disconnected from the mainstem of the creek at lower water levels. Despite these conditions, a minimum of 66 sloughs were netted in total each year of this study period. In Study Reach 1, sloughs furthest downstream were netted first. Gillnet suppression efforts took place in an upstream progression throughout the field season until all sloughs were eventually netted. In Study Reach 3, sloughs furthest upstream were netted first with progression moving downstream throughout the field season. In Study Reach 2, all the sloughs were netted at the same time for 3 straight days. The number of gillnets fished per slough was dependent on the surface area and length of each slough; gillnet number varied between 1 and 7 gillnets per slough. Each slough was given a unique number and GPS location, beginning with the slough farthest downstream within the project reach.

Gillnets were 37 m in length by 2 m in depth and composed of 6 panels of differing mesh sizes ordered in size along the length: 19 mm (0.75 in), 25 mm (1.0 in), 31 mm (1.25 in), 38 mm (1.5 in), 44 mm (1.75 in), and 51 mm (2 in). Starting in 2021, single panel nets composed of 31 mm (1.25 in) mesh and the same overall dimensions were tested to compare catchability. All deployed nets were made of monofilament with a 12.7 mm (0.5 inch) foam top line and 50 lb lead line. All gillnets were fished overnight and checked once every 24 hours; nets were checked in the order they were set. Before a gillnet was checked, the crew was instructed to disturb the aquatic weed beds by either walking or driving the boat through them such that northern pike might be herded into the gillnets prior to sampling. Netting was conducted for 3 consecutive days in each slough. Exceptions to this protocol were made as follows:

1) If zero northern pike were captured in a slough in a day’s check, the nets were pulled and moved to another slough.
2) If catches of northern pike remained at or above 5 fish in a slough, nets remained in the slough until catches fell below 5 northern pike.
3) If significant bycatch occurred, nets were pulled and moved to another slough.

If any of the 3 criteria was not met, nets in a slough were moved after the third day. Significant bycatch is defined as catching more Arctic grayling and rainbow trout combined than northern pike in a slough (Appendix A1). Depending on conditions, individual nets with the highest bycatch could be pulled or moved to other areas of the slough, or all nets in the slough could be pulled.

All northern pike removed from gillnets were dispatched, measured for fork length to the nearest millimeter, identified to sex, assessed for spawning condition (green, ripe, or spent), assessed for maturity (mature or immature), and had stomach contents identified and enumerated.

Primary Objective 2 and Secondary Objectives 4 and 5: Assessment of Juvenile Salmon

To document the relative abundance and spatial distribution of juvenile salmon in Alexander Creek, 60 minnow traps were deployed at 12 sampling sites in 2019. Minnow trapping did not occur in 2020 or 2021. Traps were baited with salmon roe and fished for approximately 24 hours. All fish were recorded to the species taxonomic level and enumerated (Secondary Objective 5), and each was measured for fork length to the nearest millimeter.

Data were recorded in a field notebook and transferred to datasheets back at the field camps. Mean lengths were calculated for all juvenile salmon by species (Secondary Objective 4). The CPUE (Primary Objective 2) was not calculated due to low sample size.

Primary Objectives 3 and 4: PIT Tag Alexander Lake Pike

The third and fourth primary objectives of this project involved a new program designed to remove northern pike from Alexander Lake while minimizing cost to ADF&G. In August 2019, ADF&G staff inserted a small PIT tag in the cheek muscle of 93 northern pike. Tagging was conducted by 3 personnel using hook-and-line capture gear throughout Alexander Lake. Captured and tagged northern pike were released at their capture location.

Announcements were made in January 2020 to the public regarding the program. Anglers could bring northern pike heads from Alexander Lake to the Palmer office any Monday until April 13 from 8:00 AM to 5:00 PM. Each head was scanned with a PIT tag reader. For each PIT tag detected, anglers received a $100 Visa gift card as well as an entry into a drawing at the end of the season for a $1,000 Visa gift card. The drawing occurred on April 15, 2020.

Secondary Objective 1: Mean Length of Captured Pike

Each northern pike captured during the suppression efforts was measured to the nearest millimeter for fork length. Mean lengths and length ranges were calculated for all fish captured each year.

