Fishery Data Series No. 20-17

Alexander Creek Northern Pike Suppression

by

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September 2020

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. 20-17

ALEXANDER CREEK NORTHERN PIKE SUPPRESSION

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ABSTRACT

To increase salmon production in the Alexander Creek drainage in Southcentral Alaska, invasive northern pike (*Esox lucius*) were suppressed annually in up to 69 side-sloughs of Alexander Creek from 2011 through 2018. During that time 20,035 invasive northern pike, ranging in length from 104 to 1,035 mm and with a greater male-to-female ratio, were captured and removed. Dietary preferences and prey distribution were analyzed with the stomach contents of 14,751 northern pike captured during suppression efforts. Of those, 17% of the northern pike stomachs were empty and 83% contained at least 1 prey item. The most common prey items in order of abundance were slimy sculpin (*Cottus cognatus*), juvenile salmon (*Oncorhynchus* spp.), threespine stickleback (*Gasterosteus aculeatus*), lamprey (Petromyzontidae), and leeches (Hirudinea). In addition, minnow-trapping events, coinciding with spring suppression efforts, were conducted annually from 2011 through 2016 to assess relative abundance and spatial and temporal distribution of juvenile salmon in Alexander Creek. For all 6 years, only 321 juvenile salmon were captured in minnow traps in spring, of which 38% were Chinook salmon (*O. tshawytscha*) and 62% were coho salmon (*O. kisutch*). Juvenile salmon catch rates in the Deshka River, a system with much less northern pike habitat, were much higher for both Chinook and coho salmon compared with Alexander Creek. After 4–6 years of northern pike suppression efforts, the 2014–2016 Alexander Creek aerial escapement indexes of spawning Chinook salmon increased to their highest levels in nearly a decade. However, low indexes in 2017 and 2018 reflect a pattern that other Susitna River systems (without northern pike) also experienced. Suppression efforts will probably need to continue for several more years before juvenile salmon productivity and adult salmon runs show strong signs of recovery.

Key words: 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*) is a predatory fish that poses a significant threat to juvenile salmon (*Oncorhynchus* spp.) in Southcentral Alaska (ADF&G 2007). 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).

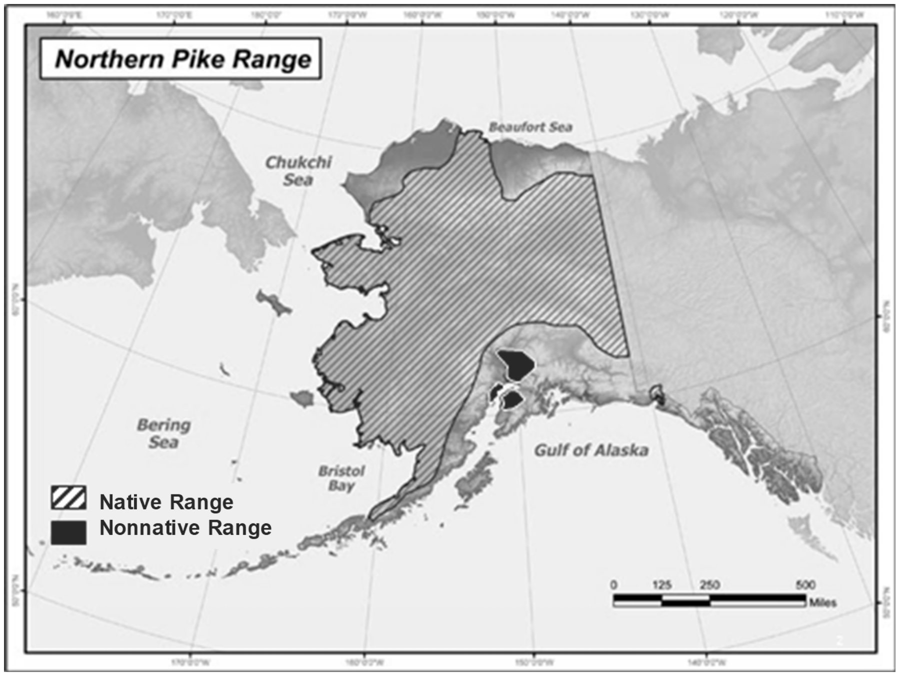

Figure 1.–Distribution of native and nonnative northern pike in Alaska.

Since the late 1990s, the presence of northern pike has coincided with reduced population sizes of multiple fish species in the Alexander Creek drainage. In recent years, aerial indices of Chinook salmon escapements have shown a downward trend with a dramatic drop in the past 15 years. The sustainable escapement goal (SEG) established by the Alaska Department of Fish and Game (ADF&G) 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. Prior to that, from 2000 through 2004, the goal was either only barely met or not achieved.

From 2006 to 2012, escapement counts fell to record lows ranging from 885 in 2006 to 150 in 2008 (Figure 2). Because of poor runs, the Chinook salmon sport fishery was severely restricted beginning in 2001, closed to harvest since 2008, and designated a “stock of concern” by the Alaska Board of Fisheries (BOF) since 2011. Aerial surveys have been flown on Alexander Creek annually since 1979 and have also shown a distinct change in Chinook salmon spawner distribution patterns. Since 1992, Chinook salmon spawners disappeared from the tributaries upstream of Alexander Lake, and since about 1998, spawning abundance has declined sharply in the mainstem of Alexander Creek both upstream and downstream of the Sucker Creek confluence. 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 (David Rutz, Alaska Department of Fish and Game, 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. 2017). 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. 2017).

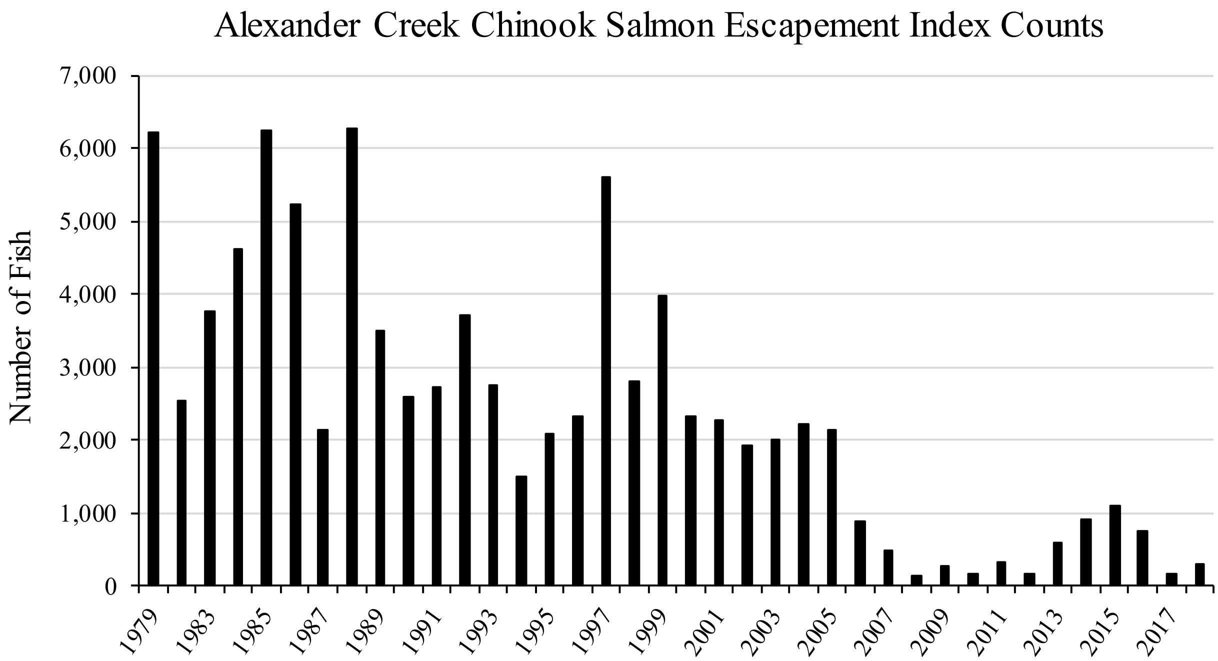

Figure 2.–Adult Chinook salmon escapement into Alexander Creek, 1979, 1982–2018.

