Regional Operational Plan No. ROP.SF.3F.2024.07

Estimated Abundance of Northern Pike in the Chatanika River Overwintering Area, 2025

by

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and

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September 2024

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

Symbols and Abbreviations

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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

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This document should be cited as follows:
Albert, M., and M. Tyers. 2024. Estimated abundance of northern pike in the Chatanika River Overwintering Area, 2025. Alaska Department of Fish and Game, Division of Sport Fish, Regional Operational Plan No. ROP.SF.3F.2024.07, Anchorage.

SIGNATURE PAGE

Project Title:	Estimated abundance of northern pike in the Chatanika River Overwintering Area, 2025.
Project leader(s):	Matthew Albert
Division, Region, and Area	Sport Fish, Region 3, Fairbanks
Grant Details/ Project Nomenclature:	F-10-38 R-3-14
Period Covered	15 August 2024–30 June 2025
Field Dates:	19–23 August 2024, 5–30 March, and 8–20 June 2025
Plan Type:	Category II

Approval

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ABSTRACT

Minto Flats, a large wetland complex located approximately 50 km west of Fairbanks, supports the largest sport fishery for northern pike *Esox lucius* within the Arctic-Yukon-Kuskokwim Management Area, as well as a substantial subsistence fishery on an overwintering aggregation of fish near the confluence of Goldstream Creek and the Chatanika River. Information on the abundance of the population present in the Chatanika River Overwintering Area (CROA) during winter is needed to ensure sport and subsistence fishery harvests are sustainable. This project will estimate the abundance and length composition of northern pike ≥600 mm FL for this population.

Key Words: northern pike, *Esox lucius*, Minto Flats, Chatanika River, Minto Lakes, Goldstream Creek, mark-recapture, abundance, radiotelemetry, ice fishing, overwintering, subsistence, exploitation, length composition.

PURPOSE

Current information about the northern pike *Esox lucius* population in Minto Flats is needed to address anticipated regulatory proposal submissions for the January 2026 Alaska Board of Fisheries meeting and assess current exploitation rates. To adequately address regulatory proposals, updated estimates of abundance and length composition are needed for the population of northern pike that overwinters in the Chatanika River Overwintering Area (CROA; Figures 1–2). Northern pike overwintering in the CROA range throughout Minto Flats during summer, and most of the fish occupy the Minto Lakes Study Area (MLSA; Figure 1; Albert et al. 2016; Albert and Tyers *In prep*). During winter months, the CROA supports a popular hook-and-line northern pike subsistence fishery. The same fish are also targeted by sport and subsistence fishers during the open water season. Harvest during the winter subsistence fishery consistently reaches levels that trigger restrictions to the summer northern pike sport fishery in Minto Flats and the Tolovana River drainage (Table 1). The overwintering population of northern pike in the CROA was last assessed in 2018 (Albert and Tyers 2020). Abundance estimates are used to ensure exploitation rates are sustainable in accordance with the Minto Flats Northern Pike Management Plans[1]. From 2019–2022 the annual northern pike exploitation rate exceeded the 20% exploitation rate threshold stipulated by the management plans in 2 of the 4 years. Obtaining a current abundance estimate will allow for assessment of recent exploitation rates to ensure sustainability of this important northern pike fishery. This project will estimate the abundance and length composition of northern pike ≥600 mm FL in the CROA using mark-recapture techniques and radiotelemetry.

BACKGROUND

Minto Flats, a large wetland complex located approximately 50 km west of Fairbanks, supports the largest sport fishery for northern pike within Region 3. The northern pike population in Minto Flats also supports a substantial year-round northern pike subsistence fishery. Fish are harvested with gillnets during the open water season and with hook-and-line gear during the winter. Most of the winter harvest occurs in the Chatanika Harvest Area (CHA) on an overwintering aggregation of fish near the confluence of Goldstream Creek and the Chatanika River (Figure 2, Table 1). Northern pike in Minto Flats are managed under joint sport and subsistence fishery management plans[1]. These plans were developed using stock assessments conducted in the early 1980s and 1990s and stipulate that exploitation rates by all users should not exceed 20% of the population

[1] Minto Flats Northern Pike Management Plan (Sport) 5 AAC 74.044
Minto Flats Northern Pike Management Plan (Subsistence) 5 AAC 01.244

annually. Exploitation rates are defined by harvests from Minto Flats reported by subsistence fishers and by estimated harvests from the annual Alaska Statewide Sport Fish Harvest Survey.

Based on the 2018 CROA, northern pike abundance estimate, annual exploitation rates in 2015–2018 averaged 7.8% of the assessed population (i.e., CROA) and did not exceed 20% in any of those years (Albert and Tyers 2020; Tables 1–2). From 2019–2022, annual exploitation rates averaged 19.8% of the assessed population and exceeded the 20% threshold in 2021 and 2022 (22.8% and 24.5%, respectively; Tables 1–2).

Abundance estimates for northern pike in Minto Flats has varied considerably, and the most recent abundance estimate in 2018 was substantially higher than previous estimates completed in 1996, 1997, 2000, 2003, and 2009 (Table 2; Roach 1997, 1998b; Scanlon 2001, 2006; Joy 2009; Albert and Tyers 2020). Abundance estimation projects are typically conducted every 3–10 years to evaluate exploitation rates of northern pike in Minto Flats. Studies conducted in the late 1980s and early 1990s were designed to estimate the abundance of northern pike in an area that included most of the Minto Flats lake and river complex (i.e., Minto Lakes and associated sloughs, Goldstream Creek, Tolovana, Tatalina, and Chatanika Rivers, as well as Swanneck and Grassy Sloughs; Burkholder 1989, 1990, 1991; Hansen and Burkholder 1992; Figure 1). However, these large open-system experiments were fraught with low sample sizes, limited mixing, size and sex biases, and high water during the spring sampling events.

Based on the difficulties encountered during these early mark-recapture studies, and on radiotelemetry studies conducted by Burkholder (1989) and Roach (1998a), the assessment area and study design for mark-recapture experiments was modified. Beginning in 1996, experiments that estimated abundance of northern pike were done within an assessment area termed the Minto Lakes Study Area (MLSA; Figure 2), and the resulting abundance estimates were used as an index of abundance for the entire Minto Flats wetland complex (Table 2; Roach 1997, 1998b; Scanlon 2001, 2006).

Despite this move to a standardized assessment area, uncertainties in the mark-recapture model assumptions and the subsequent range of inferences remained. To address these uncertainties, a mark-recapture experiment conducted in 2008 examined the MLSA that was assessed from 1996 through 2003 (Area-B), and an expanded region that included the traditional area as well as adjacent connected water bodies (Area-A; Table 2; Figure 2; Joy 2009). The expanded study area represented all the contiguous water bodies within the MLSA during normal water levels. The 2008 study (and associated telemetry research in 2007–2009) determined that utilizing the expanded Area-A was more appropriate because northern pike readily moved between Area-A and Area-B during the open water season (Joy 2009; Albert et al. 2016).

In 2018, based on the improved understanding of the seasonal movements of northern pike that utilize the MLSA during the open water season, Albert and Tyers (2020) modified the experimental methodology to provide overwintering and summer abundance estimates by adding a sampling event in the spring to supplement the 2 summer sampling events (Table 2). Previous radiotelemetry research has shown the majority of northern pike present within the MLSA during the open water season migrate to and overwinter in the Chatanika River between the Murphy Dome Road access point and the Goldstream Creek confluence (Albert et al. 2016; M. Albert, Sport Fish Biologist, ADF&G, Fairbanks, unpublished data). This area has been termed the Chatanika River Overwintering Area (CROA, Figures 1–2). Additionally, a substantial proportion (~25%) of the overwintering fish present in the CROA occupy other areas of the Minto Flats wetland complex outside of the MLSA during the open water season (Albert et al. 2016; Albert and Tyers 2020; Albert and Tyers *In prep*). The 2018 study concluded that the precision of summer MLSA abundance estimates was limited due to small sample sizes of recaptured fish and that an overwintering abundance estimate of northern pike in the CROA was most appropriate for use by fishery managers to assess population trends and exploitation rates.

OBJECTIVES

The primary objectives for 2024–2025 are to:

1. identify the spatial distribution of overwintering radiotagged northern pike ≥600 mm FL in the CROA to guide sampling activities in March 2025;
2. estimate abundance of northern pike ≥600 mm FL (approximately 30 in TL) in the CROA in March 2025 such that the estimate is within 25% of the true value 90% of the time; and,
3. estimate length composition of northern pike ≥600 mm FL captured in the CROA in March 2025 such that the estimated proportions are within 5 percentage points of the true values 95% of the time.

