Fishery Data Series No. 09-79

Estimated Abundance of Northern Pike in Minto Lakes, 2008

by

Phil Joy

December 2009

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)

Measures (fisheries)	
fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

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

FISHERY DATA REPORT NO. 09-79

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ABSTRACT

A two-event mark-recapture experiment was conducted on northern pike *Esox lucius* in Minto Lakes, Alaska during June 2008. Abundance was estimated for two areas; Area-A that included all water bodies that drained into Goldstream Creek from the Minto Lakes and Area-B, the historical assessment area that is a subset (approximately 64%) of Area-A waters. Fish were sampled and marked between May 29 and June 7, 2008 and recaptured from June 11 to June 20, 2008. Gear used included hoop nets, fyke nets, gillnets, and hook-and-line. The abundance estimate for Area-A was 16,045 northern pike ≥400 mm FL (SE = 3,132) with a 95% confidence interval from 9,906 to 22,185. For northern pike ≥600 mm FL the estimate was 2,219 (SE = 397), and for fish ≥725 mm FL the estimate was 958 (SE = 362). The abundance estimate for Area-B was 9,854 northern pike ≥400 mm FL (SE = 1,701) with a 95% confidence interval from 6,521 to 13,187. For fish ≥600 mm FL the estimate was 2,092 (SE = 448), and for fish ≥725 mm FL the estimate was 635 (SE = 236). There were significantly less northern pike in Area-B than in past years for all size classes except for fish ≥725 which were statistically similar to past estimates. Bias in estimates are discussed and it is recommended that future stock assessment projects attempt to sample all of Area-A. Calculated exploitation rates appeared to be at or near the 20% threshold set forth by the management plan.

Key words: northern pike, abundance, length distribution, Minto Lakes, Minto Flats, mark-recapture.

INTRODUCTION

The Minto Flats (approximately 50 km west of Fairbanks; Figure 1) support the largest sport fishery for northern pike *Esox lucius* within Region III of the Division of Sport Fish, and a substantial winter subsistence fishery that occurs primarily on an overwintering aggregation of fish at the confluence of Goldstream Creek and the Chatanika River (Figure 1). Based on stock assessment studies conducted in the early 1980s and 1990s, a management plan (5 AAC 70.035) was enacted in 1998 by the Alaska Board of Fisheries. The plan mandates that the exploitation rate for the population of the entire flats complex may not exceed 20% annually. To evaluate annual exploitation rates, periodic (once every 3–5 years) mark-recapture experiments are conducted to estimate abundance.

The Minto Flats wetland complex is located approximately 50 km west of Fairbanks, Alaska within the Tanana River drainage (Figure 1). This area (~200,000 ha) of marshes, lakes and boreal forest is interconnected by numerous sloughs and five rivers: Goldstream Creek and the Chatanika, Tatalina, Tolovana, and Tanana rivers (Figure 1). Except for the Tanana River, these rivers are slow flowing and meandering. The Tanana River is a large, glacial river that delineates the southern boundary of the flats and is the primary water source for Swanneck Slough. The lakes of Minto Flats are generally shallow and contain large areas of aquatic vegetation that grow over the course of the open water season. Summer habitat within the study area for northern pike covers approximately 6,000 ha (Holmes and Pearse 1987). In addition to northern pike, least cisco *Coregonus sardinella*, humpback whitefish *C. pidschian*, broad whitefish *C. nasus*, round whitefish *Prosopium cylindraceum*, sheefish *Stenodus leucichthys*, Arctic grayling *Thymallus arcticus*, burbot *Lota lota*, longnose sucker *Catostomus catostomus*, blackfish *Dallia pectoralis*, slimy sculpin *Cottus cognatus*, and lake chub *Couesius plumbeus* area found in Minto Flats. Chinook salmon *Oncorhynchus tshawytscha*, chum salmon *O. keta*, and coho salmon *O. kisutch* pass through parts of Minto Flats during migrations to riverine spawning areas.

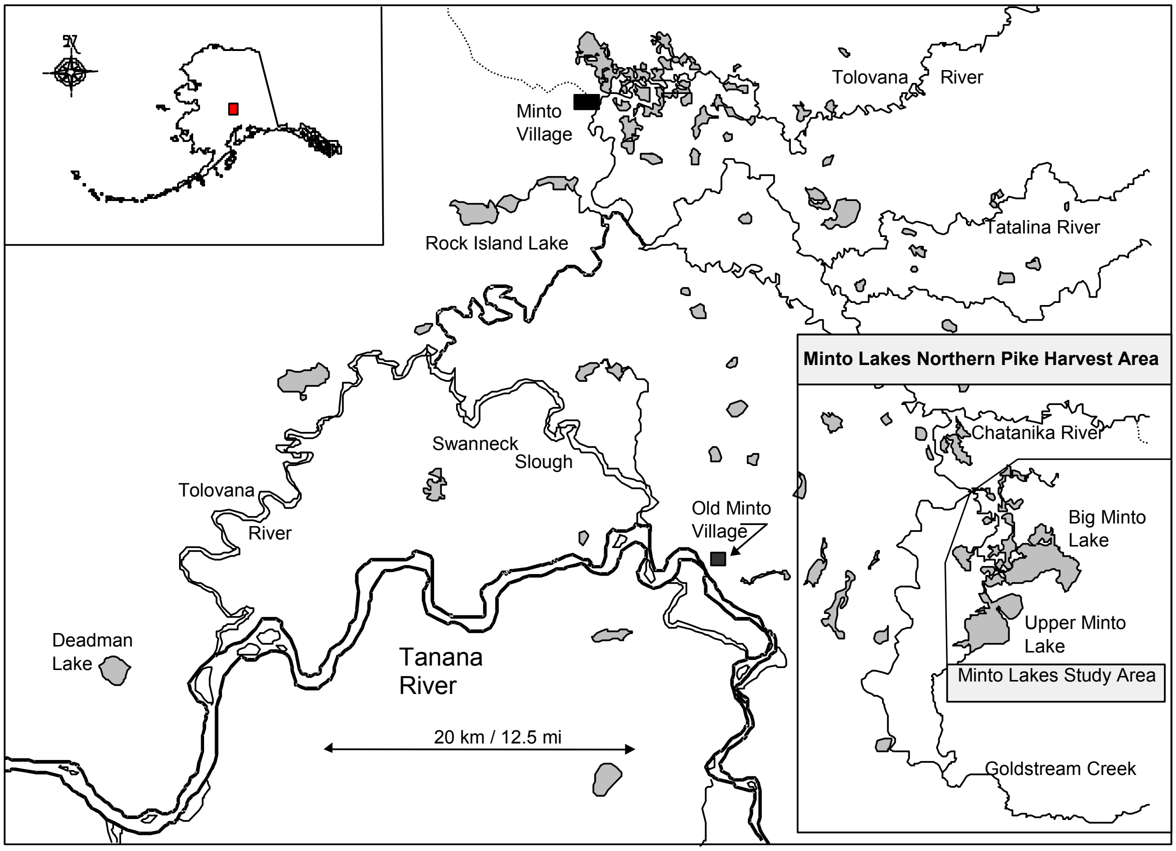

Figure 1.–Location of the Minto Lakes study area within the Minto Flats wetland complex.

Minto Flats and the Lower Chatanika River/Goldstream Creek area have supported one of the largest northern pike sport fisheries in the state (Howe et al. 1995, 1996; Howe et al. 2001a-d; Walker et al. 2003; Jennings et al 2004, 2006 a-b). In 1985 a sport fishery developed on a concentration of overwintering northern pike in the Lower Chatanika River upstream from the mouth of Goldstream Creek (Figure 1). This fishery resulted in an increase in the estimated sport harvest from 2,349 northern pike in 1984 to 4,665 fish in 1985, and 4,903 in 1986 (Table 1). Angler reports and limited creel survey data indicated that a large proportion of the harvest from this fishery was prespawning females (Holmes and Burkholder 1988; W. Busher, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication).

A subsistence fishery for northern pike has long occurred near the present village site of Minto and at historical sites in the eastern portion of Minto Flats (Andrews 1988). Gillnets are used to catch northern pike throughout the open water season and hook-and-line techniques are primarily used to capture fish through the ice. Of interest more recently has been the increase in subsistence harvests by residents of Fairbanks North Star Borough (FNSB) in 2007 and 2008 who almost exclusively target overwintering aggregations near the confluence of Goldstream Creek and the Chatanika River through the ice (Table 1).

Table 1.–Catch and harvest of northern pike in the Minto Flats and Tolovana River drainage from 1982 to 2007.

	Minto Lakes Northern Pike Harvest Area		Minto Flats Complex[a]				
Year	Sport Catch	Sport Harvest	Sport Catch	Sport Harvest	Subsistence Harvest/ FNSB residents	Total Subsistence Harvest[b]	Total Harvest
1983	N/A	2,748	N/A	3,461			
1984	N/A	2,453	N/A	3,128			
1985	N/A	4,146	N/A	5,256			
1986	N/A	4,927	N/A	6,488			
1987	N/A	1,781	N/A	2,401			
1988	N/A	1,492	N/A	1,965			
1989	N/A	1,734	N/A	2,596			
1990	4,946	1,570	6,060	2,009			
1991	5,427	2,155	6,111	2,586			
1992	6,175	1,299	6,585	1,325			
1993	19,536	2,076	24,378	3,420			
1994	47,248	8,438	52,191	9,489	84	995	10,484
1995	21,823	3,126	29,193	4,480	120	1,023	5,503
1996	12,495	2,078	16,479	2,716	79	1,616	4,332
1997	9,932	1,074	11,253	1,246	67	1,333	2,579
1998	4,105	731	4,704	772	37	431	1,203
1999	3,261	908	3,636	1,098	25	400	1,498
2000	1,402	266	1,784	390	1	352	742
2001	2,849	641	2,916	654	0	214	868
2002	8,806	483	10,085	650	14	521	1,171
2003	8,706	1,260	12,997	1,284	394	966	2,250
2004	19,205	1,199	21,159	1,390	110	393	1,783
2005	14,839	1,880	16,768	2,052	148	386	2,438
2006	7,284	935	8,447	1,204	428	788	1,992
2007	11,346	1,712	14,077	1,809	1,605	1,837	3,646

[a] Includes Minto Flats, Tolovana River and Lower Chatanika River.

[b] Subsistence harvest reported by residents of the Fairbanks North Star Borough (FNSB) and Minto Village.

The current fishing regulations were adopted in 1997. Sport anglers are allowed to angle from June 1 through October 14 and the bag limit is five northern pike per day, only one of which can be over 30 inches TL (725 mm FL). No bag or size limits exist for subsistence fishers. To help maintain the prescribed exploitation rates the sport fishery changes to a daily bag and possession limit of two northern pike with only one over 30 inches once the reported winter subsistence harvest from the Chatanika River overwintering area (that used by Fairbanks North Star Borough residents) reaches 750 northern pike, and this area is closed once the harvest reaches 1,500 northern pike.

Mark-recapture experiments 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 (Big Minto Lake and associated sloughs, Goldstream Creek, Tolovana, Tatalina, and Chatanika rivers, as well as Goldstream Creek and Swanneck Slough) (Burkholder 1989, 1990, 1991; Hansen and Burkholder 1992). 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. Current (since 1996) stock assessment methods have since been based on these past efforts and on radiotelemetry studies conducted by Burkholder (1989) and Roach (1998a). Experiments conducted in 1996 (Roach 1997), 1997 (Roach 1998b), 2000 (Scanlon 2001) and 2003 (Scanlon 2006) estimated abundance of northern pike within an assessment area (referred to as the *Minto Lakes Study Area;* Figure 1) and the resulting estimates have been used as an index of abundance for the entire Minto Flats wetland complex for management purposes (Scanlon 2006). The current study design employs a two-event experiment and is conducted between early June and early July as recommended to help ensure a closed population (Roach 1998a).

