Regional Operational Plan SF.2A.2020.01

Operational Plan: Threemile Lake Invasive Northern Pike Suppression and Chuitbuna Lake Population Assessment

by

Parker Bradley

Cody Jacobson

and

Kristine Dunker

March 2020

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

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

REGIONAL OPERATIONAL PLAN SF.2A.2020.01

OPERATIONAL PLAN: THREEMILE LAKE INVASIVE NORTHERN PIKE SUPPRESSION AND CHUITBUNA LAKE POPULATION ASSESSMENT

by
Parker Bradley
Alaska Department of Fish and Game, Division of Sport Fish, Palmer

Cody Jacobson
Alaska Department of Fish and Game, Division of Sport Fish, Palmer

and

Kristine Dunker
Alaska Department of Fish and Game, Division of Sport Fish, Anchorage

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

March 2020

The Regional Operational Plan Series was established in 2012 to archive and provide public access to operational plans for fisheries projects of the Divisions of Commercial Fisheries and Sport Fish, as per joint-divisional Operational Planning Policy. Documents in this series are planning documents that may contain raw data, preliminary data analyses and results, and describe operational aspects of fisheries projects that may not actually be implemented. All documents in this series are subject to a technical review process and receive varying degrees of regional, divisional, and biometric approval, but do not generally receive editorial review. Results from the implementation of the operational plan described in this series may be subsequently finalized and published in a different department reporting series or in the formal literature. Please contact the author if you have any questions regarding the information provided in this plan. Regional Operational Plans are available on the Internet at: http://www.adfg.alaska.gov/sf/publications/

Parker Bradley,
Alaska Department of Fish and Game, Division of Sport Fish,
1800 Glenn Hwy, Palmer, AK 99645-6736, USA

Cody Jacobson,
Alaska Department of Fish and Game, Division of Sport Fish,
1800 Glenn Hwy, Palmer, AK 99645-6736, USA

and
Kristine Dunker,
Alaska Department of Fish and Game, Division of Sport Fish,
333 Raspberry Rd, Anchorage AK 99518-1599, USA

This document should be cited as follows:
Bradley, P., C. Jacobson, and K. Dunker. 2020. Operational Plan: Threemile Lake invasive northern pike suppression and Chuitbuna Lake population assessment. Alaska Department of Fish and Game, Regional Operational Plan ROP.SF.2A.2020.01, Anchorage.

SIGNATURE/TITLE PAGE

Project Title:	Threemile Lake Invasive Northern Pike Suppression and Chuitbuna Lake Population Assessment
Project leader(s):	Parker Bradley, Cody Jacobson, and Kristine Dunker
Division, Region and Area	Division of Sport Fish, Region II, Palmer Office
Project Nomenclature:	Northern pike, Invasive species, Threemile Lake, Chuitbuna Lake, Population Assessment, Mark-Recapture, Suppression
Period Covered	May 2019 through December 2019
Field Dates:	June 1–20, 2019
Plan Type:	Category II

Approval

Title	Name	Signature	Date
Regional Invasive Species Coordinator	Kristine Dunker		
Project coleader	Parker Bradley		
Project coleader	Cody Jacobson		
Biometrician	Ben Buzzee		
Research Coordinator	Tim McKinley		

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

This project will continue to address the goal of increasing salmon abundance and restoring fisheries in the Threemile Creek drainage by suppression the invasive northern pike population in 2019. Netting and angling will be conducted throughout the drainage to catch northern pike. In addition, a mark–recapture event will be conducted in Chuitbuna Lake to estimate the population size of northern pike, followed by an initial suppression event.

Key words: invasive species, northern pike, *Esox lucius*, Threemile Creek, Chuitbuna Lake

INTRODUCTION

PURPOSE

The mission of the Alaska Department of Fish and Game (ADF&G), Division of Sport Fish (SF) is "to protect and improve the state's recreational fisheries resources," and an objective of the 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 addresses this objective. ADF&G has an aquatic nuisance species management plan (Fay 2002) and an invasive northern pike management plan (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. The activities proposed in this project are aligned with several plans and initiatives, and ADF&G believes this project will provide the first step in a long-term initiative to effectively suppress the invasive northern pike population that has been documented in the Threemile Creek drainage near the Native Village of Tyonek.

BACKGROUND

The northern pike (*Esox lucius*) is an invasive species in Southcentral Alaska that is steadily devastating salmonid populations through juvenile salmon predation in invaded waters (ADF&G 2007). The effects of this are most severe in shallow, slow moving, vegetated lakes and streams where northern pike and rearing salmonids (*Oncorhynchus* spp.) share complete habitat overlap (Sepulveda et al. 2013; Sepulveda et al. 2015). Northern pike are native throughout much of the state but do not naturally occur south and east of the Alaska Range (Figure 1). They were introduced by anglers to the Yentna River drainage in the late 1950s and subsequently spread throughout the Susitna River basin through flood events and further illegal stockings (Mills 1986). Currently, northern pike have been documented from over 120 lakes and rivers in Southcentral Alaska.

More recent, smaller-scale "secondary" northern pike infestations (i.e., originating from the Susitna River basin infestation) have been reported widely in small, coastal-run stream systems throughout the western coast of Cook Inlet (herein referred to as West Cook Inlet). West Cook Inlet is off the road system, sparsely populated, and home to hundreds of small, complex, salmon-producing stream systems. Many reports of northern pike presence have come from sport and subsistence anglers; however, most reports lack live or dead specimens, preventing conclusive identification and knowledge of the extent of infestation.

The Tyonek Tribal Conservation District's (TTCD's) initial northern pike assessments in the West Side Cook Inlet drainages between 2015 and 2017 (Swenson and Hagan *Unpublished* report) documented northern pike from several area waters (Threemile Lake complex, Chuitbuna Lake, and Second Lake), though much uncertainty remains regarding overall northern pike distribution in the region. Based on those assessments, which documented a low species richness of fish in the lakes, and based on observations by members of the community, Threemile Creek drainage was prioritized as the most significantly impacted system in which northern pike were affecting salmon. However, the Chuitbuna Lake and Indian Creek drainage (Second Lake) are also of concern for communities in the area, and control efforts are planned for these water bodies as resources become available. Threemile Creek drainage is located between the communities of Beluga and the Native Village of Tyonek and was historically used for subsistence, sport, and commercial harvest of salmon.