METHODS

STUDY AREA

The MLSA includes all waters (under non-flood conditions) available to northern pike leaving Goldstream Creek via the main interconnecting channel (Figures 1–2). More specifically, this includes all lakes (Big Minto, Upper Minto, Side, Marge, and New), all sloughs (Beaver House, Cancer, and Rotten), the main interconnecting channel (Lake Channel) that drains into Goldstream Creek, and those portions of Goldstream Creek within approximately 2 km of its confluence with Lake Channel. The CROA includes the waters of the Chatanika River downstream from the Murphy Dome access road to its confluence with Goldstream Creek (Figure 2). A general description of the Minto Flats wetland complex is presented by Holmes and Burkholder (1988), Roach (1998a), and Albert et al. (2016).

STUDY DESIGN (OVERVIEW)

To estimate the abundance of northern pike in the CROA, a two-event mark-recapture experiment will be conducted. Marking of fish will occur in the CROA in March 2025, and fish will be captured and examined for marks during June 2025 in the MLSA. To improve sampling efficiency during the marking event, radio tags will be deployed in the MLSA during August 2024 and tracked during March 2025 to identify specific overwintering locations of northern pike in the CROA. Overwintering locations will be identified by aerial and snowmachine radiotelemetry surveys conducted immediately prior to the commencement of the March 2025 marking event.

Radiotelemetry

Radiotelemetry techniques will be used to identify specific overwintering locations of radiotagged northern pike in the CROA. The overwintering locations will be utilized during the marking event (March 2025) of the abundance estimation experiment to maximize sample sizes by focusing sampling effort on areas of the CROA with the highest densities of fish. Overwintering locations will also be used to identify and target smaller, isolated groups of fish to ensure as many fish as possible are subject to capture during the marking event.

Fifty (50) radio tags will be deployed in late August once water temperatures have begun to cool (Albert et al. 2016). The fall migration of northern pike from the MLSA to the CROA does not commence until early October, with most of the outmigration occurring in November (Albert et al. 2016). The ≥60-d hiatus between radio tag deployment and outmigration provides adequate time for fish to recover from post-operative effects prior to migrating to the CROA.

Relative to fish size, radio tags will be apportioned across 2 length strata; 600–719 mm FL and ≥720 mm FL in a 3:1 ratio approximating the length composition of northern pike ≥600 mm FL sampled in the CROA during March 2018 (Albert and Tyers 2020). Radio tags will be deployed throughout the MLSA in a spatially balanced distribution to the extent possible, but a greater importance will be placed on properly distributing tags among size strata.

It is believed that overwintering locations of radiotagged northern pike will be independent of tagging location in the MLSA. Prior radiotelemetry studies of northern pike that inhabit the MLSA and CROA did not report any relationship between an individual fish's summer feeding locations in the MLSA and overwintering location in the CROA the following winter (Albert et al. 2016, Albert and Tyers *In prep*). Northern pike radiotagged within the MLSA in May and June 2007 and August 2016 distributed throughout the CROA the following winter (Figure 3; Joy 2009; Albert et. al. 2016; M. Albert, Sport Fish Biologist, ADF&G, Fairbanks, unpublished data).

Radio Tag Deployment, Equipment, and Telemetry Surveys

Radio tags will be deployed 19–23 August 2024. Fifty (50) coded VHF radio tags (Model MCFT2-3EM, Lotek Wireless Inc., Newmarket, Ontario) with a 364-day operational life will be surgically implanted into northern pike in the MLSA. Radio tags will be surgically implanted using methods described by Hart and Summerfelt (1975) and successfully utilized during previous northern pike radiotelemetry research in Minto Flats (Roach 1998a; Joy 2009; Albert et al. 2016, Albert and Tyers 2020; Albert and Tyers *In prep*).

Northern pike will be primarily captured using common sport fishing tackle and techniques or baited hookless jug lines. Surgical implantation of radio tags will occur immediately upon capture of a suitable fish. Only fish that appear to be in good body condition and are uninjured from capture will receive a radio tag. After surgery, fish will be held in a large 120 L insulated cooler filled with fresh water and released once they have recovered from anesthesia.

Radio tags will be monitored using a combination of aerial and snowmachine radiotelemetry surveys. An aerial survey will be completed in late February 2025 and snowmachine surveys will be conducted immediately before and during the March 2025 marking event. All telemetry surveys will utilize a receiver-datalogger equipped with an internal Global Positioning System (GPS; Model SRX 1200, Lotek Wireless Inc., Newmarket, Ontario). While actively surveying, the receiver-datalogger will record the frequency, unique identification code, signal strength, latitude, longitude, and motion identification code of each radio tag transmission detected.

The aerial survey will be completed with a chartered fixed-wing aircraft, by a pilot and an ADF&G representative who both have experience with aerial telemetry survey techniques and equipment. The aircraft will be outfitted with one directional antenna (Model RA-2AK, Telonics Inc., Mesa, Arizona), commonly referred to as an "H" antenna, fixed to each wing strut (i.e., 2 total "wing" antennas). The aerial survey will focus on the CROA, but to ensure overwintering locations for all live radiotagged fish as well as mortalities are determined, reaches of the Chatanika River upstream and downstream of the CROA, as well as Goldstream Creek, and the MLSA will be surveyed. While recent radiotelemetry studies have not identified overwintering northern pike in the MLSA, it will be surveyed to identify radiotagged fish that did not survive capture and radiotagging, ensuring all instrumented fish are accounted for. It is expected that ≥95% of the radiotagged fish will be detected based on the known movements of northern pike in the Minto Flats wetland complex and the typically shallow (<5 m) water depth of most waterbodies within the complex.

Snowmachine radiotelemetry surveys will be performed by an ADF&G staff member using a receiver-datalogger connected to a dipole (omnidirectional) antenna mounted to the snowmachine. The primary purpose of the snowmachine-based surveys will be to collect fine-scale (≤30 m) location data for radiotagged fish overwintering within the CROA. The snowmachine will be driven slowly (~5–10 mph) on the frozen surface of the Chatanika River while scanning for radiotagged fish. Once a radio tag is detected, the surveyor will switch to a handheld directional ("H" antenna) to determine the radiotagged fish's position as closely as possible.

The accuracy of location data resulting from aerial and snowmachine-based telemetry surveys can vary but will be sufficient for the scope of this study. It is expected that fish locations determined during the aerial survey will be within 500 m of the true location, and those determined via snowmachine surveys will be within 30 m of the true location. These expectations are based on observations from prior northern pike radiotelemetry experiments conducted in Minto Flats and are in line with, or more conservative than, estimates of radiotelemetry error reviewed and presented by Roberts and Rahel (2005) and Heim et al. (2018).

Mark-Recapture Experiment

This experiment is designed to estimate abundance and length composition of northern pike in the CROA during winter using the two-event Petersen mark-recapture model for closed populations (Seber 1982). The abundance estimate generated by this experiment will be germane to the CROA because not all fish from the overwintering area will migrate into the MLSA and be susceptible to capture during the second sampling event. It is assumed that the same proportion of marked and unmarked fish will migrate from the CROA to the MLSA, , resulting in unbiased estimates of abundance and length composition.

The two-event Petersen mark-recapture model for closed populations relies on 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 in either the first or second events, or marked and unmarked northern pike will mix completely between events;
3. marking of northern pike will not affect the probability of capture in the second event;
4. marked northern pike will be identifiable during the second event; and,
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 experiments are designed to allow the validity of these assumptions to be ensured or tested. Sufficient data will be collected to perform diagnostic tests to identify heterogeneous capture probabilities (violations of Assumption 2) and prescribed model selection procedures will be followed in the event of such violations. Diagnostic tests are not available to evaluate Assumptions 1, 3, 4, and 5. Instead, the experiment is designed to ensure that these assumptions will be met thereby avoiding potential biases. The experimental design will ensure that sample sizes will be adequate to meet objective precision criteria and perform reliable diagnostic tests.

During the March sampling event, capture methods successfully used by Joy (2009), Albert et al. (2016), and Albert and Tyers (2020) will be utilized. Fish will be captured with common ice fishing techniques, jigging both unbaited and baited single hook lures through holes drilled in the ice. All captured fish ≥600 mm FL will receive an individually numbered T-bar anchor tag (Model FD-94 Anchor Tag, Floy Tag and Manufacturing Inc., Seattle, Washington), hereafter referred to as a Floy™ tag. Efforts will be made to minimize exposure of captured fish to below freezing air temperatures while they are sampled and marked (<10 s of above ice air exposure). Portable, pop-up ice fishing huts outfitted with a heater and sampling tote will be used as much as possible for fish handling. In the unlikely event that unseasonably cold (<-18°C) air temperatures occur during the March event, all sampling activities will utilize the heated ice fishing huts to minimize stress and harm to the fish, or sampling will be suspended until weather conditions improve.

Sampling during the June event will follow similar protocols to those employed in 1996–1997, 2000, 2003, 2008, and 2018. The MLSA will be sampled by 4 two-person crews. To maximize June sample sizes, sampling effort will be directed to areas within the MLSA containing the highest densities of northern pike. While previous experiments were designed to maximize the probability of attaining equal probability of capture during each event, this experiment's sampling methodology was designed to maximize sample sizes. Unequal capture probability due to spatial selectivity is not a concern, due to the assumption that complete mixing of marked and unmarked fish occurs when they migrate from the CROA to the MLSA during the hiatus between sampling events.

