Fishery Data Series No. 12-23

Abundance, Length Composition, and Movement of the Northern Pike Population in Long Lake of the Chulitna River Drainage, 2007–2010

by

Craig J. Schwanke

May 2012

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

Symbols and Abbreviations

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

Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

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

FISHERY DATA SERIES NO. 12-23

ABUNDANCE, LENGTH COMPOSITION, AND MOVEMENT OF THE NORTHERN PIKE POPULATION IN LONG LAKE OF THE CHULITNA RIVER DRAINAGE, 2007–2010

by

Craig J. Schwanke
Alaska Department of Fish and Game, Division of Sport Fish, Dillingham

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

May 2012

This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-21 and Job No. R-2-9.

ADF&G Fishery Data Series was established in 1987 for the publication of Division of Sport Fish technically oriented results for a single project or group of closely related projects, and in 2004 became a joint divisional series with the Division of Commercial Fisheries. Fishery Data Series reports are intended for fishery and other technical professionals and are available through the Alaska State Library and on the Internet: http://www.adfg.alaska.gov/sf/publications. This publication has undergone editorial and peer review.

Craig J. Schwanke,
Alaska Department of Fish and Game, Division of Sport Fish,
546 Kenny Wren Road, P.O. Box 230, Dillingham, AK 99576-0230, USA

This document should be cited as:
Schwanke, C. J. 2012. Abundance, length composition, and movement of the northern pike population in Long Lake of the Chulitna River drainage, 2007–2010. Alaska Department of Fish and Game, Fishery Data Series No. 12-23, Anchorage.

The Alaska Department of Fish and Game (ADF&G) administers all programs and activities free from discrimination based on race, color, national origin, age, sex, religion, marital status, pregnancy, parenthood, or disability. The department administers all programs and activities in compliance with Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act (ADA) of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972.

If you believe you have been discriminated against in any program, activity, or facility please write:
ADF&G ADA Coordinator, P.O. Box 115526, Juneau, AK 99811-5526
U.S. Fish and Wildlife Service, 4401 N. Fairfax Drive, MS 2042, Arlington, VA 22203
Office of Equal Opportunity, U.S. Department of the Interior, 1849 C Street NW MS 5230, Washington DC 20240

The department's ADA Coordinator can be reached via phone at the following numbers:
(VOICE) 907-465-6077, (Statewide Telecommunication Device for the Deaf) 1-800-478-3648,
(Juneau TDD) 907-465-3646, or (FAX) 907-465-6078

For information on alternative formats and questions on this publication, please contact:
ADF&G, Division of Sport Fish, Research and Technical Services, 333 Raspberry Road, Anchorage AK 99518 (907) 267-2375.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

In 2007, a multi-event mark–recapture experiment was conducted to estimate the abundance and length distribution of northern pike (*Esox lucius*) in Long Lake of the Chulitna River drainage. Radio telemetry was used to track the movements of 40 radiotagged northern pike through the spring of 2010. The estimated abundance of northern pike at least 485 mm fork length (FL) was 13,625 fish (SE 1,690). The greatest proportions of northern pike were between 501 and 600 mm FL (proportion 0.57, SE 0.01) or between 401 to 500 mm FL (proportion 0.21, SE 0.01). The proportion of active transmitters that remained in Long Lake during seasonal periods from summer 2007 to spring 2010 ranged from 1.00 (SE 0.00) to 0.71 (SE 0.17).

Keywords: northern pike, *Esox lucius*, Long Lake, Chulitna River, telemetry, mark–recapture, abundance, length composition.

INTRODUCTION

Northern pike (*Esox lucius*) are common and indigenous throughout the Bristol Bay Management Area; however, drainages that support large trophy northern pike over 1,020 mm (40 in) in length are rare. The Chulitna River drainage of Lake Clark supports a unique opportunity for anglers to catch trophy northern pike in Southwest Alaska. Northern pike are reportedly abundant at 3 locations within the drainage: Nikabuna lakes, Long Lake, and the sloughs of the lower Chulitna River near its confluence with Lake Clark (Figure 1). It is not uncommon for an angler to catch northern pike over 1,020 mm (40 in) in length and fish over 1,270 mm (50 in) have been reported. Catch and harvest from 1996 to 2004 have been low with the highest effort (301 angler days), catch (663 fish), and harvest (491 fish) documented in 1999 (Howe et al. 2001a-d; Jennings et al. 2004, 2006a-b, 2007; Walker et al. 2003). Some subsistence harvest of northern pike in the Chulitna River drainage does occur, but harvest numbers are unknown.

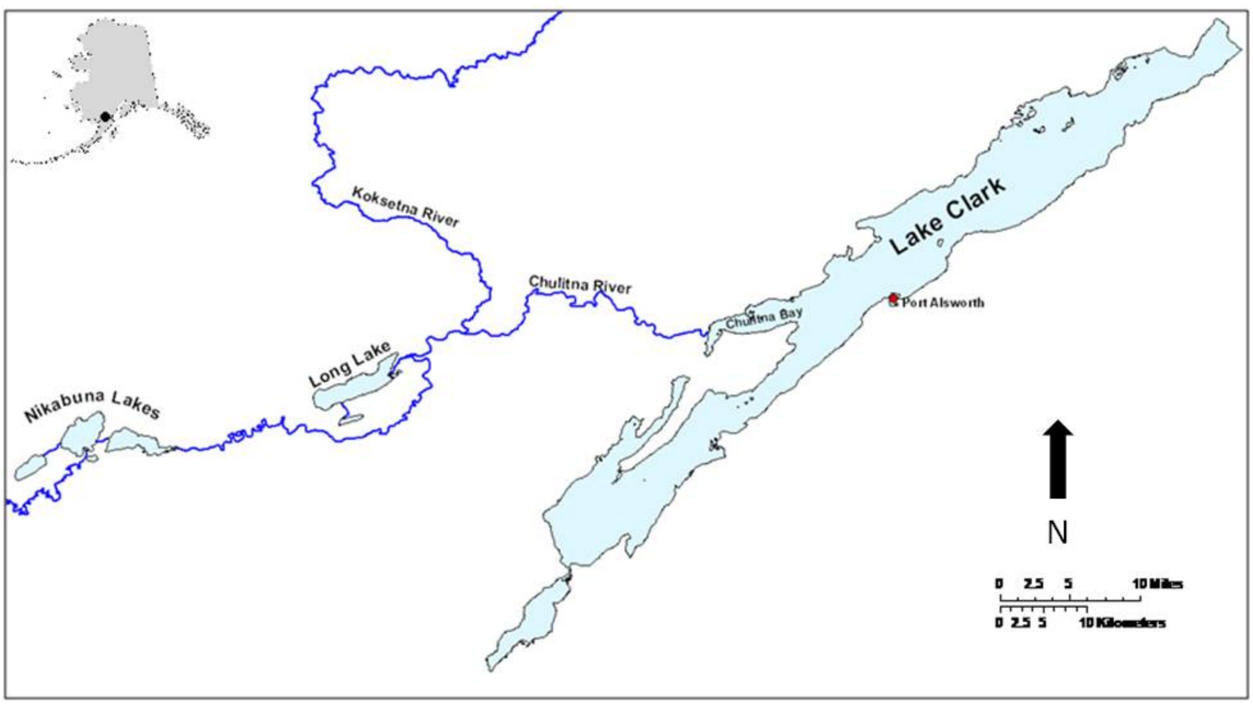

Figure 1.–Chulitna River drainage of Lake Clark in southwest Alaska.

In 2006, the Bristol Bay Fish and Game Advisory Committee presented a proposal to the Alaska Board of Fisheries (BOF) expressing concern that the harvest of large northern pike would result in a population of small northern pike because cannibalism by large northern pike may be an important factor in regulating the size structure of northern pike populations (Mann 1982, Pierce et al. 1995). In response to this concern, BOF amended the bag limit for northern pike in the Chulitna drainage from 5 per day, 5 in possession, 1 over 30 inches (~720 mm fork length, FL) to 5 per day, 5 in possession, none of which may be larger than 30 inches, with the intent of preserving large northern pike in the drainage.