Source: Oslund et al. (2017). Data for 2016–2018 unpublished, ADF&G, Division of Sport Fish, Palmer.

OVERVIEW OF NORTHERN PIKE SUPPRESSION PROJECT

A crucial objective of the ADF&G Division of Sport Fish (SF) strategic plan is to "minimize impacts of invasive species on fish stocks, recreational fisheries, and fish 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). 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 re-establishment 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, relieving some of the predation pressure on salmon fry, fingerling, and smolt could increase juvenile salmon abundance by contributing to greater survival (Muhlfeld et al. 2008; Sepulveda et al. 2013). Over time, greater survival of juvenile salmon may result in larger annual runs of these species and increased numbers of resident fish populations. Eventually, ADF&G hopes 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).

To accomplish this, a spring northern pike gillnetting program was initiated in 2011 after feasibility studies in 2009 and 2010; this program was then conducted annually in up to 69 side-channel sloughs adjacent to the mainstem 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 an 85% reduction in northern pike catch in the targeted sloughs.

Figure 3.–Side channels and sloughs along Alexander Creek

Coincident with suppression, data on the catch-per-unit-effort (CPUE) and relative abundance of juvenile salmonids in Alexander Creek have 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 increased salmon productivity. Adult Chinook salmon runs to Alexander Creek have been indexed by ADF&G via aerial surveys since 1979 (Oslund et al. 2017). Because of the multigenerational composition of the Chinook salmon runs and, to a lesser degree, coho salmon runs, it is not anticipated that any broad scale increases in adult salmon abundance will be observed until at least 2020. Progeny from a single year class may rear up to 2 years in fresh water and spend from 1 to 5 years in the ocean prior to returning to their natal streams. Given this and the fact that, initially, straying may account for recolonization of historical spawning areas, it is possible that the reestablishment of spawning areas will take a long time. This project has laid the foundation for long-term salmon restoration in the Alexander Creek drainage.

OBJECTIVES

The goal 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 goals, this project had 4 primary and 3 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) Reduce the number of northern pike in up to 69 side channel sloughs of Alexander Creek between May 7 and June 7 such that the final daily catch in each slough is equal to or less than 15% of the peak daily catch or until the catch remains at less than 2 northern pike for 3 consecutive days.
2) Reduce the number of northern pike in 20 side channel sloughs of Alexander Creek between August and September for 3–5 days each or until the final daily catch in each slough is equal to or less than 15% of the fall peak daily catch.
3) Calculate the mean CPUE of juvenile salmonids from minnow trap surveys in Alexander Creek in May and June to evaluate if a 60% increase in mean CPUE above the 2011 baseline of 0.06 has occurred and compare these with CPUEs of juvenile salmonids from minnow trap surveys in the Deshka River (where northern pike have had less of an impact).

Secondary Objectives

1) Calculate the mean length, length range, and sex and maturity ratios for northern pike in gillnet catches.
2) Dissect northern pike captured in gillnets for stomach content analysis to investigate dietary patterns.
3) Identify and enumerate all bycatch (nontarget species) captured in gillnets during northern pike suppression efforts.

METHODS

STUDY AREA

Alexander Creek is a remote river system that flows into the west side of the Susitna River approximately 12.9 RKM upstream from where the Susitna River drains into Cook Inlet (Figure 4). Aside from Alexander Lake and adjacent wetlands, several clearwater tributaries draining Mount Susitna and the Beluga Mountains contribute to the mainstem flow. Sucker Creek, the most prominent tributary, enters the mainstem at approximately RKM 32.2 and currently provides the majority of spawning and rearing habitat for Chinook and coho salmon. Alexander Creek's mainstem can be characterized as a tannin-stained, low gradient, slow velocity, meandering channel with a large portion of the river comprising dense vegetative mats. The creek's length is approximately 66 km (40 miles) from its headwaters at 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 marshes, and numerous backwater side-sloughs and oxbow-channels that are typically shallow stagnant waters with low flows containing dense aquatic vegetation, all of which provide optimum spawning and rearing habitat for northern pike. 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 Objectives 1 and 2: Northern Pike Suppression

In the spring of each of the study years (2011–2018), and in the summer and fall of 2014–2016, gillnetting was conducted in the side-sloughs of Alexander Creek. From approximately early May to early June, while they congregated for spawning, and then once monthly in July, August, and September from 2014 to 2016 (water level permitting), northern pike were targeted in up to 69 side-sloughs of Alexander Creek with variable mesh gillnets. For the spring suppression efforts, 2 to 3 field camps were set up along the mainstem of Alexander Creek. For the summer and fall sampling efforts, a 2-man roving crew was assigned. The first camp was located in the lower river near Trail Creek at RKM 32.2 and sampled Study Reach 1; the second camp was upstream of the confluence with Sucker Creek (RKM 37) and sampled Study Reach 2; and the third camp was at the outlet of Alexander Lake (RKM 64.4) and sampled Study Reach 3 (Figure 4). Two technicians were assigned to each field camp and were responsible for gillnetting sloughs along their corresponding study reach. Each study reach had between 12 and 23 side-slough channels that were targeted. The numbers of sloughs sampled from year to year varied depending upon water levels because many of the sloughs dried out or became hydrologically disconnected from the mainstem of the creek at lower water levels. Despite these conditions, at least 51 sloughs were netted in total each year. Sloughs furthest downstream in each study reach were fished first. The number of gillnets fished per slough was dependent on the surface area and length of each slough (gillnet saturation varied between 1 and 5 gillnets per slough). Gillnet suppression efforts took place in an upstream progression throughout the field season until all sloughs were eventually fished. Each slough was given a unique number and GPS location, beginning with the slough farthest downstream.

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). All deployed nets were made of monofilament with a 9.5 mm (three-eighths inch) foam top line and 30 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 boats through them such that northern pike might be herded into the gillnets prior to sampling. Nets were moved periodically throughout the season to optimize catches. As a guideline, netting ceased for most sloughs once a day’s catch was equal to or less than 15% of the largest catch obtained in any of the previous days of netting the slough, fewer than 2 northern pike were caught over a 3-day period, or the slough became hydrologically disconnected from the main river.