During the June sampling event, crews will use a combination of winged hoop nets (1.06 m diameter hoops with 2.22 cm bar mesh and two 15 m wings), floating multifilament gillnets (210/4 multifilament net twine, 2.54 cm bar mesh, 2.44 m deep, 45.7 m long), baited hook-less jug lines, and common sport fishing tackle and techniques to capture northern pike. Fyke and hoop nets will generally be set at constriction points, such as across sloughs or off prominent shoreline features. Fyke and hoop nets will be checked at least twice daily, once in the evening prior to the end of the workday and again the next morning. The frequency of net checks will be increased if catches are high. In between setting and checking fyke or hoop nets, each crew will also fish 2 gillnets in their daily assigned section. Nets will be checked every 10–20 min depending on catch rates and the condition of captured fish. Within a section, gillnets will be systematically fished by leap frogging nets along the shoreline (e.g. 15–30 m intervals) until the crew's assigned section has been fully sampled over the 8–9 h workday. While gillnets are deployed and monitored, each crew will also use baited hook-less jug lines and standard sport fishing tackle to capture additional fish. The number of fyke and hoop nets assigned to each crew will vary slightly (2–4 of each) depending on the types of available habitats in each section. For example, a crew sampling in a section comprised mainly of "slough" habitats may require additional fyke and/or hoop nets to block off multiple channels.

Evaluation of Assumptions

Assumption 1 (closure): Relative to the assumption of closure, it is expected that a substantial proportion (~25%) of the fish marked in the CROA during the March sampling event will not move into the MLSA and therefore not be susceptible to capture during the June sampling event.

However, the abundance estimates will be germane to the CROA and unbiased if the following conditions are met:

a. *The same proportion of marked and unmarked fish of the population of inference will migrate into the MLSA from the CROA.* This will be assumed. The 2018 experiment did not detect a significant relationship between fish size and migration to the MLSA versus elsewhere in Minto Flats (Albert and Tyers 2020).

b. *Fish will mix completely between the March and June sampling events.* This will be assumed, and is a reasonable assumption to make, because all fish must travel >8 km from the CROA to the MLSA. In 2008 and 2018, fish radiotagged at a single location in the CROA in March were dispersed widely throughout the MLSA when relocated in late May (Figure 4; M. Albert, Sport Fish Biologist, ADF&G, Fairbanks, unpublished data; Albert and Tyers 2020).

c. *There is no immigration, (fish entering Minto Lakes from somewhere other than the Chatanika River overwintering area).* Immigration is expected to be negligible in this case. There has been no recent evidence that indicates northern pike overwinter in the MLSA, or that significant numbers of fish migrate to the MLSA from overwintering areas other than the CROA (Albert et al. 2016; Albert and Tyers 2020; Albert and Tyers *In prep*).

Growth recruitment over the timeframe of the experiment is expected to be negligible or within measurement error (< 10 mm). However, lengths of all recaptured fish will be examined for potential biases caused by growth recruitment (see Data Analysis section).

Mortality related to spawning could potentially occur. It will be assumed that marked and unmarked fish will have similar rates of mortality during the experimental period. As such, abundance estimates will remain unbiased.

Assumption 2 (spatio-temporal influences on capture probability): The planned sampling efforts in the CROA during March may not subject all fish within the area to equal probabilities of capture. Systematically sampling the entire CROA using common ice fishing techniques is not feasible within the fiscal and logistical confines of this study and would likely lead to a decreased sample size due to the heterogeneous spatial distribution of northern pike within the area and minimal movements from mid-winter until break-up (Figure 3; Albert et al. 2016, Albert and Tyers *In prep*). It is assumed that all northern pike that migrate from the CROA to the MLSA will mix completely prior to the June sampling event. Thus, even if capture probabilities vary significantly due to spatial selectivity in both sampling events, Assumption 2 will still be satisfied. During studies conducted in 2007–2009, fish radiotagged in the CROA at 1 or 2 discrete locations distributed widely throughout the MLSA, which indicates that if not complete, very high levels of mixing occur during the spring migration (Figure 4; M. Albert, Sport Fish Biologist, ADF&G, Fairbanks, unpublished data; Albert and Tyers 2020). Similar observations of large-scale dispersal from the CROA to spawning and summer habitats in the MLSA were made by Roach (1998a) between April and June of 1995 and 1996, and by Joy in 2007 (P. Joy, Sport Fish Biologist, ADF&G, 18 December 2007, memorandum).

Assumption 2 (length bias in capture probabilities): During the 2018, experiment some evidence of size-selective sampling was identified for both the March and June sampling events (Albert and Tyers 2020). Small sample sizes of recaptured (m_2) fish limited the detection power of diagnostic tests as well as the ability to appropriately stratify by length when size-selective sampling was detected. Sampling methodology for the current experiment has been modified to increase sample sizes to improve both diagnostic test power and the ability to address identified biases. During the June and August sampling events of the 2018 experiment, capture gear and fish size were examined. No differences in the sizes of fish captured with sport fishing tackle, winged hoop nets, or gillnets were detected, but fish captured using baited hookless jug lines were significantly larger on average (~165 mm larger; Albert and Tyers 2020). Equal probability of capture by size will be examined (see Data Analysis section), and if necessary, a length-stratified model will be used (Appendix A).

Assumption 3 (handling effects on probability of capture in the second or third events): The hiatus between the March and June sampling events (approximately 9–10 weeks) is assumed to be sufficient to allow marked fish to recover from the effects of handling prior to recapture. During the first sampling event (March), fish exposure to below freezing air temperatures will be kept to a minimum. Hooking or capture mortality will be assumed to be very low (i.e., ≤1%), particularly because any captured fish showing any signs of injury or major stress will not be tagged.

Assumptions 4 and 5 (marked northern pike are identifiable upon recapture and all fish are correctly reported): These assumptions will be assured by sampling methods and study design. All northern pike ≥600 mm FL captured in the March event will be double marked using individually numbered Floy™ tags (primary mark) and a partial fin clip (secondary mark). Floy™ tags will be placed at the base of the dorsal fin on the left flank and fin clips will be visible when fish are laid left side up on a measuring board. Fin clips will be specific to sampling events (i.e., left pectoral fin for the first event and right pectoral fin for the second event) and used to identify a recaptured fish in case the primary mark is lost, as well as to prevent resampling within an event. All captured fish will be thoroughly examined for tags and fin clips and all observed markings (tag number, tag color, fin clip, presence of radio tag, and tag wound) will be recorded. Fish that appear to be in poor health will be measured, recorded on the data sheet, and will not receive a primary mark or be included in the mark-recapture experiment.

Sample Size

Radiotelemetry (Objective 1)

Sample sizes related to the radiotelemetry portion of this experiment were determined by fiscal constraints. The observations of Roach (1998a) and the results of previous radiotelemetry research were used to ensure the number of live radiotagged northern pike would be adequate to provide an acceptable representation of the overwintering distribution of northern pike in the CROA (Albert et al. 2016; Albert and Tyers *In prep*). It is expected that no less than 30 (75%) of the 40 fish radiotagged in August 2024 will be alive and present in the CROA in March 2025.

Assuming that radio tags will be deployed randomly throughout the sampled population, the number of radio tags found in a given seasonal use area used by some proportion of the population can be assumed to be Binomially distributed; therefore, the probability of detecting such an area can be estimated using quantiles from a Binomial distribution with a size parameter equal to the number of surviving radiotagged fish, and a probability parameter equal to the proportion of the population considered.

Furthermore, the probability of detecting all or some proportion of seasonal use areas used by a given proportion of the population may be approximated by considering a worst-case scenario of the maximum number of areas to detect. For example, a maximum of 20 areas may be used by at least 5% of the population. Assuming random deployment of tags and mutual independence of the area a fish is later detected in, the number of areas detected may also be assumed to be Binomially distributed.

If at least 30 radiotagged fish are present in the CROA in March 2025, this will provide a 95.8% chance of detecting (that is, observing at least one radiotagged fish in) a given area used by 10% of the population, and at least a 93.6% chance of detecting 90% of the seasonal use areas used by 10% of the population. Detection probabilities are further detailed in Table 3.

Abundance Estimates (Objective 2)

The 2018 abundance estimation experiment included 3 sampling events (March, June, and August). Achieving the desired precision criteria for the CROA abundance estimate for fish ≥600 mm FL necessitated pooling the samples attained in the June and August sampling events. Doing so resulted in an abundance estimate with a relative precision of 0.20 (Albert and Tyers 2020). The sampling methodology of this experiment does not include an August sampling event but has been modified to increase sample sizes in both the March and June sampling events (see Study Design).

The methods of Robson and Regier (1964) for a Petersen mark-recapture experiment were used to estimate sample sizes required to achieve desired objective precision criteria (Table 4). Sample sizes were calculated using the most recent abundance estimate of northern pike ≥600 mm FL in the CROA, as well as hypothetical abundances corresponding to the lower and upper bounds of the 90% CI of the 2018 estimate.