During July of 2006, staff from the Alaska Department of Fish and Game (ADF&G) sampled northern pike with hoop traps, hook and line, and gillnets in the lower Chulitna River, Chulitna Bay of Lake Clark, and Long Lake. Estimates were made of catch per unit effort and FL composition for each gear type (C. J. Schwanke, Sport Fish Biologist, ADF&G, Dillingham, unpublished). In addition, the logistics of conducting research during the spring were ascertained and likely spawning locations were identified.

The goal of this study was to obtain information on the current stock of northern pike in Long Lake of the Chulitna River drainage. A mark–recapture study was conducted during May and June of 2007 to estimate the abundance of northern pike in Long Lake. Length and maturity compositions of the northern pike population were estimated as well. These length composition and abundance estimates represent the condition of the population at the time the size-limit regulation was imposed, and allow future evaluation of the effectiveness of the new regulation in maintaining the size composition of the northern pike population. In addition, radio telemetry was used to determine seasonal movements of northern pike in Long Lake and to aid in the evaluation of assumptions for the mark–recapture abundance estimate. At the same time as the Long Lake study, northern pike in the lower Chulitna River were radiotagged by the United States National Park Service (NPS) stationed at Lake Clark. Movement data of the 2 populations were compared to see if mixing occurs among the locations.

OBJECTIVES

The 2007 research objectives for Long Lake were as follows:

1) Estimate the abundance of northern pike at least 300 mm FL.

2) Estimate the length composition of the population of northern pike at least 300 mm FL.

3) Estimate the proportion of northern pike residing in Long Lake in the spring of 2007 that remained in Long Lake for each of the 5 time periods: postspawning (late June 2007), summer (August 2007), winter (January 2008), prespawning (late April 2008), and spring (May) of 2008.

TASKS

Additional project tasks were as follows:

1) Estimate the length distributions of northern pike susceptible to hook-and-line gear, gillnetting, and hoop traps in Long Lake.

2) Estimate the proportion of sexually mature northern pike by sex and length class.

METHODS

Description of Study Area

Long Lake (982 ha) is approximately 33.8 km (21 mi) upriver from Lake Clark and is connected to the Chulitna River by a 1.6 km (1 mi) long slough (Figure 1). Long Lake is 4 km (2.5 mi) long and can be accessed by boat or float-equipped aircraft.

Abundance Estimation

Experimental and Sampling Design

This study was designed to estimate abundance and length composition of northern pike in Long Lake using multiple-event mark–recapture techniques for a closed population (Seber 1982) and was designed to satisfy the following assumptions:

1) The population was closed (northern pike did not enter the population via birth, growth [into the sampled size class], or immigration, or leave the population via death or emigration, during the experiment).
2) All northern pike had a similar probability of capture during each sampling event, or marked and unmarked northern pike mixed completely between events.
3) Marking did not affect the probability of capture in the later sampling events.
4) Marks were identifiable during all subsequent sampling events.
5) All marked northern pike were reported when recovered in all subsequent sampling events.

Failure to satisfy these assumptions may result in a biased estimate; therefore, the experiment was designed to allow the validity of these assumptions to be ensured or tested (see Evaluation of Assumptions section below).

Sampling Methods

Four sampling events were conducted between 20 May and 16 June, immediately following ice breakup. The study area was divided into 4 subareas to distribute effort and to allow for assessment of fish movement. These subareas were selected based on available spawning habitat (shallow vegetated areas) and the majority of spawning habitat was located on the east end of the lake. As a result, the east end of the lake was divided into three subareas to allow for more effort at the east end of the lake. The 4 subareas in Long Lake were 1) a series of 3 interconnected ponds at the south half of the east end, 2) the slough connecting Long Lake to the Chulitna River including a section of the south half of the east end of the lake, 3) the north half of the east end, and 4) the western half of the lake (Figure 2). Sampling in each subarea occurred in half-day increments.

Northern pike were captured with hoop traps, gillnets, and hook and line. The hoop traps had a 0.9 m (3 ft) diameter opening, and were 3.7 m (12 ft) long. Each hoop trap had two 15 m (50 ft) wings that were 1.5 m (5 ft) deep to funnel northern pike into the trap, and were generally placed with one wing extended toward the shoreline and the other out away from shore. In sloughs with a width of less than 18 m (60 ft), 2 traps were sewn together to block out migrating or emigrating fish such that fish moving in either direction were caught. Hoop traps were fished overnight and checked periodically during the day.

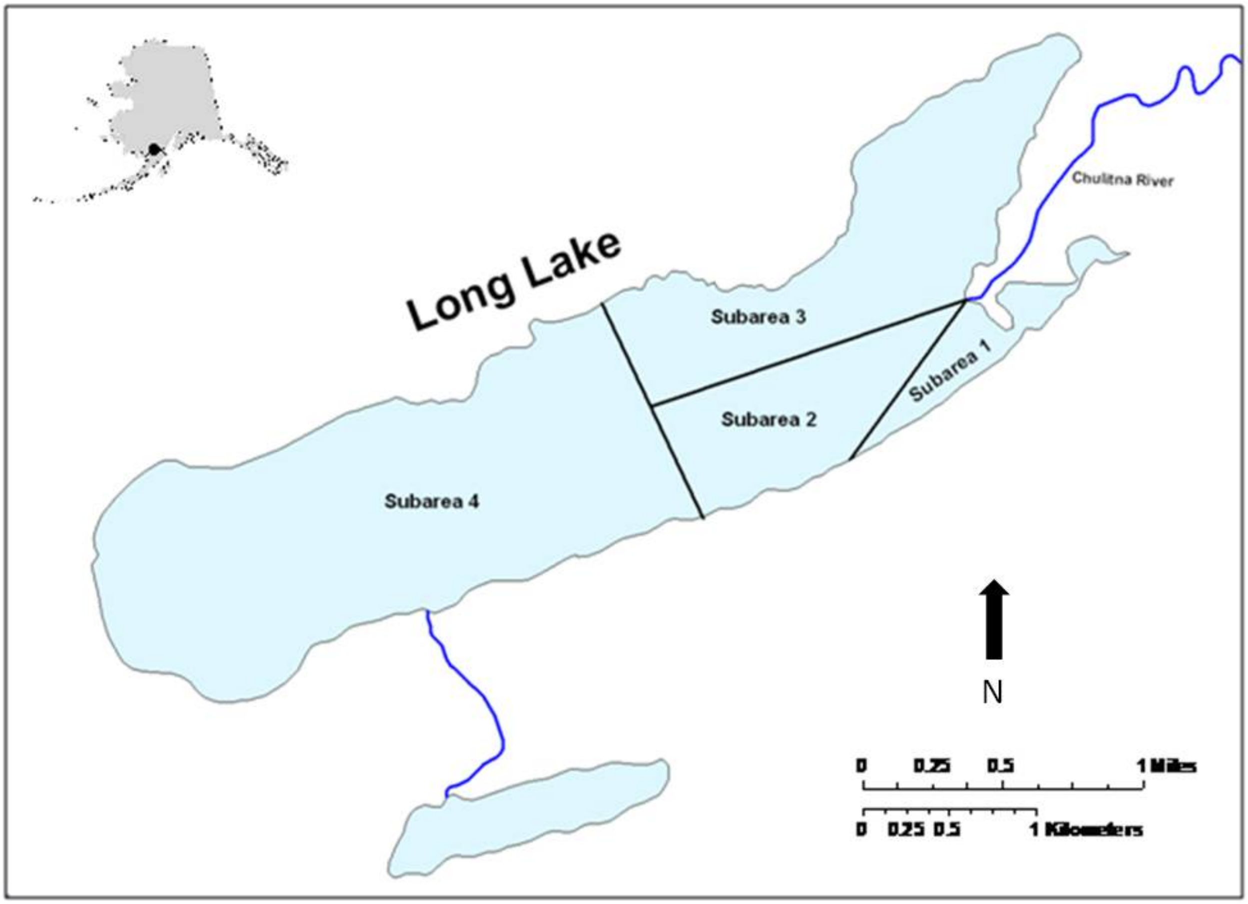

Figure 2.–Long Lake of the Chulitna River drainage was divided into 4 subareas, labeled subareas1–4.