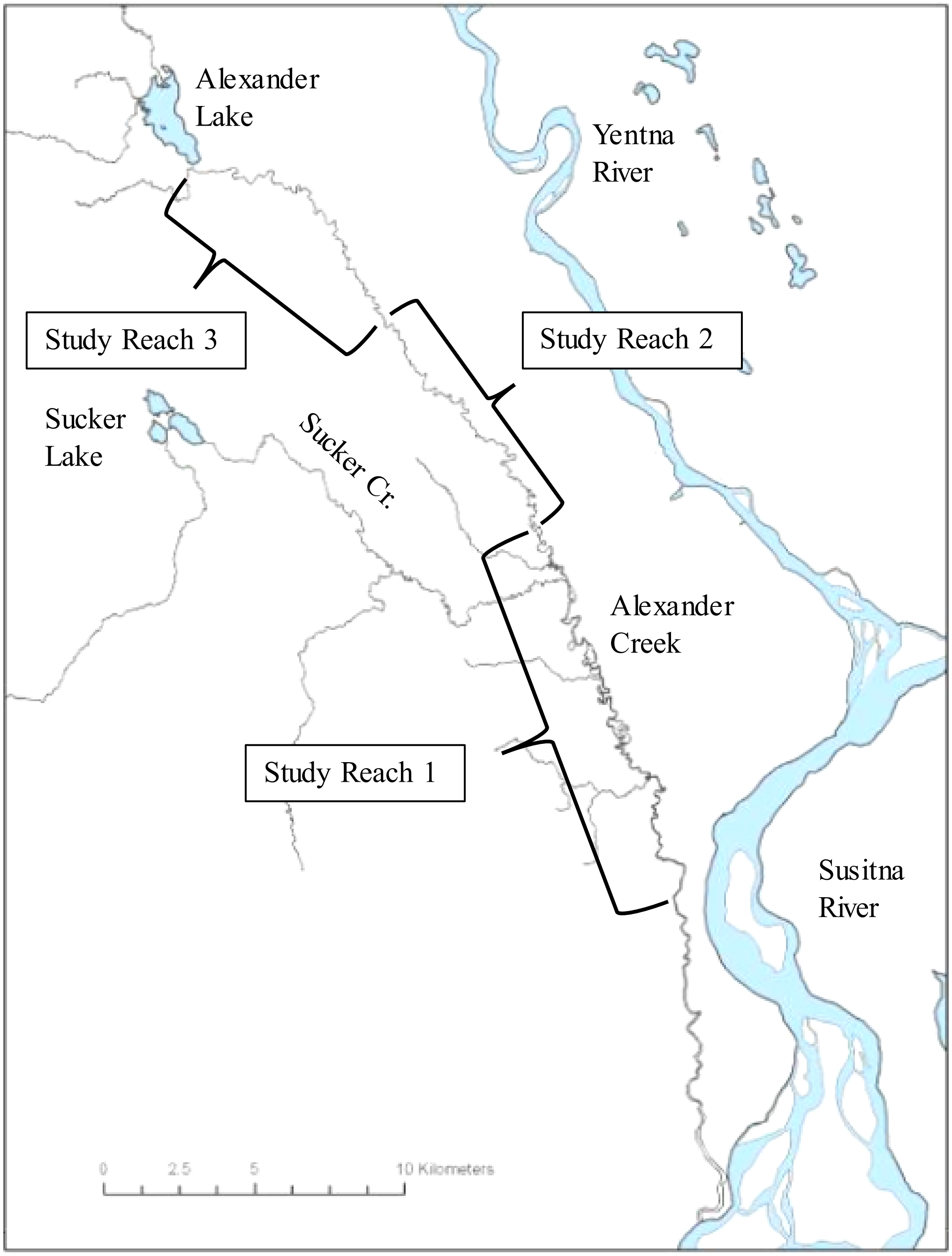

Figure 4.–Map of the Alexander Creek drainage, tributaries, and study reaches.

Primary Objective 3: Assessment of Juvenile Salmon

To document relative abundance and the spatial and temporal distribution of juvenile salmon in Alexander Creek, 180 minnow traps were deployed annually in 2 separate events by 3 field crews in early May and early June throughout an approximately 48 km stretch of Alexander Creek. In addition, between 2014 and 2016, minnow trapping was also conducted on Alexander Creek between June and August. Although this increased minnow-trapping effort was scheduled on a bimonthly basis, actual sampling was conducted more opportunistically based on water levels.

Water levels on Alexander Creek for much of the summer and fall months are fairly low and boat access to a large portion of the creek is not possible. Rather than risk boat and motor problems, minnow-trapping events were only undertaken when water conditions were conducive to riverboat travel. In addition, the Deshka River was also minnow-trapped approximately 1 week following the Alexander minnow trap events (2014–2016) to compare catch numbers from a system that is highly impacted by invasive northern pike (Alexander Creek) to a productive salmon system that is less impacted by invasive northern pike (Deshka River).

These data will provide a rough estimate or benchmark for measuring future success of suppression efforts on Alexander Creek. All minnow traps were soaked for approximately 24 hours prior to checking (Swales 1987). All fish captured in the traps were identified to species and enumerated. A select number of juvenile salmon were measured to the nearest millimeter of fork length. 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. The CPUE was calculated as the catch of juvenile salmon per trap set:

$$CPUE = \frac{f_t}{t} \tag{1}$$

where f_t is the number or juvenile salmon captured, t is the total number of minnow traps deployed, and $CPUE$ is the number of juvenile salmon captured per trap set.

Secondary Objective 1: Mean Length, Sex, and Maturity

For the 8 study years (2011–2018), the majority of northern pike captured during the suppression efforts were measured to the nearest millimeter for fork length and examined for sex determination and maturity.

Mean Length

Mean lengths and length ranges were calculated for all fish captured each year.

Sex Composition

Field crews were instructed to identify sex of northern pike captured during the suppression efforts. Sex was only documented for the portion of northern pike that were dissected for stomach contents and physically examined for presence of gonads or for those fish that extruded reproductive products. The percent of northern pike identified to sex for all study years was calculated as the number of males or females identified divided by the total number of northern pike identified to sex. If crew members were not positive of the sex, they labeled it as unknown.

Maturity

As with sex composition, maturity of northern pike captured during suppression efforts was only verified for those northern pike that were either extruding reproductive products (eggs or milt) or through physical examination of gonads from those fish that were dissected for stomach analysis.

Secondary Objective 2: Stomach Content Analysis

To document spatial and temporal shifts of prey items (particularly juvenile salmon) in the diets of northern pike, stomach contents of northern pike captured during suppression efforts were identified and enumerated. Approximately 50% of captured northern pike were dissected by ADF&G during 2011 and 2012, and greater than 90% were dissected between 2013 and 2018.

Prey items in stomachs were identified to the lowest possible taxonomic level and enumerated. Stomach contents of captured northern pike were also documented by river section to investigate spatial and temporal availability of food items. Because several species of invertebrates and vertebrates could be found within each stomach, the proportion of nonempty stomachs containing a particular food item (e.g., salmonids, resident fish, or other vertebrates) was calculated from the total number of nonempty stomachs examined. This method did not consider the amount or mass of food items per stomach. However, it provides a general assessment of prey items ingested at the time of sampling (Hyslop 1980). Stomach contents were collected and analyzed using established methods (Diana 1979).

Secondary Objective 3: Assessment of Bycatch

As with all major gillnet suppression projects, a certain amount of bycatch (catch of nontarget species) was expected (Massengill 2010; Rutz 1996, 1999). All bycatch for each of the study years was enumerated and identified to species. Attempts were made to remove all live bycatch from gillnets as quickly and carefully as possible and release them away from gillnet locations to minimize their chance of being recaptured. Over the duration of the study, gillnets were deployed strategically (i.e., within a slough, nets were deployed adjacent to shoreline that was farther from the mainstem Alexander Creek) to reduce bycatch and maximize northern pike catch.

RESULTS

PRIMARY OBJECTIVES

Primary Objectives 1 and 2: Northern Pike Suppression

During this study (2011–2018), sampling crews fished gillnets for a total of 199,953 gillnet hours to catch 20,035 northern pike from up to 69 side-slough channels in a 48 RKM stretch of Alexander Creek. Of the 20,035 northern pike caught during the study, 19,577 were caught in the spring (Table 1). Timing of spring sampling was highly variable and depended largely on timing of spring break-up (Table 2). Spring netting effort and catches were greatest in the initial years of the study and the average number of northern pike captured per slough decreased from a peak of 58 northern pike per slough in 2011 and 2013, to 20 northern pike per slough in 2017 and 2018. Spring catch per unit effort (CPUE) showed no discernible trend throughout the project, except for a steady increase since 2015. The northern pike reduction quota (Objective 1: less than or equal to 15% of peak daily catch or a daily catch of less than 2 northern pike 3 days in a row) was met with varying success as a result of difficulties due to technician turnover, some lack of adherence to the project plans, and bycatch driving early abandonment of sloughs. Success rates for achieving reduction quota varied from only 63% of sloughs achieving this goal in 2018 to 98% in 2016. However, for the sloughs that were sampled until Objective 1 was met (a subset of the data that are directly comparable), the average time taken to meet the objective has steadily decreased from an average of 6.4 days in 2011 to 3.3 days in 2018 ($P = 0.03$) (Figure 5).