The March and June sample sizes are achievable based on past experiments (Roach 1998b; Scanlon 2006; Joy 2009; Albert and Tyers 2020). Adequate sample sizes were successfully attained in the CROA during the 2018 experiment when 1,237 northern pike ≥600 mm FL received marks in 15 days of sampling effort. Using overwintering locations of radiotagged fish in the CROA to guide the March 2025 capture efforts is expected to result in a sample size greater than that attained in 2018. Similarly, during June 2018 in the MLSA, 404 northern pike ≥600 mm FL were examined in 10 days of sampling effort. That sampling effort was structured and standardized spatially and temporally to ensure equal probability of capture of the fish present in the MLSA. This was done because the 2018 experiment included a June–August MLSA abundance estimate. For the current experiment that will not be necessary because only the abundance in the CROA will be estimated. It is assumed that complete mixing of marked and unmarked fish will occur during the hiatus when fish migrate from the CROA to the MLSA. This will allow the June sampling effort to focus on the areas of the MLSA containing the highest densities of northern pike and is expected to result in a sample size greater than that attained in 2018. If the sample size for the March event is not achieved, the sample size for the June event will need to be increased to ensure precision criteria are met. The subsequent effects to the sample sizes for the June sampling event are outlined in Table 4. If the required sample size for the June event increases substantially, sampling effort will need to be increased.

Length Composition Estimate (Objective 3)

The methods of Thompson (1987) for multinomial proportions were used to calculate the sample size requirement for the length composition estimate. Approximately 509 northern pike ≥600 mm

FL from each sampling event must be sampled to achieve the desired precision criteria when using a non-stratified estimator. This is similar or smaller than the expected sample size needed for the associated abundance estimate (Objective 2) even if data from only one event can be used in the analysis (Table 4; Appendix A).

DATA COLLECTION

Radiotelemetry

Data collected from each radiotagged fish will include:

1) date and time of capture;
2) GPS location (decimal-degree format, WGS 84 datum);
3) radio tag frequency;
4) unique individual radio tag identification code;
5) measurement of fish length to nearest mm FL;
6) type of fin clip;
7) capture method (i.e. baited jig, baited tip-up);
8) any notes pertinent to the surgical procedure; and,
9) any notes of interest (if applicable) including general capture and radiotagging location, capture and handling observations (significant exposure to below freezing air temperatures), significant wounds (present prior to capture or due to capture), overall condition of fish, sex, or tag and/or fin clip scars.

Data items 1–9 will be recorded on data forms printed on Rite in the Rain ® paper (Appendix B1).

During all radiotelemetry surveys, the receiver-datalogger will automatically record date, time, location (decimal-degree format, WGS 84 datum) radio tag frequency, unique individual radio tag identification code, signal strength, and motion identification code. Approximate locations will also be manually transcribed on a printed map.

Recovery of radio tags from northern pike harvested in the sport and subsistence fisheries will rely on voluntary reporting. All pertinent information regarding reports of radiotagged fish that are harvested or found as mortalities will be recorded and entered into a separate worksheet contained within the master Excel workbook (Appendix B2).

Mark-Recapture Experiment

Data collected from all sampled fish will include:

1) date and time of capture;
2) sampling area (CROA, Area-A, or Area-B);
3) GPS location (decimal-degree format, WGS 84 datum);
4) type of capture gear;
5) measurement of fish length to nearest mm FL;
6) if tagged, the number printed on the Floy™ tag and tag color;
7) type of fin clip;
8) if a recapture (as Y or N); and,
9) any notes of interest (if applicable) to include but not limited to general capture location description, significant wounds (already present or due to capture), overall condition of fish, sex (if identifiable), tag and/or fin clip scars, or presence of a radio tag.

Data items 1–9 will be recorded onto data forms printed on water resistant paper (Rite in the Rain® paper, JL Darling LLC, Tacoma, Washington; Appendix B3).

Recovery of marked northern pike harvested in the sport and subsistence fisheries will rely on voluntary reporting. Efforts will be made to inform users participating in the fisheries that marked fish are present in Minto Flats. Informational flyers will be posted in the ADF&G Fairbanks office and distributed with subsistence permits, the Fairbanks and Minto-Nenana Fish and Game advisory committees will be notified of the project, and flyers will be posted on regulatory markers in the Chatanika Harvest Area (similar boundaries as the CROA). When marked fish are reported, department staff will collect as much of the following information as possible:

1) Floy™ tag number;
2) location that harvest occurred;
3) fin clip location on fish;
4) date of harvest;
5) presence of radio tag;
6) if radiotagged, tag frequency and identification number; and,
7) contact information for the individual who reported the harvest.

Data items 1–7 will be recorded on data forms (Appendix B2). Forms and instructions will be provided to frontline staff at the Fairbanks ADF&G office and to the Tanana Area Sport Fish management biologist.

When harvests of marked fish are reported, the primary goal is to determine the Floy™ tag number and location of harvest. Department personnel taking reports of harvested marked fish will forward all information to the project biologist in a timely manner. If additional information is required regarding the reported harvest, and contact information is available, the project biologist will attempt to contact the member of the public who made the report. All pertinent information regarding reports of marked northern pike that are harvested or found as mortalities will be entered into a separate worksheet within an Excel workbook containing all project data.

DATA REDUCTION

Mark-recapture data will be transferred from data forms to Excel worksheets for analysis and archival. Column headings will correspond to headings on attendant data forms (Appendix B1-B3). Additional columns may be added for clarity. Data will be entered, examined for obvious errors, and corrected immediately following the field collection period.

Radiotelemetry data will be imported into an Excel worksheet formatted to be compatible with ArcMap 10.8.2 (Esri, Redlands, CA). After each radiotelemetry survey, the receiver-datalogger will be downloaded and the resulting text file (.csv) will be converted into an Excel file. Tracking data will be sorted by fish. Locations recorded for each detected fish will be sorted by radio tag signal strength and the location corresponding to the highest signal strength will be chosen as the "best" approximation of the fish's true location. Sorted and refined survey data will be merged into a master telemetry Excel worksheet. The worksheet will contain all available information for each radiotagged fish in a single row. Columns in the worksheet will include: radio tag frequency and identification code, date and time of capture, location of capture (decimal-degree format, WGS 84 datum), capture gear, length (mm FL), sex, location during each survey (decimal-degree format, WGS 84 datum), and migratory fate. Assigned migratory fates are defined as:

1) migrated to CROA;

2) migrated to an overwintering location in the Chatanika River outside of the CROA;
3) migrated to an overwintering location in Minto Flats outside of the Chatanika River and CROA;
4) did not migrate, still alive;
5) mortality prior to migration; or,
6) unknown.

Mortalities will be assigned a migratory fate if possible and an additional column will denote the final fate of each radiotagged fish (live, unknown cause of mortality, harvested, or undetermined). For harvested fish, additional columns will include date of harvest, location of capture, and contact information of the fisher who returned or reported the tag. Fish will be declared a mortality if a fish is harvested or if a radio tag indicates no motion has occurred for a period of 24 h in 2 consecutive surveys and the recorded locations for each survey are within a 200 m radius of each other.

Radiotelemetry and mark-recapture data will be combined into one Excel workbook for archival. The resulting file will be saved to the ADF&G Division of Sport Fish Docushare Intranet site and on the project biologist's computer at the ADF&G Division of Sport Fish office in Fairbanks, Alaska. The file name, a description of data contained within the file, and the file location on the Docushare site will be provided in the final Fishery Data Series report.

Selected data and all R code use for operational planning and data analysis will be available in a Github repository, found at https://github.com/ADFG-DSF/MintoPike_MR_Telemetry.

DATA ANALYSIS

RADIOTELEMETRY (OBJECTIVE 1)

Radiotelemetry data will guide March 2025 sampling activities; no further analysis will be conducted. The locations of radiotagged fish detected and deemed alive during March 2025 will be plotted on a map and included in the final FDS report as an appendix.

ABUNDANCE ESTIMATES (OBJECTIVE 2)

Prior to diagnostic testing (Appendix A), the marking and recapture lengths of all recaptured northern pike will be examined for growth-recruitment using paired t-tests at a significance level of 0.05. If significant growth is detected, lengths of sampled fish in the second event will be corrected. If growth is constant between all sizes of fish, growth correction will be done by subtracting the mean growth of recaptured fish from the lengths of all fish captured in the second event. If growth varies by fish size, a regression that allows growth to vary by fish size will be used for second event length corrections (Gulland 1969).