Secondary Objective 2: Condition, Sex, Maturity, and Stomach Contents

Condition

The primary purpose of documenting northern pike spawning condition was to determine when the netting was occurring relative to the spawn. Before each northern pike was dissected, it was squeezed to determine if the fish would produce milt or eggs. If it did, the fish was considered ripe. If not, after opening the belly, the gonads were examined. Females that were still full of eggs and did not produce any eggs from squeezing were considered green (not yet ripe). Females that had few to no eggs remaining were considered spent. Males are rarely green after spring break up, so males that did not produce milt after squeezing were considered spent.

Sex

Sex was often determined from examining the extruded sex product (eggs or milt) during initial spawning condition assessment. If product was not produced, the belly was opened, and the gonads were visually examined to determine if each fish was male or female. If crew members were not positive of the sex, they labeled it as unknown. This was typically only the case for small immature fish.

Maturity

As with sex composition, maturity of northern pike captured during suppression efforts was determined by examining reproductive products or through physical examination of gonads. Small fish with undeveloped gonads were labeled as immature.

Stomach Contents

The primary purpose for conducting stomach content investigations was to document the presence and spatial distribution of juvenile salmon selected as prey items, and to assess shifts in northern pike diet over time. Other prey items selected by northern pike were also identified and documented.

Stomachs of each northern pike captured during suppression efforts were examined for contents. Stomachs were labeled as either empty or containing items. Only items in the animal kingdom were included in this assessment (sticks, rocks, leaves, etc., were not considered food items and not included). All stomach contents were recorded in the field to taxonomic order for undigested invertebrates and lowest taxonomic level possible for undigested fish. A small percentage of captured northern pike (2–4%) were eaten by otters while in the net, resulting in missing stomach parts and preventing data collection. Otter predation was noted in the data sheets.

Secondary Objective 3: Check for PIT Tags

Each camp was given a PIT-tag scanner. Prior to dissection, each northern pike was scanned for a PIT tag. If a tag was detected, the tag number was recorded in the data sheets.

RESULTS

PRIMARY OBJECTIVES

Primary Objective 1: Northern Pike Suppression

During this study (2019–2021), sampling crews fished gillnets for a total of 32,344 gillnet hours to catch 6,192 northern pike from between 66 and 71 side-slough channels annually in a 48 RKM stretch of Alexander Creek (Table 1). The field season dates, although highly dependent on spring breakup, were similar, with netting beginning in mid-May and lasting 12 to 15 days. Catches and CPUE of northern pike increased dramatically between 2019 and 2020. As a result of these higher catch rates, the average duration of netting in each slough increased from 2.7 days in 2019 to 3.6 days in 2020 and 2021.

Table 1.–Spring northern pike gillnet catch and effort for Alexander Creek sloughs, 2019–2021.

Year	Start	End	NP catch	Total net-hours	Number of sloughs	Average catch/ slough	CPUE NP/net-hour	Sloughs: Number of sloughs fished	Sloughs: Average duration netted (days)	Sloughs: Range duration netted (days)
2019	10 May	22 May	869	8,174	67	13	0.106	66	2.7	1–10
2020	12 May	27 May	2,888	12,084	70	41	0.239	71	3.6	1–11
2021	13 May	27 May	2,435	12,086	68	36	0.201	69	3.6	1–12
Total			6,192	32,344						

Note: NP = northern pike.

Comparing catches by camp, the lower camp had higher catches and higher CPUE compared to the upper camp in 2019 and 2020 (Table 2). The middle camp was only staffed for 2–3 days. As a result, overall catches were lower there than the other camps, but average CPUE was highest in 2020 and 2021 because netting didn't continue after northern pike were depleted from the sloughs. Northern pike catch rates are generally highest in the first day or two of netting and decrease with time after removal efforts deplete the population.

Table 2.–Summary of northern pike catch by camp, 2019–2021.

	Lower camp			Middle camp			Upper camp		
Year	NP catch	Total net hours	CPUE NP/net-hour	NP catch	Total net hours	CPUE NP/net-hour	NP catch	Total net hours	CPUE NP/net-hour
2019	470	4,414	0.106	54	707	0.076	345	3,053	0.113
2020	1,735	6,958	0.249	374	1,270	0.268	775	3,856	0.211
2021	1,399	6,529	0.214	423	1,540	0.275	613	4,016	0.153

Note: NP = northern pike.