As part of the department's periodic assessment of the Minto Flats northern pike stock, we performed a mark-recapture experiment in 2008 to determine the abundance and size composition of northern pike within the current study (index) area. Abundance and size composition was also estimated for an expanded area that included the index area and peripheral water bodies within the Minto Lakes complex. Telemetry data from a pilot study in 2007 indicated that fish moved freely between the historic index area and peripheral water bodies such as Upper Minto Lake (Joy *unpublished*).

OBJECTIVES

The research objectives for 2008 were to:

1. estimate the abundance of northern pike ≥400 and ≥600 mm FL in Area-A and Area-B during June of 2008 such that the estimates were with in 25% of the actual value 90% of the time; and,

2. estimate the length composition of northern pike ≥400 mm FL in Area-A and Area-B during June of 2008 and for the spawning population during May 2008 such that the estimates of the proportions were within 5 percentage points of the actual value 95% of the time.

Area-A refers to the entire Minto Lakes complex and includes all water bodies that drain into Goldstream Creek through the lake channel (Figure 2). Area-B refers to the study area traditionally defined in past experiments (Figure 2).

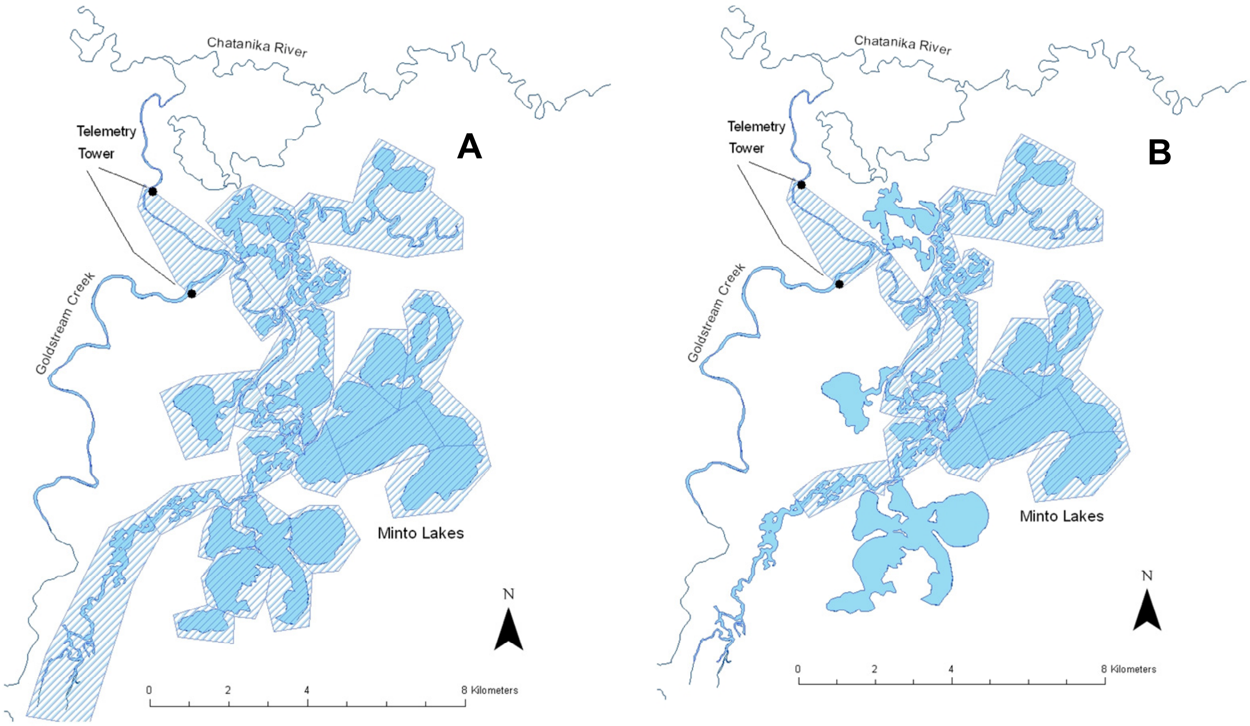

Figure 2.–Study Area-A comprising all of the Minto Lakes complex and study Area-B which is limited to the sections of the Minto Lakes complex sampled in previous experiments. Area-A1 is the portion of Area-A not included in Area-B. Area-B comprises roughly 64% of Area-A.

METHODS

STUDY AREA

Area-A was defined as all lakes (Big Minto, Upper Minto, "Side", "Marge", "New"), all sloughs (Cancer, Rotten) and the interconnecting "Lake Channel" that drains into Goldstream Creek, and those portions of Goldstream Creek within an approximately 2-km radius of the confluence with Goldstream Creek and Lake Channel (Figures 2-4). Essentially, Area-A included all habitable waters (under non-flood conditions) accessible from Goldstream Creek via Lake Channel. Area-B coincided with sampling sections from past experiments and excluded New, Upper Minto and Marge lakes, the upper portion of Rotten Slough, and Goldstream Creek (Figures 2-4). In previous experiments, Area-B was subdivided into 16 sections to facilitate distribution of effort and assumption testing and this partitioning was utilized in 2008. Area-A used the partitioning scheme of Area-B plus eight additional sections (24 total) (Figure 3). Lastly, the waters of Area-A that are not included inside of Area-B are hereafter referred to as Area-A1.

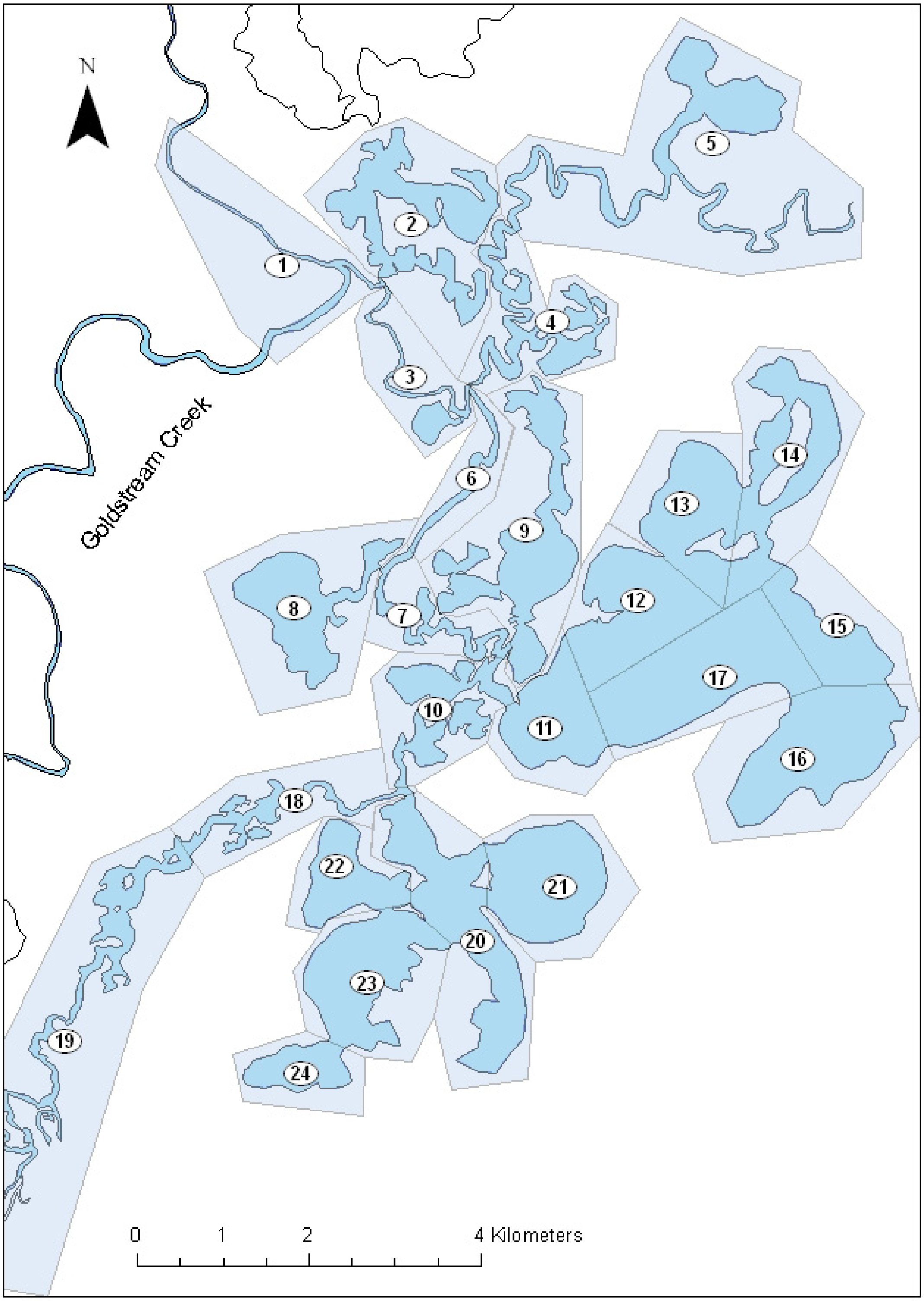

Figure 3.–Minto Lakes study area delineated by study sections for the purposes of distributing sampling effort.

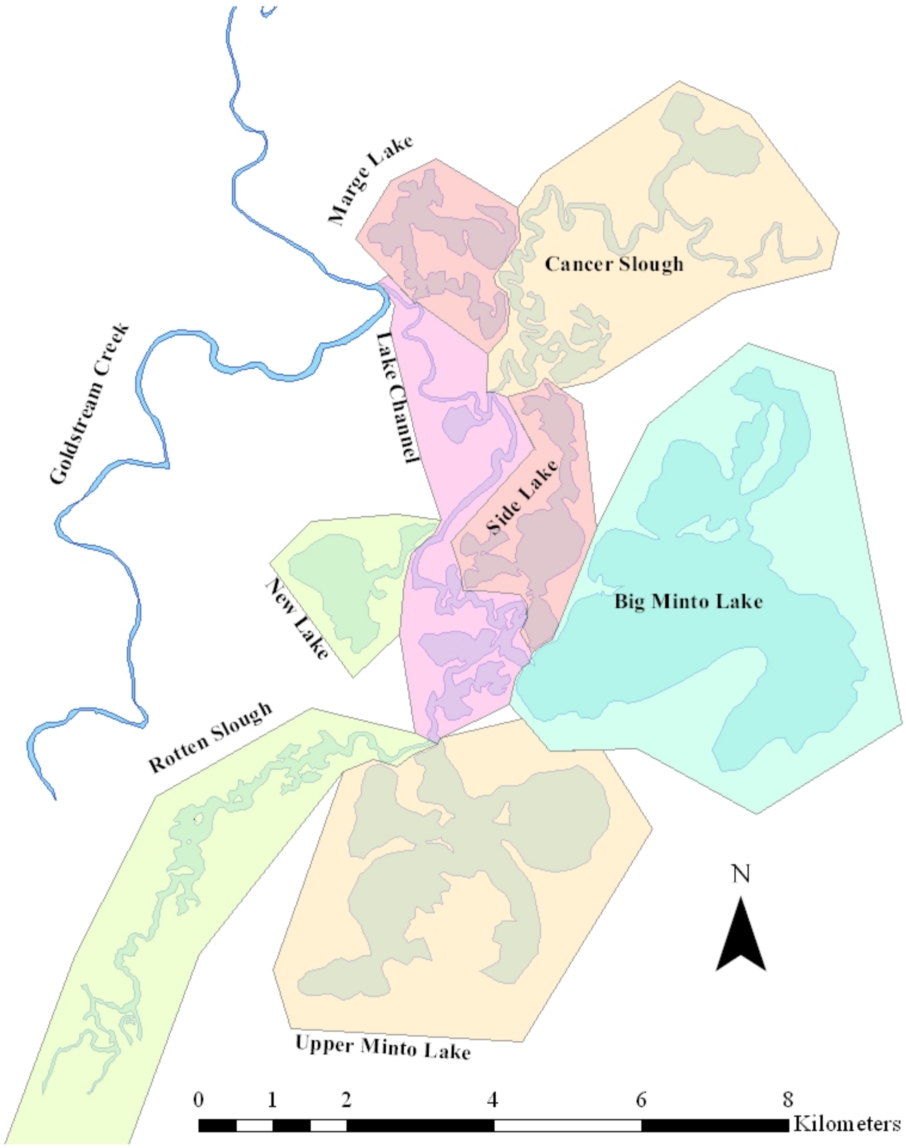

Figure 4.–Minto Lakes study area with the separate water bodies delineated.