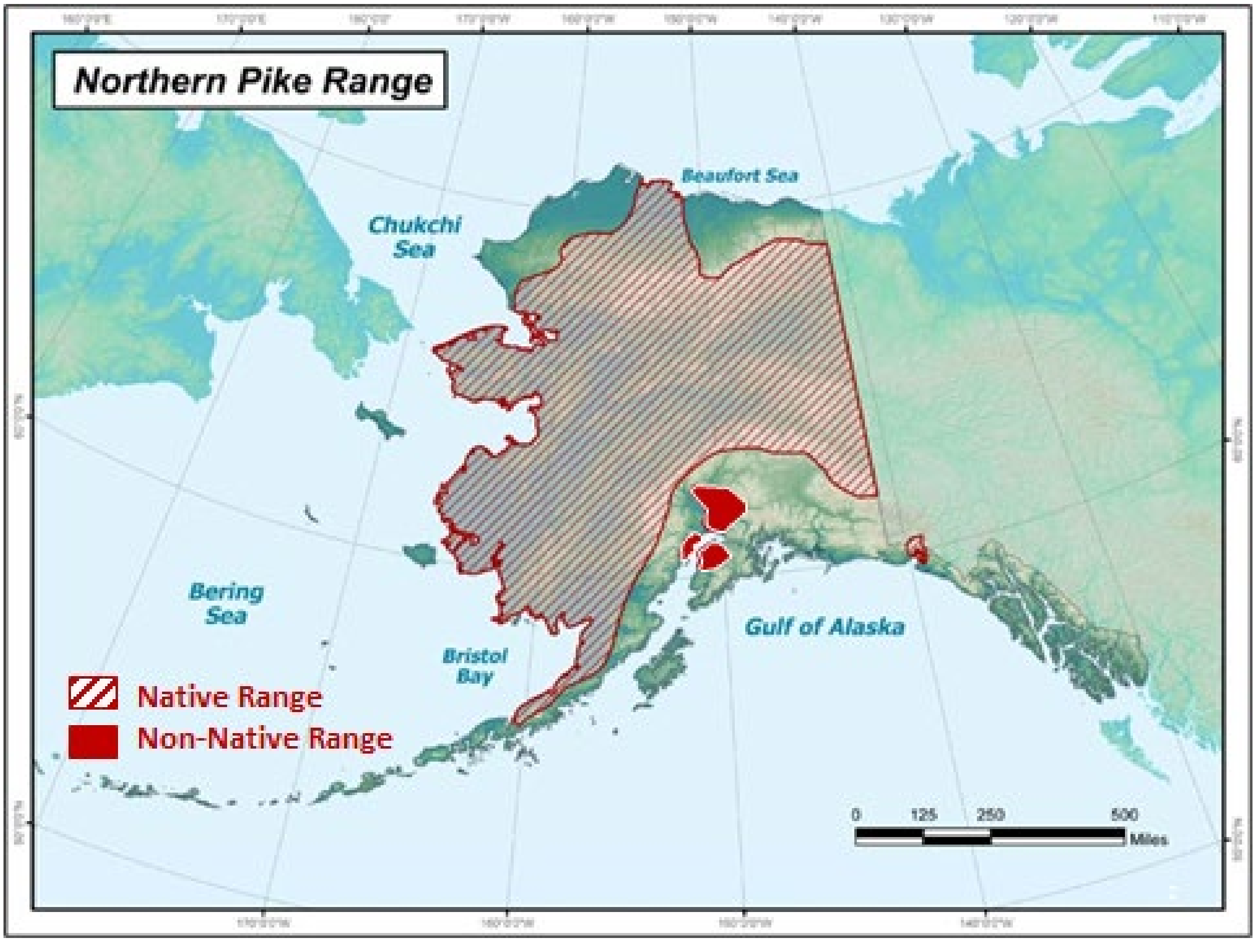

Figure 1.–Northern pike range in Alaska.

The Native Village of Tyonek (NVT) is a Dena'ina Athabascan village located 43 miles southwest of Anchorage along Cook Inlet and is home to approximately 200 people. There are no roads to Tyonek so access is via boat or small aircraft. The remote setting and cultural heritage of NVT makes subsistence activities of paramount importance, and many of these activities focus on salmon. The total subsistence harvest for Tyonek in 2013 was 16,766 pounds of salmon or 118 pounds per capita (Jones et al 2015). Although Threemile Creek is located about 3 miles north of Tyonek, northern pike in that system are suspected of reducing salmon populations in Threemile Creek and therefore decreasing the number of salmon returning along the West Cook Inlet beaches where Tyonek's subsistence fishing occurs. Additionally, the outlet creek of Chuitbuna Lake provides rearing habitat for juvenile coho salmon. With northern pike thriving in the Threemile Creek and Chuitbuna Lake drainages without established containment or control, their potential to continue spreading into surrounding waterbodies in and around Tyonek and into vulnerable drainages along West Cook Inlet remains high without management intervention.

Survey data collected to date suggest the Threemile Creek drainage has been the most severely affected of the surveyed waters. As a result, ADF&G partnered with TTCD and Cook Inlet Aquaculture Association (CIAA) in 2018 to conduct an initial population assessment and suppression event in the Threemile Lake complex which includes Threemile Lake, West Threemile Lake, Lower Lily Pad Lake, and Upper Lily Pad Lake. Results suggest that the initial suppression event successfully removed more than half (57%) of the northern pike population ≥300 mm fork length (FL). This lake complex is a strong candidate for annual invasive northern pike suppression like ongoing efforts in Alexander Creek (Rutz et al. *In prep*). Initiating an effort like this could directly benefit salmon populations and both subsistence and sport fisheries in the Tyonek region. Most importantly, management of this invasive northern pike population might also hinder expansion of northern pike to other vulnerable drainages along West Cook Inlet. In addition to this effort, and because Chuitbuna Lake is easily accessible and contains a northern pike population, ADF&G and TTCD plan to estimate the population size of northern pike in Chuitbuna Lake, assess specific northern pike population characteristics, and begin an initial suppression program.

The long-range goal of the partnership between TTCD, NVT, CIAA, and ADF&G is to reduce the impact of invasive northern pike on rearing salmonids by removing as many northern pike from Chuitbuna Lake and the Threemile Lake complex as possible. Relieving some of the predation pressure on salmon fry and smolt should increase their abundance by contributing to greater survival (Muhlfeld et al. 2008). Over time, greater survival of juvenile salmon may result in larger annual returns of adult salmon that support sport and subsistence fisheries in the TTCD. Increased salmon productivity in the Threemile Creek drainage coupled with reductions in the northern pike population could eventually allow salmonids to recover. In other parts of Alaska where northern pike are native, and even in other drainages in Southcentral where they are not (e.g., the Deshka River), northern pike and salmonids can coexist; however, habitat complexity that allows salmonids opportunities to avoid predators is hypothesized to be a strong factor in mitigating predator-prey interactions within these fish communities (Sepulveda et al. 2013). In the Threemile Lake complex, where the habitat is relatively homogenous providing ideal conditions for northern pike, salmonids are unable to avoid predation and hence their populations can drastically decline (Dunker et al. 2018). Through annual suppression of the northern pike population in this area, the partnership hopes to eventually restore salmonid production to sustainable levels in the Threemile Creek drainage.

To effectively design and implement an annual northern pike suppression program, it is necessary to begin with a baseline estimate of the size of the northern pike population (e.g., Baxter and Neufeld 2015). In 2018, a population estimate was performed in combination with a suppression event that doubled as a recapture event in the Threemile Creek drainage. In Threemile Lake, including Lower Lily Pad Lake, it was estimated there were 1,063 ± 102 (95% CI) northern pike ≥300 mm prior to suppression. The suppression efforts reduced that population by 57%. In West Threemile Lake, it was estimated there were 45 ± 11 northern pike ≥300 mm prior to suppression. The suppression efforts reduced that population by 49%. Finally, in Upper Lily Pad Lake, it was estimated there were 221 ± 70 northern pike ≥300 mm prior to suppression. Suppression efforts reduced that population by 56%. These baseline data will facilitate future evaluation of the suppression program because direct comparisons can be made between this initial baseline and northern pike population levels following periods of suppression. Further, the abundance estimate can be used to model annual removal targets to increase the effectiveness of the suppression program and determine, on an annual basis, if suppression activities are successfully meeting those targets. Because the pilot year for estimating abundance in the Threemile Lake complex was successful, efforts will continue with suppression in that system, and the project will proceed to assess the initial population size of northern pike in Chuitbuna Lake.