Gillnets were 15 m (50 ft) long, 3.0 m (10 ft) deep with 5.1 cm (2 in) square mesh. Gillnets were fished perpendicular to the shoreline in sloughs or parallel to patches of weedy habitat on large bodies of water. Initially, each net was checked every 20 minutes and the length of time for each gillnet set was reduced if the condition of captured fish was compromised or if mortalities occurred. The crew fished up to 2 gillnets at a time. The amount of time gillnets and hoop traps were set and the amount of time spent angling were recorded for the estimation of catch per unit effort (CPUE). Time spent angling consisted of the amount of time each technician was actively fishing. Time spent changing lures, minor gear maintenance, and landing fish were considered active angling. Time spent sampling fish or moving from one subarea to another was not included.

While the field crew allowed gillnets and hoop traps to soak, they sampled fish with hook and line. Hook-and-line gear consisted of medium/heavy spinning tackle. A variety of lures were used including spoons, spinner baits, rubber jigs, and surface plugs. All hooked fish were landed as quickly as possible, placed in a tote of freshwater, sampled, and released.

All captured northern pike, at least 300 mm FL, were examined for tags and finclips, measured to the nearest millimeter, marked with individually numbered Floy[1] tags, and given a finclip as a secondary mark. Sexual maturity and sex was determined with the observation of gametes (sperm or eggs) when fish were lightly squeezed on each side of the abdomen directionally from the pectoral to pelvic fins. If sex could not be determined, the sex of the fish was classified as unknown. The gear used to capture the fish was also recorded. Biological data were initially recorded on a biological sampling field form and then transcribed according to ADF&G Standard Age-Weight-Length (AWL) Mark-Sense Form, Version 1.2. The biological sampling form was also used to record the time that each gear type was used for estimating CPUE.

Evaluation of Assumptions

Assumption 1—closed population

Fieldwork dates were chosen to coincide with the probable spawning period of northern pike in Long Lake and the study area encompassed likely spawning areas. During this time period, the northern pike population was likely "closed" because northern pike concentrate in spawning areas. In addition, the short duration of the experiment helped guard against significant immigration or emigration, as well as rendering recruitment via growth into the sampled size-class insignificant. Natural mortality during the experiment was assumed insignificant and little sport fishing effort was observed during the project (C. Larson, Sport Fish Technician, ADF&G, Dillingham, personal communication).

The selection of a statistical test for a "closed population" depended upon which abundance estimation model was ultimately chosen during analysis. If Model M_o or M_h (Otis et al. 1978) were chosen, then the closure test developed by Pollock (1974) would be used. If model M_t was chosen, the test of closure developed by Stanley and Burnham (1999) (CLOSETEST) would be used.

Assumption 2—same probability of capture for each event

Size-selective sampling

Tests for size-selective sampling were based on the Kolmogorov-Smirnov (K-S) test (Conover 1980) and were conducted for a 2-sample experiment. Size stratification of these data were performed, if necessary, to minimize bias in abundance estimation. Two series of tests were conducted.

The first series of tests was used to evaluate size-selective sampling for events *1* through *T-1* as "marking" events (where *T* is the total number of sampling events). For each event *t*, the cumulative length frequency distributions were compared for 1) those marked fish that were handled during event *t* and released alive into the lake, and 2) those fish from (1) that were observed at least once as recaptures during events *t+1* through *T*. Rejection of the null hypothesis (no difference in distributions) would indicate size-selective sampling during event *t*.

The second series of tests was used to evaluate size-selective sampling for events *t+1* through *T* as "recapture" events. For each event *t*, the cumulative length frequency distributions were compared for 1) those fish that were inspected for marks during event *t*, and 2) those fish from (1) that were recaptures of fish marked during events *1* through *t-1*. Rejection of the null hypothesis (no difference in distributions) would indicate size-selective sampling during event *t*.

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

If size-selective sampling was detected and stratification was necessary to reduce bias, the data would be stratified by size after inspecting the cumulative length frequency distributions to identify near-optimal stratification breaks, and diagnostic tests for size selectivity would be repeated for each size strata. Once a stratification scheme that minimized potential bias from size selectivity within strata was identified, further diagnostic testing and model selection for estimating abundance would be conducted independently for each size stratum.

Contingency table analyses were used to test for unequal probability of capture between lake subareas. Three types of tests were adapted from tests described by Seber (1982) to evaluate equal probability of capture between temporally or geographically distinct sample nodes and mixing between sampling events.

The first type of test evaluated equal probability of capture between lake subareas after a particular "marking" event *t*. Only those fish with marks that were handled during an event *t* and released alive into the lake were considered "marked" fish, both those marked initially during event *t* and those that were marked previously and recaptured during event *t*. Contingency tables were constructed and tested for all but the final sampling event. For each "marking" event *t* ($t = 1$ to $T-1$ where *T* is the total number of sampling events), rows were comprised of lake subareas and the 2 entries (columns) for each row were 1) those fish that were recaptures of "marked" fish, and 2) those fish that were captured but not "marked." For each subarea, columns 1 and 2 contained the respective "marked" and "unmarked" sums of all individual fish inspected for marks in that subarea during events $t+1$ through *T*; all subsequent observations of individual fish were ignored regardless which subarea these later observations were made in. This contingency table analysis tests the null hypothesis that the probability that an inspected fish (recaptured during events $t+1$ through *T*) was "marked" during event *t* is independent of the subarea where the fish was inspected. Rejection of the null hypothesis would be considered evidence that for marking event *t*, marked fish did not have an equal probability of recapture across subareas. Adjacent subareas (rows) would be pooled where sample sizes were considered small and there was no apparent evidence of heterogeneity between subareas considered for pooling.

The second type of test evaluated equal probability of capture of fish marked in different lake subareas for a particular "recapture" event *t*. Contingency tables were constructed and tested for all but the first sampling event. For each "recapture" event *t* ($t = 2$ to *T*), rows were comprised of lake subareas and the 2 entries (columns) for each row were 1) those fish that were "recaptured" during event *t*, and 2) those fish that were not "recaptured" during event *t*. For each subarea, columns 1 and 2 contained the respective "recaptured" or "not recaptured" sums of all individual fish sampled and marked for the first time in that subarea during events *1* through $t-1$; all subsequent observations of individual fish were ignored regardless of the subarea these later observations were made in, and all fish known to have died or been removed from the lake prior to event *t* were excluded. This contingency table analysis tests the null hypothesis that the probability that any previously marked fish is "recaptured" during event *t* is independent of the subarea where the fish was originally marked. Rejection of the null hypothesis would be considered evidence that for recapture event *t*, fish marked in a particular lake subarea did not have an equal probability of recapture. Adjacent subareas (rows) would be pooled where sample sizes were small and there was no apparent evidence of heterogeneity between subareas considered for pooling.

If unequal probability of capture between subareas was not detected for any sampling events, or was only detected for either the first or last sampling event, it would be concluded that geographic heterogeneity in probability of capture was not a potential source of bias in estimating abundance and program MARK (Version 5.1, White and Burnham 1999) could be used to identify the most appropriate closed-population multi-event model for estimating abundance.

If geographic capture heterogeneity was detected at levels sufficient to bias abundance estimation, the multi-event closed-population model approach would be abandoned and the data would be reconstructed and analyzed as a 2-event closed population experiment to estimate abundance. The first several days of sampling data (approximately half) would be grouped and treated as the first (marking) sampling event and the remaining days of sampling data would be grouped and treated as the second (recapture) sampling event. Replicate observations of individual fish within each of these 2 groupings would be ignored. Only fish that were sampled and tagged during the first grouping would be considered "marked," and any of the "marked" fish observed in the second grouping would be considered "recaptures."