In Study Reach 2 during 2021, single-mesh nets with 31 mm mesh were utilized in combination with the 6-panel multi-mesh nets of the same dimensions. Comparing catches where both net types were set in the same slough, average CPUE (pike/net) was 4.2 for multi-mesh nets and 6.5 for single-mesh nets (Table 3). However, bycatch of Arctic grayling was much higher in single-mesh nets. Based on the number of northern pike captured in each panel in the multi-mesh nets, the middle 4 mesh sizes, which made up 66.6% of the net length, accounted for 93% of the northern pike catches (Table 4).

Table 3.–Summary of catch by net type for Alexander Creek sloughs where both net types were set, 2021

Net type	Number of net sets	Number of northern pike	CPUE northern pike/net	Number of Arctic grayling
Single mesh	15	99	6.5	29
Multi-mesh	12	50	4.2	7

Table 4.–Northern pike catch by mesh size in Study Reach 2 of Alexander Creek, 2021.

	Mesh size					
	19 mm	25 mm	31 mm	38 mm	44 mm	51 mm
Number of northern pike	7	73	71	64	33	9
Percent of total catch	3%	28%	28%	25%	13%	4%

Primary Objective 2 and Secondary Objectives 4 and 5: Assessment of Juvenile Salmon from Minnow Traps

A total of 60 minnow traps were set in late June 2019 and fished for one 24-hour period. Traps were set throughout Study Reaches 1 and 2, but only partially in Study Reach 3 due to low water preventing safe boat passage. A total of 3 juvenile Chinook salmon and 9 juvenile coho salmon were captured, all in Study Reach 1. Slimy sculpin (*Cottus cognatus*; n = 10), juvenile burbot (*Lota lota*; n = 4), longnose sucker (*Catostomus catostomus*; n = 1), and northern pike (n = 1) were the only other species that were captured. The northern pike was 71 mm FL and presumably age 0. Minnow trapping was not continued in the following seasons due to lack of sufficient sample size to draw any meaningful conclusions, and very low water typically occurring during this time. Salmon catches were too low to report as data in CPUE form.

Average Chinook salmon (n = 3) fork length was 76 mm and ranged 73–80 mm. Average coho salmon (n = 9) fork length was 57 mm and ranged 44–75 mm. No other juvenile salmonids were captured.

Primary Objectives 3 and 4: PIT Tagged Alexander Lake Pike

A total of 93 northern pike were PIT-tagged over the course of 3 days in mid-August 2019, ranging from 400 mm to 985 mm FL. Starting in January 2020 through April 2020, a total of 499 northern pike heads were brought in for scanning by 35 participants. Of those, a total of 13 PIT tags were detected. As a result, 13 $100 Visa gift cards were handed out and one $1,000 Visa gift card was awarded during the end-of-season drawing for a total cost of $2,300. This project was discontinued in future years due to budget cuts.

SECONDARY OBJECTIVES

Secondary Objective 1: Mean Length of Captured Northern Pike

Northern pike sampled in spring from all study years (2019–2021) ranged from 158 mm to 890 mm FL (Table 5). As expected (Casselman 1974), female northern pike were larger than males for each of the study years.

Table 5.–Mean, minimum, and maximum fork lengths (mm) for male, female, and all northern pike combined captured in Alexander Creek during spring suppression efforts, 2019–2021.

Sex	Statistic	2019	2020	2021
Male				
	Mean	415	417	425
	Min	180	195	200
	Max	687	731	745
Female				
	Mean	483	445	454
	Min	287	212	188
	Max	812	890	668
All				
	Mean	430	427	424
	Min	180	159	158
	Max	812	890	804

Secondary Objective 2: Condition, Sex, Maturity, and Stomach Contents

Condition

Because crews wait until most or all of the ice is out of the Susitna River before boating to Alexander Creek, most of the northern pike were sampled after they spawned (Table 6). Males generally become ripe before females and stay ripe after the females have spawned. Nearly 100% of the females were already spent when sampling occurred in 2020 and 2021.

Table 6.–Proportion of male and female northern pike by spawning condition during the spring suppression project in Alexander Creek, 2019–2021.

	Males			Females		
Year	Green (%)	Ripe (%)	Spent (%)	Green (%)	Ripe (%)	Spent (%)
2019	0.0	93.0	7.0	0.80	3.1	96.1
2020	0.0	92.6	7.4	0.0	0.4	99.6
2021	0.0	89.6	10.4	0.0	0.8	99.2

Sex and Maturity

Male to female ratios were relatively even over the 3 study years and ranged from 0.98:1 in 2020 to 1.10:1 in 2019 (Table 7). A small percentage of fish, which were primarily immature, were labeled as "unknown" each year.