For the abundance estimate, size-selective sampling will be tested using Kolmogorov-Smirnov tests. If stratification by size is required, capture probability will be examined for each stratum, and total abundance and its variance estimate will be calculated by summing strata estimates. These tests and possible actions for data analysis are outlined in Appendix A1. Typically, spatio-temporal violations of Assumption 2 would be evaluated using consistency tests described by Seber (1982; Appendix A2). However, this is not possible or necessary in this study because complete mixing of marked and unmarked fish is expected to occur during the hiatus (see Evaluation of Assumptions). If no stratification is required, the abundance estimate will be calculated using Chapman's (1951) modification of the Petersen estimator. The Chapman estimator will be calculated using:

$$\widehat{N}=\frac{(n_2+1)(n_1+1)}{(m_2+1)}-1 \tag{1}$$

where:

$\widehat{N}$= the estimated abundance of northern pike;

n_1= the number of northern pike marked and released during the first event;

n_2= the number of northern pike examined for marks during the second event; and,

m_2= the number of marked northern pike recaptured in the second event.

The variance of this estimator will be calculated as:

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

LENGTH COMPOSITION (OBJECTIVE 3)

The results from the Kolmogorov-Smirnov tests for size-selective sampling will be used to determine if stratification is necessary and if data from the first, second, or both events should be used for length composition estimates. For cases I–III (Appendix A1), stratification is not necessary and length proportions (25 mm FL categories), and variances of proportions, for northern pike will be estimated using samples from event(s) without size selectivity using:

$$\hat{p}_k = \frac{n_k}{n} \tag{3}$$

where:

$\hat{p}_k =$ the proportion of northern pike that are within length category *k*;

n_k = the number of northern pike sampled that are within length category *k*; and,

n = the total number of northern pike sampled.

The unbiased variance of this proportion is estimated as (Cochran 1977):

$$\hat{V}[\hat{p}_k] = \frac{\hat{p}_k(1-\hat{p}_k)}{n-1}. \tag{4}$$

If diagnostic tests indicate case IV (Appendix A1), there is size-selectivity during both events and data must be stratified to eliminate variability in capture probabilities within strata for at least one or both sampling events. Formulae to adjust length composition estimates are presented in Appendix A1.

SCHEDULES, REPORTS, AND MILESTONES

Project activities and an approximate timeline are given below. Information from this project will be summarized in a Fisheries Data Series (FDS) report.

Date(s)	Project Activity
July 2024	Complete staffing plan, organize, and purchase supplies and equipment for August radio tag deployment.
19–23 August 2024	Deploy 40 radio tags into northern pike in the MLSA.
February 2025	Complete staffing plan for mark recapture experiment, prepare equipment and purchase supplies for March marking event.
4–10 March 2025	Complete aerial and snowmachine surveys of the CROA to locate radiotagged fish.
10–28 March 2025	Marking (first) event. Mark northern pike captured through the ice in the CROA.
May 2025	Prepare equipment and purchase supplies for June recapture event.
17–26 June 2025	Recapture (second) event. Capture and examine northern pike for marks in the MLSA.
August 2025	Data analysis completed.
October 2025	Draft FDS report submitted to project biometrician.
December 2025	Draft FDS report submitted to research supervisor.
March 2025	Final report completed.

RESPONSIBILITIES

Matthew Albert	Fishery Biologist 2, Project Leader Author project operational plan, supervise and assist with field sampling, complete data analysis, and author final report.
Matt Tyers	Biometrician 3 Provide biometric assistance for study design, project operational plan and final report.
James Savereide	Fishery Biologist 4, Research supervisor Review project operational plan and final reports.
April Behr	Fishery Biologist 3, Resident Species Research Supervisor Review project operational plan, final report, and assist with field sampling.
Laura Gutierrez	Fishery Biologist 2 Plan and execute radio tag deployment in August, conduct radiotelemetry surveys, and assist with field sampling.
Andy Gryska	Fishery Biologist 3, Fairbanks Area Management Biologist Review project operational plan and final report and assist with field sampling.
Corey Schwanke	Fishery Biologist 2 Assist with field sampling.
Brian Collyard	Fish and Wildlife Technician 4 Sampling crew leader. Assist with purchasing, field project preparation, logistics, and field sampling.
Joseph Spencer	Fishery Biologist 1 Assist with field logistics and sampling.
Rick Queen	Fish and Wildlife Technician 5 Assist with field sampling.
Matt Stoller	Fish and Wildlife Technician 3 Assist with field sampling.
Hunter Parini	Fish and Wildlife Technician 3 Assist with field sampling.
Vacant	Fish and Wildlife Technician II Assist with field sampling.
Vacant	Fish and Wildlife Technician II Assist with field sampling.
Vacant	Fish and Wildlife Technician II Assist with field sampling.

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TABLES AND FIGURES

Table 1.–Estimated northern pike effort and harvest from Minto Flats reported by sport and subsistence users, 2004–2023. Shaded rows indicate years that subsistence fishery harvest in the CHA exceeded 750 fish and triggered a reduced sport fishery bag and possession limit.

	Sport fishery[a]			Subsistence fishery[bc]					
Year	Angler -days	Catch	Harvest	Permits issued	Permits fished	CHA harvest[d]	Total subsistence harvest[e]	Total harvest by all users	Annual exploitation rate
2004	2,128	21,461	1,389	99	42%	–	393	1,783	–[f]
2005	3,241	16,911	2,052	80	39%	–	386	2,438	–[f]
2006	2,623	8,449	1,206	101	54%	–	865	2,069	–[f]
2007	2,846	14,258	1,839	118	47%	–	1,837	3,646	–[f]
2008	1,330	3,951	387	147	54%	–	1,363	1,749	–[f]
2009	3,263	7,913	873	113	46%	–	563	1,436	–[f]
2010	1,802	8,088	608	96	43%	–	125	734	–[f]
2011	1,485	3,911	422	70	41%	27[g]	110	532	–[f]
2012	1,053	4,481	412	73	48%	243[g]	525	937	–[f]
2013	1,719	3,273	382	77	57%	154[g]	231	613	–[f]
2014	2,126	2,218	597	106	54%	377[g]	478	1,075	–[f]
2015	1,147	4,417	372	120	55%	516[g]	765	1,137	7.7%[h]
2016	714	2,584	196	201	64%	855[g]	1,020	1,216	8.3%[h]
2017	2,590	8,553	589	93	44%	21	137	726	4.9%[h]
2018	826	1,968	390	175	59%	832	1,040	1,430	9.7%[h]
2019	1,751	4,581	746	245	63%	937	1,633	2,379	16.2%[h]
2020	998	1,089	286	329	58%	965	2,005	2,266	15.4%[h]
2021	983	2,839	251	425	63%	1,538	3,092	3,404	23.2%[h]
2022	961	1,149	300	349	60%	1,419	3,299	3,599	24.5%[h]
2023	–	–	–	346	54%	1,199	1,847	–	–
Averages									
2004–2022	1,768	6,426	700	158	52%	644	938	1,623	–
2019–2022	1,173	2,415	396	337	61%	1,215	2,507	2,912	19.8%

Note: The Minto Flats complex includes the lakes and flowing water of Minto Flats, Tolovana River drainage, Lower Chatanika River, and Goldstream Creek. En dash=no data.

[a] *Source*: Alaska Sport Fishing Survey database [Intranet]. 2004–2022. Anchorage, AK: Alaska Department of Fish and Game, Division of Sport Fish (cited May 24, 2024). Available from: https://intra.dsf.dfg.alaska.local/swhs_est/.

[b] *Source* (2004–2021): Ransbury, S. R. and C. M. Gleason. 2022. An overview of Minto Flats northern pike subsistence and sport fisheries: A report to the Alaska Board of Fisheries, January 2023. Alaska Department of Fish and Game, Special Publication No. 22-18, Anchorage.

[c] *Source* (2022–2023): OceanAK: The integrated data system for the Alaska Department of Fish and Game. 2012. ADF&G, Division of Commercial Fisheries, Data Resource Management Staff. https://www.adfg.alaska.gov/analytics/ (accessed August 8, 2024) [ADF&G internal use only].

[d] Chatanika Harvest Area (CHA) fishing location has been documented on permits since 2011. Prior to 2011, fishing occurred in the CHA but fishing location was not specified on permits.

[e] Includes subsistence harvest in the CHA and Minto Flats Complex.

[f.] CROA abundance estimate not available for calculation of exploitation rate.

[g] CHA harvest in 2011–2016 was adjusted using residency information and date of harvest.

[h] Exploitation rate calculated using the 2018 abundance estimate of northern pike ≥600 mm FL in the CROA.

Table 2.–Estimated northern pike abundance in the Minto Lakes Study Area (MLSA), 1996–1997, 2000, 2003, 2008, and 2018 and in the Chatanika River Overwintering Area (CROA), 2018.

Year	≥600 mm FL (~24 in TL) Abundance (SE)	≥720 mm FL (~30 in TL) Abundance (SE)	Citation
1996[a]	7,616 (2,488)	2,389 (779)	Roach 1997
1997[a]	3,251 (348)	671 (73)	Roach 1998b
2000[a]	5,331 (1,152)	1,162 (361)	Scanlon 2001
2003[a]	7,683 (2,347)	1,406 (492)	Scanlon 2006
2008[a]	2,092 (448)	635 (236)	Joy 2009
2008[b]	2,219 (397)	958 (362)	Joy 2009
2018[c]	11,956 (5,836)	–	Albert and Tyers 2020
2018[d]	14,675 (1,631)	3,207 (549)	Albert and Tyers 2020

SE=standard error

[a] Abundance estimates for MLSA Study Area-B (the traditional survey area).