For the 2-sample experiment described above, diagnostic testing using contingency table analysis for geographic capture heterogeneity would be conducted. If geographic capture heterogeneity was detected in both the first and second sampling event, the partially stratified model described by Darroch (1961) would be necessary to estimate abundance. If geographic capture heterogeneity was not detected in either the first or second sampling event, or both, Chapman's modification to the Petersen estimator (Seber 1982) would be appropriate for estimating abundance.

Assumption 3—no marking effect on capture probability

No handling or marking-induced behavioral effects were anticipated because fish were landed quickly with hook-and-line gear, placed in a tote of fresh water, and sampled quickly. In addition, hoop traps were checked frequently. In the rare event that a fish appeared injured or overly stressed, it was not tagged or included in the experiment.

Assumption 4—identifiable marks

This assumption was addressed by double-marking each northern pike captured during each sampling event. Tag loss was noted whenever a fish was recovered during the second and later events with a secondary mark (finclip) but without a Floy tag. In addition, tag placement was standardized, which enabled the fish handlers to verify tag loss by locating recent tag wounds. Because of the short duration of the experiment, no tag loss was anticipated.

Assumption 5—all recovered marked fish were reported

All fish were thoroughly examined for tags or recent finclips. All markings (tag number, tag color, finclip and tag wound) for each fish were recorded.

Abundance Estimation

While this project was designed to estimate abundance of northern pike at least 300 mm FL, the smallest fish recaptured was 485 mm FL; therefore, all abundance and diagnostic proportion estimates used were limited to northern pike at least 485 mm FL.

If the assumptions of the mark–recapture model were not violated, the data would be partitioned into 4 capture events and analyzed with Program MARK (White and Burnham 1999). Because all fish were tagged with uniquely numbered Floy tags, a full range of MARK models described for "Closed Captures" and "Closed Captures with Heterogeneity" data types could be assessed.

The proper estimator would be selected by examining the Akaike Information Criterion (AIC) for each model (Burnham and Anderson 2002).

Length and Maturity Composition

Length proportions, in 25 mm FL categories, and variance were estimated as a binomial proportion as follows (Cochran 1977):

$$\hat{p}_i = \frac{n_i}{n} \tag{1}$$

where

n_i = number of northern pike (≥485 mm FL) of length class i, and

n = total number of northern pike (≥485 mm FL) sampled.

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

$$V\hat{a}r(\hat{p}_i) = \frac{\hat{p}_i(1-\hat{p}_i)}{n-1}. \tag{2}$$

The proportion of sexually mature northern pike by sex and length class was also estimated as a binomial proportion as follows (Cochran 1977):

$$\hat{p}_{sim} = \frac{n_{sim}}{n_{si}} \tag{3}$$

where

n_{sim} = number of northern pike (≥485 mm FL) of sex s, in length class i, and maturity status m,

n_{si} = total number of northern pike (≥485 mm FL) of sex s, in length class i sampled.

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

$$V\hat{a}r(\hat{p}_{sim}) = \frac{\hat{p}_{sim}(1-\hat{p}_{sim})}{n_{si}-1}. \tag{4}$$

RADIOTELEMETRY

Experimental and Sampling Design

Transmitters were surgically implanted in 40 northern pike. Transmitter deployment was spread among the 4 subareas based on the sampling effort among subareas. Northern pike receiving a transmitter were anesthetized with clove oil as described by Anderson et al. (1997). Lotek Wireless Fish and Wildlife Monitoring (Model MCFT-3L) radio transmitters with unique codes spread over 4 frequencies (163.256, 163.269, 163.281 and 163.294) and a battery capacity of 339 days were surgically implanted in the coelomic cavity of selected northern pike through a 2–3 cm incision along the *linea alba*, anterior to the pelvic girdle (Hart and Summerfelt 1975). The incision was closed with 3 to 5 sutures. The outlet incision for the trailing antenna was posterior to the pelvic girdle. Each radio tag weighed 20 g. The procedure used for the placement of trailing antenna was similar to that described by Ross and Kleiner (1982). During the surgical procedure, fresh water was poured over the gills to prevent suffocation. Radiotagged fish were retained in a tote of freshwater until equilibrium was regained and then released near the site of capture.

The movements and seasonal distribution of radiotagged fish were documented by aerial tracking surveys, radiotracking stations, and boat tracking surveys. Aerial surveys occurred during the summer (June–October), winter (November–March), and during the spring spawning period (May) for 36 months following implantation. Boat surveys occurred during the spring of 2007 to document movement among subareas and to assess closure assumptions of the abundance estimate. All frequencies were programmed into a Lotek receiver-scanner. Locating fish consisted of flying over the Long Lake study area and the Chulitna River near Long Lake in a systematic manner while listening for transmitter signals with a 4-element Yagi antenna mounted on a fixed-wing aircraft. Location of a radiotagged fish was determined using a map and a Global Positioning System (GPS) unit.

A radiotracking station was placed at the confluence of the slough draining Long Lake into the Chulitna River. The fixed stations were comprised of integrated components: a solar panel connected to a 12-volt battery, a Lotek high frequency programmable radio receiver, data collection computer (DCC), and two 4-element Yagi antennas. In addition, the NPS study on the lower Chulitna River had radio tags of the same frequency range, which allowed for greater coverage between the two studies during tracking events.

Timing and location of radiotagged fish was recorded in a table summarizing the fates of all radiotagged northern pike. Aerial surveys, boat surveys, fixed station data, "ground-truthing" of radio tags, and harvest reports were also recorded in this fate table.

For each survey, the fate of each radiotagged fish was categorized as P_X, AL, or R (see Appendix A1 for details), where P_X was the location and status of a transmitter, AL was assigned to tags that were not detected at the time of a survey but were detected later, and R was assigned to tags that were removed from the study when a fish was judged to be dead.

Northern pike spend considerable time in shallow water habitats which aided in the location of transmitters during radiotracking surveys. The NFM fate (Appendix A1) was assigned to fish when no movement was observed after several tracking events and denotes non-fishing mortality for fish judged to be dead. The FM fate was assigned to fish reported to be harvested in a fishery.

The proportions and their variances of northern pike residing in Long Lake in the spring of 2007 that remained in Long Lake during the summer, winter, and spring of 2007, 2008, 2009, and the winter and spring of 2010 were calculated as follows:

$$\hat{p}_{remained,i} = \frac{x_{remained,i}}{n_i} \quad \text{and} \tag{5}$$

$$V(\hat{p}_{remained,i}) = \frac{\hat{p}_{remained,i}\,(1-\hat{p}_{remained,i})}{n_i - 1} \tag{6}$$

where

$\hat{p}_{remained,i}$ = the proportion of northern pike that remained in Long Lake at the time of survey *i* (*i* = summer, winter, spring of 2007, 2008, 2009 and 2010),

$x_{remained,i}$ = number of radiotagged fish that remained in Long Lake at the time of survey *i*, and

n_i = known functioning radio tags at time of survey *i*.

RESULTS

Sampling at Long Lake occurred from May 20 to 25 and May 30 to 16 June 2007 for a total of 23 days. A total of 1,875 northern pike 300 mm FL or larger were sampled with a combination of hook and line, hoop traps, and gillnets. A total of 1,799 fish were sampled with hook and line, 74 with hoop traps, and 2 with gill nets (Appendix D1). Hook and line was the most effective sampling gear with a CPUE of 7.93 fish per hour (Appendix D1).

The length distribution of northern pike captured with hook and line ranged from 331 to 1,095 mm FL (Figure 3, Appendix B1) with a mean of 557 mm FL (SE 2.00). The length distribution of northern pike captured with hoop traps ranged from 300 to 1,200 mm FL (Figure 3, Appendix B1) with a mean of 594 mm (SE 19.49). The 2 fish captured with gillnets were 617 and 660 mm FL with a mean of 639 mm (SE 21.5).