OBJECTIVES

This project will lay the foundation from which a long-term northern pike suppression program can be effectively designed and evaluated by estimating the population size of northern pike in Chuitbuna Lake while continuing suppression efforts in the Threemile Lake complex.

PRIMARY OBJECTIVES

1) Estimate the population size of northern pike ≥300 mm FL in Chuitbuna Lake such that the estimate is within 25% of the true population size 90% of the time.
2) Suppress the northern pike population in the Threemile Lake complex using angling and overnight gillnet sets.

SECONDARY OBJECTIVES

1) Calculate the means and determine the ranges of fork lengths (FL) of northern pike in Chuitbuna Lake and the Threemile Lake complex.
2) Document stomach contents, sex, weights, and ages of northern pike in Chuitbuna Lake and the Threemile Lake complex.

METHODS

STUDY AREA

This project will take place in the Tyonek Tribal Conservation District (TTCD). The TTCD shares its boundaries with Alaska Game Management Unit 16B. The District's eastern edge is the Susitna River, its northern and western boundaries are the divide of the Alaska Range, and its southern border is Cook Inlet. Population and infrastructure in the region are limited but centered on the Tyonek-Beluga corridor. The Tyonek-Beluga corridor hosts a population of roughly 200 people and has over 80 miles of unimproved roads and 3 airstrips. Waterbodies in proximity to this small population corridor are classified as the Tyonek Area Watershed (Figure 2). The watershed has 378 lakes and approximately 1,624 river miles of freshwater and is home to all 5 species of Pacific salmon. Juvenile salmonids are preferred prey for northern pike and the negative effects of northern pike infestations on salmonid populations in the region is well documented (Sepulveda et al. 2013).

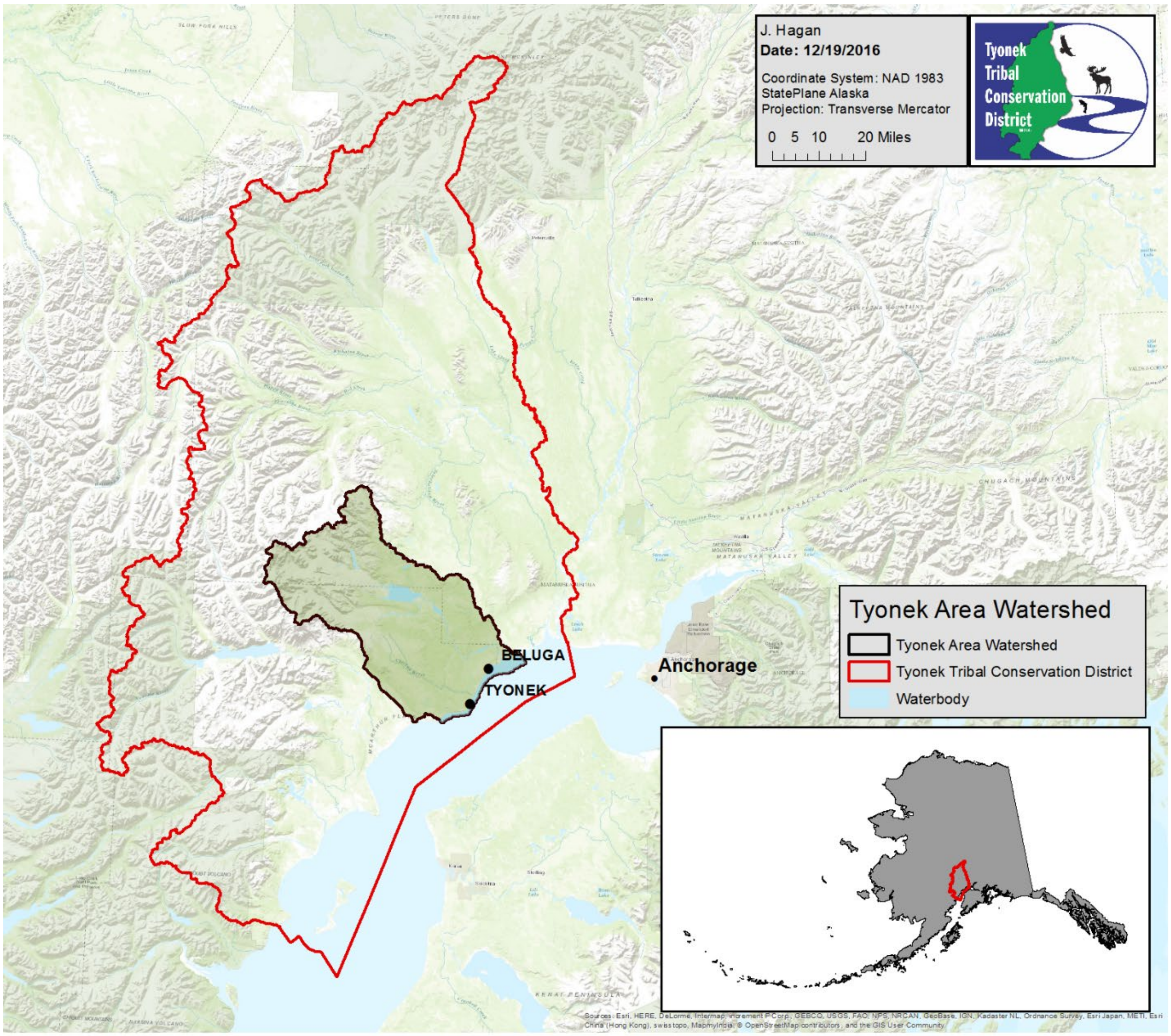

Figure 2.–Map of the Tyonek Area Watershed.

Waterbodies with direct access to the Tyonek-Beluga road system are the most heavily used for sport and subsistence fishing activities. The Threemile Lake complex has several access points including a motorized watercraft launch accessible by all-terrain vehicle (ATV) and is the most heavily used area for sport fishing activities in the region, and Chuitbuna Lake is accessible from the road system (Figure 3). The Threemile Creek watershed is a complex stream system covering 20.4 square miles. There are more than 20 interconnected lakes and several more ephemeral lakes within the watershed. Due to the low-gradient landscape, flooding can connect closed lakes for periods of time and connect off-channel habitat and oxbows. The system is groundwater dominated.