STUDY DESIGN (OVERVIEW)

To estimate the abundance of northern pike in Area-A and -B, a two-event mark-recapture experiment was conducted. The experiment was nearly identical in sampling design to previous studies except that additional sections were added (Area-A1) and sampling effort increased. All sections within Area-A were sampled from May 29 to June 6 (1st event) and from June 12 to 20 (2nd event). Abundance for Area-B was estimated by excluding Area-A1 from the analysis.

In addition, this experiment was designed and implemented in conjunction with a radiotelemetry experiment being conducted by a graduate student from the University of Alaska Fairbanks (UAF). Major objectives of this study to be completed during 2010 are to examine underlying assumptions of mark-recapture models and to further refine and improve upon the study design. Results from the UAF study are not complete; however, the timing of radio-tagged northern pike moving in and out of the study area were used with regard to closure assumptions for our mark-recapture experiment in 2008. The timing data was collected by a telemetry tower stationed on Goldstream Creek below its confluence with Lake Channel (Figure 2).

Mark-Recapture Experiment

This experiment was designed to estimate abundance and length composition of northern pike within Area-A and Area-B of the Minto Flats using two-event Petersen mark-recapture techniques for a closed population (Seber 1982) designed to satisfy the following assumptions:

1. the population was closed (northern pike did not enter the population, via growth or immigration, or leave the population, via death or emigration, during the experiment);
2. all northern pike had a similar probability of capture in the first event or in the second event, or marked and unmarked northern pike mixed completely between events;
3. marking of northern pike did not affect the probability of capture in the second event;
4. marked northern pike were identifiable during the second event; and,
5. all marked northern pike trout were reported when recovered in the second event.

Failure to satisfy these assumptions may result in biased estimates; therefore, the experiment was designed to allow the validity of these assumptions to be ensured or tested. Assumption 1 was assessed by examining movement of radio-tagged pike past the telemetry tower on Goldstream Creek. Sufficient data was collected to perform diagnostic tests to identify heterogeneous capture probabilities (violations of Assumption 2) and prescribed model selection procedures were followed in the event of such violations. Diagnostic tests were not available to evaluate Assumptions 3, 4 and 5; instead, the experiment was designed to ensure that these assumptions were met thereby avoiding potential biases. The design ensured that sample sizes were adequate to meet objective precision criteria and to perform reliable diagnostic tests.

Between May 28 and June 20, two sampling events occurred, each using similar sampling protocols and gear types as were employed in 1996 (Roach 1997), 1997 (Roach 1998a), 2000 (Scanlon 2001), and 2003 (Scanlon 2006). A systematic method was used to sample northern pike in the Minto Flats Study Area to ensure all areas were sampled with roughly equal sampling effort over the course of each sampling event. The study area was composed of eight water bodies (Figure 4) containing 24 sections (Figure 3). Four two-person crews sampled roughly 1.5 sections per day for eight days, covering each section twice during each event. This sampling protocol resulted in exceeding precision expectations using an eight person crew in 1997 operating under normal water conditions and a four-person crew were determined to be insufficient in 2003 (Scanlon 2006). Increasing the effort expended in 2003 from four to six persons accommodated needs for Area-B and increasing the crew size further from six to eight addressed expanding the study area to Area-A.

During each event in 2008, crews used a combination of hoop traps (3-ft diameter with 1-in bar mesh, and two 25-ft wings), fyke traps (4-ft x 4-ft frames, 1-in bar mesh, with 50-ft center lead), variable mesh gill nets (80 ft x 6 ft with 1-in, 1.5-in, 2-in, and 2.5-in bar mesh) and hook-and-line gear to capture northern pike. Sampling in the first event was extended for an extra 24 h in some of the higher yielding areas as fishing proved slower than anticipated.

Fyke and hoop traps were generally set at constriction points, such as across sloughs or off of shoreline points. Traps were deployed in assigned sections in the morning and checked twice, once in the evening and once the next morning before being relocated to a new section. When not contending with traps, each crew fished two gillnets in their assigned areas, checking on each net every 10 min, depending on catch rates and the condition of the fish. Within a section, gillnets were systematically fished by leapfrogging nets along the shoreline (e.g. 50-ft to 100-ft intervals) until the crews assigned section(s) had been sampled over an ~8-h work day. Crews also used hook-and-line sampling in the vicinity of gillnets.

Evaluation of Assumptions Relative to Study Design

Assumption 1 (closure):

Relative to Area-A, no movement of fish into or out of Area-A was anticipated during the experiment. In 1996 and 1997, virtually all pre-spawning radio-tagged fish (i.e. 57 of 58 in 1996) migrated up Goldstream Creek from downriver overwintering areas and entered Area-A by June, and remained there until July (Roach 1998b). A similar pattern was observed in 2007 when all radio-tagged pike migrating up Goldstream Creek entered Area-A by May 15 and no radio-tagged pike were observed leaving the Minto Lakes (Area-A) until late June when a lone fish left (Joy *unpublished*). As part of the UAF experiment two telemetry towers were located on Goldstream Creek above and below the lake channel (Figure 2). Movement of radio-tagged northern pike past the tower was used to indicate closure with regard to Area-A.

Relative to Area-B, some movement between Area-B and -A1 was anticipated. In 2007, a relatively large number of northern pike were observed in areas such as Upper Minto Lake and Marge Lake during mid-June (i.e. approximately 30% of tags within Area-A) (Joy *unpublished*). This is in contrast to previous studies which demonstrated closure for Area-B. The degree of movement in 2008 that may have occurred between Area-B and adjacent waters such as Upper Minto Lake and the magnitude of any associated biases was uncertain, however UAF telemetry study will permit an independent evaluation. For the purposes of this experiment, the evaluation of closure was limited to using movement data collected from recaptured northern pike.

This study was of short duration, and therefore, growth recruitment was rendered insignificant (i.e. growth expected to be <10 mm or within measurement error).

A final issue was potential mortality associated with spawning. In 2007, a relatively large proportion (16%) of the radio tags that entered Area-A died by May 31, and this proportion increased to 43% by June 31 (Joy *unpublished*). These results were in contrast to those observed by Roach (1998a) where only 6 of 54 tags (11%) died during a similar period from April 8 to July 1 of 1996. The cause for this discrepancy is unknown (e.g. tagging or natural mortality).

Assumption 2 (geo-temporal influences on capture probability):

Complete mixing during the experiment was not anticipated. Therefore, our systematic sampling strategy was an attempt to subject all fish to an equal probability of capture during both events. The design also relied on local mixing (i.e., at the scale of a water body) to produce a uniform marked proportion at that scale and to mitigate potential bias due to pockets of fish isolated from sampling. Our sampling strategy was nearly identical in terms of gear and distribution of sampling effort that was successfully employed by Roach (1998b) and Scanlon (2006) in which statistically similar capture probabilities were observed in the second event.

Assumption 2 (length selectivity): It was unknown if fish would have equal probability of capture by length. The combination and distribution of gear in 2008 was similar to that used by Roach (1998b) and Scanlon (2006) when no size selectivity in either event for fish ≥400 mm FL was detected. Data sufficient for investigating this potential bias and adjusting for it was collected and analyzed as described in subsequent sections.

Assumption 3 (effect of marking): The 10-day hiatus between individual sampling sections was assumed to be sufficient to allow marked fish to recover from the effects of handling (i.e. marking-induced changes in behavior) during the first event, and therefore, assumption 3 was presumably not violated.

Assumptions 4 (mark durability) and 5 (all marked fish recorded in second event): These assumptions were ensured by the sampling methods. All fish ≥400 mm FL were double marked using individually numbered Floy™ tags (primary mark) and a partial fin clip (secondary mark) - each fin clip was specific to the sampling event. All fish were tagged similarly at the base of the dorsal fin on the left flank, and the secondary mark was visible when fish were sampled. The event-specific fin clip was used to prevent resampling within an event. All fish were thoroughly examined for tags or recent fin clips. All markings (tag number, tag color, fin clip, and tag wound) for each fish were recorded.

DATA ANALYSIS

Abundance Estimate

Relative to Assumption 1 (closure), the movements of radio-tagged northern pike past the tracking stations on Goldstream Creek was used to evaluate immigration or emigration during the experiment relative to Area-A. Movement data from recaptured fish was used to evaluate immigration or emigration relative to Area-B. A more detailed and rigorous evaluation of this assumption relative to Area-B will be undertaken at a later date as part of the UAF thesis.

Relative to Assumption 2, for each attendant abundance estimate differences in capture probability related to fish size and location were examined. Size-selective sampling was tested using Kolmogorov-Smirnov tests. The tests and possible actions for data analysis are outlined in Appendix A1. If stratification by size was required, capture probability by location was examined for each stratum, and the variance was calculated as the sum of variances across strata.

For the abundance estimates (Objective 1), differences in capture probability by location were checked using tests for consistency of the Petersen estimator (Seber 1982) performed at the scale of a water body (Appendix A2). If all three of these tests were significant, then a geographically stratified estimator would be used. If movement of marked fish between strata was observed (incomplete mixing), the methods of Darroch (1961) would be used to compute a partially stratified abundance estimate. If no movement of marked fish between geographic strata was observed, a completely stratified abundance estimate would be computed using the Chapman-modified Petersen estimator (Seber 1982) or the methods of Darroch (1961). Otherwise, at least one of the three consistency tests would fail-to-reject the null hypothesis and it would be concluded that at least one of the conditions in Assumption 2 was satisfied

If any of the three tests for consistency were not significant, abundance was estimated using Chapman's modification of the Petersen two-sample model (Seber 1982). These estimates were calculated using:

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

where:

$\hat{N}$ = the abundance of northern pike for each respective stratum (e.g. fish ≥400 mm FL in Area-B during June);

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

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

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

Variances of this estimator were calculated as:

$$\hat{Var}\left[\hat{N}\right] = \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)} \tag{2}$$

Length Composition (Objective 2)

For each respective abundance estimate (e.g. fish ≥400 mm FL in Area-B during June), Kolmogorov-Smirnov tests performed to test for size-selective sampling and test outcomes were used to determine if stratification was necessary and if data from the first, second or both events were to be used. For cases I-III (Appendix B1) stratification was not necessary and length proportions (25-mm FL categories) and variances of proportions for northern pike would be estimated using samples from the 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 were within length category k;

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

n = the total number of northern pike sampled.