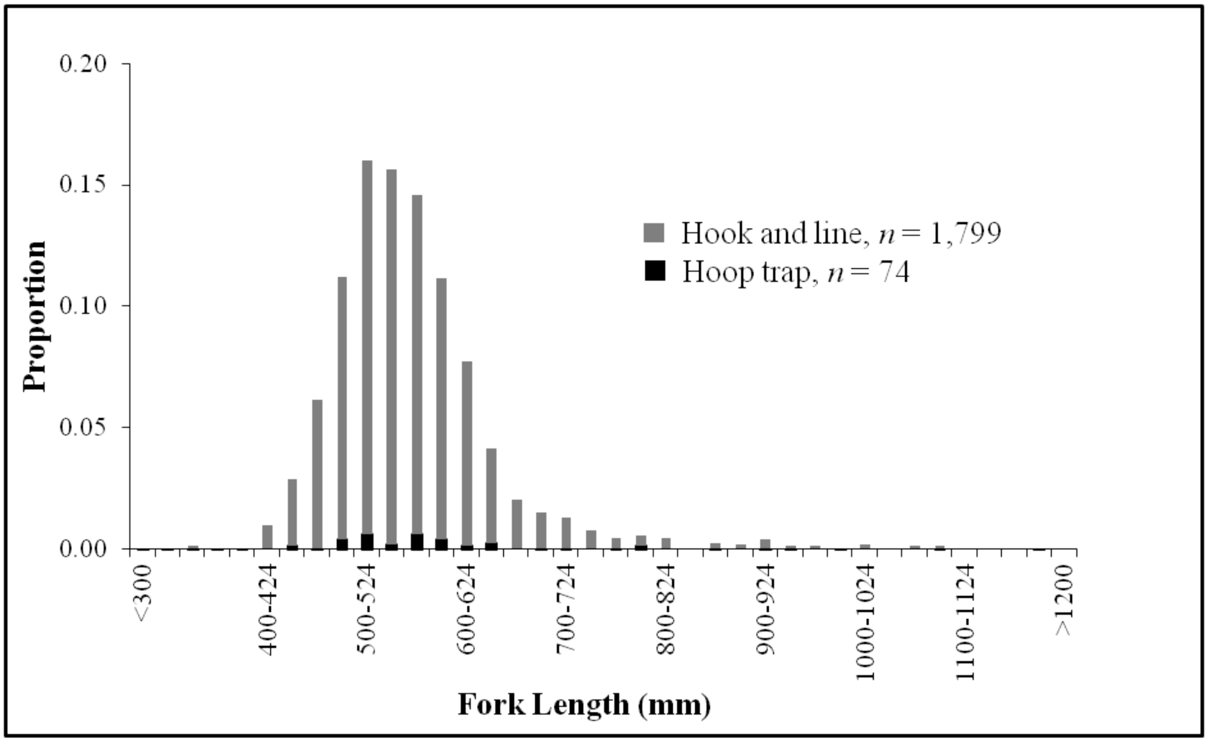

Figure 3.–Length distribution of northern pike at least 300 mm FL captured with hook and line and hoop traps from Long Lake, 2007.

ABUNDANCE ESTIMATION

A total of 1,693 individual northern pike at least 300 mm FL were captured with hook and line and hoop traps over the 4-week sampling period. Of these fish, 57 were recaptured once and 1 was recaptured twice. The smallest recaptured fish was 485 mm FL, therefore, for the following analysis we considered only 1,461 of the sampled fish, which were at least 485 mm FL. There were no observed tag losses or mortalities during the experiment. There was no significant evidence of size-selective sampling detected for fish at least 485 mm FL (Table 1). Probability of capture did not vary significantly between sampling subareas (Tables 2 and 3).

The different abundance models produced in MARK were compared by examining the model Akaike Information Criterion (AIC) (Burnham and Anderson 2002, Table 4). Model M_t (Chao 1987), which allows the probability of capture to vary among capture occasions, fit the data best. Using model M_t, the abundance estimate of northern pike at least 485 mm FL in Long Lake was 13,625 fish (SE 1,690).

Table 1.–Results of a series of Kolmogorov-Smirnov (K-S) tests by sampling event used to identify and correct for size-selective sampling of northern pike in Long Lake, 2007.

	K-S test series #1[a]				K-S test series #2[b]			
Event (t)	Marks released (n_1)	Number of recaptures from event t	K-S test statistic (D)	P-value	Captures inspected (n_2)	Recapture in captures	K-S test statistic (D)	P-value
1	256	22	0.083	0.999				
2	327	23	0.275	0.078	327	4	0.371	0.649
3	644	14	0.317	0.128	644	25	0.244	0.115
4					292	30	0.272	0.036

Note: the K-S test statistic is based on a comparison of the cumulative length frequency distributions.

[a] Evaluates "marking" events for size-selective sampling.

[b] Evaluates "recapture" events for size-selective sampling.

Table 2.–Results of contingency table analysis to identify geographic recapture heterogeneity after a particular "marking" event *t* in Long Lake, 2007.

Marking event (t)	Subareas[a]	Marked[b] (m_2)	Unmarked[b] (n_1-m_2)	Capture probability[b] (m_2/n_1)	χ^2	*df*	P-value
1	1	1	176	0.0056	6.13	3	0.105
	2	22	365	0.0293			
	3	8	391	0.0201			
	4	2	273	0.0073			
2	1	3	139	0.0211	3.36	3	0.339
	2	6	323	0.0182			
	3	11	271	0.0390			
	4	3	167	0.0176			
3	1	3	29	0.0938	6.36	3	0.095
	2	9	124	0.0677			
	3	0	71	0.0000			
	4	2	54	0.0357			

[a] Long Lake was divided into 4 subareas; see Figure 2.

[b] n_1 = sum of fish inspected for marks (made during marking event *t* or marked previously and released alive during marking event *t*) during capture event *t+1* through event 4 within a particular subarea; m_2 = the number of inspected fish found to have marks.

Table 3.–Results of contingency table analysis to identify unequal probability of recapture during event *t* based on marking location in Long Lake, 2007.

Capture event (*t*)	Subareas[a]	Recaptured (m_2)	Not recaptured (n_1-m_2)	Capture probability (m_2/n_1)	χ^2	*df*	*P*-value
2	1	1	33	0.0294	1.67	3	0.644
	2	2	79	0.0250			
	3	1	106	0.0093			
	4	0	34	0.0000			
3	1	3	69	0.0417	2.97	3	0.396
	2	9	122	0.0687			
	3	9	225	0.0385			
	4	4	138	0.0282			
4	1	6	175	0.0331	3.85	3	0.278
	2	9	320	0.0274			
	3	6	427	0.0139			
	4	9	247	0.0352			

[a] Long Lake was divided into 4 subareas; see Figure 2.

[b] n_1 = sum of fish marked for the first time in a particular subarea during events 1 through *t-1*; m_2 = the number of fish marked in a particular subarea that were recaptured during event *t*.

Table 4.–Comparison of abundance models produced by MARK for northern pike in Long Lake, 2007.

Model	AICc	Delta AICc	AICc weight	Model likelihood	Number of parameters	Deviance
M_t	-14000.6	0.00	1	1	5	18.04
M_b	-13781.4	219.17	0	0	2	243.22
M_o	-13771.3	229.27	0	0	2	253.32

Note: AIC_c = small sample version of Akaike information criterion, Delta AIC = differences relative to smallest AIC value (Burnham and Anderson 2002); M_t = model from which Darroch estimator is derived, M_b = model from which Zippin estimator is derived, and M_o = null model (Otis et al. 1978).

LENGTH AND MATURITY COMPOSITION

A total of 1,875 northern pike at least 300 mm FL were measured for length. The largest northern pike captured was 1,200 mm FL and overall mean length was 559 mm FL (SE 2.08). The proportion of northern pike between 501 and 600 mm FL comprised an estimated 0.57 (SE 0.01) of the sample, followed by the 401 to 500 mm FL length class (0.21, SE 0.01) (Figure 3). Approximately 0.04 (SE 0.00) of the fish were larger than 720 mm FL (30 in). The sex and maturity of 55 northern pike were determined by the observation of gametes, of which 41 were male and 14 were female. The length of males ranged from 414 to 692 mm FL with a mean of 520 mm FL (SE 10.35). The length of females ranged from 508 to 680 mm FL with a mean of 616 mm FL (SE 13.09).