[b] Abundance estimate for MLSA Study Area-A (the expanded survey area including Area-B and additional adjacent water bodies).

[c] Abundance estimate for MLSA Study Area-A.

[d] Abundance estimates for CROA.

Table 3.–Estimated detection probability of a single area, and of multiple areas, used by a given proportion of the population, assuming 30 instrumented fish survive and are detected in the CROA in March 2025 and assuming 1–3 instrumented fish are detected in each area.

		Probability of detecting		
Proportion of population	Detection threshold	Single area	90% of areas	100% of areas
20%	1 fish	99.9%	99.4%	99.4%
10%	1 fish	95.8%	93.6%	64.8%
5%	1 fish	78.5%	16.5%	0.8%
20%	2 fish	98.9%	94.8%	94.8%
10%	2 fish	81.6%	42.7%	13.1%
5%	2 fish	44.6%	0.0%	0.0%
20%	3 fish	95.6%	79.8%	79.8%
10%	3 fish	58.9%	4.0%	0.5%
5%	3 fish	18.8%	0.0%	0.0%

Table 4.–Projected effects to required sample sizes for the June sampling event calculated using the 2018 abundance estimate and the lower and upper bounds of the 90% CI for the estimate at varying expected sample sizes for the March (n_1) sampling event.

	Hypothetical abundance of northern pike ≥600 mm FL in the CROA		
	11,992[a]	14,675[b]	17,358[c]
March (n_1)	Required June sample size (n_2) to achieve precision criteria		
n_1=n_2	698[d]	776[d]	848[d]
700	696	861	1,025
800	608	754	899
900	539	669	799
1,000	483	601	718
1,100	437	544	651
1,200	398	497	596
1,237[e]	385[e]	481[e]	577[e]
1,300	365	457	548
1,400	337	422	507
Expected number of recaptures (m_2)	38–41	39–40	40–41

Note: All required sample sizes to achieve precision criteria were calculated using the methods of Robson and Regier (1964).

[a] Hypothetical abundance at the lower bound of the 90% CI of the 2018 CROA abundance estimate.

[b] 2018 CROA abundance estimate.

[c] Hypothetical abundance at the upper bound of the 90% CI of the 2018 CROA abundance estimate.

[d] Required sample sizes calculated to achieve precision criteria if n_1=n_2.

[e] Required sample sizes calculated to achieve precision criteria if using n_1 from the 2018 experiment.

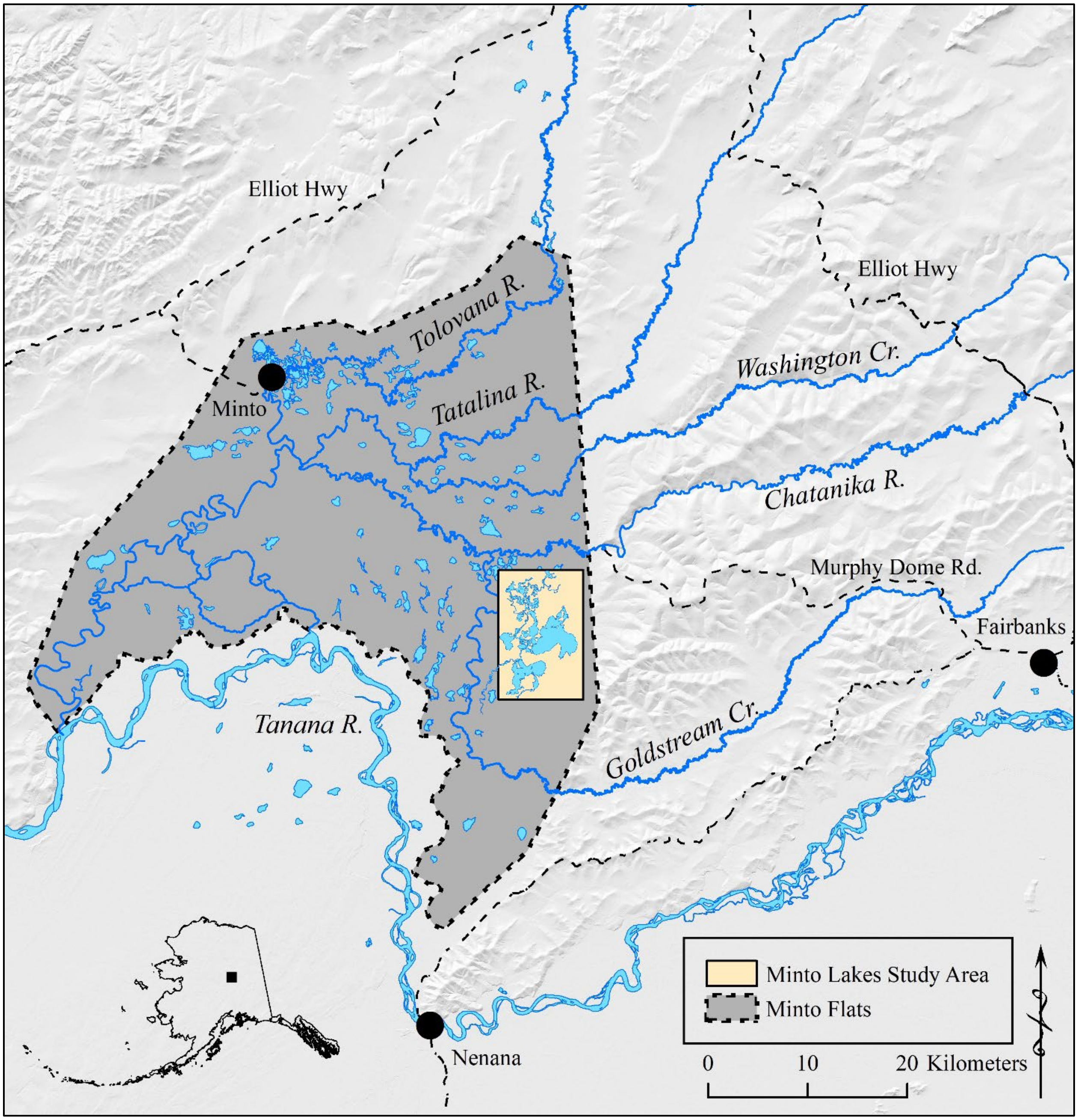

Figure 1.–Map depicting the location of the Minto Lakes Study Area (MLSA) within the Minto Flats wetland complex.