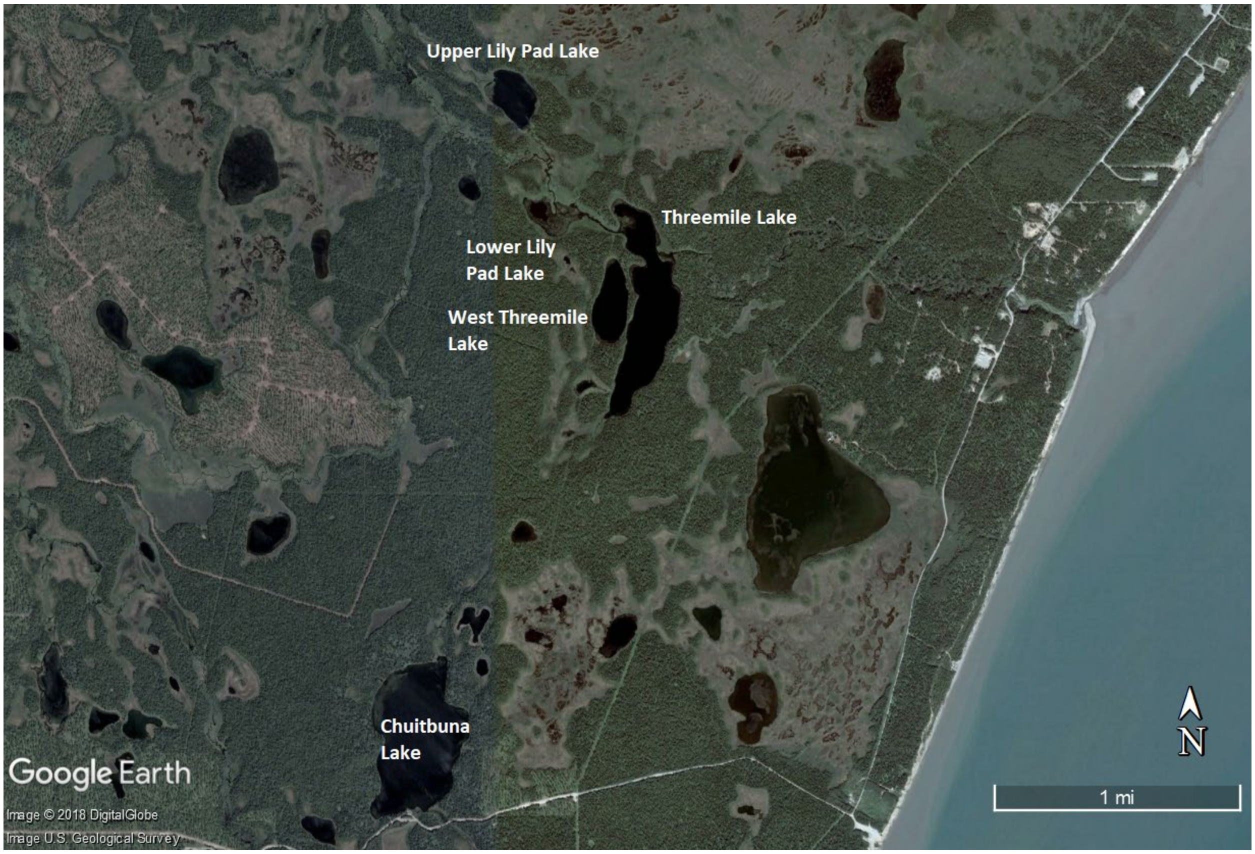

Figure 3.–Map of the study area.

STUDY DESIGN

Chuitbuna Lake Northern Pike Population Estimate

This study is designed to estimate the abundance of northern pike in Chuitbuna Lake (Figure 4) using 2-event Petersen mark–recapture techniques for a closed population (Seber 1982). Such techniques are designed to satisfy the following assumptions:

1) the population is closed (northern pike do not enter the population, via growth or immigration, or leave the population, via death or emigration, during the experiment)
2) all northern pike will have a similar probability of capture during the first event or during the second event, or marked and unmarked northern pike will mix completely between events
3) marking of northern pike will not affect the probability of capture during the second event
4) marked northern pike will be identifiable during the second event
5) all marked northern pike will be reported when recovered in the second event

Failure to satisfy these assumptions may result in biased estimates; therefore, the study is designed to ensure these assumptions are reasonably valid.

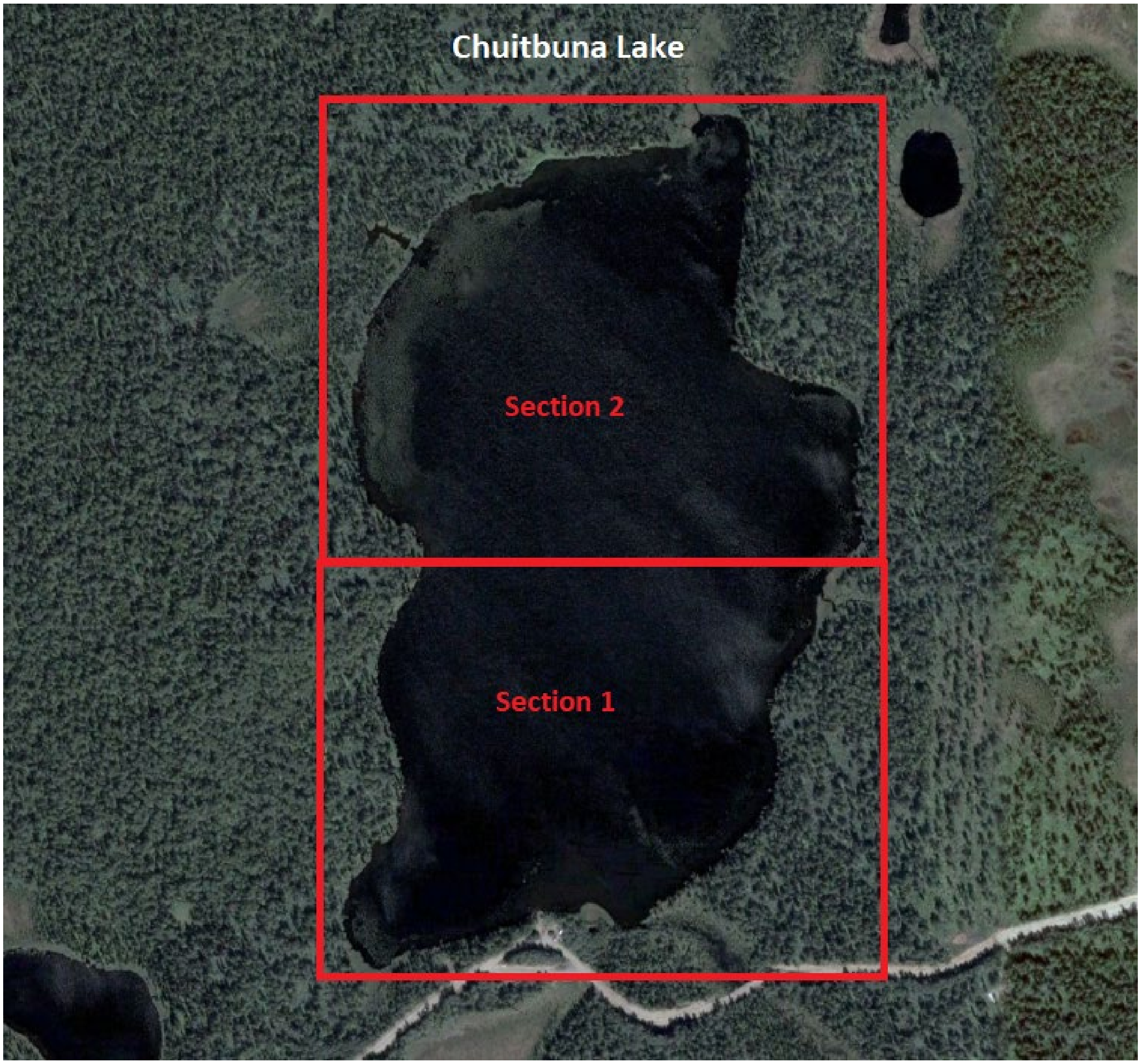

Figure 4.–Chuitbuna Lake divided into 2 sections for the mark–recapture population estimate.