Table 7.–Sex composition and ratios for northern pike caught in Alexander Creek in spring during the northern pike suppression efforts, 2019–2021.

Year	Male	Female	Known sex	Male (%)	Female (%)	M:F ratio	Unknown	Overall total
2019	402	365	767	52.4	47.6	1.10:1	73	840
2020	1,375	1,398	2,773	49.6	50.4	0.98:1	55	2,828
2021	1,198	1,110	2,308	51.9	48.1	1.08:1	180	2,488
All years	2,975	2,873	5,848	50.9	49.1	1.04:1	308	6,156

Stomach Contents

During the 3 study years (2019–2021), 6,024 northern pike stomachs were analyzed, of which 5,347 (88.8%) contained at least 1 food item (Table 8). The percentage of northern pike stomachs containing at least 1 prey item varied from 87.1% in 2020 to 90.3% in 2019.

Table 8.–Number and percentage of examined stomachs for northern pike caught in Alexander Creek during spring suppression netting that contained at least 1 prey item, 2019–2021

	Number of stomachs			Percent of stomachs	
Year	Empty	Nonempty	Total	Empty (%)	Nonempty (%)
2019	81	753	834	9.7	90.3
2020	364	2,452	2,816	12.9	87.1
2021	232	2,142	2,374	9.8	90.2
All years	677	5,347	6,024	11.2	88.8

Of the 5,347 northern pike stomachs that contained at least 1 prey item, top prey items identified in order of abundance (number of items found in all stomachs) were as follows: 16,057 macroinvertebrates (primarily Odonata and Amphipoda); 11,219 juvenile salmon (*Oncorhynchus* spp.), including those identified to species and, because of their state of digestion, those only identified to genus; 4,229 leeches (Hirudinea); 4,212 lamprey (Petromyzontidae); 3,929 wood frogs (*Lithobates sylvaticus*); 2,972 threespine stickleback (*Gasterosteus aculeatus*); and 2,761 slimy sculpin. Other items are listed in Appendix B1.

During the study, we were able to identify 4 of the 5 species of Pacific salmon found in Alaska in the stomachs of northern pike: Chinook salmon, coho salmon, chum salmon (*O. keta*), and pink salmon (*O. gorbuscha*). However, due to the digested state of most of the juvenile salmon identified in the stomach contents, we were only able to identify a small portion to species. For this report, all Pacific salmon species identified in stomach contents were referred to as juvenile salmon.

Of the 6,024 northern pike stomachs examined for content, 1,423 contained a total of 11,219 juvenile salmon. The average number of salmon per stomach increased dramatically in Study Reach 1 between 2019 and 2020, and remained relatively high in 2021 (Figure 5). Study Reach 1 consistently had the highest percentage of stomachs containing at least 1 juvenile salmon, followed by Study Reach 2, then Study Reach 3 containing virtually none (Figure 5).

The consumption rate of juvenile salmon increased with size of northern pike up to the 500 mm size class (Figure 6). The 400–499 mm size class had the highest average consumption rate of juvenile salmon with an average of 2.5 salmon per stomach. This was also the most common size class of northern pike captured.