RADIO TELEMETRY

From 21 May through 5 June 2007, 40 radio tags were implanted into northern pike from Long Lake. For unknown reasons, the battery life of the tags was longer than anticipated, with most tags remaining active through spring 2010 (approximately 3 years). The fates of all radiotagged fish from summer 2007 to spring 2010 are summarized in Table 5. Of 40 radiotagged fish, 21 were categorized as mortalities by the end of summer 2007. One tag was never located after implantation, which left 18 active radiotags during the summer of 2007. The proportion of active transmitters that remained in Long Lake during seasonal periods from summer 2007 to spring 2010 ranged from 1.00 (SE 0.00) to 0.71 (SE 0.17) (Table 6). One fish (3.256/25) moved into the Chulitna River and the rest remained in Long Lake during summer 2007. This fish moved back into Long Lake during fall 2007, and remained in Long Lake for the remainder of the study. Two other fish eventually left Long Lake. During fall 2008, 1 fish (3.269/29) moved into the Chulitna River and to Lake Clark for the winter of 2009/2010. It was located in the Lower Chulitna River during spring 2010. The other fish (3.269/30) left Long Lake during summer 2008 and was next located upstream of Long Lake approximately 20 miles in Nikabuna lakes during summer 2009. It returned to Long Lake during spring 2010.

Table 5.–The fates of radiotagged northern pike in Long Lake from summer 2007 to spring 2010.

Frequency/code	Date deployed	FL	Subarea where tagged[a]	Sumr 07	Winter 07/08	Spr 08	Sumr 08	Winter 08/09	Spr 09	Sumr 09	Winter 09/10	Spr 10
3.256/21	21 May	600	3	L_{NFM}	R	R	R	R	R	R	R	R
3.256/22	22 May	784	3	L_{NFM}	R	R	R	R	R	R	R	R
3.256/23	21 May	805	2	L	L	L	AL	L	L	L	L	L
3.256/24	21 May	1010	3	L	L	L	L	L	L	L	L	L
3.256/25	21 May	692	2	UC	L	L	L	L	L	L	L	L
3.256/26	2 Jun	668	4	L	L_{NFM}	R	R	R	R	R	R	R
3.256/27	3 Jun	715	1	L	L_{NFM}	R	R	R	R	R	R	R
3.256/28	4 Jun	650	4	L_{NFM}	R	R	R	R	R	R	R	R
3.256/29	2 Jun	663	4	L	AL	L	L	AL	AL	L	AL	AL
3.256/30	31 May	701	1	L_{NFM}	R	R	R	R	R	R	R	R
3.269/21	31 May	715	3	L_{NFM}	R	R	R	R	R	R	R	R
3.269/22	2 Jun	1022	4	L	L_{NFM}	R	R	R	R	R	R	R
3.269/23	1 Jun	825	3	L_{NFM}	R	R	R	R	R	R	R	R
3.269/24	5 Jun	807	5	L	L_{NFM}	R	R	R	R	R	R	R
3.269/25	4 Jun	788	2	L_{NFM}	R	R	R	R	R	R	R	R
3.269/26	2 Jun	892	4	L	L	L	L_{NFM}	R	R	R	R	R
3.269/27	1 Jun	650	3	L_{NFM}	R	R	R	R	R	R	R	R
3.269/28	3 Jun	621	1	L_{NFM}	R	R	R	R	R	R	R	R
3.269/29	2 Jun	735	4	L	L	L	L	UC	AL	AL	C	LC
3.269/30	31 May	733	1	L	L	L	AL	AL	AL	N	N	N

-continued-

Table 5.–Part 2 of 2.

Frequency/code	Date deployed	FL	Subarea where tagged[a]	Sumr 07	Winter 07/08	Spr 08	Sumr 08	Winter 08/09	Spr 09	Sumr 09	Winter 09/10	Spr 10
3.281/21	31 May	616	1	L	L_{NFM}	R	R	R	R	R	R	R
3.281/22	31 May	712	1	L_{NFM}	R	R	R	R	R	R	R	R
3.281/23	4 Jun	681	4	L_{NFM}	R	R	R	R	R	R	R	R
3.281/24	3 Jun	703	1	L	L_{NFM}	R	R	R	R	R	R	R
3.281/25	22 May	614	4	L_{NFM}	R	R	R	R	R	R	R	R
3.281/26	1 Jun	620	3	L_{NFM}	R	R	R	R	R	R	R	R
3.281/27	5 Jun	770	2	L_{NFM}	R	R	R	R	R	R	R	R
3.281/28	31 May	711	2	L_{NFM}	R	R	R	R	R	R	R	R
3.281/29	5 Jun	705	5	L_{NFM}	R	R	R	R	R	R	R	R
3.281/30	22 May	613	4	L	L	L	AL	L_{NFM}	R	R	R	R
3.294/21	1 Jun	794	3	L	L	L	L	L	L	L	L	L
3.294/22	1 Jun	928	3	L	L	L	L	L	L	AL	AL	AL
3.294/23	31 May	691	2	L_{NFM}	R	R	R	R	R	R	R	R
3.294/24	4 Jun	884	4	AL	AL	AL	AL	AL	AL	AL	AL	AL
3.294/25	22 May	625	4	L_{NFM}	R	R	R	R	R	R	R	R
3.294/26	4 Jun	910	4	L_{NFM}	R	R	R	R	R	R	R	R
3.294/27	5 Jun	721	2	L_{NFM}	R	R	R	R	R	R	R	R
3.294/28	2 Jun	686	4	L	L	L	L_{NFM}	R	R	R	R	R
3.294/29	22 May	874	3	L	AL	AL	AL	AL	AL	AL	AL	AL
3.294/30	4 Jun	983	2	L_{NFM}	R	R	R	R	R	R	R	R

Note: L= Long Lake, UC = upper Chulitna River, LC = lower Chulitna River, C = Lake Clark, N = Nikabuna lakes, AL = at large (not detected at time of survey, and not a confirmed mortality), L_{NFM} = non-fishing mortality at Long Lake, and R = removed from study.

[a] Long Lake was divided into 4 subareas; see Figure 2.

Table 6.–The proportion of radiotagged northern pike in Long Lake from summer 2007 to spring 2010.

	Sumr 07	Winter 07/08	Spr 08	Sumr 08	Winter 08/09	Spr 09	Sumr 09	Winter 09/10	Spr 2010
Located in Long Lake	17	11	11	8	6	6	6	5	5
Functioning tags	18	11	11	9	8	8	8	7	7
Proportion (SE)	0.94	1.00	1.00	0.89	0.75	0.75	0.75	0.71	0.71
Standard error	0.06	0.00	0.00	0.04	0.15	0.15	0.15	0.17	0.17

DISCUSSION

In 2007, sampling occurred after northern pike had completed spawning. Access to Long Lake was not possible, due to ice on Lake Clark, until a few days before sampling commenced on 20 May. Only 55 of the sampled fish expelled gametes or small amounts of remnant eggs or sperm, indicating that they had spawned that spring and that spawning was complete. The large percentage of males in the post-spawning sample is possibly due to males being more easily identified during the post spawn phase due to the presence of remnant sperm. The majority of fish captured during the project did not expel gametes and were of unknown sex; some of these fish were likely post-spawning individuals. Pearse and Clark (1992) radiotagged northern pike in Volkmar Lake of interior Alaska and found that northern pike were relatively mobile, with large daily movements after spawning. Thus, it was likely that fish had dispersed throughout Long Lake by the time sampling commenced on May 20, and were not concentrated on the east end of the lake where the most spawning habitat was identified. As a result, sampling in this study was more evenly distributed throughout the entire lake and less concentrated on the east end of the lake than originally planned.