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

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

If diagnostic tests indicated case IV, there was size-selectivity during both events and data was 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.

RESULTS

SUMMARY

Within Area-A a total of 809 northern pike between 425 and 990 mm FL were marked (n_1), and 679 northern pike between 355 and 1,010 mm FL were examined (n_2), of which 40 were recaptures (m_2). Within Area-B, 607 northern pike between 425 and 990 mm FL were marked, and 497 fish between 355 and 1007 mm FL were examined, of which 28 were recaptures. Of all recaptured northern pike, one had lost its tag and was identified by its fin clip.

During the second event, dead northern pike were observed around the study area. An exact accounting was not made until partway through the second event. In total 17 tagged fish were found, and it was estimated that ~50% of all dead fish discovered were tagged.

DIAGNOSTIC TEST RESULTS

Area-A. Diagnostic tests indicated length stratification at 605 mm FL was required (Table 2). For both length strata (400-604 mm and ≤605 mm FL), geographic stratification was not needed because probabilities of capture in the first or second event were not significantly different at two scales examined (Table 2, Appendix C1 and C2). The fine scale consisted of testing capture probabilities among the 24 sampling sections and the course scale consisted of testing among the 9 water bodies that make up the study area (Figures 3 and 4). Diagnostic tests failed to indicate that complete mixing occurred (Table 3, Appendix C1 and C2).

Area-B. Diagnostic tests indicated no length stratification (Table 2). Geographic stratification was not needed because probabilities of capture in second event were not significantly different at the two scales examined (Table 2). Diagnostic tests failed to indicate that complete mixing occurred (Table 3, Appendix C1 and C2).

Table 2.–Results of diagnostics used to detect and correct size-selective sampling (Appendix A1) for estimating abundance and length composition of northern pike in the Minto Lakes, 2008.

Area and Length Strata		Comparison and Test Statistic: n_1 vs. m_2	n_2 vs. m_2	Result
Area-A				
≥400 mm FL		D = 0.266 P value = 0.007	D = 0.288 P value = 0.003	Length selectivity detected, Case IV; 605 mm selected as break point
	400-604 mm FL	D = 0.210 P-value = 0.444	D = 0.165 P-value = 0.754	Case I, do not stratify, use lengths from both events for comp analysis.
	≥605 mm FL	D = 0.215 P-value = 0.248	D = 0.128 P-value = 0.128	Case I, do not stratify, use lengths from both events for comp analysis.
Area-B				
≥400 mm FL		D = 0.215 P-value = 0.152	D = 0.231 P-value = 0.104	Case I, do not stratify, use lengths from both events for comp analysis.

Table 3.–Results of consistency tests for the Petersen estimator (Appendix A2) for estimating abundance of northern pike in the Minto Lakes Study Area 2008.

	Consistency Test		
	I	**II**	**III**
Length, Area and Scale	**Complete Mixing**	**Equal Probability of Capture, 1st Event**	**Equal Probability of Capture, 2nd Event**
Area-A			
400-604 mm FL, Fine Scale		χ^2 = 57.4 P-value = 0.000	χ^2 = 19.6 P-value = 0.67
400-604 mm FL Course Scale	χ^2 = 112.72 P-value = 0.000	χ^2 = 17.69 P-value = 0.02	χ^2 = 9.78 P-value = 0.28
≥605 mm FL, Fine Scale		χ^2 = 14.40 P-value = 0.91	χ^2 = 19.70 P-value = 0.13
≥605 mm FL, Course Scale	χ^2 = 115.11 P-value = 0.000	χ^2 = 7.73 P-value = 0.46	χ^2 = 10.71 P-value = 0.22
Area-B			
≥400 mm FL, Fine Scale		χ^2 = 28.4 P-value = 0.028	χ^2 = 19.3 P-value = 0.253
≥400 mm FL, Course Scale	χ^2 = 30.38 P-value = 0.02	χ^2 = 13.8 P-value = 0.032	χ^2 = 6.58 P-value = 0.361

Movement. Sixty-three radio-tagged northern pike migrated past the tracking tower between April 22, 2008 and May 14, 2008 (Figure 5). Aerial and ground surveys indicated that northern pike moved into the Minto Lakes as soon as ice conditions allowed. A flight on April 24, when only 7.9% of radio-tags had passed the tracking tower, revealed water flowing over substantial ice still frozen to the creek bottom (Figures 6-7). On April 29, when 79.4% of radio tags had passed the tracking tower, the ice had lifted off the bottom but still covered a majority of the water ways and substantial portions of the lake system. By May 1 Goldstream Creek and the Lake Channel were still almost completely covered in ice (Figures 6 and 7) and 84.1% of radio-tagged northern pike had passed the tracking tower (Figure 5).

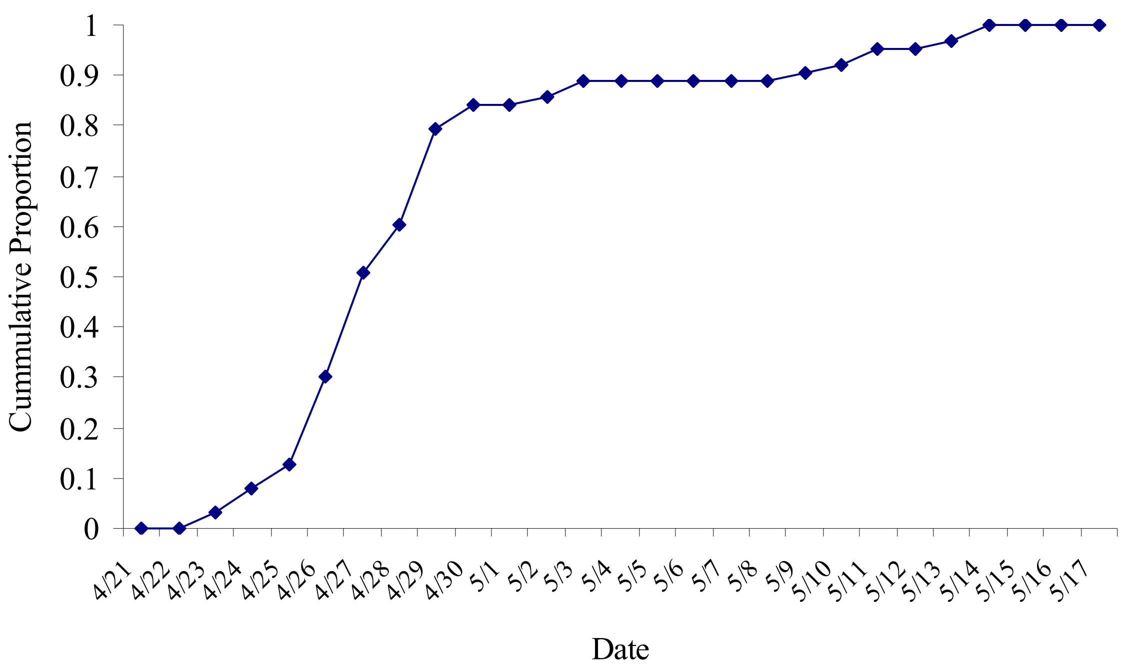

Figure 5.–The cumulative proportion of radio-tagged northern pike (63 total) passing the tracking tower on Goldstream Creek below the lake channel draining the Minto Lakes.

Figure 6.–Photographs of ice conditions on Goldstream Creek at its confluence with the Lake Channel draining the Minto Lakes taken on April 24, (A, B), April 29 (C, D) and May 1, 2008 (E,F). Picture A shows Lake Channel draining into Goldstream Creek with ice still frozen to the substrate and water flowing over the top of the ice. Picture B is a closer view of Goldstream Creek showing substantial ice still anchored to the substrate with an open lead running through the ice. C and D show the ice that had been frozen to the substrate on April 24 is now free from the substrate and floating. There is still a considerable mass of ice occupying the channel and creek. In E and F fresh snow illustrates the extent and mass of ice still present in the Lake Channel and Goldstream Creek on May 1, 2008.

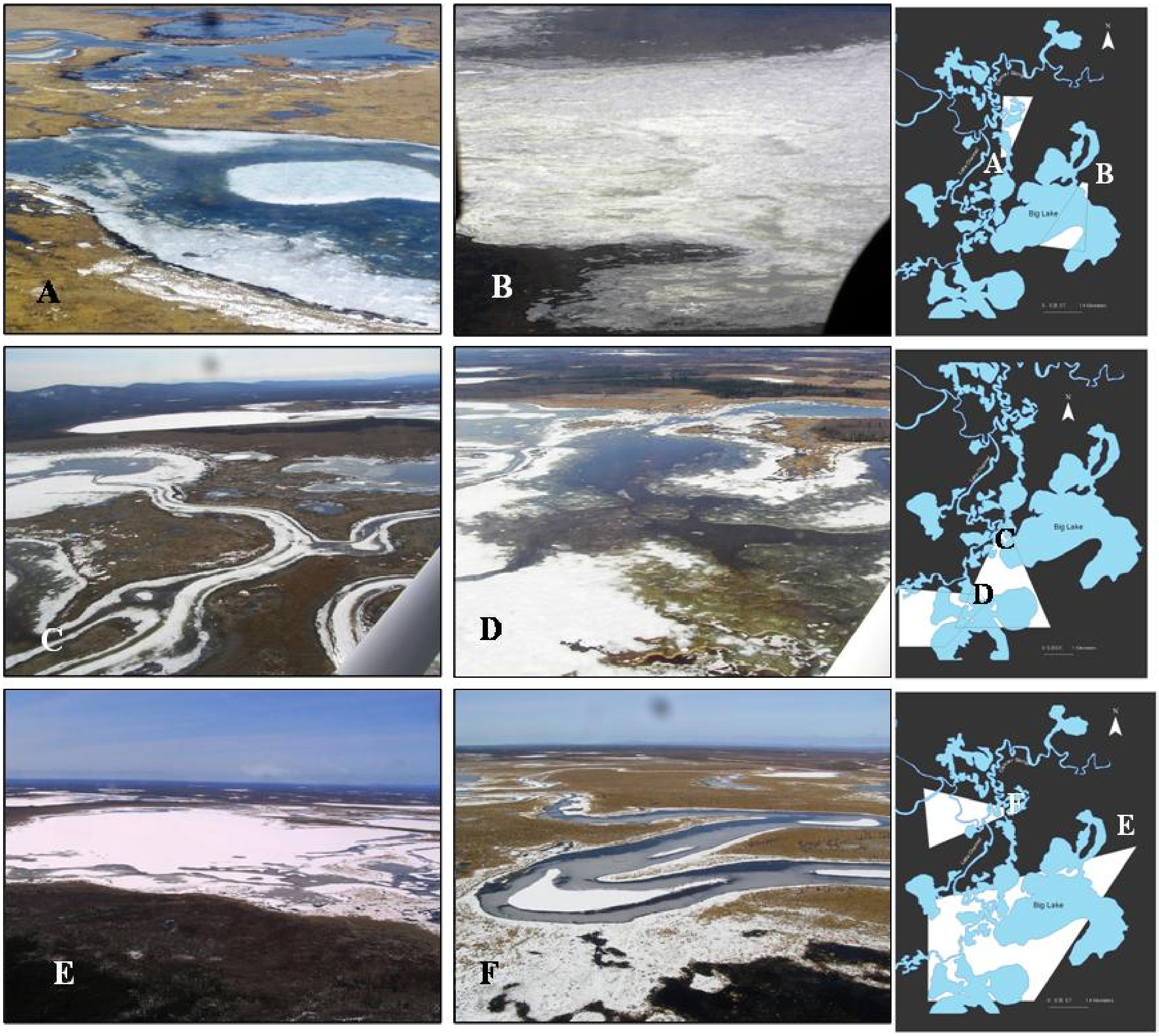

Figure 7.–Photographs displaying ice conditions in the Minto Lakes on April 24 (A, B), April 29 (C, D) and May 1, 2008 (E,F). Maps illustrate the angle and content of photographs.