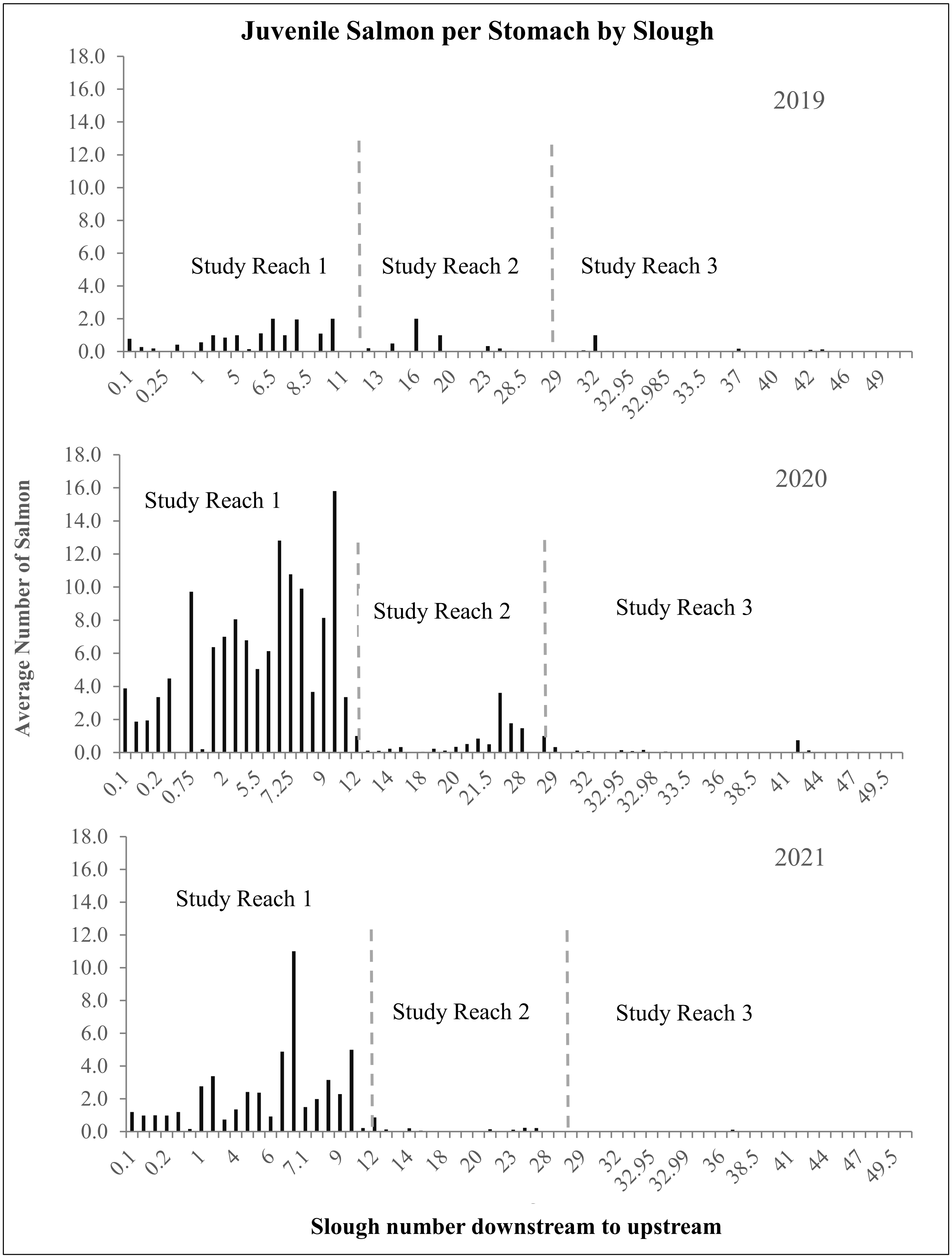

Figure 5.–Average number of salmon per pike stomach for each slough 2019–2021. Study reach boundaries indicated by dotted line.