Sampling

Fyke nets will be deployed as a barrier in the outlet of Chuitbuna Lake to prevent immigration and emigration of northern pike during the study and ensure that Assumption 1 is not violated. To aid in the evaluation of assumptions and ensure sampling effort is uniformly distributed, the lake complex has been divided into 2 sections (Figure 4). The mark event will take place during 1–4 June, and the recapture event will take place during 16–20 June.

During the mark event, at least 2 crew members will fish using hook-and-line gear and 2 crew members will deploy and monitor gillnets to sample northern pike for 8 hours each day over the course of 4 days. Up to 10 gillnets will be deployed each day in a given section along the littoral zone. Nets will be distributed uniformly in the littoral zone of each section, and locations will be recorded with GPS for repeatability. Throughout the sampling period, the crew will continuously boat along the nets and remove any northern pike that are captured. If it takes greater than 30 minutes between net checks or northern pike in the nets appear impaired because of time spent in the nets, some of the gillnets may be removed to reduce capture or handling mortality. The angling crew will work in the opposite section from the gillnet crew, and the 2 crews will alternate sections each day so that by the end of the 4 days each section will be sampled twice by both gear types. Captured northern pike will be measured for fork length (FL) in millimeters, and all individuals ≥300 mm FL will be tagged with an individually numbered Floy T-bar tag[1] and released where caught. Floy T-bar tags will be inserted through the proximal pterygiophore at the mid-length of the dorsal fin. A left pelvic fin clip will serve as a secondary mark to control for tag loss. Sample crews will record length and tag number data on the Northern Pike Capture Form (Appendix A1).

An 11-day hiatus will separate the mark event from the recapture event. Mixing of tagged and untagged individuals should occur within this timeframe but this assumption will be tested during data analysis.

Similar methods will be employed during the recapture event except that 20 gillnets will be used, and the gillnets will be left to soak overnight. All captured northern pike will be immediately dispatched and examined for tags. Periodically throughout the day, dispatched northern pike will be brought over to a processing station where 2 crew members will measure each northern pike for fork length and weight, remove the otoliths and cleithrum for ageing, and dissect each northern pike to document stomach contents and sex. These data will be recorded on the Northern Pike Stomach Sampling Form (Appendix A2). Because all northern pike will be killed during this event, the recapture event will serve as the first opportunity to begin suppression of the northern pike population in Chuitbuna Lake. Though the recapture event will allow for opportunistic suppression during this project, a formal suppression plan for future years will be developed after the current project concludes.

The fyke net will remain in place blocking the outlet for the duration of the study and will be monitored daily to ensure it is effectively preventing fish passage.

Evaluation of Mark–Recapture Assumptions

Assumption 1 (the population is closed): It is likely Assumption 1 will not be violated because the outlet of Chuitbuna Lake will be blocked off with a fyke net during this study. In addition, this study will be of short duration, and therefore, growth, recruitment, and mortality will be insignificant. Also, if northern pike are mortally injured during the mark event (e.g., hook through the eye, bleeding gills) or seem unusually stressed, the fish will be sacrificed and processed (see Data Collection) rather than marked.

Assumption 2 (equal probability of capture during an event or mixing between events): We do not know if northern pike will mix completely during the 11-day hiatus between events. However, Assumption 2 will be met if all fish are subject to the same probability of capture during each sampling event. Fishing effort for both anglers and gillnets will be distributed in proportion to the distribution of northern pike. Based on catch rates and visual observations, effort will be increased in areas where densities appear relatively high (e.g., shallow vegetated bays and outlet areas) and decreased where there appear to be few fish available (e.g., deep water zones). Sample sizes are expected to be large enough to provide sufficient power for tests of heterogenous capture probabilities. Differences in capture probability related to fish size, sex, and location will be tested

---

[1] Product names used in this publication are included for completeness but do not constitute product endorsement.

for as described in Appendices B1 and B2. If significant differences are detected, stratified estimates of abundance and its variance will be used.

Assumption 3 (marking does not affect probability of recapture): The hiatus between mark and recapture events should allow marked fish to recover from the effects of handling and marking during the first event; therefore, Assumption 3 should be valid. However, it is unknown if fish captured in gillnets during the mark event will avoid this gear during the recapture event, but the heavy use of hook and line sampling should mitigate such an effect, if it exists.

Assumption 4 (marked fish will be identifiable in the second event): This assumption will be addressed by double-marking each northern pike captured during the first event. Tag loss will be noted when a fish is recovered during the second event with a first-event fin clip but without a Floy tag. In addition, tag placement will be standardized, which will enable the fish handler to verify tag loss by locating recent tag wounds.

Assumption 5 (all marked fish will be reported in the second event): All fish will be thoroughly examined for tags or recent fin clips. All markings (tag number, fin clip, and tag wound) for each fish will be recorded.

Sample Size

As stated previously, the abundance estimate for northern pike in Chuitbuna Lake established through this study will be used to model future northern pike suppression goals. This estimate will also serve as the baseline from which the northern pike suppression activities can be evaluated for their effectiveness. Because no previous estimates of abundance are available, we will use density estimates obtained from Upper Lily Pad Lake—a nearby lake with similar habitat structure—to estimate the potential number of northern pike ≥300 mm in Chuitbuna Lake. In 2018, Upper Lily Pad Lake, with 0.73 miles of shoreline, was initially estimated to have 221 northern pike ≥300 mm or 303 northern pike per mile of shore. If the density of northern pike is similar, then we can expect a population of around 564 northern pike in Chuitbuna Lake (which has 1.87 miles of shoreline). Based on this estimate, 125 fish will need to be sampled during each sampling event to meet the precision criterion of Objective 1 (Robson and Regier 1964).

A reasonable estimate of the number of obtainable samples is based on previous catch rates of northern pike in Chuitbuna Lake and the available man power and allotted time for the project. In 2017, limited gillnetting (250 net hours) resulted in capture of 25 northern pike (0.1 per gillnet hour). In 2018, targeted gillnetting (for 8 hours) resulted in capture of 13 northern pike (1.6 per gillnet hour). Assuming 2017 results are the same for this study, a gillnetting crew fishing 10 gillnets for 8-hour sets per day for 4 days at a rate of 0.1 pike per net hour are likely to catch approximately 32 northern pike. This does not include fish the angling crew will catch (which can sometimes exceed 30 fish per day based on catch rates from this project in 2018). Given these values, a sufficient sample size for both sampling events is anticipated.

Threemile Lake Complex Northern Pike Suppression

Results from initial suppression in 2018 showed a substantial portion (57%) of the population from the Threemile Lake complex could be removed in 10 days. Similar effort will be employed moving forward with the attempt to maintain a level of mortality in the population that exceeds recruitment so the population will decline over time.