No radio-tagged northern pike were recorded as having left the study area during the course of the mark-recapture experiment. Therefore, with regard to Area-A, evidence demonstrated that the population was closed to emigration and immigration via Goldstream Creek.

For Area-B recaptured northern pike provided evidence of significant immigration to Area-B from Area-A1 (Figure 8). While no tagged fish that were marked in Area-B were captured outside Area-B, seven northern pike tagged in Area-A1 were recaptured in Area-B. Given that a total of only 40 northern pike were recaptured in the entire study, this may be indicative of significant immigration to Area-B from outlying water bodies.

Forty-six percent (18/39) of recaptured northern pike were recaptured in the same study section in which they were marked (Appendix C1) and 54% (21/39) recaptured northern pike were recaptured in the same water body in which they were marked (Appendix C2). The distance moved between marking and recapture ranged from 8 to 9,876 m with an average of 1,961 m (SE = 2,573). This movement, or partial mixing provided sufficient evidence that no fish were isolated from the experiment.

ABUNDANCE ESTIMATE

Area-A. Estimated abundances of northern pike in Area-A were:

1) 400-625 mm FL: 14,074 (SE = 3,113) with a 95% confidence interval from 7,973 to 20,175;
2) >605 mm FL: 1,971 (SE = 350) with a 95% confidence interval from 1,285 to 2,658;
3) ≥400 mm FL: 16,045 (SE = 3,132) with a 95% confidence interval from 9,906 to 22,185;
4) ≥600 mm FL: 2,219 (SE = 397) with a 95% interval from 1,441 to 2,998; and,
5) ≥725 mm FL: 958 (SE = 362) with a 95% interval from 248 to 1,667.

Area-B. Estimated abundances of northern pike in Area-B were:

1) ≥400 mm FL: 9,854 (SE = 1,701) with a 95% confidence interval from 6,521 to 13,187;
2) ≥600 mm FL: 2,092 (SE = 448) with a 95% interval from 1,214 to 2,971; and,
3) ≥725 mm FL: 635 (SE = 236) with a 95% interval from 173 to 1,097.

Historical Comparisons. Comparisons are germane to Area-B. The 2008 estimate for fish ≥400 mm FL was significantly less than that seen in 2003 (25,227 northern pike, SE = 4,529) (Scanlon 2006) (z-score = 3.18, P-value <0.01) and that seen in 1997 (16,546 northern pike, SE = 1,754) (z-score = 2.74, P-value <0.01) (Roach 1997) (Figure 9).

For northern pike ≥600 mm FL the 2008 was significantly less fish than in 2000 (5,331 northern pike, SE = 1,152) (z-score = 2.62, P-value <0.01) and 1997 (3,251 northern pike, SE = 174) (z-score = 2.41, P-value <0.01). There were also significantly fewer northern pike ≥725 mm FL than in 2003 (1,405 northern pike, SE = 288) (z-score = 2.07, P-value = 0.02). However, the 2008 estimate for pike ≥725 mm FL was not significantly different from that observed in 1997 (672 northern pike, SE = 48) (z-score = 0.15, P-value = 0.44) (Figure 10).

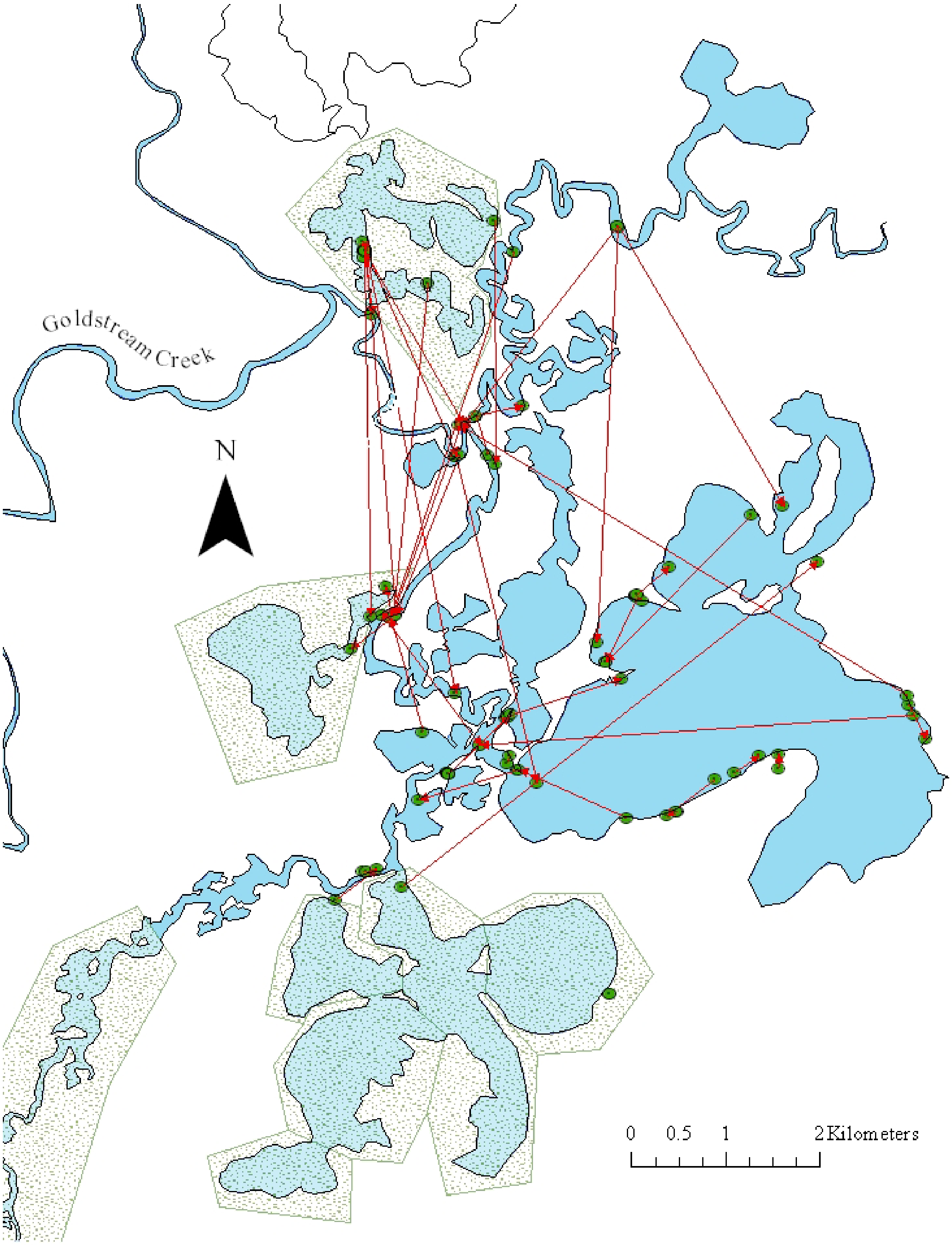

Figure 8.–Map displaying the movement of recaptured northern pike between their sample locations. Arrows point from tagging location to recapture location. Dots without arrows represent fish that were recaptured in the same spot as they were marked. Shaded areas represent Area-A sections not included in Area-B.

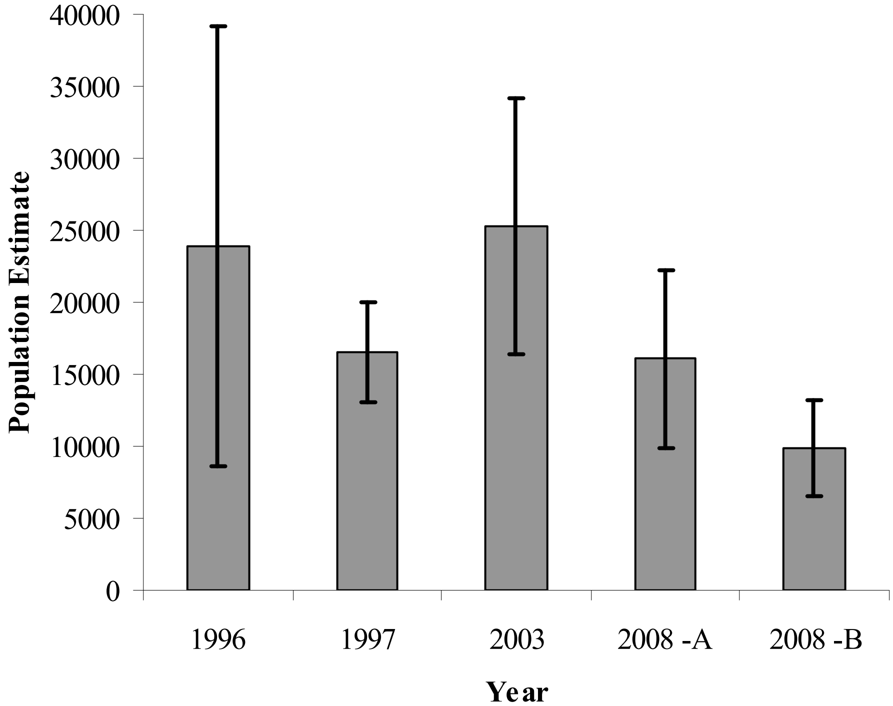

Figure 9.–The estimated abundance of northern pike ≥400 mm FL in Area-B of the Minto Lakes study area. Error bars represent 95% confidence intervals.

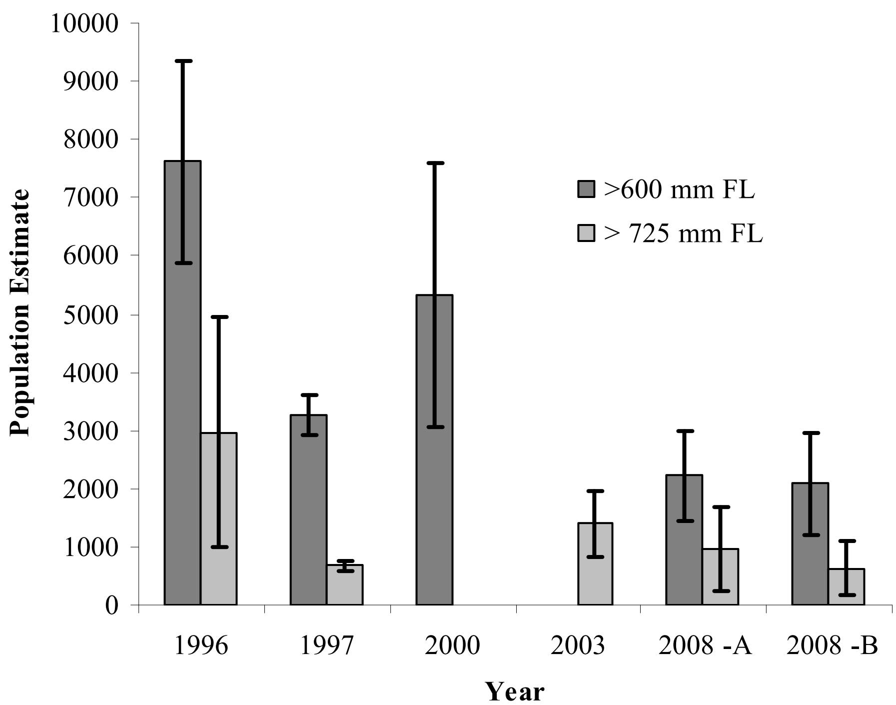

Figure 10.–The estimated abundance of northern pike ≥600 and ≥725 mm FL in Area-B of the Minto Lakes study area. Error bars represent 95% confidence intervals.