Table 1.–Spring northern pike gillnet catch and effort for Alexander Creek sloughs, 2011–2018.

						Sloughs			
Year	NP catch	Total net-hours	Total net-days	Average catch/slough	CPUE NP/net-hour	Number fished	Not achieving quota	Achieving quota	Achieving quota (%)
2011	3,987	38,383	1,599	58	0.104	69	7	62	90%
2012	2,988	39,659	1,652	47	0.075	63	4	59	94%
2013	3,626	23,976	999	58	0.151	62	16	46	74%
2014	2,814	23,520	980	46	0.120	61	6	55	90%
2015	1,926	25,248	1,052	31	0.076	63	3	60	95%
2016	2,108	24,096	1,004	35	0.087	60	1	59	98%
2017	997	11,064	461	20	0.090	51	14	37	73%
2018	1,131	9,111	380	20	0.124	56	21	35	63%
Total	19,577	195,057	8,127			485	72	413	85%

Note: NP means northern pike. Quota is obtaining a daily catch less than or equal to 15% of peak daily catch or having a daily catch of less than 2 northern pike for 3 consecutive days during spring gillnetting.

Table 2.–Field sampling dates for the northern pike suppression project, spring 2011–2018.

Year	Start date	End date
2011	12 May	5 Jun
2012	8 May	31 May
2013	25 May	12 Jun
2014	7 May	29 May
2015	5 May	27 May
2016	28 Apr	22 May
2017	13 May	29 May
2018	16 May	27 May

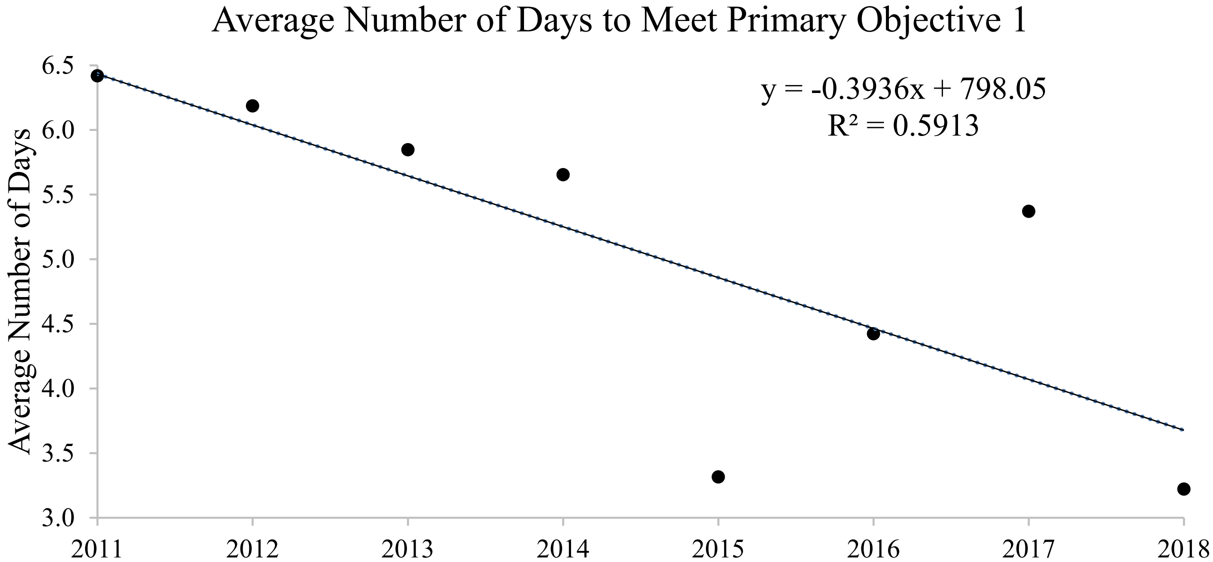

Figure 5.–Average number of days it took to meet Primary Objective 1 for each slough that met the objective, spring 2011–2018.

Fall gillnetting turned out to be logistically prohibitive and not as productive, primarily due to low water. Many sloughs that had water in the spring were dry in the fall. Additionally, traveling the creek by boat was difficult and hard on equipment, so fall netting was not continued after 2016. In total, 458 northern pike were captured during these efforts in 2014–2016 (Table 3).

Table 3.–Fall northern pike gillnet catch and effort for Alexander Creek sloughs, 2014–2016.

						Sloughs			
Year	NP catch	Total net-hours	Total net-days	Average catch/slough	CPUE NP/net-hour	Number fished	Not achieving quota	Achieving quota	Achieving quota (%)
2014	256	1,800	75	8	0.142	31	22	9	29%
2015	64	336	14	10	0.190	7	6	1	14%
2016	138	312	13	35	0.442	4	3	1	25%
Total	458	2,448	102			42	31	11	26%

Note: NP means northern pike. Quota is obtaining a daily catch less than or equal to 15% of peak daily catch during fall gillnetting or having a daily catch of less than 2 northern pike for 3 consecutive days.

Primary Objective 3: Assessment of Juvenile Salmon

For the spring sampling portion of the study, a total of 180 minnow traps were fished for 2 separate 24-hour periods annually from 2011 through 2016. Timing of these trapping events coincided with spring gillnet suppression efforts. During the spring juvenile salmon assessments, success of capturing juvenile salmon was very low; only 319 juvenile salmon were captured during the entire 6 years of the project. Catches included 123 Chinook salmon and 196 coho salmon (Table 4). Additional minnow-trapping took place in June through August of 2014 through 2016 and resulted in the capture of 528 juvenile salmon, of which 200 were Chinook salmon and 328 were coho salmon.

Table 4.–Number of juvenile Chinook salmon (KS) and coho salmon (SS) captured in minnow traps by study reach and year in Alexander Creek, 2011–2016.

			Species			
Season	Year	Study reach	KS	SS	Total	Percent
Spring						
	2011	1	17	3	20	100
		2	0	0	0	0
		3	0	0	0	0
		Total	17	3	20	
	2012	1	9	11	20	51
		2	7	12	19	49
		3	0	0	0	0
		Total	16	23	39	
	2013	1	15	11	26	42
		2	15	21	36	58
		3	0	0	0	0
		Total	30	32	62	
	2014	1	7	23	30	54
		2	4	10	14	25
		3	3	9	12	21
		Total	14	42	56	
	2015	1	10	22	32	48
		2	6	13	19	28
		3	6	10	16	24
		Total	22	45	67	
	2016	1	12	25	37	49
		2	7	15	22	29
		3	5	11	16	21
		Total	24	51	75	
	All years		123	196	319	
Summer, Fall	2014	1	21	19	40	57
		2	3	12	15	21
		3	3	12	15	21
		Total	27	43	70	
	2015	1	9	53	62	47
		2	17	30	47	35
		3	5	19	24	18
		Total	31	102	133	
	2016 [a]	1	142	182	324	100
		2	0	1	1	0
		3	–	–	–	–
		Total	142	183	325	
	All years		200	328	528	
Total			323	524	847	

Note: During each minnow trap set, half the traps were set in sloughs and half the traps were set in the creek channel.

[a] Water was too low to access Study Reach 3 and most of Study Reach 2.

In 2011, 100% of the 20 juvenile salmon captured during the minnow-trapping events came from Study Reach 1 (Table 4, Figure 6). In 2012, 49% of captured salmon came from Study Reach 2, and by 2013, that had increased to 58%. In 2014, high water events thwarted sampling efforts throughout most of the spring, but 56 juvenile salmon were still captured in the minnow traps. This was the first year of the study in which juvenile salmon were captured in all 3 study reaches. Between 2014 and 2016, over 20% of the juvenile salmon captured in Alexander Creek came from Study Reach 3.