Sampling

The sample area has been divided into 6 sections (Figure 5). A total of 20 gillnets will be utilized in this suppression event. For sections 1–4, 20 gillnets will be deployed first in one section, fished overnight, and then moved to the next section the following day. Gillnetting effort will be split between Sections 5 and 6, with each section receiving 10 gillnets that will be set overnight on the same night. After all sections have received an overnight gillnet set (total of 5 nights), the gillnet sets will be repeated as before in each section for a total of 10 nights of netting effort (each section receiving a total of 2 nights of netting). In addition, an angling crew (2–4 people) will sample sections 1–4 and section 6. Anglers will fish each section for 8 hours a day for 2 days, totaling 10 days of angling effort. Section 5 was not productive for anglers in 2018 and thus will not receive angling effort.

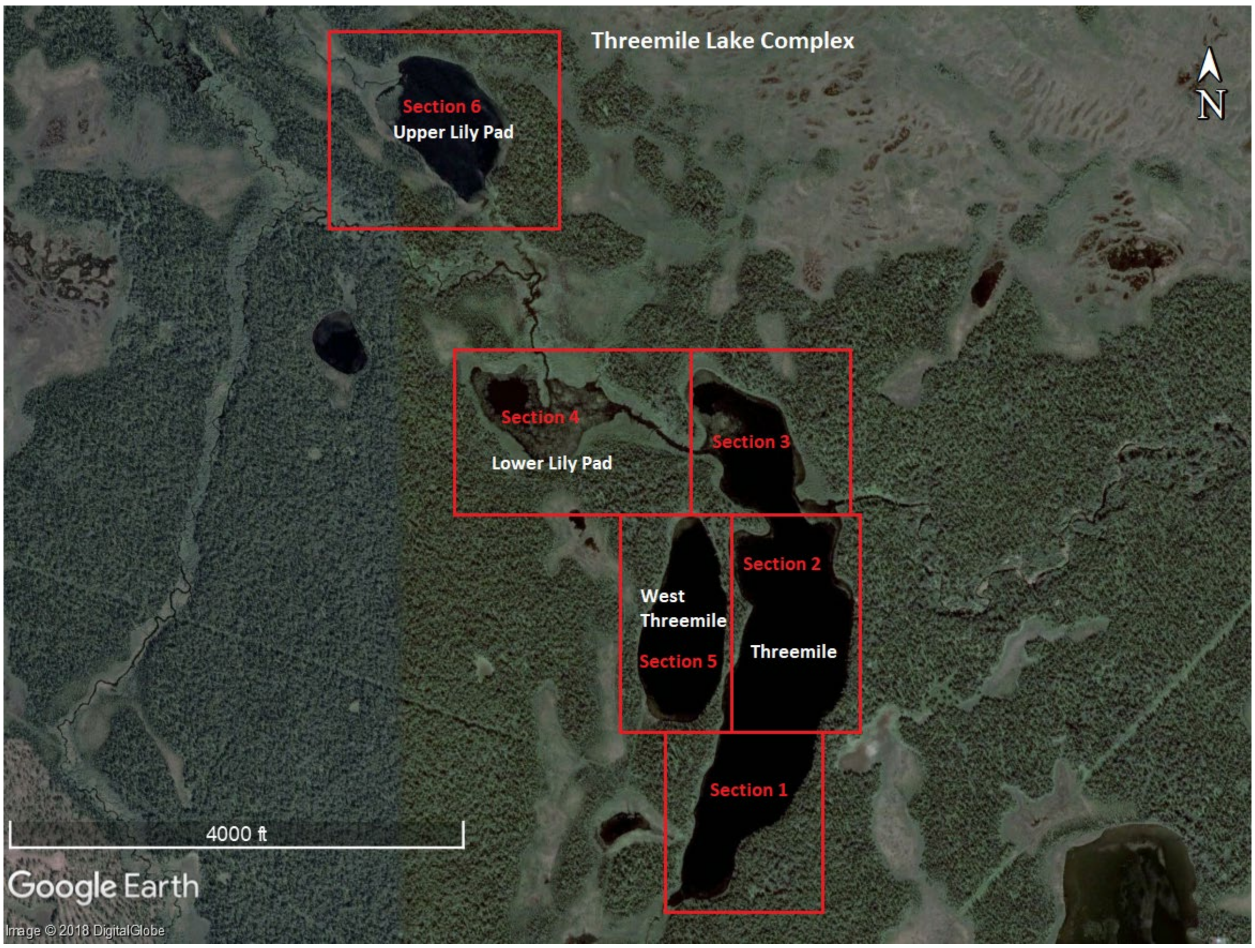

Figure 5.–Threemile Lake complex. Lake sections delineated in red.

All captured northern pike will be immediately dispatched and measured for fork length. Presence of tags from the 2018 mark–recapture study will be noted if present, along with tag number. These data will be recorded on the Northern Pike Catch Form (Appendix A1). Periodically throughout the day, dispatched northern pike will be brought over to a processing station where 2 crew members will measure each northern pike for fork length and weight, remove the otoliths, and dissect each northern pike to document stomach contents and sex. These data will be recorded on the Northern Pike Stomach Sampling Form (Appendix A2).

DATA COLLECTION

Chuitbuna Lake Northern Pike Population Estimate

All capture data will be recorded on water resistant paper following the format in Appendix A1. For each northern pike ≥300 mm FL caught during the mark event, its fork length and tag number will be recorded before being released. Any mark-event northern pike that die during handling and all recapture-event northern pike will be processed for fork lengths, weight, age (by counting annuli on cleithra bones), sex, stomach contents, and examined for a tag or tag loss. All data will be recorded on data sheets (Appendix A2). Also, any northern pike <300 mm FL will be dispatched and processed in the same manner.

Threemile Lake Northern Pike Suppression

All capture data will be recorded on water resistant paper following the format in Appendix A1. Additionally, all captured northern pike will be dispatched and processed for fork lengths, weight, sex, stomach contents, and have otoliths removed. All data will be recorded on data sheets (Appendix A2).

DATA REDUCTION

Data will be transferred from data sheets to Microsoft Excel worksheets for analysis.

DATA ANALYSIS

Chuitbuna Lake Northern Pike Population Estimate

Abundance and its variance will be estimated with the Chapman's modification of the Petersen estimator (Chapman 1951):

$$\hat{N} = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1 \quad (1)$$

and

$$\hat{V}(\hat{N}) = \frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2(m_2 + 2)} \quad (2)$$

where

n_1 = the number of fish marked during the first sampling event;

n_2 = the number of fish examined during the second sampling event; and,

m_2 = the number of fish captured during the second event with marks from the first event.

If tests indicate heterogenous capture probabilities related to size, length, or location, a stratified estimate of abundance and its variance will be used (Appendix B1).

SCHEDULE AND DELIVERABLES

Dates	Activity
May 2019	Purchase equipment and field camp gear Confirm field crews Transfer equipment
June 1–4	Chuitbuna Lake mark event
June 5–15	Threemile Lake complex northern pike suppression Collect northern pike length, weight, sex, stomach data, and otoliths Mixing event for Chuitbuna Lake
June 16–20	Chuitbuna Lake recapture event Collect northern pike length, weight, sex, stomach data, cleithra, otoliths
July 2019	Data entry
Winter 2019	Analyze data and write project report Model future northern pike suppression targets

RESPONSIBILITIES

Kristine Dunker, Fishery Biologist III, ADF&G
Duties: Provide oversight and make recommendations on study designs and project plans; assist with data analysis and project reporting; coordinate and assist with the completion of project deliverables.