LENGTH COMPOSITION

The length distribution of northern pike sampled in Area-A is displayed in Figure 11. The estimated proportion of northern pike ≥725 mm FL was 0.096 (SE < 0.01). The overall length distribution was, in general, similar to those observed in past experiments (Figure 12).

The length distribution of fish from Area-B was significantly larger than Area-A1 (D-statistic = 0.088, P-value = 0.019) although the difference did not appear to be large (Figure 11).

The length distribution of northern pike sampled in hoop traps were significantly larger than those sampled by gillnet (D-statistic = 0.197, P-value = 0.000), which were in turn significantly larger than those sampled by hook-and-line (D-statistic = 0.161, P-value = 0.001) (Figure 13).

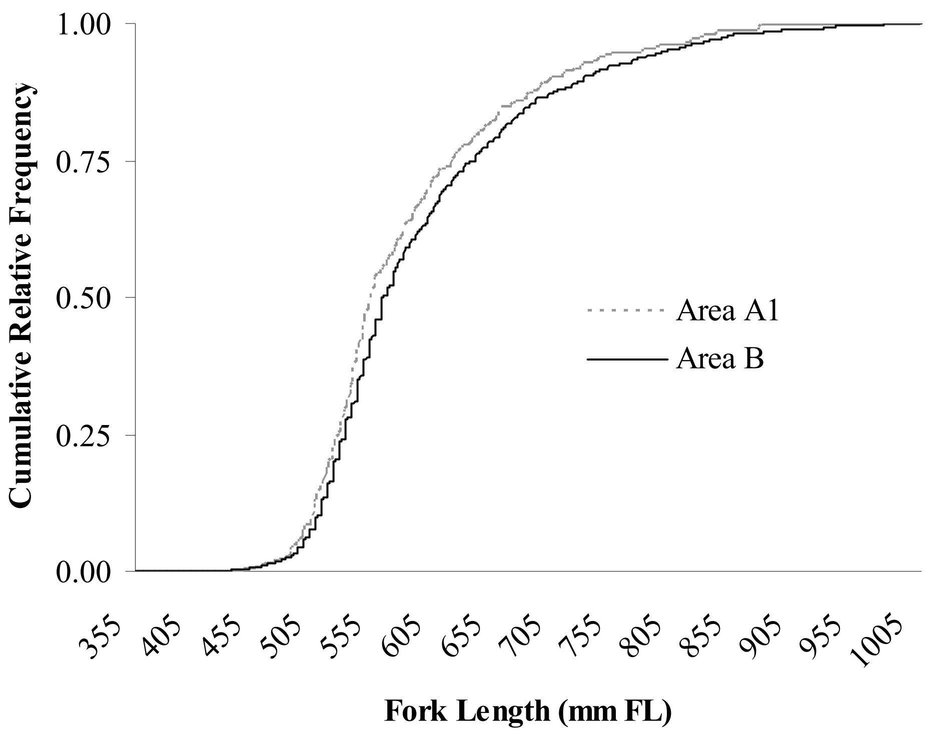

Figure 11.–The cumulative relative frequency of northern pike sampled inside Area-B and -A1 in the Minto Lakes study area in 2008.

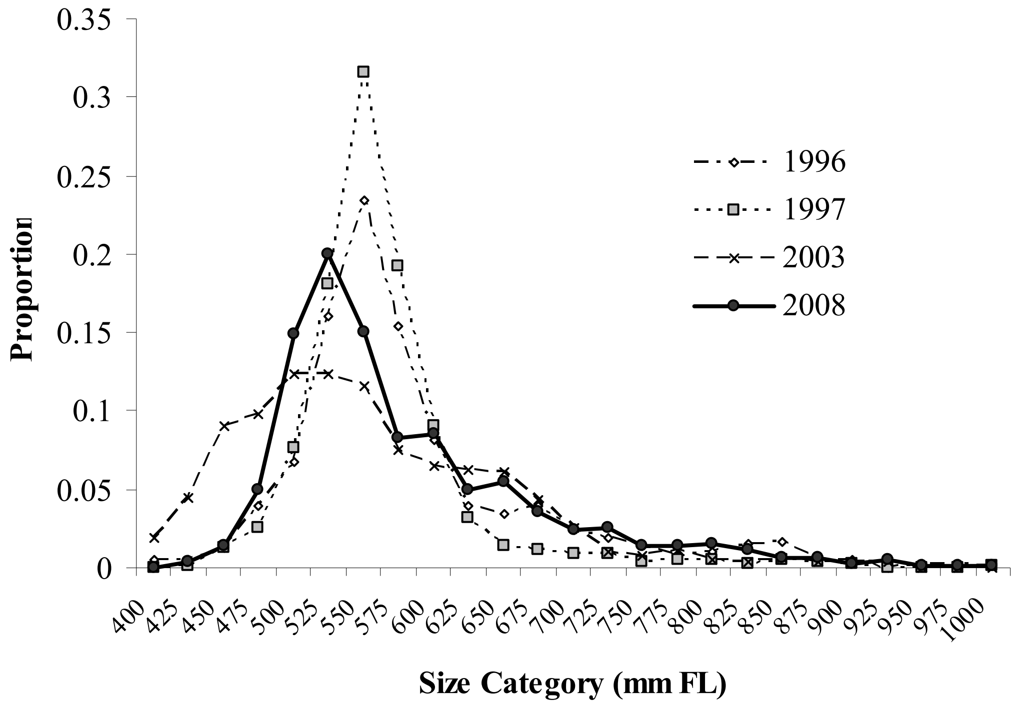

Figure 12.–Length distribution of northern pike sampled in 2008, 2003 (Scanlon 2006), 1997 (Roach 1997) and 1996 (Roach 1998b).

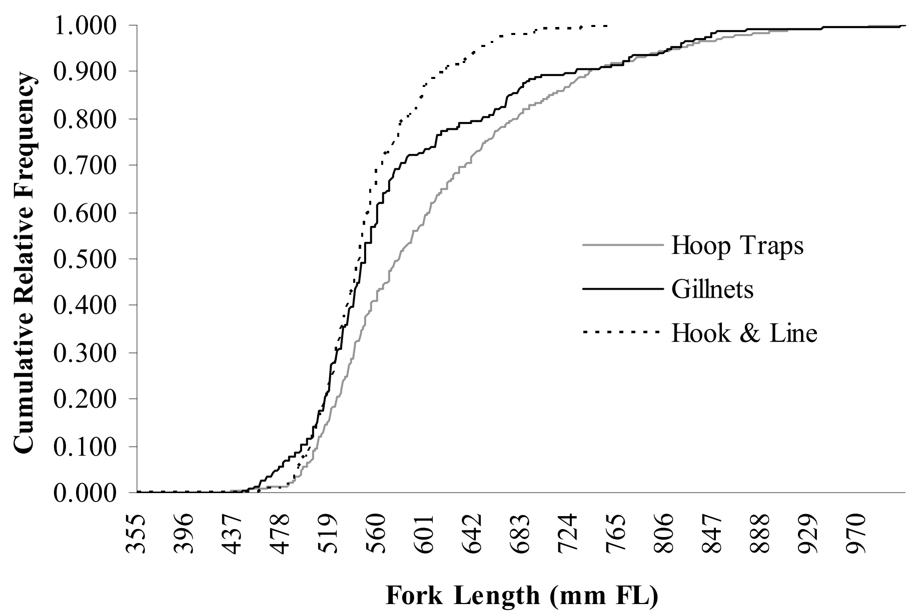

Figure 13.–Cumulative relative frequency of fork lengths of northern pike sampled by hoop traps, gillnets and hook-and-line in the Minto Lakes study area 2008.

DISCUSSION

MODEL PRECISION AND BIAS

The stated objectives of this project were met, although abundance estimates were not within the desired precision criteria (±25% at 90% alpha level). For northern pike ≥400 mm FL the relative precision at the 90% level was ±33% for Area-A and ±29% for Area-B. For northern pike ≥600 mm FL, the relative precision was ±30% for Area-A and ±36% for Area-B. The need to stratify abundance estimates due to the low capture probability for smaller fish likely contributed to the uncertainty in the estimates. Increasing sample sizes in future experiments would likely improve relative precision of abundance estimates, but would require more effort either from additional crew members or extended sampling periods during both events.

Several violations of model assumptions were observed. Observed mortalities of tagged pike suggested some handling mortality that would result in estimates biased high for both Area-A and Area-B. Additional violations of the closure assumption were caused by natural mortality during the sampling hiatus and emigration from Area-A1 to Area-B. However, it was not believed that any of these violations resulted in significant bias (i.e. ≥ 10%) and that the overall accuracy of the abundance estimates was sufficient for management.

The ratio of tagged: untagged dead fish discovered during the second event was about twice that of our observed capture probabilities (Appendix C1), demonstrating that some tagging mortality occurred. The magnitude of the tagging or natural mortality was not believed to be severe because the overall number of mortalities discovered was small. Dead fish were easily spotted due to their white bellies and the study area was thoroughly covered by several crews over the course of the experiment. Tagging mortality would result in an estimate biased high compared to the true population. Tagging mortality has been an issue in Minto Lakes pike studies in past years (Scanlon 2006) and thus population trends illustrated are likely to reflect reality.

Within Area-A tagging mortalities were the only observed violation of the closure assumptions and thus the estimate should be considered minimally biased high. Area-B, in contrast, suffered from an additional violation of closure assumptions with the apparent immigration of pike from Area-A1. This was indicated by the recapture of 7 fish in Area-B that were initially marked in Area-A1 while no fish initially marked in Area-B were recaptured in Area-A1. These results coincided with the results from Scanlon (2006) which concluded that there was a general movement of fish from outlying areas to core areas over the course of the experiment.

The combined effects of immigration and emigration generally lead to a positive bias with an unknown magnitude. Tagging mortality also results in a positive bias and in this study the magnitude of tagging mortality bias could not be accurately quantified. Therefore, the estimates for Area-B were problematic as the degree and direction of bias's were confounded.

Despite bias' in Area-B estimates deriving from mortalities and immigration, data from radio-telemetry studies of pike lends credence to the scale of the Area-A and Area-B estimates. The proportion of the Area-A estimate contained in the Area-B estimate (61%) was in the range of the 36%–58% of observed radio tags observed in Area-B in 2007 (Joy *unpublished*) and the relative size of Area-B to Area-A (~0.64:1). Given that current data suggests a fundamentally sound estimate for Area-A (knowingly biased high given tagging mortalities) the estimate derived for Area-B appears reasonable despite confounding biases resulting from immigration and tagging mortality.