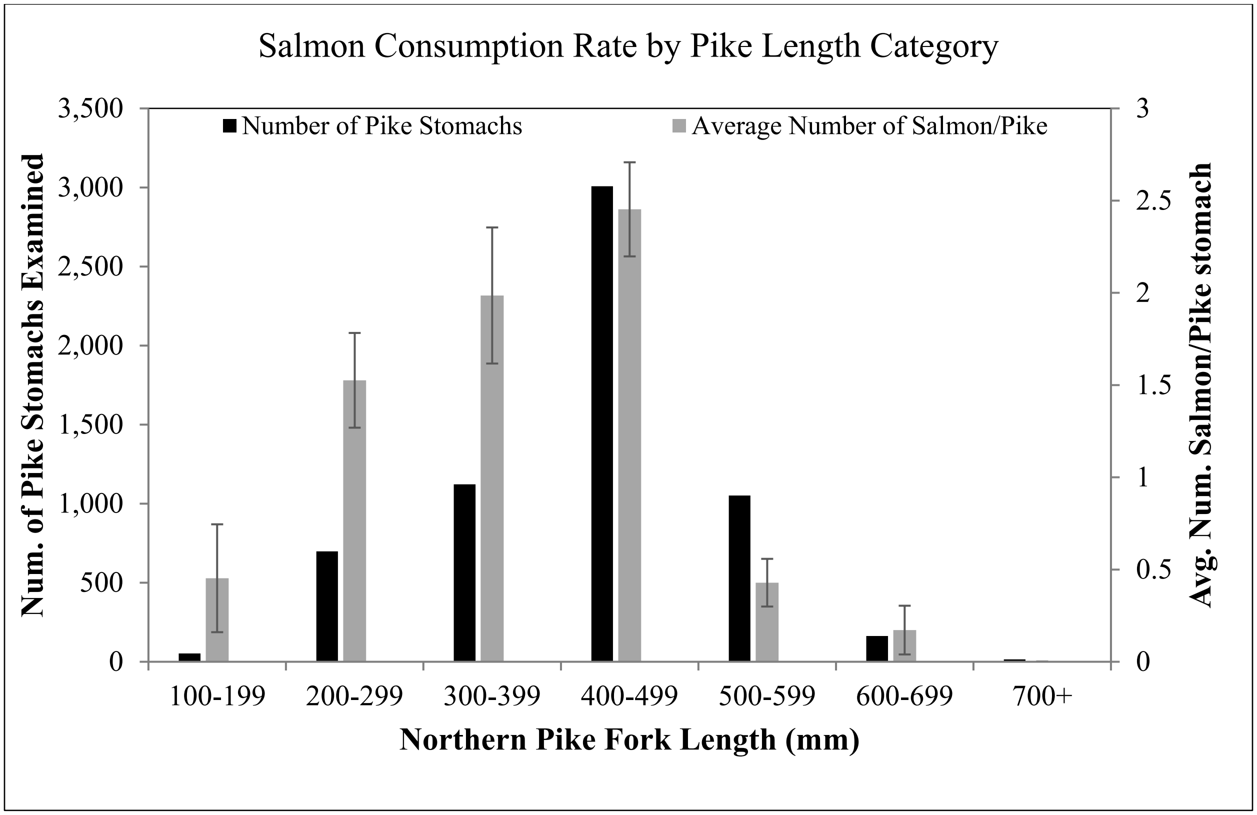

Figure 6.–Length frequency distribution of northern pike captured in Alexander Creek during 2019–2021 with stomachs assessed for content and average number of juvenile salmon (±2 SE) per northern pike stomach by size class.

Secondary Objective 3: Check Northern Pike for PIT tags

A total of 4 PIT tags were detected in northern pike captured in Alexander Creek in 2020. Two tags were detected in Study Reach 3, and 1 tag each was detected in Study Reaches 1 and 2. These fish were at large for approximately 9 months, and average growth since that time was 8 mm. A total of 13 known tags were removed from Alexander Lake over the winter, leaving up to 80 at large during the time of spring 2020 sampling. No tags were detected in 2021.

DISCUSSION AND RECOMMENDATIONS

DISCUSSION

The impacts to salmon from invasive northern pike in Alexander Creek became obvious in the early 2000s and continue to be significant 2 decades later. Since the northern pike suppression project began in 2011, a total of 25,204 northern pike have been removed from Alexander Creek. Although northern pike catches remain high and Chinook salmon index counts continue to fail to meet minimum escapement goals, there are some small encouraging trends emerging, suggesting the northern pike removal project is having a positive impact on salmonid populations. First, 2019 had the highest adult Chinook salmon index counts since 2005 (Figure 2). The following year in 2020, juvenile salmon abundance appeared to be elevated as indicated by high counts in northern pike stomachs (Figure 5). A similar pattern was documented in 2016 when higher numbers of juvenile salmon were documented in northern pike stomachs following a relatively high Chinook salmon run the prior year (Rutz et al. 2020). However, most of the production in both cases was limited to the habitat downstream of the confluence with Sucker Creek when, historically, the entire drainage supported healthy salmon production.