Parker Bradley, Fishery Biologist II, ADF&G
Duties: Serve as the primary project biologist; assist with planning and coordinating field logistics; author project report and presentations to the public.

Cody Jacobson, Fishery Biologist I, ADF&G
Duties: Assist with planning and coordinating field logistics and equipment procurement; supervise field activities and technicians.

Ben Buzzee, Biometrician IV, ADF&G
Duties: Provide guidance on study design; assist with postseason data analysis; review project operational plans and reports.

Nicole Swenson, Biologist, Tyonek Tribal Conservation District
Duties: Provide guidance on study design; coordinate field logistics and equipment procurement.

Justin Trenton, Environmental Director, Native Village of Tyonek
Duties: Community outreach, field work, and equipment procurement.

Andy Wizik, Biologist, Cook Inlet Aquaculture Association
Duties: Provide guidance on study design, assist in the field, and procure equipment.

Fish and Wildlife Technician, ADF&G
Duties: Assist with field activities.

REFERENCES CITED

ADF&G (Alaska Department of Fish and Game). 2007. Management plan for invasive northern pike in Alaska. Alaska Department of Fish and Game, Southcentral Northern Pike Control Committee, Anchorage.

Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R. Irvine. 1996. Computer analysis of data from stratified mark−recovery experiments for estimation of salmon escapements and other populations. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2106.

Baxter, J.T., and M. Neufeld. 2015. Lower Columbia River northern pike suppression and stomach analysis – 2014. Final report to Teck Trail Operations, British Columbia Ministry of Forests, Lands, and Natural Resource Operations, 28 pp.

Chapman, D. G. 1951. Some properties of hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics. 1:131–160.

Darroch, J. N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48:241–260.

Dunker, K., A. Sepulveda, R. Massengill, and D. Rutz. 2018. The northern pike, a prized native but disastrous invasive. Pages 356-398 in C. Skov, and P. A. Nilsson, editors. Biology and ecology of pike. CRC Press, Boca Raton, FL.

Fay, V. 2002. Alaska aquatic nuisance species management plan. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Informational Report 5J02-10, Juneau. http://www.adfg.alaska.gov/FedAidpdfs/RIR.5J.2002.10.pdf

Jones, B., D. Holen, and D. S. Koster. 2015. The harvest and use of wild resources in Tyonek, Alaska, 2013. Alaska Department of Fish and Game Division of Subsistence, Technical Paper No. 404, Anchorage.

Mills, M. J. 1986. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report 1985-1986, Project F-10-1(27)RT-2, Juneau. http://www.adfg.alaska.gov/FedAidPDFs/FREDf-10-1(27)RT-2.pdf

Muhlfeld, C. C., D. H. Bennett, R. K. S. B. Marotz, and M. Boyer. 2008. Using bioenergetics modeling to estimate consumption of native juvenile salmonids by nonnative northern pike in the upper Flathead River System, Montana. North American Journal of Fisheries Management 28(3):636-648.

Robson, D. S., and H. A. Regier. 1964. Sample size in Petersen mark-recapture experiments. Transactions of the American Fisheries Society 93:215–226.

Rutz, D. S., and K. J. Dunker. *In prep*. Alexander Creek northern pike suppression 2011–2016. Alaska Department of Fish and Game, Fishery Data Series Report, Anchorage.

Schwarz, C. J., and C. G. Taylor. 1998. Use of stratified-Petersen estimator in fisheries management: estimating the number of pink salmon (*Oncorhynchus gorbuscha*) spawners in the Fraser River. Canadian Journal of Fisheries and Aquatic Sciences 55:281-296.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. 2nd edition. Griffin and Company, Ltd. London.

Sepulveda, A. J., D. S. Rutz, A. W. Dupuis, P. A. Shields, and K. J. Dunker. 2015. Introduced northern pike consumption of salmonids in Southcentral Alaska. Ecology of Freshwater Fish 24(4):519–531.

Sepulveda, A. J., D. S. Rutz, S. S. Ivey, K. J. Dunker, and J. A. Gross. 2013. Introduced northern pike predation on salmonids in southcentral Alaska. Ecology of Freshwater Fish 22(2):268–279.

Swenson, N. and J. Hagan. *Unpublished*. Invasive Northern Pike (*Esox lucius*) in the Tynoek Tribal Conservation District: Field Methods Report, 2017.

APPENDIX A: SAMPLING FORMS

Appendix A1.–Northern pike capture form.

Northern Pike Capture Form 2019							
Lake: Samplers:		Section #		Start Date: Stop Date:			
Net #	GPS	Start Time	Stop Time	Fish Spp.	Fork Length	Tag #	Comments

Appendix A2.–Northern pike stomach sampling form.

Northern Pike Stomach Sampling Form, 2019										
Date:				**Lake:**					**Samplers:**	**Page:**
Number	Tag #	Recap (**R or Blank**)	Section #	Net #	Fork Length (mm)	Weight (g)	Sex (**M, F, U**)	Stomach contents **(Yes/No)**	Stomach Content	Comments about fish or stomach content; deformatie

APPENDIX B: TESTS FOR SELECTIVE SAMPLING AND CONSISTENCY IN MARK–RECAPTURE EXPERIMENTS

Appendix B1.–Detection and mitigation of selective sampling during a 2-event mark–recapture experiment.

Size- and sex-selective sampling may cause bias in 2-event mark–recapture estimates of abundance and size and sex composition. Kolmogorov–Smirnov (KS) 2-sample tests are used to detect size-selective sampling, and contingency table analyses (chi-square tests of independence) are used to detect evidence of sex-selective sampling.

Results of the KS and chi-square tests will dictate whether the data need to be stratified to obtain an unbiased estimate of abundance. The nature of the detected selectivity will also determine whether the first, second, or both event samples are used for estimating size and sex compositions.

Definitions

M = lengths or sex of fish marked in the first event

C = lengths or sex of fish inspected for marks in the second event

R = lengths or sex of fish marked in the first event and recaptured in the second event

Size-Selective Sampling: KS Tests

Three KS tests are used to test for size-selective sampling:

KS Test 1	C vs. R	Used to detect size selectivity during the 1st sampling event. H_o: Length distributions of populations associated with C and R are equal
KS Test 2	M vs. R	Used to detect size selectivity during the 2nd sampling event. H_o: Length distributions of populations associated with M and R are equal
KS Test 3	M vs. C	Used to corroborate the results of the first two tests. H_o: Length distributions of populations associated with M and C are equal

Sex-Selective Sampling: Chi-Square Tests

Three contingency table analyses (chi-square tests on 2 × 2 tables) are used to test for sex-selective sampling (chi-square = χ^2):

X^2 Test 1	C vs. R	Used to detect sex selectivity during the 1st sampling event. H_o: Sex is independent of the C–R classification
χ^2 Test 2	M vs. R	Used to detect sex selectivity during the 2nd sampling event. H_o: Sex is independent of the M–R classification
χ^2 Test 3	M vs. C	Used to corroborate the results of the first two tests. H_o: Sex is independent of the M–C classification

There are several possible results of selectivity testing, their interpretation, and prescribed actions (Table B1-1).

-continued-

Table B1-1.–Possible results of selectivity testing, interpretation, and action.