It is thus believed that the Area-B estimate was not severely biased (i.e. ≥ 10%) and can be reliably used for management and interpretation of population trends because the study design has remained constant and the Area-B estimate appears reasonable given the more reliable estimate derived for Area-A. Until analysis is completed on the radiotelemetry project that occurred concurrently with this mark-recapture study the Area-B estimate should be regarded as potentially biased, but a more or less accurate estimate that correctly reflects the population status of northern pike in the Minto Lakes.

Movement data from recaptured fish indicated that mixing did occur to a certain degree, however the exact nature and degree of movement of fish remains to be elucidated by the UAF radiotelemetry study. Detailed radiotracking will demonstrate peak periods of activity and the amount and degree of movement occurring on a daily basis in northern pike. Data of this nature may be used to determine the proportion of fish being subjected to capture during each of the events and the degree to which the population mixes between events. This will aid in refining study designs and for evaluating results from present and past studies.

SUGGESTIONS FOR FUTURE STUDIES

Future studies on northern pike should avoid sampling using traps immediately following spawning as a precaution against potential increases in handling stress during this time of year. Pike have been safely handled during spawning in lakes where beach seines are the primary sampling gear (Scanlon 2001, Pearse and Burkholder 1993, Hansen and Pearse 1995). However, spawning and post-spawning pike held in potentially crowded hoop and fyke traps appear to suffer from handling effects. All observed tagging mortalities in 2008 were of fish captured in hoop or fyke traps. There were no observed mortalities of fish sampled by either gillnet or hook-and-line gear. Projects that require trapping gear would best be delayed until after June 7 as this would leave ample time for fish to recuperate from spawning and still occur within the closure window observed from radio-tagged pike. A better understanding of the daily movement patterns of northern pike may help identify optimal times to check traps so as to reduce the amount of time fish are likely to be held.

The study area in 2008 was expanded from past experiments (i.e. Area-A1 was added) to better reflect the contiguous pike habitat within the Minto Lakes. Although this required greater fishing effort (and subsequent expense) it eliminated potential closure violations relative to Area-A. Using the more restricted Area-B left large areas of the contiguous population unsampled and subject to closure issues as fish move back and forth between lakes and sloughs. Only between 36% and 58% of radio-tagged pike tracked in 2007 within Area-A were observed in Area-B during June 2007 (Joy *unpublished*). The point estimate for Area-B (9,854) was 61% of the Area-A estimate of 16,045 northern pike. While these proportions are from different years and may not be directly comparable, they do suggest that a sizable portion of the population occupies habitat outside of the margins of the traditional study area.

The 2007 telemetry data and 2008 UAF telemetry data (Matt Albert, Fisheries Graduate Student, Unpublished Data) contrasts with the distribution of radio-tagged northern pike observed by Roach (1998b). Roach found little to no use of Upper Minto Lake by radio-tagged northern pike in contrast to what has been observed in 2007 (Joy *unpublished*) and 2008. Roach's tags were placed in fish within Area-B, however, and may reflect fidelity to particular areas rather than proportional usage of the Minto Lakes complex. It is also possible given the shallow nature of

Area-A1 that varying water levels between years may affect distribution of northern pike in the complex.

Given these results, it is advisable that the department continue to make efforts to sample the entire Minto Lakes defined in Area-A. The expense of an additional crew of two people to sample Area-A1 is worth a more reliable and accurate population assessment of the Minto Lakes. This still allows for the derivation of Area-B estimates for historical comparisons while also providing a more biologically accurate estimate of the population that better satisfies model assumptions.

Nevertheless, should the department find it more practical, fiscally and logistically, to return to sampling in Area-B, certain considerations may be taken to mitigate sources of bias in the derived estimates. By delaying sampling until well after the completion of spawning and checking traps more frequently or at different intervals biologists may reduce or eliminate potential handling mortalities. The ongoing telemetry research will ultimately be used to address potential biases and improve the study design.

The pre-spawning migration of northern pike up Goldstream Creek and into the Minto Lakes in late April and early May would seem to provide an ideal opportunity to either count the entire population or to mark a large number of fish. An attempt was made to do this in 2008 however ice conditions prevented any sampling from taking place (Figure 6 and 7). As described above, the majority of pike moved into the study area while the majority of the surface was still covered in thick layers of ice. Efforts to fish gear in small leads in the ice proved fruitless because the channel could not be blocked and large pans of ice quickly destroyed gear and traps. Additionally, high water levels that are common during the spring thaw cause the Chatanika River and Goldstream Creek to back up into the Minto Lakes thus preventing the ice from being flushed out in a single "ice-out" event. It is not recommended that this approach be attempted again as only the most ideal conditions would allow sampling to occur.

MANAGEMENT IMPLICATIONS

The estimates produced in this experiment, despite a likely positive bias, demonstrated a significantly smaller population of northern pike ≥400 mm FL in Area-B since 1996. There were similarly less fish in 2008 than in past years for northern pike ≥600 mm FL. For fish over 725 mm FL, poor precision precluded detecting all but extreme changes in abundance.

While it has been demonstrated that there were significantly fewer pike in Area-B than in past years, the causes for the described decline are unknown as the variables controlling the population dynamics are not understood. One may ascribe smaller populations to increases in harvest and catch over the past few years and, indeed, increased fishing pressure may be partially responsible for the observed trends. However, harvest estimates were well within historical levels (Table 1, Figure 14) and variation in natural mortality is suspected by ADF&G staff as a significant factor in this system (Brase 2008). Additionally, climate change over the past 50 years has resulted in a measurable and noticeable drying of the Minto Flats Wildlife Refuge characterized by lowering water tables and fewer ponds (Riordan et al. 2006, Riordan 2005). Such trends may result in less habitat for northern pike. It is likely that several factors are driving changes in northern pike abundance in the Minto Lakes and identifying and quantifying the causes of population declines remains beyond the scope of this experiment.

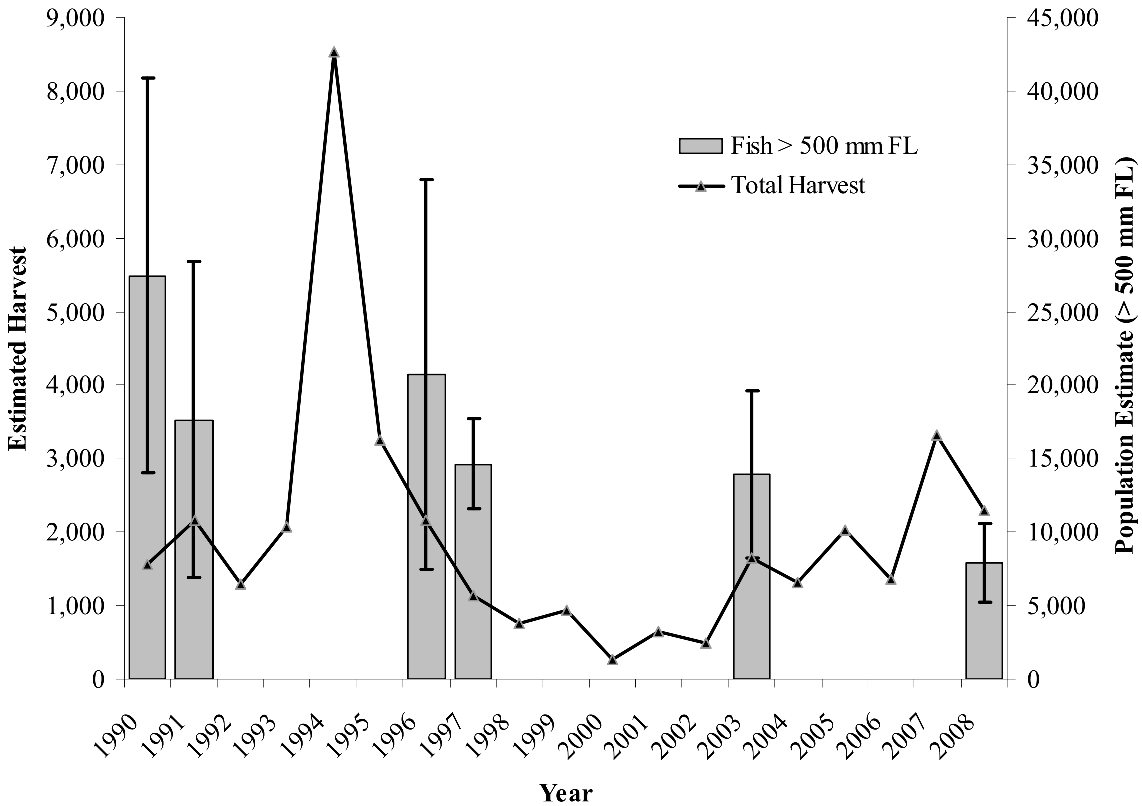

Figure 14.–Historical harvest estimates for all northern pike and population estimates for northern pike ≥500 mm FL in the Minto Flats. Error bars represent 95% confidence intervals.

Exploitation rates calculated based on population estimates and harvest estimates appear to be substantially higher than they were during the last stock assessment in 2003 and above that recommended in the management plan. If one considers the pike harvested by Fairbanks North Star Borough resident subsistence permit holders a reasonable estimate of the subsistence harvest from the Minto Lakes region (Table 1), then the mean estimated total harvest of northern pike from the sport and subsistence fishery for the period 2005 through 2007 was 2,236 northern pike which represented 13.9% of the estimated abundance of northern pike ≥400 mm FL in the Minto Lakes summer population. Based on the population estimated in Area-B, the historically used area for estimating abundance and calculating exploitation rates, the exploitation rate was 22.7% which was considerably higher than the exploitation rate of 5% calculated in 2003 (Scanlon 2006). In evaluating exploitation rates relative to management, it is recommended that the results and discussion for this study be taken into consideration, particularly the far greater abundance of fish identified in Area-A. The premise of the management plan calls for exploitation rates to be based on the abundance of fish within the Minto Lakes, which is more accurately represented by Area-A, rather than Area-B.

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REFERENCES CITED

Andrews, E. 1988. The harvest of fish and wildlife for subsistence by residents of Minto, Alaska. Alaska Department of Fish and Game, Technical Paper No. 137, Juneau.

Bailey, N. T. J. 1951. On estimating the size of mobile populations from capture-recapture data., Biometrika 38: 293-306.

Bailey, N. T. J. 1952. Improvements in the interpretation of recapture data. Journal of Animal Ecology 21:120-127.

Brase, A. L. J. 2008. Fishery management report for recreational fisheries in the Lower Tanana River Management Area, 2006. Alaska Department of Fish and Game, Fishery Management Report No. 08-27, Anchorage.

Burkholder, A. 1989. Movements, stock composition, and abundance of northern pike in Minto Flats during 1987 and 1988. Alaska Department of Fish and Game, Fishery Data Series No. 116, Juneau.

Burkholder, A. 1990. Stock composition of northern pike in Minto Flats during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-25, Anchorage.

Burkholder, A. 1991. Abundance and composition of northern pike, Harding Lake, 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-09, Anchorage.

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

Cochran, W. G. 1977. Sampling techniques, 3rd edition. New York, John Wiley and Sons.

Conover, W. J. 1980. Practical nonparametric statistics, 2nd edition. New York, John Wiley and Sons.