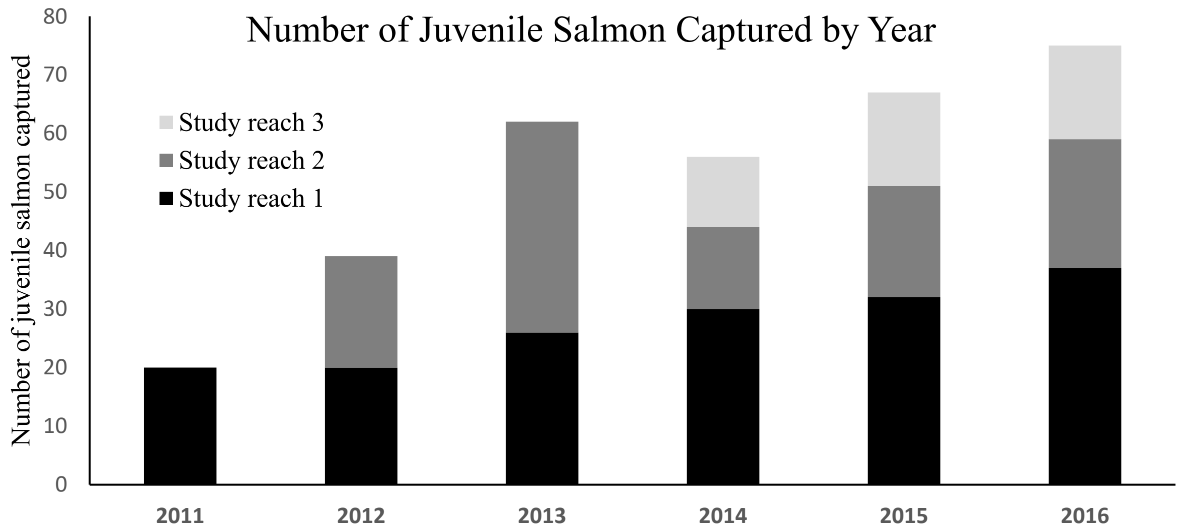

Figure 6.–Number of juvenile (Chinook and coho) salmon minnow trap catches from each study reach, spring 2011–2016.

CPUE, as measured by catch of juvenile salmon per trap, was estimated for all minnow-trapping events in Alexander Creek and the Deshka River (Table 5). Catches for spring minnow-trapping events on Alexander Creek were low for both juvenile Chinook and coho salmon. From 2011 to 2016, CPUE for juvenile Chinook salmon did not significantly increase. However, during that time, CPUE for juvenile coho salmon showed a steady increase from 0.01 fish/trap in 2011 to 0.14 fish/trap in 2016. The baseline CPUE for juvenile salmonids combined in 2011 was 0.06 fish/trap and by 2016, that had increased 246% to 0.21 fish/trap. Alexander Creek minnow trapping was not completed in 2017 and 2018 due to extenuating field circumstances.

For the summer minnow-trapping efforts on Alexander Creek (2014–2016), CPUE was variable for both Chinook and coho salmon, with highest catch rates occurring in 2016. Low water conditions that year prevented sampling in study reaches 2 and 3. Because sampling occurred primarily in Study Reach 1, where catches are typically highest, the catch rates may be skewed higher than for other years when all study reaches were sampled. Minnow-trapping events were also conducted on the Deshka River from 2014 to 2016 approximately 1 week following each Alexander trapping event. As expected, catch rates for both Chinook and coho salmon averaged much higher on the Deshka River than Alexander Creek (Table 5).

Table 5.–Number of traps, total number captured, and CPUE (number of fish per minnow trap set) of juvenile Chinook and coho salmon in Alexander Creek in 2011–2016 and the Deshka River in 2014–2016.

Location	Year	Traps	Chinook	Coho	Chinook CPUE	Coho CPUE
Alexander Creek Spring	2011	360	17	3	0.05	0.01
	2012	360	16	23	0.04	0.06
	2013	360	30	32	0.08	0.09
	2014	360	14	42	0.04	0.12
	2015	360	22	45	0.06	0.13
	2016	360	24	51	0.07	0.14
	Total	2,160	123	196	0.06	0.09
Alexander Creek Summer, Fall	2014	1,080	27	43	0.03	0.04
	2015	670	31	102	0.05	0.15
	2016	150	142	183	0.95	1.22
	Total	1,900	200	328	0.11	0.17
Deshka River	2014	300	362	620	1.21	2.07
	2015	300	132	1,295	0.44	4.32
	2016	125	151	521	1.21	4.17
	Total	725	645	2,436	0.89	3.36

Note: Minnow trap events in the Deshka River occurred approximately 1 week after each Alexander Creek trap event.

SECONDARY OBJECTIVES

Secondary Objective 1: Length, Sex, and Maturity

Northern pike sampled in spring from all study years (2011–2018) ranged in fork length from 104 mm to 1,035 mm (Table 6). The fork length, means, and ranges for each study year are shown in Table 6. As expected, female northern pike were larger (Casselman 1974) than males for each of the study years.

Table 6.–Mean, minimum, and maximum fork lengths (mm) for male, female, and all northern pike combined captured in Alexander Creek during spring suppression efforts 2011–2018.

Sex	Statistic	2011	2012	2013	2014	2015	2016	2017	2018
Male									
	Mean	450	406	406	424	419	424	436	437
	Min	189	188	187	188	171	200	197	235
	Max	806	690	748	750	690	632	698	743
Female									
	Mean	493	477	432	445	451	438	468	489
	Min	218	202	189	192	168	197	232	360
	Max	775	1,035	967	832	740	800	765	702
All									
	Mean	430	402	416	428	422	423	438	443
	Min	110	174	187	170	104	152	185	184
	Max	834	1,035	967	832	740	800	765	743

Over all study years, 19,710 northern pike (from spring suppression netting) were examined for sex determination, of which 15,094 (77%) were identified to sex, whereas 4,616 (23%) were documented as unknown sex (Table 7). Of the northern pike identified to sex, 9,312 (62%) were males and 5,782 (38%) were females. The male-to-female ratio was initially very high in 2011 and 2012; however, the number of unknown-sex fish was also high in those years.

From 2011 to 2018, 19,216 northern pike were examined for maturity. Of those examined, 12,179 (63%) were identified as mature, 1,245 (7%) were determined to be immature, and 5,792 (30%) were documented as unknown.

Table 7.–Sex composition and ratios for northern pike caught in Alexander Creek in spring during the northern pike suppression efforts, 2011–2018.

Year	Male	Female	Known sex	Male (%)	Female (%)	M/F ratio	Unknown	Overall total
2011	1,774	507	2,281	0.78	0.22	3.5:1	1,935	4,216
2012	1,321	511	1,832	0.72	0.28	2.6:1	1,115	2,947
2013	1,986	1,427	3,413	0.58	0.42	1.4:1	129	3,542
2014	1,337	1,089	2,426	0.55	0.45	1.2:1	392	2,818
2015	968	788	1,756	0.55	0.45	1.2:1	204	1,960
2016	902	792	1,694	0.53	0.47	1.1:1	410	2,104
2017	504	336	840	0.6	0.4	1.5:1	152	992
2018	520	332	852	0.61	0.39	1.6:1	279	1,131
All years	9,312	5,782	15,094	0.62	0.38	1.6:1	4,616	19,710

Secondary Objective 2: Stomach Content Analysis

The primary purpose for conducting stomach content investigations was to document the presence and spatial and temporal distributions of juvenile salmon selected as prey items and, to a lesser extent, identify and document other prey items selected by northern pike.

During the 8 study years (2011–2018), 14,751 northern pike stomachs were analyzed, of which 12,188 (83%) contained at least 1 food item (Table 8). The percentage of northern pike stomachs containing at least 1 prey item varied from 81% in 2015 and 2016 to 85% in 2017.