	KS or χ^2 Test				
Case	M vs. R (2nd event test)	C vs. R (1st event test)	M vs. C (1st vs. 2nd event)	Interpretation and Action	
I	Fail to reject H_o	Fail to reject H_o	Fail to reject H_o	Interpretation:	No selectivity during either sampling event.
				Action:	
				Abundance:	Use a Petersen-type model without stratification.
				Composition:	Use all data from both sampling events.
II	Reject H_o	Fail to reject H_o	Reject H_o	Interpretation:	No selectivity during the 1st event but there is selectivity during the 2nd event.
				Action:	
				Abundance:	Use a Petersen-type model without stratification.
				Composition:	Use data from the 1st sampling event without stratification. 2nd event data only used if stratification of the abundance estimate is performed, with weighting according to Equations B1–B3 below.
III	Fail to reject H_o	Reject H_o	Reject H_o	Interpretation:	No selectivity during the 2nd event but there is selectivity during the 1st event.
				Action:	
				Abundance:	Use a Petersen-type model without stratification.
				Composition:	Use data from the 2^{nd} sampling event without stratification. 1st event data may be incorporated into composition estimation only after stratification of the abundance estimate and appropriate weighting according to Equations B1–B3 below.
IV	Reject H_o	Reject H_o	Either result	Interpretation:	Selectivity during the 1st and 2nd sampling event.
				Action:	
				Abundance:	Use a stratified Petersen-type model, with estimates calculated separately for each stratum. Sum stratum estimates for overall abundance.
				Composition:	Combine stratum estimates according to Equations B1–B3 below.
V	Fail to reject H_o	Fail to reject H_o	Reject H_o	Interpretation:	The results of the 3 tests are inconsistent.
				Action:	Need to determine which of Cases I–IV best fits the data. Inconsistency can arise from high power of the M vs. C test or low power of the tests involving R. Examine sample sizes (generally M or C from <100 fish and R from <30 are considered small), magnitude of the test statistics (D_{max}), and the *P*-values of the three tests to determine which of Cases I–IV best fits the data.

-continued-

Composition estimation for stratified estimates

An estimate of the proportion of the population in the *k*th size or sex category for stratified data with *I* strata is calculated as follows:

$$\hat{p}_k = \sum_{i=1}^{I} \frac{\hat{N}_i}{\hat{N}} \hat{p}_{ik} \qquad \text{(B1)}$$

with variance estimated as

$$var[\hat{p}_k] \approx \frac{1}{\hat{N}^2} \sum_{i=1}^{I} \left(\hat{N}_i^2 \, var[\hat{p}_{ik}] + \left(\hat{p}_{ik} - \hat{p}_k \right)^2 var[\hat{N}_i] \right) \qquad \text{(B2)}$$

where

$\hat{p}_{ik}$ = estimated proportion of fish belonging to category *k* in stratum *i*,

$\hat{N}_i$ = estimated abundance in stratum *i*, and

$\hat{N}$ = estimated total abundance

where

$$\hat{N} = \sum_{i=1}^{I} \hat{N}_i \qquad \text{(B3)}$$

Appendix B2.–Tests of consistency for the Petersen estimator (Seber 1982: p. 438).

Tests of Consistency for Petersen Estimator

Three contingency table analyses are used to determine if the Petersen estimate can be used (Seber 1982). If any of the null hypotheses are not rejected, then a Petersen estimator may be used. If all three of the null hypotheses are rejected, a temporally or spatially-stratified estimator (Darroch 1961) should be used to estimate abundance.

Seber (1982) describes 4 conditions that lead to an unbiased Petersen estimate, some of which can be tested directly:

1) Marked fish mix completely with unmarked fish between events.
2) There is an equal probability of capture in event 1 and equal movement patterns of marked and unmarked fish.
3) There is an equal probability of capture in event 2.
4) The expected number of marked fish in a recapture stratum is proportional to the number of unmarked fish.

In the following tables, the terminology of Seber (1982) is followed, where *a* represents fish marked in the first event, *n* is the number of fish captured in second event, and *m* is the number of marked fish recaptured; $m_{\bullet j}$ and $m_{i\bullet}$ represent summation over the *i*th and *j*th indices, respectively.

I. Mixing Test

Tests the hypothesis (condition 1) that movement probabilities (θ_{ij}), describing the probability that a fish moves from marking stratum *i* to recapture stratum *j*, are independent of marking stratum: H_0: $\theta_{ij} = \theta_j$ for all *i* and *j*.

Area–time	Area–time recapture stratum (*j*)				Not recaptured
marking stratum (*i*)	1	2	…	*t*	$a_i - m_{i\bullet}$
1	m_{11}	m_{12}	...	m_{1t}	$a_1 - m_{1\bullet}$
2	m_{21}	m_{22}	...	m_{2t}	$a_2 - m_{2\bullet}$
...	...	...	...	...	…
s	m_{s1}	m_{s2}	...	m_{st}	$a_s - m_{s\bullet}$

II. Equal Proportions Test[2] (SPAS[3] terminology)

Tests the hypothesis (condition 4) that the marked to unmarked ratio among recapture strata is constant: H_0: $\Sigma_i a_i\theta_{ij} / U_j = k$, where *k* is a constant, U_j is unmarked fish in stratum *j* at the time of 2nd event sampling, and a_i is number of marked fish released in stratum *i*. Failure to reject H_0 means the Petersen estimator should be used only if the degree of closure among tagging strata is constant; i.e., $\Sigma_j\theta_{ij} = \lambda$ (Schwarz and Taylor 1998: p. 289). A special case of closure is when all recapture strata are sampled, such as in a fishwheel to fishwheel experiment, where $\Sigma_j\theta_{ij} = 1.0$, otherwise biological and experimental design information should be used to assess the degree of closure.

-continued-

[2]There is no 1:1 correspondence between Tests II and III and conditions 2–3 above. It is pointed out that equal probability of capture in event 1 will lead to (expected) non-significant Test II results, as will mixing, and that equal probability of capture in event 2 along with equal closure ($\Sigma j\theta ij = \lambda$) will also lead to (expected) nonsignificant Test III results.

[3] Stratified population analysis system (Arnason et al. 1996).

II. Equal Proportions Test (continued)

	Area–time recapture stratum (j)			
	1	2	…	t
Recaptured ($m_{.j}$)	$m_{\bullet 1}$	$m_{\bullet 2}$	…	$m_{\bullet t}$
Unmarked ($n_j - m_{.j}$)	$n_1 - m_{\bullet 1}$	$n_2 - m_{\bullet 2}$	…	$n_t - m_{\bullet t}$

III. Complete Mixing Test (SPAS terminology)

Tests the hypothesis that the probability of resighting a released animal is independent of its stratum of origin: H_0: $\Sigma_j \theta_{ij} p_j = d$, where p_j is the probability of capturing a fish in recapture stratum j during the second event, and d is a constant.

	Area–time marking stratum (i)			
	1	2	…	s
Recaptured (m_i)	$m_{1\bullet}$	$m_{2\bullet}$	…	$m_{s\bullet}$
Not recaptured ($a_i - m_{i\bullet}$)	$a_1 - m_{1\bullet}$	$a_2 - m_{2\bullet}$	…	$a_s - m_{s\bullet}$