The reason for the sharp rise in northern pike catch rates in 2020, after several years of steadily declining catch rates, is difficult to identify. However, several factors can contribute to the fluctuation in northern pike populations: quality and availability of spawning and rearing habitat, food availability, water temperature, water level fluctuations, fishing pressure, and availability of overwintering habitat. Because suppression efforts take place primarily after spawning has concluded, it is highly likely the captured northern pike all contributed to producing future offspring that year. Survival rate from egg to juvenile stage is highly variable for northern pike (Franklin and Smith 1963; Hassler 1970; Wright and Shoesmith 1988; Casselman and Lewis 1996), but it is possible the past several years provided optimum hatching and rearing conditions for high survival. Although our catches show we can reduce the number of northern pike in specific sloughs within a given year, the extensive northern pike spawning and rearing habitat in Alexander Creek likely allows for a recruitment rate that is at or above the mortality rate (even with netting), resulting in either no change or increases in the overall northern pike population abundance between years (Zelasko et al. 2016). However, many factors can affect population trends and stability, and it has been shown that animal populations can have varying responses to additional mortality as a result of suppression efforts (Abrams and Quince 2005; Zipkin et al. 2009; Zelasko et al. 2016).

Another factor likely contributing to northern pike population fluctuations is the presence and treatment of an invasive plant, elodea (*Elodea canadensis*), in Sucker and Alexander Lakes. This plant was first discovered in 2014 in Alexander Lake, and by 2016, about 70% of the lake was infested with dense mats of the plant. Initial treatments in 2016 were not successful in eradicating the plant. By 2018, both lakes were completely covered with elodea. It is likely this provided not only plenty of spawning habitat for northern pike, but plenty of rearing habitat for juvenile northern pike. In the summer of 2019, treatments occurred again for the elodea and were successful in significantly reducing the biomass by the fall. Full scale treatments began the following year. However, it is unclear what impact the presence of elodea had on the northern pike population, and if treatments caused northern pike to leave the lake and move downstream where they were then captured in high numbers in the spring of 2020.

Analysis of northern pike stomach contents showed that both the number of prey and the number of northern pike stomachs containing a particular prey item varied from year to year. In recent years, there has been a significant increase in the numbers of not only juvenile salmon, but also wood frogs, lamprey, leeches, and macroinvertebrates (Rutz et al. 2020). It is possible that the variability may be related to the availability of prey rather than the selectivity for prey (Rutz 1996, 1999; Sepulveda et al. 2013, 2015). Northern pike are opportunistic feeders, and the seasonal change in the diet of northern pike appears to be related to the availability of prey items in many instances (Frost 1954; Lawler 1965; Chapman 1989). However, one consistent pattern is that the presence of northern pike in examined stomachs remains relatively low, with less than 1% of examined northern pike stomachs containing northern pike.

Overall length distributions of captured northern pike were similar during this study period compared to prior years (2011–2018), with fish in the 400–499 mm size class being the most dominant (Rutz et al. 2020). However, in prior years, the average consumption rate of juvenile salmonids was similar between all size classes <500 mm, averaging 0.8 to 1.0 salmon per stomach

(Rutz et al. 2020). During this study period, the average number of salmon per stomach (2.5 salmon) was highest in the 400–499 mm size class. Sepulveda et al. (2015) showed that northern pike ages 2 to 4 had the greatest overall consumption of juvenile salmonid biomass compared to other ages. Within 1 summer, it was estimated that northern pike in Alexander Creek could consume up to 1.66 metric tons of juvenile salmonids (Sepulveda et al. 2015). In Shell Lake, another southcentral Alaska waterbody impacted by invasive northern pike, bioenergetics modeling showed larger pike (age 5) consumed more salmon biomass per capita than smaller northern pike (Courtney et al. 2018). Many other studies have shown that northern pike can prey heavily on rearing and migrating salmonids (Smirnov et al. 1977; Movchan and Checkenkov 1979; Larsson 1985; Pervozvanskiy et al. 1988; Muhlfeld at al. 2008).

There has now been 11 years of consecutive northern pike suppression in Alexander Creek, and the minimum Chinook salmon escapement index has yet to be met. However, Chinook salmon typically mature and return between 3 and 7 years of age, meaning it could still take some time before we can demonstrate with confidence that our efforts are having a positive impact on salmon. Although it is not expected that Chinook salmon abundance on Alexander Creek will ever rebound to historical levels prior to the introduction of invasive northern pike, a more reasonable expectation of success may be between 40% and 60% of the historical average, or slightly above minimum escapement. At the lowest point, Chinook salmon escapements fell to 5% of the historical average in 2008. Although there appears to be subtle but positive signs that this suppression effort is helping stabilize the salmon populations, more data are needed to fully assess the effectiveness of this project.