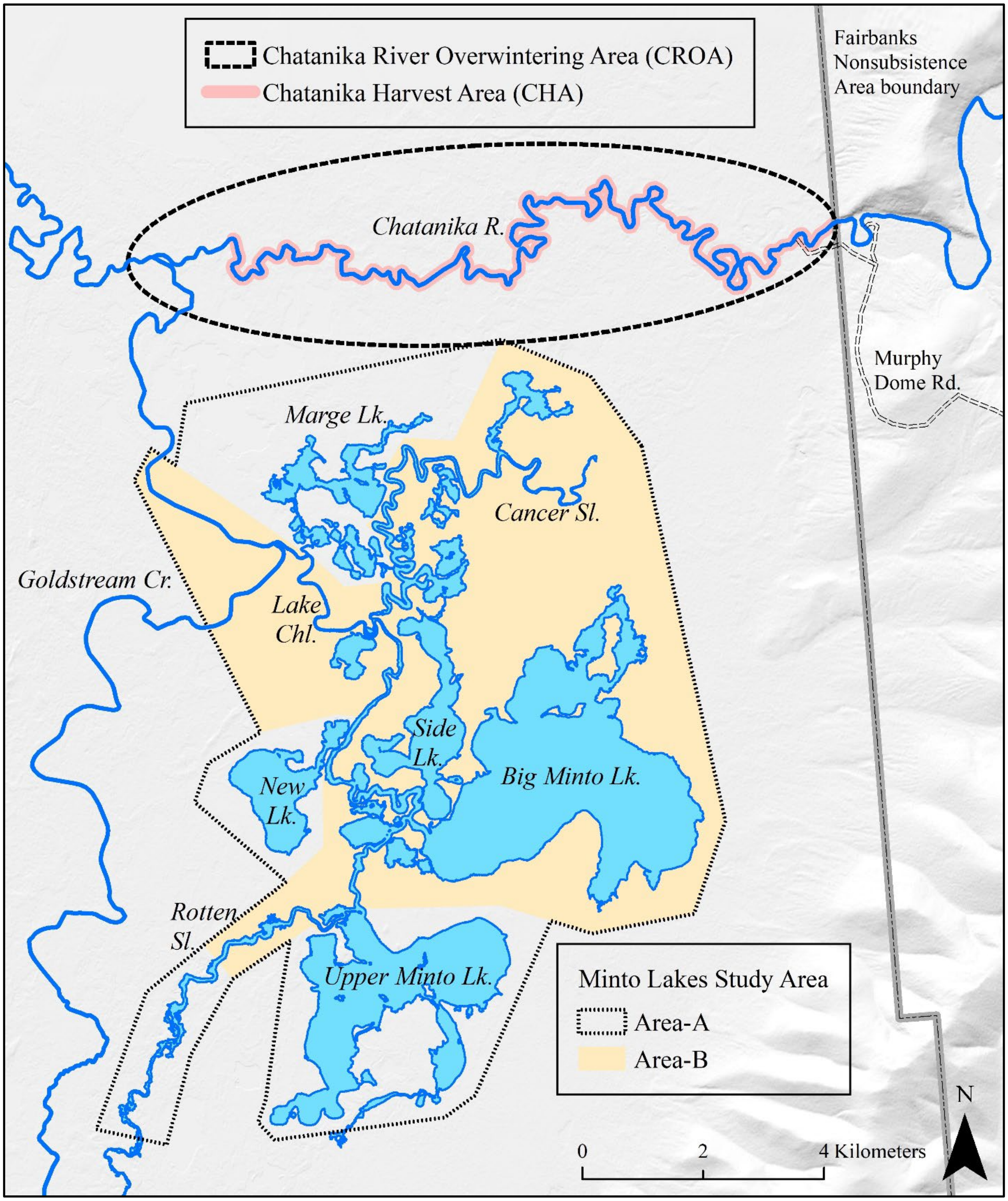

Figure 2.–Map of the Chatanika River Overwintering Area (CROA), Chatanika Harvest Area (CHA), Minto Lakes Study Area (MSLA)-A, MLSA-B, and the major water bodies in the MLSA. The CHA extends from 1 river mile above Goldstream Creek upstream to the Fairbanks nonsubsistence area boundary. Area-B is the historical population assessment area, while Area-A is an expanded assessment area that includes Area-B and adjacent connected water bodies. The Chatanika River flows downstream from right to left.

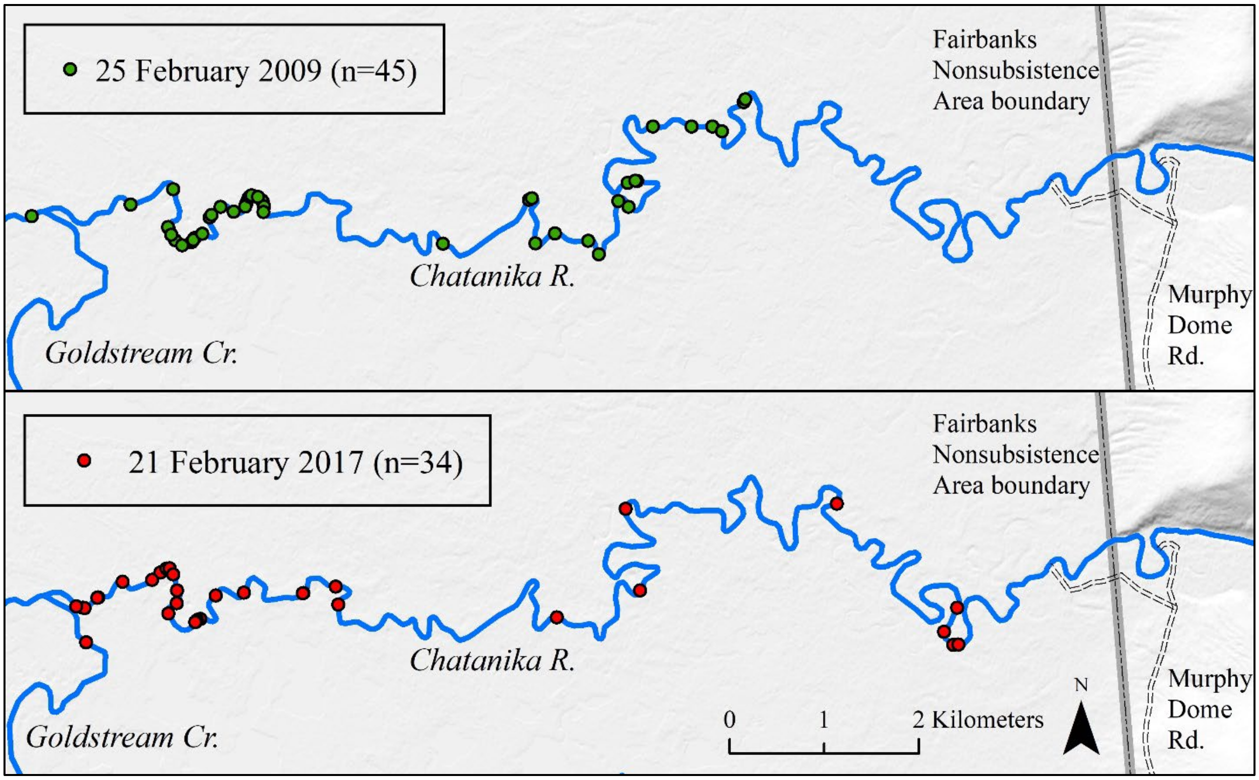

Figure 3.–Map depicting distributions of overwintering radiotagged northern pike within the Chatanika River overwintering area on 25 February 2009 and 21 February 2017. There is one location per individual fish for each year.

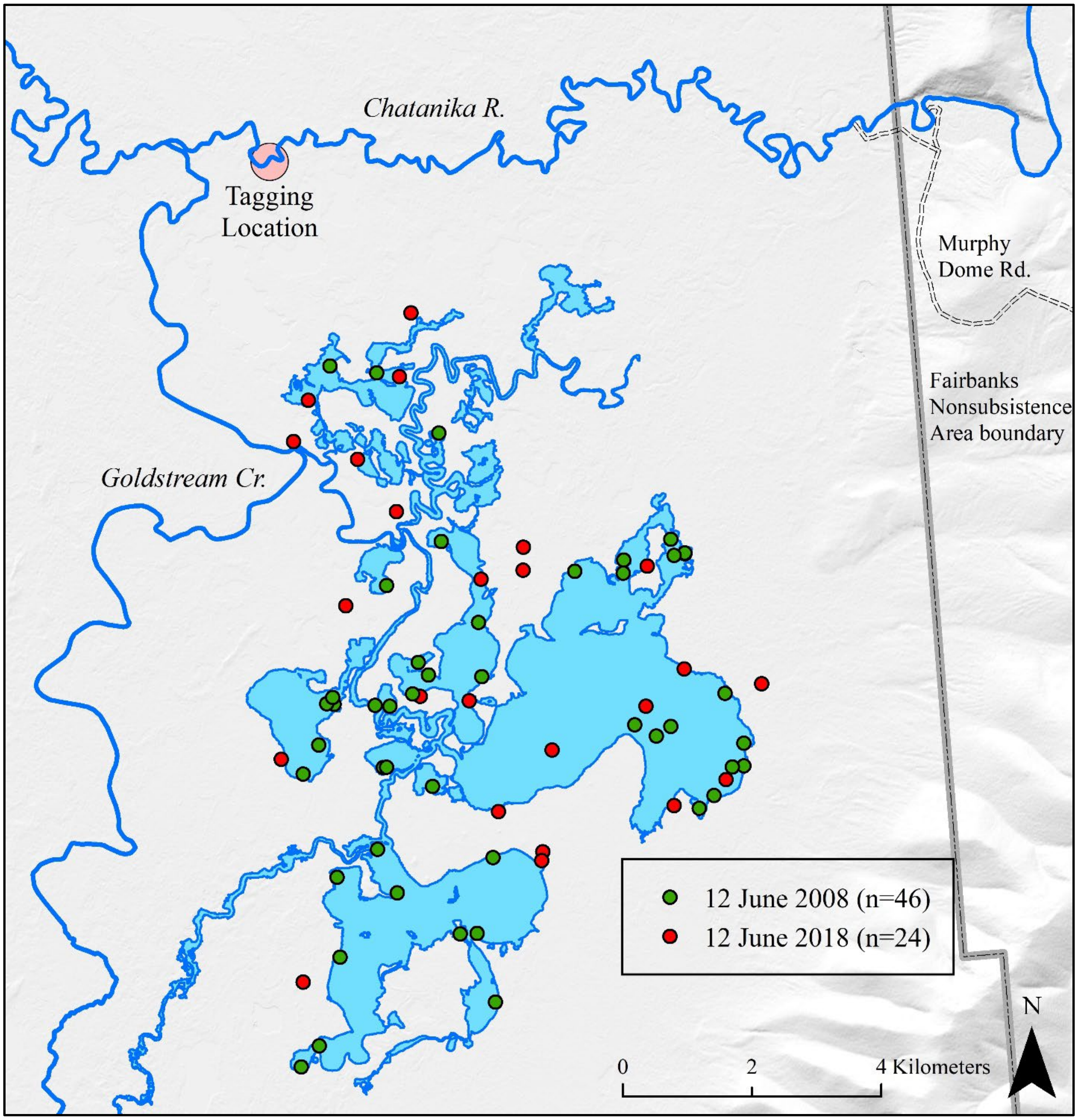

Figure 4.–Map depicting distributions of radiotagged northern pike within the MLSA on 12 June 2008 and 2018. Fish were radiotagged in the Chatanika River from 18–20 March 2008 and 9–13 March 2018. The approximate tagging area is denoted by the rose-colored circle and there is one location per individual fish for each year. Green dots indicate locations observed in 2008 and red dots indicate locations observed in 2018.