The lack of spawning fish also impacted the effectiveness of gillnets as a sampling gear. It was anticipated that gillnets would be an effective sampling gear for concentrated spawning northern pike. However, northern pike were already dispersed from spawning locations and passively fished gillnets were not an effective means of sampling fish due to slow catch rates and the need to continuously monitor the gear to prevent mortality. The active sampling technique of angling was much more effective. Passively fished hoop nets may have been more effective (but not more efficient) than gillnets because they were allowed to fish for long periods due to low mortality of fish confined to the hoop trap.

Mortality of radiotagged fish was high during this study. The reason for this is unknown; however, 6 different individuals conducted the surgical implantations, some of whom had little prior experience with the technique. If only the most experienced personnel conducted the surgical implantation, the mortality rate might have been lower. The surviving fish showed no discernible pattern of movement within Long Lake, and appeared to mix between lake subareas over the course of the study. One fish left Long Lake and exhibited extensive downstream movement to Lake Clark. Another fish moved upstream to Nikabuna lakes. One of 40 northern pike tagged in Chulitna Bay exhibited movement to Long Lake during the spring and subsequently returned to Chulitna Bay (D. Young, Fisheries Biologist, NPS, Lake Clark National Park and Preserve, personal communication). Despite the small sample size, these movements indicate that northern pike stocks in the Chulitna River system exhibit some mixing. It is unknown how extensive this mixing is; research in 2006 indicated a significant difference in length compositions between northern pike sampled in the Chulitna Bay and those in Long Lake. Furthermore, northern pike in Long Lake had eroded fins while fish in Chulitna Bay did not, suggesting distinct stocks of northern pike between these 2 areas.[2]

---

[2] Schwanke, C. Unpublished. Chulitna River Northern Pike FY07 Field Work Completed Summer 2006. Alaska Department of Fish and Game, Division of Sport Fish. Memo dated 14 February, 2007, Dillingham, Alaska.

The 2007 population estimate of 13,825 northern pike at least 485 mm FL indicates a density of at least 13.9 pike/ha in Long Lake. This is a higher density estimate than lakes predominantly populated by northern pike in the interior of Alaska. There are abundance estimates over many years for both George Lake (373 ha) and Volkmar Lake (1,823 ha) and the largest densities estimated were 9 pike/ha and 11 pike/ha, respectively for fish at least 450 mm FL (Wuttig and Reed 2010). This higher density of northern pike in Long Lake may be partly explained by low exploitation. Despite a bag limit of 5 northern pike per day, the recent 5 year (2003–2007) average harvest is 6 fish per year, with no harvest reported for most years (Jennings et al. 2006b, 2007, 2009a-b, 2010). The average harvest for George and Volkmar lakes during the same period is 548 and 24 fish per year (Jennings et al. 2007 2006b, 2007, 2009a-b, 2010).

The additional harvest may partially explain the difference in density estimates. However, within a lake, northern pike population structure can vary based on a number of factors, including species interactions and environmental factors that affect lake productivity (Pierce et al. 2003). The interior lakes have similar species; however, the Chulitna River system has large spawning populations of lake whitefish (*Coregonus clupeaformis*) and least cisco (*Coregonus sardinella*) (D. Young, Fish Biologist, NPS, Port Alsworth, personal communication). Long Lake may be more productive (higher density and larger fish) for northern pike because it is connected to a river system that contains migratory whitefish and least cisco, which are a preferred food source, and are indicators of lakes that produce large northern pike (Jacobson 1992). No studies have been completed that assess environmental factors such as temperature, alkalinity, and water transparency on the productivity of northern pike in these lakes. It is unknown if these factors contribute to different northern pike densities.

Heavily exploited lakes with high densities of northern pike where anglers target larger fish, can often lead to slow growth rates, which results in populations of small northern pike (Pierce and Tomcko 2003). In addition, the exploitation of large pike may reduce the self regulating impact of cannibalism on small pike, which may reduce the size structure of pike populations. As indicated by the abundance estimate and high CPUE of angling during the study, Long Lake currently has a high density of northern pike and a low exploitation rate. The low exploitation rate, as well as a bag limit that prevents the retention of northern pike over 760 mm (30 in) long, protects large pike. These circumstances will likely ensure that large pike remain a component of the Long Lake system and that the current size structure is maintained. However, periodic examination of the length composition of this population is recommended to monitor the size structure of the northern pike population.

ACKNOWLEDGMENTS

I would like to thank Troy Jaecks, Cody Larsen, Chase Jalbert, Zachary Finley, and Lance Westing for their dedication and hard work on the field portion of this project. Special thanks to Dan Young and his employer, U.S. National Park Service, for conducting the majority of radiotracking. I would also like to thank Patricia Hansen for her assistance with biometric design, analysis, and review of this project.

REFERENCES CITED

Anderson, W. G., R. S. McKinley, and M. Colavecchia. 1997. The use of clove oil as an anesthetic for rainbow trout and its effect on swimming performance. North American Journal of Fisheries Management Vol. 17:2.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. 2nd edition. Springer-Verlag, New York.

Chao, A. 1987. Estimating the population size for capture-recapture data with unequal catchability. Biometrics, 43:783-791.

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

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

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

Hart, L., and R. Summerfelt. 1975. Surgical procedures for implanting ultrasonic transmitters into flathead catfish (*Pylodictic olivaris*). Transactions of the American Fisheries Society 104:56-59.

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. http://www.adfg.alaska.gov/FedAidPDFs/fds97-29(revised).pdf

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. http://www.adfg.alaska.gov/FedAidPDFs/fds98-25(revised).pdf

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001c. Revised Edition. Participation, catch, and harvest in Alaska sport fisheries during 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-41 (revised), Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds99-41(revised).pdf

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001d. Participation, catch, and harvest in Alaska sport fisheries during 1999. Alaska Department of Fish and Game, Fishery Data Series No. 01-08, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds01-08.pdf

Jacobson, P. C. 1992. Analysis of factors affecting growth of northern pike in Minnesota. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Investigational Report 164, St Paul, Mn.

Jennings, G. B., K. Sundet, and A. E. Bingham. 2007. Participation, catch, and harvest in Alaska sport fisheries during 2004. Alaska Department of Fish and Game, Fishery Data Series No. 07-40, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds07-40.pdf

Jennings, G. B., K. Sundet, and A. E. Bingham. 2009a. Estimates of participation, catch, and harvest in Alaska sport fisheries during 2005. Alaska Department of Fish and Game, Fishery Data Series No. 09-47, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/FDS09-47.pdf

Jennings, G. B., K. Sundet, and A. E. Bingham. 2009b. Estimates of participation, catch, and harvest in Alaska sport fisheries during 2006. Alaska Department of Fish and Game, Fishery Data Series No. 09-54, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/FDS09-54.pdf

Jennings, G. B., K. Sundet, and A. E. Bingham. 2010. Estimates of participation, catch, and harvest in Alaska sport fisheries during 2007. Alaska Department of Fish and Game, Fishery Data Series No. 10-02, Anchorage. http://www.adfg.alaska.gov/FedAidpdfs/Fds10-02.pdf

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. http://www.adfg.alaska.gov/FedAidPDFs/fds04-11.pdf

REFERENCES CITED (Continued)

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. http://www.adfg.alaska.gov/FedAidpdfs/fds06-34.pdf

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. http://www.adfg.alaska.gov/FedAidpdfs/fds06-44.pdf

Mann, R. H. K. 1982. The annual food consumption and prey preference of pike (*Esox lucius*) in the River Frome, Dorset. Journal of Animal Ecology 51:81-95.

Otis, D. L., K. P. Burnham, G. C. White, and D. R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildlife Monograph No. 62.

Pearse, G. A., and J. H. Clark. 1992. Movements and distributions of radio tagged northern pike in Volkmar Lake. Alaska Department of Fish and Game, Fishery Data Series No. 92-28, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds92-28.pdf

Pierce, R. B., and C. M. Tomcko. 2003. Interrelationships among production, density, growth, and mortality of northern pike in seven north-central Minnesota lakes. Transactions of the American Fisheries Society 132: 143-153.

Pierce, R. B., C. M. Tomcko, and T. L. Margenau. 2003. Density dependence in growth and size structure of northern pike populations. North American Journal of Fisheries Management 23:331-339.