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

Hansen, P. A. and G. A. Pearse. 1995. Abundance and composition of northern pike in Volkmar and Deadman lakes, 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-07, Anchorage.

Hansen, P. A., and A. Burkholder. 1992. Abundance and stock composition of northern pike in Minto Flats, 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-48, Anchorage.

Holmes, R. A. and A. Burkholder. 1988. Movements and stock composition of northern pike in Minto Flats. Alaska Department of Fish and Game, Fishery Data Series No. 53, Juneau.

Holmes, R. A., and G. A. Pearse. *Unpublished*. Northern pike stock status and regulatory concerns in the Arctic Yukon Kuskokwim Region. Alaska Department of Fish and Game Report to the Alaska Board of Fisheries, 1987.

Howe, A. L., G. Fidler, A. E. Bingham, and M. J. Mills. 1996. Harvest, catch, and participation in Alaska sport fisheries during 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-32, Anchorage.

Howe, A. L., G. Fidler, and M. J. Mills. 1995 Harvest, catch, and participation in Alaska sport fisheries during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-32, Anchorage.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001a. Revised Edition. Harvest, catch and participation in Alaska sport fisheries during 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-29 (revised), Anchorage.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001b. Revised Edition. Harvest, catch and participation in Alaska sport fisheries during 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-25 (revised), Anchorage.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001c. Revised Edition. Harvest, catch and participation in Alaska sport fisheries during 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-41 (revised), Anchorage.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001d. Revised Edition. Harvest, catch and participation in Alaska sport fisheries during 1999. Alaska Department of Fish and Game, Fishery Data Series No. 01-08, Anchorage.

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2004. Participation, catch, and harvest in Alaska sport fisheries during 2001. Alaska Department of Fish and Game, Fishery Data Series No. 04-11, Anchorage.

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2006a. Participation, catch, and harvest in Alaska sport fisheries during 2002. Alaska Department of Fish and Game, Fishery Data Series No. 06-34, Anchorage.

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2006b. Participation, catch, and harvest in Alaska sport fisheries during 2003. Alaska Department of Fish and Game, Fishery Data Series No. 06-44, Anchorage.

Joy, P. *Unpublished*. Alaska Department of Fish and Game, Division of Sport Fish, Fairbanks. Summary of Minto northern pike radio-telemetry project. 2007 memorandum from Philip Joy to Matt Evenson, Regional Research Supervisor Region III, Division of Sport Fish summarizing results for 2007 pilot study.

Pearse, G. A. and A. Burkholder. 1993. Abundance and composition of the northern pike populations in Volkmar, George, T, and East Twin lakes, 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-10, Anchorage.

Riordan, B. A. 2005. Using remote sensing to examine changes of closed-basin surface water area in interior Alaska from 1950-2002. Masters Thesis, University of Alaska Fairbanks.

Riordan, B., D. Verbyla and A. D. McGuire. 2006. Shrinking ponds in subarctic Alaska based on 1950-2002 remotely sensed images, Journal of Geophysical Research, 111, G04002, doi: 10.1029/2005JG000150.

Roach, S. M. 1997. Abundance and composition of the northern pike population in Minto Lakes, 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-17, Anchorage.

Roach, S. M. 1998a. Abundance and composition of the northern pike population in Minto Lakes, 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-12, Anchorage.

Roach, S. M. 1998b. Site fidelity, dispersal, and movements of radio-implanted northern pike in Minto Lakes, 1995–1997. Alaska Department of Fish and Game, Fishery Manuscript No. 98-01, Anchorage.

Scanlon, B. P. 2001. Abundance and composition of the northern pike populations in Volkmar Lake and Minto Lakes, 2000. Alaska Department of Fish and Game, Fishery Data Series No. 01-29, Anchorage.

Scanlon, B. 2006. Abundance and composition of the northern pike population in Minto Lakes, 2003. Alaska Department of Fish and Game, Fishery Data Series No. 06-74, Anchorage.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, second edition. Charles Griffen and Company, Limited, London.

Walker, R. J., C. Olnes, K. Sundet, A. L. Howe, and A. E. Bingham. 2003. Participation, catch, and harvest in Alaska sport fisheries during 2000. Alaska Department of Fish and Game, Fishery Data Series No. 03-05, Anchorage.

APPENDIX A

Appendix A1.–Detection of length or sex selective sampling during a 2-sample mark recapture experiment and its effects on estimation of population size and population composition.

Length selective sampling: The Kolmogorov-Smirnov two sample test (Conover 1980) is used to detect significant evidence that length selective sampling occurred during the first or second sampling events. The second sampling event is evaluated 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 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. A third test, comparing M and C, is conducted and used to evaluate the results of the first two tests when sample sizes are small. Guidelines for small sample sizes are <30 for R and <100 for M or C.

Sex selective sampling. Contingency table analysis (Chi^2-test) is generally used to detect significant evidence that sex selective sampling occurred during the first of second sampling events. The counts of observed males to females are compared between M&R, C&R, and M&C as described above, using the null hypothesis that the probability that a sampled fish is male or female is independent of sample. When the proportions by gender are estimated for a sample (usually C), rather an observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are compared between samples using a two sample test (e.g., Student's t-test).

M vs. R	**C vs. R**	**M vs. C**
Case I:		
Fail to reject H_o	Fail to reject H_o	Fail to reject H_o

There is no length/sex selectivity detected during either sampling event.

Case II:

Reject H_o	Fail to reject H_o	Reject H_o

There is no length/sex selectivity detected during the first event but there is during the second event sampling.

Case III:

Fail to reject H_o	Reject H_o	Reject H_o

There is no length/sex selectivity detected during the second event but there is during the first event sampling.

Case IV:

Reject H_o	Reject H_o	Reject H_o

There is length/sex selectivity detected during both the first and second sampling events.

Evaluation Required:

Fail to reject H_o	Fail to reject H_o	Reject H_o

Sample sizes and powers of tests must be considered:

A. If sample sizes for M vs. R and C vs. R tests are not small and sample sizes for M vs. C test are very large, the M vs. C test is likely detecting small differences which have little potential to result in bias during estimation. *Case I* is appropriate.

B. If a) sample sizes for M vs. R are small; b) the M vs. R p-value is not large (~0.20 or less); and, c) the C vs. R sample sizes are not small and/or the C vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of length/sex selectivity during the second event which the M vs. R test was not powerful enough to detect. *Case I* may be considered but *Case II* is the recommended, conservative interpretation.

-continued-

C. If a) sample sizes for C vs. R are small; b) the C vs. R p-value is not large (~0.20 or less); and, c) the M vs. R sample sizes are not small and/or the M vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of length/sex selectivity during the first event which the C vs. R test was not powerful enough to detect. *Case I* may be considered but *Case III* is the recommended, conservative interpretation.

D. If a) sample sizes for C vs. R and M vs. R are both small; and, b) both the C vs. R and M vs. R p-values are not large (~0.20 or less), the rejection of the null in the M vs. C test may be the result of length/sex selectivity during both events which the C vs. R and M vs. R tests were not powerful enough to detect. *Cases I, II, or III* may be considered but *Case IV* is the recommended, conservative interpretation.

Case I. 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. 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. 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. 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. 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.

If 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:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}_\Sigma} \hat{p}_{ik} \text{, and} \tag{1}$$

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

where:

j = the number of sex/length strata;

$\hat{p}_{ik}$ = the estimated proportion of fish that were age or length k among fish in stratum i;

$\hat{N}_i$ = the estimated abundance in stratum i;

$\hat{N}_\Sigma$ = sum of the $\hat{N}_i$ across strata.

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 temporally or geographically stratified estimator (Darroch 1961) should be used to estimate abundance.

I.-Test for complete mixing[a]

Area/Time	Area/Time Where Recaptured				Not Recaptured
Where Marked	**1**	**2**	**…**	**t**	(n_1-m_2)
1					
2					
…					
s					

II.-Test for equal probability of capture during the first event[b]

	Area/Time Where Examined			
	1	**2**	**…**	**t**
Marked (m_2)				
Unmarked (n_2-m_2)				

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

	Area/Time Where Marked			
	1	**2**	**…**	**s**
Recaptured (m_2)				
Not Recaptured (n_1-m_2)				

[a] This tests the hypothesis that movement probabilities (θ) from time or area *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 time or area designations: 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 time or area designations: 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

Appendix B1.–Data files used to estimate parameters for abundance estimation of northern pike in the Minto Lakes in 2008.

Data File	Description
MintoPike2008_RawData.xls	File includes all northern pike sampled for mark-recapture experiment from Minto lakes during spring 2008.

Note: Data files have been archived at the Alaska Department of Fish and Game, Research and Technical Services, Anchorage, Alaska 99518; and are available from the authors, Division of Sport Fish, 1300 College Road, Fairbanks, AK 99701.

APPENDIX C

Appendix C1.–Number of northern pike ≥400 mm FL marked (n_1), examined (n_2) and recaptured (m_2) by study section in the Minto Lakes in May and June 2008.

Study section where marked	Study section where captured																										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	m_2	n_1	m_2/n_1[b]
1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	0.14
2	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	84	0.05
3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	12	0.08
4	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3	23	0.13
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47	0.00
6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	12	0.08
7	0	3	0	1	0	0	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	27	0.30
8	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4	59	0.07
9	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	38	0.03
10	0	0	0	0	0	0	0	1	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	4	73	0.05
11	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	30	0.07
12	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	4	94	0.04
13	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	43	0.02
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	0.00
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0.00
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	0.00
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	4	42	0.10
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	0.00
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0.00
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0.00
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	36	0.03
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0.00
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0.00
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0.00
m^2	0	11	1	1	1	0	1	6	0	4	0	5	0	0	2	0	5	1	0	0	1	0	0	0			
n^2	5	49	7	47	27	19	27	60	26	38	15	58	37	31	16	26	36	21	21	26	29	12	32	13			
(m^2/n^2)[a]	0.00	0.22	0.14	0.02	0.04	0.00	0.04	0.10	0.00	0.11	0.00	0.09	0.00	0.00	0.13	0.00	0.14	0.05	0.00	0.00	0.03	0.00	0.00	0.00			

[a] Probability of capture during the first event

[b] Probability of capture during the second event.

Appendix C2.–Number of northern pike ≥400 mm FL marked (n_1), examined (n_2) and recaptured (m_2) by water body in the Minto Lakes in May and June 2008.

		Water body where recaptured											
		LC	ML	CS	NL	SL	A10	BL	UL	RS	m_2	n_1	$(m_2/n_1)^b$
Water body where marked	LC	1	6	1	2	0	1	0	0	0	11	58	0.19
	ML	0	4	0	0	0	0	0	0	0	4	71	0.06
	CS	0	0	1	1	0	0	1	0	0	3	83	0.04
	NL	0	1	0	2	0	0	0	0	1	4	59	0.07
	SL	0	0	0	0	0	1	0	0	0	1	38	0.03
	A10	0	0	0	1	0	2	1	0	0	4	283	0.01
	BL	1	0	0	0	0	0	10	0	0	11	80	0.14
	UL	0	0	0	0	0	0	0	1	0	1	47	0.02
	RS	0	0	0	0	0	0	0	0	0	0	90	0.00
	m_2	2	11	2	6	0	4	12	1	1			
	n_2	58	83	40	60	26	211	46	42	112			
	$(m_2/n_2)^a$	0.03	0.13	0.05	0.1	0.00	0.02	0.26	0.02	0.01			

[a] Probability of capture during the first event

[b] Probability of capture during the second event.