APPENDIX A:
STATISTICAL TESTS FOR ANALYZING DATA FOR SEX AND SIZE BIAS

Appendix A1.–Procedures for detecting and adjusting for size or sex selective sampling during a 2-sample mark recapture experiment.

OVERVIEW

Size and sex selective sampling may result in the need to stratify by size and/or sex in order to obtain unbiased estimates of abundance and composition. In addition, the nature of the selectivity determines whether the first, second or both event samples are used for estimating composition. The Kolmogorov-Smirnov two sample (K-S) test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first or second sampling events and contingency table analysis (Chi-square test) is generally used to detect significant evidence that sex selective sampling occurred during the first or second sampling events.

K-S tests are used to evaluate the second sampling event by comparing the length frequency distribution of all fish marked during the first event (M) with that of marked fish recaptured during the second event (R), using the null test hypothesis (H_o) of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during the second event (C) with that of R. Chi-square tests are used to compare the counts of observed males to females between M&R and C&R according to the null hypothesis that the probability that a sampled fish is male or female is independent of the sample. When the proportions by gender are estimated for a subsample (usually from C), rather than observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are compared using a two-sample test (e.g. Student's t-test).

Mark-recapture experiments are designed to obtain sample sizes sufficient to 1) achieve precision objectives for abundance and composition estimates; and, 2) ensure that the diagnostic tests (i.e., tests for selectivity) have power adequate for identifying selectivity that could result in significantly biased estimates. Despite careful design, experiments may result in inadequate sample sizes leading to unreliable diagnostic test results due to low power. As a result, detection and adjusting for size and sex selectivity involves evaluating the power of the diagnostic tests.

The protocols that follow are used to classify the experiment into one of four cases. For each case the following are specified: 1) whether stratification is necessary; 2) which sample event's data should be used when estimating composition; and, 3) the estimators to be used for composition estimates when stratifying. The first protocols assume adequate power. These are followed by supplemental protocols to be used when power is suspect and guidelines for evaluating power.

PROTOCOLS GIVEN ADEQUATE POWER

Case I:

M vs. R	**C vs. R**
Fail to reject H_o	Fail to reject H_o

There is no size/sex selectivity detected during either sampling event. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events.

Case II:

M vs. R	**C vs. R**
Reject H_o	Fail to reject H_o

There is no size/sex selectivity detected during the first event but there is during the second event sampling. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from second event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata.

-continued-

Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case III:

M vs. R	**C vs. R**
Fail to reject H_o	Reject H_o

There is no size/sex selectivity detected during the second event but there is during the first event sampling. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from first event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case IV:

M vs. R	**C vs. R**
Reject H_o	Reject H_o

There is size/sex selectivity detected during both the first and second sampling events. The ratio of the probability of captures for size of sex categories can either be the same or different between events. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

When stratification by sex or length is necessary prior to estimating composition parameters, an overall composition parameters (p_k) is estimating by combining within stratum composition estimates using:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}_\Sigma} \hat{p}_{ik} \text{, and} \qquad \text{(A1-1)}$$

$$\hat{V}[\hat{p}_k] \approx \frac{1}{\hat{N}_\Sigma^2} \left(\sum_{i=1}^{j} \hat{N}_i^2 \hat{V}[\hat{p}_{ik}] + \left(\hat{p}_{ik} - \hat{p}_k \right)^2 \hat{V}[\hat{N}_i] \right) \qquad \text{(A1-2)}$$

where:
- j = the number of sex/size strata;
- $\hat{p}_{ik}$ = the estimated proportion of fish that were age or size k among fish in stratum i;
- $\hat{N}_i$ = the estimated abundance in stratum i; and,
- $\hat{N}_\Sigma$ = sum of the $\hat{N}_i$ across strata.

PROTOCOLS WHEN POWER IS SUSPECT (RE-CLASSIFYING THE EXPERIMENT)

When sample sizes are small, power needs to be evaluated when diagnostic tests fail to reject the null hypothesis. If this failure to identify selectivity is due to low power (that is, if selectivity is actually present) data will be pooled when stratifying is necessary for unbiased estimates. For example, if both the M vs. R and C vs. R tests failed to identify selectivity due to low power, Case I may be selected when Case IV is true. In this scenario, the need to stratify could have been overlooked leading to biased estimates. The protocols outlined in the next section should be followed when sample sizes are small.

Appendix A2.–Tests of consistency for the Petersen estimator (from Seber 1982, page 438).

TESTS OF CONSISTENCY FOR PETERSEN ESTIMATOR

Of the following conditions, at least one must be fulfilled to meet assumptions of a Petersen estimator:

1. Marked fish mix completely with unmarked fish between events;
2. Every fish has an equal probability of being captured and marked during event 1; or,
3. Every fish has an equal probability of being captured and examined during event 2.

To evaluate these three assumptions, the chi-square statistic will be used to examine the following contingency tables as recommended by Seber (1982). At least one null hypothesis needs to be accepted for assumptions of the Petersen model (Bailey 1951, 1952; Chapman 1951) to be valid. If all three tests are rejected, a geographically stratified estimator (Darroch 1961) should be used to estimate abundance.

I.-Test For Complete Mixing [a]

Section	Section Where Recaptured				Not Recaptured
Where Marked	**A**	**B**	**…**	**F**	(n_1-m_2)
A					
B					
...					
F					

II.-Test For Equal Probability of capture during the first event[b]

	Section Where Examined			
	A	**B**	**…**	**F**
Marked (m_2)				
Unmarked (n_2-m_2)				

III.-Test for equal probability of capture during the second event[c]

	Section Where Marked			
	A	**B**	**…**	**F**
Recaptured (m_2)				
Not Recaptured (n_1-m_2)				

[a] This tests the hypothesis that movement probabilities (θ) from section *i* (*i* = 1, 2, ...s) to section *j* (*j* = 1, 2, ...t) are the same among sections: H_0: $\theta_{ij} = \theta_j$.

[b] This tests the hypothesis of homogeneity on the columns of the 2-by-t contingency table with respect to the marked to unmarked ratio among sections: H_0: $\Sigma_i a_i \theta_{ij} = kU_j$, where k = total marks released/total unmarked in the population, U_j = total unmarked fish in stratum *j* at the time of sampling, and a_i = number of marked fish released in stratum *i*.

[c] This tests the hypothesis of homogeneity on the columns of this 2-by-s contingency table with respect to recapture probabilities among sections: H_0: $\Sigma_j \theta_{ij} p_j = d$, where p_j is the probability of capturing a fish in section *j* during the second event, and d is a constant.

APPENDIX B:
DATA FORMS

Appendix B1.–Data form for radio tag deployment.

Date:	Crew:	Daily Page:	Data Page:

Time	Latitude	Longitude	Water Temp C or F?	FL	Freq	Code	Notes

Appendix B2.–Data form for reported radiotagged or marked northern pike.

<table>
<tr><td>Date of Report:</td><td>Report taken by:</td><td colspan="2">Location/Method of report:</td></tr>
<tr><td colspan="4" align="center">Reporter Information</td></tr>
<tr><td colspan="4">Name:</td></tr>
<tr><td colspan="4">Phone:</td></tr>
<tr><td colspan="4">Email:</td></tr>
<tr><td colspan="4">Would like follow-up? (circle one) Yes / No</td></tr>
<tr><td colspan="4" align="center">Radiotagged/Marked Fish Information</td></tr>
<tr><td colspan="3">Date of capture/recovery:</td><td>Fish Length:</td></tr>
<tr><td colspan="3">Recovery Method:</td><td>Fork or total length (circle one)</td></tr>
<tr><td colspan="3">Disposition: (circle one)
Harvested/Mortality or Released/Alive</td><td>Sex: (circle one)
Male or Female or Unknown</td></tr>
<tr><td colspan="3">General Location:</td><td>Floy Tag # and color:</td></tr>
<tr><td colspan="3">Latitude:</td><td>Radio tag frequency:</td></tr>
<tr><td colspan="3">Longitude:</td><td>Radio tag code:</td></tr>
<tr><td colspan="4">Notes or observations:</td></tr>
</table>

Appendix B3.–Data form for sampling northern pike during mark-recapture experiment events.

Date:		**Area:**		**Crew:**		**Daily Page:**		**Data Page:** **(for Albert, leave blank)**
Time	**Lat**	**Long**	**Gear**	**FL (mm)**	**Tag #**	**Fin Clip**	**Recap (Y/N)**	**Notes**