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, 2011–2018.

	Number of stomachs			Percent of stomachs	
Year	Empty	Nonempty	Total	Empty	Nonempty
2011	274	1,218	1,492	18	82
2012	249	1,109	1,358	18	82
2013	563	2,853	3,416	17	83
2014	445	2,242	2,687	17	83
2015	352	1,511	1,863	19	81
2016	361	1,579	1,940	19	81
2017	144	793	937	15	85
2018	173	883	1056	16	84
All years	2,563	12,188	14,751	17	83

Of the 12,188 northern pike stomachs that were nonempty and examined for content, top prey items identified in order of abundance (number of items found in all stomachs) were as follows: 14,157 slimy sculpin (*Cottus cognatus*), 11,318 juvenile salmon (*Oncorhynchus* spp. including those identified to species and, because of their state of degeneration, those only identified to genus), 6,808 threespine sticklebacks (*Gasterosteus aculeatus*), 6,334 lamprey (*Petromyzontidae*), and 4,194 leeches (Hyrudinea). Other items are listed in Appendices A1 and A2.

During the study, we were able to identify 3 of the 5 species of Pacific salmon found in Alaska in the stomachs of northern pike: Chinook salmon, coho salmon, and chum salmon (*O. keta*). However, due to the degenerative 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 14,751 northern pike stomachs examined for content, 2,706 contained a total of 11,318 juvenile salmon (Appendices A1 and A2). The percent of all examined stomachs containing juvenile salmon has fluctuated annually and by study reach (Figure 7). 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.

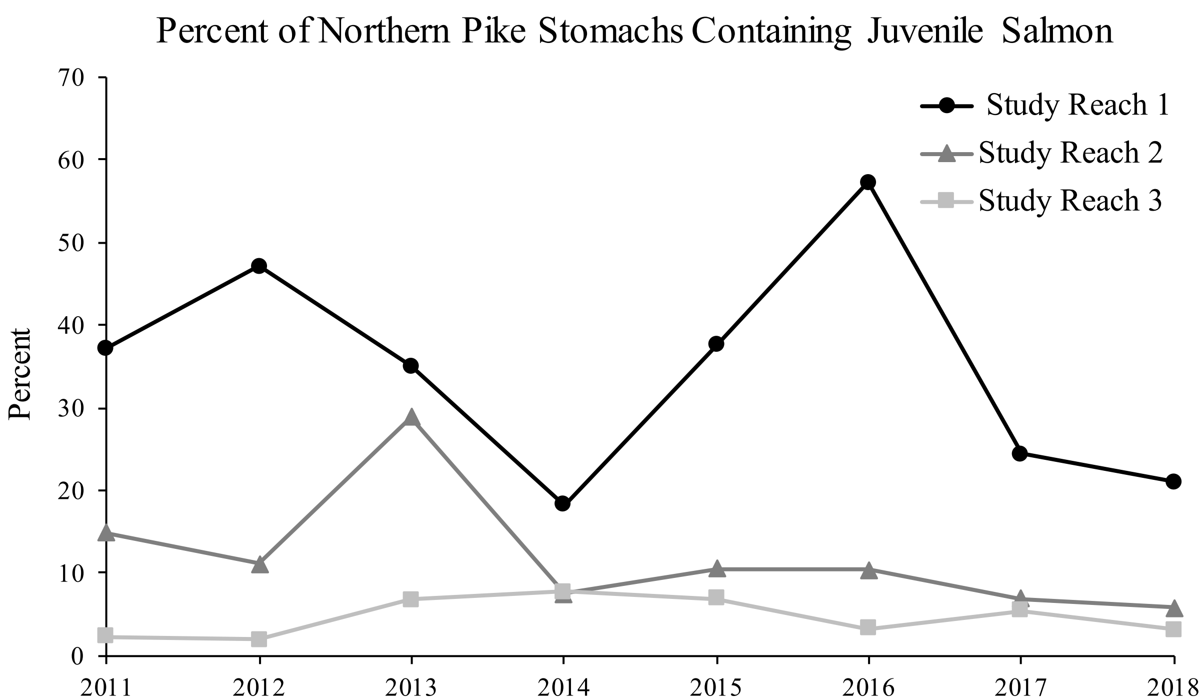

Figure 7.–Percent of northern pike stomachs containing at least 1 juvenile salmon by study reach along Alexander Creek, 2011–2018.

Smaller northern pike had a demonstrably higher consumption rate of juvenile salmon than larger pike (Figure 8). Nearly 25% of examined stomachs from small northern pike (100–200 mm) contained at least 1 juvenile salmon. The smaller size classes had a higher average number of juvenile salmon per stomach, with northern pike in the 201–300 mm size class having the highest average (Figure 8). On average, 1 juvenile salmon was recovered per examined stomach for northern pike in the 201–300 mm size class.

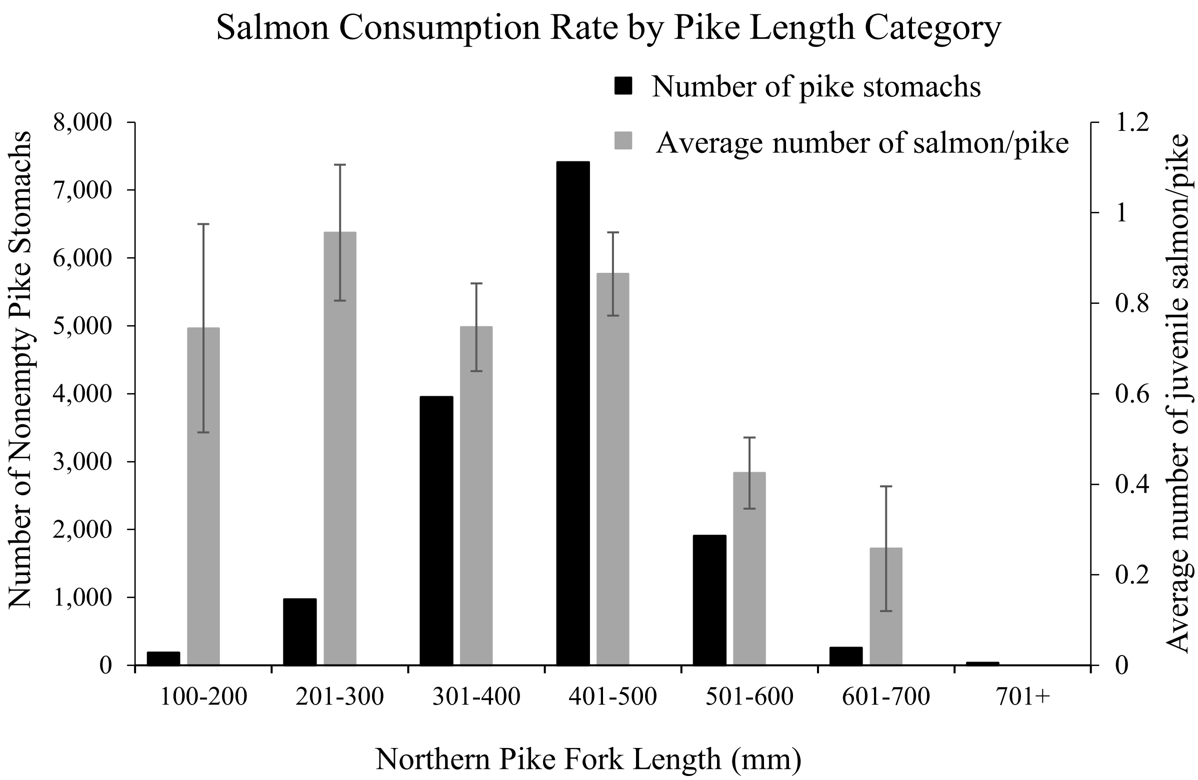

Figure 8.–Length frequency distribution of northern pike captured in Alexander Creek during 2011–2018 with stomachs assessed for content and average number of juvenile salmon (±2 SE) per northern pike stomach by size class.