RECOMMENDATIONS

Although results are not yet conclusive, suppression of northern pike appears to be promising in terms of salmon recovery. We recommend continuing the northern pike suppression efforts on Alexander Creek for several more years at a consistent level. Additional effort may be put into sampling as early as possible to capture female northern pike before they spawn, which would hopefully increase the impact on the overall population as has been documented in Box Canyon Reservoir in Washington state (Joe Maroney, Kalispel Tribe, unpublished data). Testing of various gill nets (single mesh vs. multi-mesh) should also continue to find ways to maximize catch rates of northern pike. Future northern pike suppression efforts on Alexander Creek will be essential for restoration of both anadromous and resident fish populations as well as reestablishing sport fisheries. The expense of instituting a consistent and cost-effective northern pike suppression project is reasonable if it can restore what was once a multimillion-dollar sport fishery. These suppression efforts will likely be required indefinitely into the future to ensure the northern pike population remains at a level suitable for Alexander Creek to also support a productive salmon fishery.

In addition, we recommend that Alexander Creek remain a high-priority system for Chinook salmon aerial surveys because this index continues to be a quick and cost-effective means of monitoring the strength of the adult Chinook salmon runs to Alexander Creek.

Historical information from aerial surveys shows that prior to northern pike encroachment, up to 10% of the Chinook salmon escapement and a significant portion of the coho salmon escapement from the Alexander Creek drainage could be attributed to tributaries located upstream of Alexander Lake (Bear, Toms, Deep, and No-name Creeks). These tributaries have been devoid of spawning salmon for the past 2 decades. If it is decided that salmon production can be reestablished upstream of the outlet of Alexander Lake, then it will become necessary to expand northern pike suppression efforts to include Alexander Lake and portions of those previously mentioned tributaries, especially after the elodea is eradicated and salmon may once again have access to those areas.

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APPENDIX A: BYCATCH

Appendix A1.–Bycatch (nontarget species) of animals captured in gillnets during the northern pike spring suppression efforts on Alexander Creek, 2019–2021.

Year	Arctic grayling	Whitefish	Longnose sucker	Rainbow trout	Burbot	Chinook salmon	Coho salmon	Dolly Varden	Alaska blackfish	Muskrat	Beaver	Bird
2019	176	9	64	30	3	1	0	3	0	3	0	5
2020	137	27	95	32	1	0	0	0	0	9	0	12
2021	189	50	109	13	2	0	0	0	4	9	0	24
Total	502	86	268	75	6	1	0	3	4	21	0	41

APPENDIX B: STOMACH CONTENTS

Appendix B1.–Number of individual food items found in 5,347 nonempty northern pike stomachs collected during spring suppression in Alexander Creek, 2019–2021.

		Year			
Prey category	Prey Item	2019	2020	2021	All years
Fish	Juvenile salmon (*Oncorhynchus* spp.)	270	8,767	2,182	11,219
	Lamprey (Petromyzontidae)	281	1,957	1,973	4,211
	Threespine stickleback (*Gasterosteus aculeatus*)	397	1,903	672	2,972
	Slimy sculpin (*Cottus cognatus*)	287	1,320	1,154	2,761
	Unknown fish	225	422	404	1,051
	Burbot (*Lota lota*)	143	121	122	386
	Rainbow trout (*O. mykiss*)	42	64	67	173
	Arctic grayling (*Thymallus arcticus*)	55	54	35	144
	Other fish[a]	15	29	46	90
	Whitefish (Coregoninae)	10	36	29	75
	Northern pike (*Esox lucius*)	4	16	29	51
Invertebrates	Unknown macroinvertebrate	635	979	4,181	5,795
	Scud (Gammaridae)	0	50	5,667	5,717
	Leech (Hyrudinea)	601	1,606	1,621	3,828
	Dragonfly (Anisoptera)	632	517	1,709	2,858
	Caddisfly (Trychoptera)	0	89	0	89
	Beetle (Coleoptera)	6	30	46	82
	Snail (Gastropoda)	0	2	3	5
	Damselfly (Zygoptera)	0	2	0	2
Amphibian	Wood frog (*Rana sylvatica*)	170	1,548	2,211	3,929
Mammal	Rodent (Rodentia)	1	0	22	23
	Nonempty stomachs	753	2,452	2,142	5,347

[a] Other fish include Dolly Varden (*Salvelinus malma*), longnose sucker (*Catostomus catostomus*), eulachon (*Thaleichthys pacificus*), and Alaska blackfish (*Dallia pectoralis*).