Pierce, R. B., C. M. Tomcko, and D. H. Schupp. 1995. Exploitation of northern pike in seven small north-central Minnesota Lakes. North American Journal of Fisheries Management 15:601-609.

Pollock, K. H. 1974. The assumption of equal catchability of animals in tag-recapture experiments. Ph.D. Thesis, Cornell University, Ithaca, NY.

Ross, M. J., and C. F. Kleiner. 1982. Shielded-needle technique for surgically implanting radio-frequency transmitters in fish. The Progressive Fish Culturist 44(1):41-43.

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

Stanley, T. R., and K. P. Burnham. 1999. A closure test for time-specific capture-recapture data. Environmental and Ecological Statistics 6(2):197-209.

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. http://www.adfg.alaska.gov/FedAidPDFs/fds03-05.pdf

White, G. C., and K. P. Burnham. 1999. Program Mark: Survival estimation from populations of marked animals. Bird Study 46 Supplement, 120-138.

Wuttig, K. G., and D. J. Reed. 2010. Abundance and composition of northern pike in Volkmar Lake, 2005, and George Lake, 2006. Alaska Department of Fish and Game, Fishery Data Series No. 10-69, Anchorage. http://www.adfg.alaska.gov/FedAidpdfs/FDS10-69.pdf

APPENDIX A: KEY TO FATE CATEGORIES

Appendix A1.–Key to fate categories assigned to each northern pike radiotagged in 2007.

Category	Variable	Parameter	Definition
P_X [a]			denotes tag location
	P	L	Long Lake
	P	UC	upper Chulitna River
	P	LC	lower Chulitna River
	P	C	Lake Clark
	P	N	Nikabuna lakes
	X	NFM	denotes "non-fishing mortality" for fish judged to be dead at the time of survey.
	X	FM	denotes "fishing mortality" for fish reported as harvested.
	X	SL	denotes "slough" for fish found in a slough of the Chulitna River.
AL			denotes "at large," indicating that the tag was not detected at the time of the survey and not a confirmed mortality.
R			denotes "removed;" used after an $_{NFM}$ or $_{FM}$ designation

[a] For example, L_{NFM} denotes non-fishing mortality for radiotagged fish at Long Lake.

APPENDIX B: LENGTH DISTRIBUTIONS OF NORTHERN PIKE CAPTURED WITH HOOK-AND-LINE GEAR AND HOOP TRAPS

Appendix B1.–Length composition of Long Lake northern pike (≥300 mm FL) sampled by hook-and-line gear or hoop traps, 2007.

Length class	Hook-and-line sampling			Hoop trap sampling		
(mm FL)	Count	Proportion	SE	Count	Proportion	SE
300–324	0	0	0	1	0.0135	0.0134
325–349	0	0	0	2	0.0270	0.0189
350–374	2	0.0011	0.0008	1	0.0135	0.0134
375–399	0	0	0	1	0.0135	0.0134
400–424	0	0	0	1	0.0135	0.0134
425–449	18	0.0100	0.0023	0	0	0
450–474	51	0.0284	0.0039	3	0.0405	0.0229
475–499	114	0.0634	0.0058	1	0.0135	0.0134
500–524	203	0.1130	0.0075	7	0.0946	0.0340
525–549	290	0.1614	0.0087	11	0.1486	0.0414
550–574	290	0.1614	0.0087	4	0.0541	0.0263
575–599	262	0.1458	0.0083	11	0.1486	0.0414
600–624	202	0.1124	0.0075	7	0.0946	0.0340
625–649	142	0.0790	0.0064	3	0.0405	0.0229
650–674	73	0.0406	0.0047	5	0.0676	0.0292
675–699	38	0.0211	0.0034	0	0	0
700–724	26	0.0145	0.0028	2	0.0270	0.0189
750–774	22	0.0122	0.0026	2	0.0270	0.0189
775–799	14	0.0078	0.0021	0	0.0000	0.0000
800–824	6	0.0033	0.0014	2	0.0270	0.0189
825–849	7	0.0039	0.0015	3	0.0405	0.0229
850–874	8	0.0045	0.0016	0	0	0
875–899	2	0.0011	0.0008	0	0	0
900–924	3	0.0017	0.0010	2	0.0270	0.0189
925–949	4	0.0022	0.0011	0	0	0
950–974	6	0.0033	0.0014	1	0.0135	0.0134
975–999	2	0.0011	0.0008	1	0.0135	0.0134
1000–1024	3	0.0017	0.0010	0	0.0000	0.0000
1025–1049	1	0.0006	0.0006	1	0.0135	0.0134
1050–1074	4	0.0022	0.0011	0	0	0
1075–1099	1	0.0006	0.0006	0	0	0
1100–1124	3	0.0017	0.0010	0	0	0
1125–1149	2	0.0011	0.0008	1	0.0135	0.0134
1150–1174	0	0	0	0	0	0
1175–1199	0	0	0	0	0	0
>1200	0	0	0	1	0.0135	0.0134

APPENDIX C: LIST OF ARCHIVED DATA FILES

Appendix C1.–List of archived data files for northern pike study at Long Lake in the Chulitna River drainage in southwestern Alaska, 2007.

File name	Description (location, species, capture technique, data collected, dates sampled)
s-014800b12007 [a]	Long Lk; northern pike; hook & line; sex, length, weight & tag data, dd-dd Mmm
LongLakeBristolBay2007PikeTelemetryLocationSheet.xls	Long Lk, northern pike; radio telemetry tracking locations, dd-dd Mmm

Note: Archived at the Alaska Department of Fish and Game (ADF&G), Division of Sport Fish, Research and Technical Services at 333 Raspberry Road, Anchorage, AK 99518-1565.

[a] Text file of biological data scanned from mark-sense forms (ADF&G, Standard Age Weight Length Form, Version 1.2).

APPENDIX D: CATCH PER UNIT EFFORT OF SAMPLING GEAR FOR NORTHERN PIKE IN LONG LAKE, 2007

Appendix D1.–Date, effort (h), and catch per effort (fish/h) of hook-and-line, hoop trap, and gillnet sampling gear for northern pike in Long Lake, 2007.

	Hook and Line			Hoop Traps			Gillnet		
Date	Caught	Effort (h)	CPUE (fish/h)	Caught	Effort (h)	CPUE (fish/hr)	Caught	Effort (h)	CPUE (fish/hr)
20 May	44	7.7	5.74	0	0	0	0	0	0
21 May	72	6.2	11.68	11	28.5	0.27	2	3.1	0.65
22 May	66	7.3	9.00	13	47.5	0.27	0	2	0
23 May	96	9.5	10.11	0	21	0	0	1	0
24 May	10	1.3	7.50	0	0	0	0	2	0
30 May	39	3.4	11.41	0	0	0	0	0	0
31 May	114	14.0	8.14	8	41	0.17	0	0	0
1 Jun	143	20.8	6.86	4	48	0.14	0	0	0
2 Jun	95	15.3	6.20	0	26	0	0	0	0
3 Jun	168	13.8	12.22	0	45	0	0	0	0
4 Jun	179	24.2	7.40	0	48	0	0	0	0
5 Jun	164	19.2	8.56	0	48	0	0	0	0
6 Jun	144	13.8	10.41	7	28	0.15	0	0	0
7 Jun	35	4.7	7.50	1	48	0.02	0	0	0
8 Jun	42	6.3	6.63	0	48	0	0	0	0
9 Jun	38	9.6	3.97	0	48	0	0	0	0
10 Jun	86	11.8	7.27	21	48	0.44	0	0	0
11 Jun	58	6.5	8.92	0	48	0	0	0	0
12 Jun	79	11.5	6.87	0	48	0	0	0	0
13 Jun	41	5.8	7.03	9	48	0.19	0	0	0
14 Jun	56	9.2	6.11	0	48	0	0	0	0
15 Jun	18	3.0	6.00	0	48	0	0	0	0
16 Jun	12	2.0	6.00	0	16	0	0	0	0
Total	1799	227	7.93	74	829	0.09	2	8.1	0.25