Secondary Objective 3: Assessment of Bycatch

Northern pike gillnet suppression efforts for the 8 study years yielded a total of 4,645 nontarget animals (bycatch). The predominant nontargeted species captured were Arctic grayling, longnose sucker (*Catostomus catostomus*), and whitefish (which include humpback whitefish *Coregonoeus pidschian* and round whitefish *Prosopium cylindraceum*; Table 9). Bycatch varied from year to year from a low of 205 animals in 2016 to a high of 1,182 in 2013. After accounting for netting effort, there were no obvious trends or patterns of bycatch over time.

Table 9.–Bycatch (nontarget species) of animals captured in gillnets during the northern pike spring suppression efforts on Alexander Creek, 2011–2018.

Year	Arctic grayling	Whitefish	Longnose sucker	Rainbow trout	Burbot	Chinook salmon	Coho salmon	Dolly Varden	Muskrat	Beaver	Vole	Bird	Total
2011	175	175	139	18	12	2	1	0	32	1	1	15	571
2012	593	113	220	52	37	8	0	1	21	2	0	37	1,084
2013	387	211	456	93	7	12	0	3	16	0	0	10	1,195
2014	356	257	101	37	2	3	0	2	10	1	0	17	786
2015	542	121	108	43	6	8	1	0	7	0	1	27	864
2016	92	11	50	19	4	6	3	0	7	0	0	13	205
2017	95	46	80	36	0	0	0	0	4	2	0	14	277
2018	146	13	75	18	4	0	0	0	8	1	0	7	272
Total	2,386	947	1,229	316	72	39	5	6	105	7	2	140	4,645

DISCUSSION AND RECOMMENDATIONS

DISCUSSION

The impacts to salmon of invasive northern pike in Alexander Creek became obvious in the early 2000s. Comparing the index Chinook salmon escapement counts between Alexander Creek (with good northern pike habitat) and the nearby Talachulitna River (without good northern pike habitat), both of which have very similar escapement goals (2,100–6,000 for Alexander Creek and 2,200–5,000 for the Talachulitna River), shows that prior to 2001, the 2 systems were similar, and after 2001, Alexander Creek had distinctly smaller escapements (Figure 9). The differences in the Alexander Creek Chinook salmon escapements were especially obvious by 2003 when every westside Cook Inlet stream with an escapement goal exceeded the upper end of their goals by 15% to 91%. In the same year, the Alexander Creek index fell just under the lower end of the escapement goal. Index counts in Alexander Creek have continued to follow the population trends of the Talachulitna River, however, at much-reduced numbers.

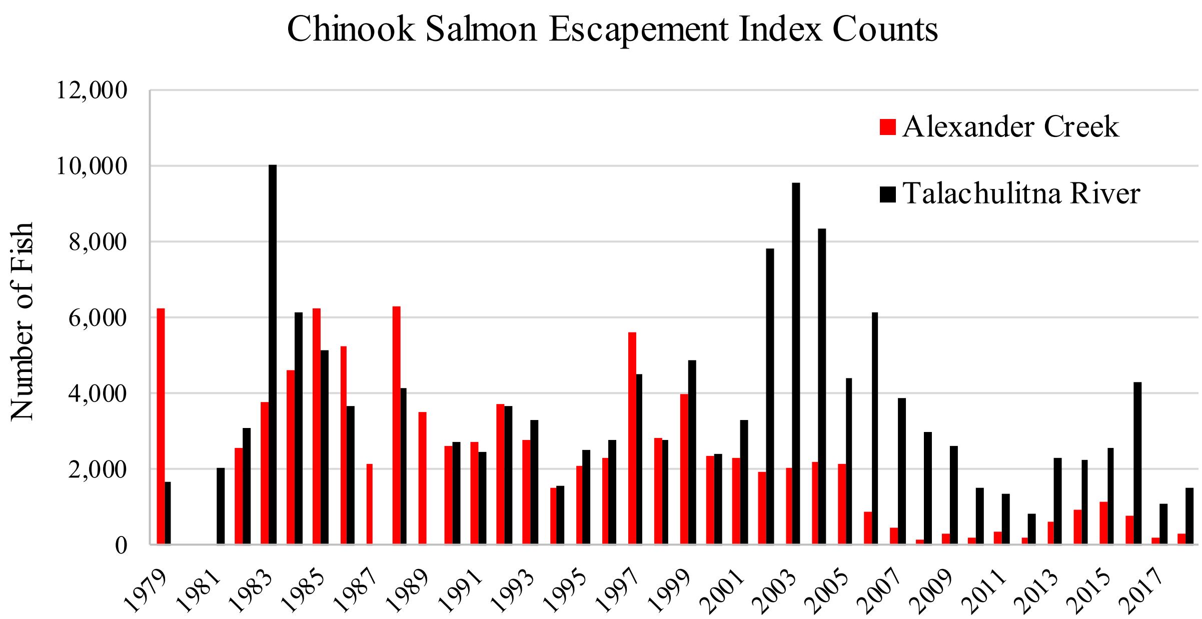

Figure 9.–Adult Chinook salmon escapement into Alexander Creek and the Talachulitna River, 1979–2018.

A study on the effectiveness of gillnetting in removing invasive northern pike from lakes on the Kenai Peninsula demonstrated that catch rates of northern pike could be substantially reduced within 2 years of continuous northern pike suppression (Massengill 2010), although this may just be the case for small lakes with limited northern pike habitat. Northern pike populations in larger systems with more northern pike habitat may be more difficult to suppress. For example, in the Yampa River, Colorado, suppression efforts initially reduced the population of northern pike, but eventually the population stopped decreasing (Zelasko et al. 2016). However, northern pike suppression efforts in Box Canyon Reservoir in Washington resulted in a 98% decrease in relative abundance from 2012 to 2017 (Joe Maroney, Kaslispel Tribe, Spokane, personal communication). Some of that success may be attributed to the fact that their suppression efforts began in March, possibly before most of the northern pike spawned. Bioenergetics modeling of other broad-scale invasive fish control programs, such as the systematic removal of lake trout (*Salvelinus namaycush*) to conserve cutthroat trout (*O. clarki*) stocks in Yellowstone Lake, demonstrates that suppression projects in large systems can dramatically reduce predation pressure on native fishes and bolster their recovery over time (Ruzycki et al. 2003). One challenge with the Alexander Creek northern pike suppression project is that a baseline population estimate for northern pike in Alexander Creek does not exist because it was logistically and financially prohibitive to develop one at the onset of this project. However, without baseline population estimates for northern pike in Alexander Creek, it is now difficult to assess the impact of our suppression efforts on the overall population of northern pike. Our catches show we can reduce the number of northern pike in specific sloughs within a given year. However, with extensive northern pike spawning and rearing habitat in Alexander Creek, it is possible the recruitment rate is near the mortality rate (even with netting), resulting in no change in overall northern pike population numbers between years. 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).

Although the CPUE of northern pike has been variable between years, there has been a steady increase in catch rates since 2015. The reason for this increase is unknown, but it is possible the establishment of another invasive species has something to do with the increase. In 2014, a small patch of the common waterweed elodea (*Elodea canadensis*) was discovered in Alexander Lake. By 2016, about 70% of the lake was infested with dense mats of this aquatic vegetation. Chemical treatments used to eradicate the elodea in 2016 were unsuccessful and to date, both Alexander and Sucker Lakes are completely infested. Prior studies of northern pike movement in the Alexander Creek system had shown little movement of northern pike between Alexander Lake and Alexander Creek (Rutz et al. 2020). However, we speculate the dense mats of elodea have now displaced northern pike from the lake into the creek, which could explain the increase in catch rates.

Although we do not have a population estimate for northern pike in Alexander Creek, we do have other ways of measuring the success of the Alexander Creek northern pike suppression. Numbers of juvenile salmon captured in minnow traps during the study were far below our original expectations, but we did observe some positive trends. The consistent increase in juvenile salmon distribution up the drainage suggests their production and survival rates may be improving, possibly as a result of northern pike suppression efforts. Additionally, overall CPUE rates in the minnow traps, although very low, did increase each year. It will be important for minnow-trapping events to continue and be conducted consistently to evaluate the response of salmonid populations further.

Another positive sign of salmon recovery comes from observations during aerial surveys and net bycatch. Recolonization of historical Chinook salmon spawning areas on Alexander Creek's mainstem, both upstream and downstream of the confluence with Sucker Creek, was observed in 2014–2016 as well as increases in abundance of other salmon species (chum, coho, and pink salmon).

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, and no significant trends were observed. It is possible that the variability may be related to when certain prey are available rather than 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, stomach analysis did show a high relative consumption rate of juvenile salmonids, particularly by smaller northern pike (less than 500 mm). Pervozvanskiy et al. (1988) showed that northern pike account for up to 35% of the stocked Atlantic salmon (*Salmo salar*) smolt mortality in the Keret′ River in Russia. Larsson (1985) found that at least 50% of migrating Baltic salmon (*Salmo salar*) are lost to predation from northern pike during downstream migration. Information obtained from the Por′ya River (Karelian Autonomous Republic, Old Russia) showed that in some years, northern pike consume 30–33% of migrating wild juvenile Atlantic salmon (Smirnov et al. 1977). According to Movchan and Checkenkov (1979), more than 70% of juvenile hatchery salmon released in the Shuya River (White Sea Basin) from the Kem Hatchery are eaten by northern pike. Because stomach content analysis of Alexander Creek northern pike was only conducted for less than 1 month of the year, and all northern pike stomachs were not sampled, it is likely that only a small fraction of the juvenile salmon ingested by northern pike over the course of the study were enumerated. 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).

Given only 8 years of restoration efforts (since 2011) and the fact that Chinook salmon can typically mature and return between 3 and 7 years, it will probably take another 2–4 years before we can demonstrate with confidence that our efforts are having an impact on salmon. Though 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. At the lowest point, Chinook harvest fell to a low of 6% of the historical average in 2008. Given the positive signs observed during this project, it appears the suppression efforts on Alexander Creek are benefiting salmonid production on this system and moving closer toward that goal.

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. This would involve 4 ADF&G technicians operating out of 2 field camps and gillnetting the side sloughs for a fixed unit of time before moving nets. 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). If suppression efforts continue to show promise for salmon and considering that northern pike numbers would probably rebound if suppression efforts were discontinued, we also recommend that a much smaller, cost-effective version of northern pike suppression be continued in perpetuity. This reduced effort would consist of a roving crew of 2 ADF&G technicians gillnetting up to 60 or more side sloughs adjacent or attached to Alexander Creek’s mainstem for a 1-month period commencing in early May. Additionally, a dedicated minnow-trapping event should take place in June so that crews in May can focus on capturing 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.

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 run returning 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 be re-established 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: STOMACH CONTENTS

Appendix A1.–Number of individual food items found in nonempty northern pike stomachs collected during spring suppression in Alexander Creek, 2011–2018.

	Year								
Food item	2011	2012	2013	2014	2015	2016	2017	2018	All years
Juvenile salmon (*Oncorhynchus* spp.)	1,576	1,594	1,298	742	2,021	3,493	297	297	11,318
Rainbow trout (*O. mykiss*)	30	13	28	17	51	52	34	31	256
Whitefish (Coregoninae)	40	25	31	108	32	26	31	6	299
Arctic grayling (*Thymallus arcticus*)	51	112	241	398	198	95	25	19	1,139
Northern pike (*Esox lucius*)	39	6	17	24	5	7	8	7	113
Slimy sculpin (*Cottus cognatus*)	1,266	2,153	5,296	2,351	1,178	1,154	306	453	14,157
Burbot (*Lota lota*)	76	115	105	751	250	152	91	126	1,666
Unknown fish	207	141	416	332	338	219	172	207	2,032
Threespine stickleback (*Gasterosteus aculeatus*)	511	242	1,737	999	857	619	800	1,043	6,808
Other fish [a]	0	0	27	30	53	49	45	48	252
Lamprey (Petromyzontidae)	675	281	1,620	1,319	570	785	770	314	6,334
Leech (Hyrudinea)	540	455	698	758	489	628	199	427	4,194
Snail (Gastropoda)	16	2	14	7	2	5	2	0	48
Scud (Gammaridae)	115	243	115	2,060	85	92	34	8	2,752
Dragonfly (Anisoptera)	205	97	496	471	162	294	131	91	1,947
Damselfly (Zygoptera)	1	0	21	0	1	0	0	1	24
Caddisfly (Trychoptera)	12	0	7	17	5	13	49	1	104
Beetle (Coleoptera)	41	9	29	49	18	10	1	42	199
Macroinvertebrate	98	279	249	74	105	68	48	595	1,516
Wood frog (*Rana sylvatica*)	108	30	39	183	56	50	9	152	627
Rodent (Rodentia)	23	1	0	2	10	0	8	2	46
Nonempty stomachs	1,218	1,109	2,853	2,242	1,511	1,579	793	883	12,118

[a] Other fish include Dolly Varden (*Salvelinus malma*) and longnose sucker (*Catostomus catostomus*).

Appendix A2.–Numbers of stomachs containing particular food items from northern pike collected during spring suppression in Alexander Creek, 2011–2018.

	Year								
Food item	2011	2012	2013	2014	2015	2016	2017	2018	All years
Juvenile salmon (*Oncorhynchus* spp.)	281	273	751	292	366	508	111	124	2,706
Rainbow trout (*O. mykiss*)	29	12	28	17	51	48	30	29	244
Whitefish (Coregoninae)	33	23	30	100	31	26	28	6	277
Arctic grayling (*Thymallus arcticus*)	47	104	212	372	180	93	24	19	1,051
Northern pike (*Esox lucius*)	29	6	17	23	5	7	8	7	102
Slimy sculpin (*Cottus cognatus*)	391	458	1,289	685	440	473	167	175	4,078
Burbot (*Lota lota*)	51	99	97	442	211	140	77	107	1,224
Unknown fish	136	111	314	267	269	176	131	152	1,556
Threespine stickleback (*Gasterosteus aculeatus*)	156	95	676	456	319	281	270	300	2,553
Other fish [a]	0	0	14	21	31	43	38	43	190
Lamprey (Petromyzontidae)	301	168	917	686	349	455	392	197	3,465
Leech (Hyrudinea)	166	136	286	261	225	272	123	153	1,622
Snail (Gastropoda)	4	1	8	3	2	5	2	0	25
Scud (Gammaridae)	27	18	52	59	35	13	4	7	215
Dragonfly (Anisoptera)	51	41	231	181	79	112	82	26	803
Damselfly (Zygoptera)	1	0	17	0	1	0	0	1	20
Caddisfly (Trychoptera)	6	0	4	9	1	5	16	1	42
Beetle (Coleoptera)	30	3	23	26	9	9	1	9	110
Macroinvertebrate	37	77	210	56	41	17	28	121	587
Wood frog (*Rana sylvatica*)	59	24	31	101	45	47	7	83	397
Rodent (Rodentia)	20	1	0	2	8	0	8	2	41
Nonempty stomachs	1,218	1,109	32,853	2,242	1,511	1,579	793	883	12,188

[a] Other fish include Dolly Varden (*Salvelinus malma*) and longnose sucker (*Catostomus catostomus*).