Fishery Data Series No. 01-29

Abundance and Composition of the Northern Pike Populations in Volkmar Lake and Minto Lakes, 2000

by

Brendan P. Scanlon

December 2001

Alaska Department of Fish and Game **Division of Sport Fish**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

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

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
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	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
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
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

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	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
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.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
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
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 01-29

ABUNDANCE AND COMPOSITION OF THE NORTHERN PIKE POPULATIONS IN VOLKMAR LAKE AND MINTO LAKES, 2000

by

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ABSTRACT

Populations of northern pike *Esox lucius* within Volkmar Lake and the Minto Lakes Study Area were studied using mark-recapture techniques in the summer of 2000. In Volkmar Lake, abundance of northern pike was estimated to be 1,491 fish (SE = 369) ≥ 300 mm FL, and 615 fish ≥ 450 mm FL. The 95% profile-likelihood bounds were 950 and 2,442 fish ≥ 300 mm FL. For comparison, the last estimate of abundance of northern pike ≥ 300 mm FL for Volkmar Lake was 2,810 fish (SE = 302), and of northern pike ≥ 450 mm FL was 2,318 fish (SE = 236). Ages determined from the scales of 100 northern pike ≥ 300 mm FL ranged from age-3 to age-12 and of these, 25% (SE = 1%) were age-5. The estimated average percent error of the scale reader in observing the same age twice from a Volkmar Lake northern pike scale in 2000 was 6.1%, and the mean error in assigning the proper incremental age from these scales was 0.83 years.

In the Minto Lakes Study Area, estimated abundance of northern pike ≥ 600 mm FL was 5,331 fish (SE = 1,152; CV = 22%). The 95% profile-likelihood bounds were 3,074 and 7,588 fish ≥ 600 mm FL. For comparison, the estimates of abundance of northern pike ≥ 600 mm FL from previous years were 7,616 fish (SE = 883) in 1996 and 3,251 fish (SE = 174) in 1996. Ages determined from the scales of 100 northern pike ≥ 400 mm FL ranged from age-2 to age-11 and of these, 24% (SE= =1.9%) were age-6. The estimated average percent error of the scale reader in observing the same age twice from a Minto Lakes northern pike scale in 2000 was 6.8%, and the mean error in assigning the proper incremental age from these scales was 0.95 years.

Key Words: Northern pike, *Esox lucius*, population abundance, age composition, length composition, Volkmar Lake, Minto Lakes, mark-recapture.

INTRODUCTION

The Alaska Department of Fish and Game (ADF&G) initiated northern pike *Esox lucius* studies in the Arctic-Yukon-Kuskokwim Region of Alaska (AYK) to insure that annual harvests do not exceed surplus production of northern pike. Objectives designed to meet this goal have included estimates of abundance, length composition, age composition, mortality rates, recruitment, and movements of northern pike within selected lakes and wetland complexes in AYK. The establishment of these long-term data series has resulted in estimates of sustainable yield for northern pike populations in Volkmar, George, T, and Harding lakes (Pearse and Hansen 1993; Roach and McIntyre 1999).

Studies of northern pike in Volkmar Lake began in 1985 with objectives to estimate abundance and length and age composition, and continued on an annual basis until 1994. Beach seines proved to be the most effective capture gear of those used (gill nets, various traps and fyke nets, and seines) for study of this northern pike population (Peckham and Bernard 1987). As a result of northern pike studies in Volkmar Lake, The Alaska Board of Fisheries responded to stock declines and reduced the daily bag and possession limit from five fish to one in 1997.

Prior to 1996, ADF&G conducted mark-recapture experiments in Minto Flats from 1987 through 1991 (Burkholder 1989, 1990, 1991; Hansen and Burkholder 1992). Generally, these sampling events were conducted during spring or fall movements of northern pike and were concentrated in the Minto Lakes area of Minto Flats. The designs of these between-season and between-year mark-recapture experiments were contingent upon either, 1) marked fish being distributed throughout Minto Flats during the recapture event to estimate abundance of northern pike for the entire Minto Flats; or, 2) the fidelity of northern pike to the area of Minto Lakes from one season to the next or one year to the next to estimate abundance for a subpopulation of northern pike. These studies were abandoned after 1991 because investigations indicated that these assumptions were not valid for between-year or between-season experiments. It was hypothesized that a

within-season estimate of abundance for the Minto Lakes area of Minto Flats may be more practical and less susceptible to bias from site infidelity.

A Minto Lakes northern pike radiotelemetry study from 1995 to 1997 suggested the feasibility of using a single-season mark-recapture experiment to estimate abundance and composition (Roach 1998a). Using information gained from that study, a 6,000 ha study area (hereafter referred to as Minto Flats Area I) was defined for sampling based upon the summer movements of tagged northern pike. In 1996 (Roach 1997), a northern pike mark-recapture experiment was conducted which was different than previous years. The hiatus between the marking event and the recapture event was reduced by a magnitude of months to several days, sampling took place in June instead of early May or September, and the study area was uniformly sampled instead of sampling only a limited number of locations. The hiatus was reduced to eliminate the need to adjust estimates of abundance because of growth recruitment between events and reduce the opportunity for fish to leave or enter the study area. Based on the radiotelemetry data, which indicated negligible northern pike movement into and out of the Minto Lakes area during June compared to the spring and fall, sampling took place in June.

Even though the 1996 mark-recapture experiment was viewed a success in that it resulted in an estimate of abundance, low catch rates were a nagging problem and resulted in a broad confidence interval. Improving upon the 1996 experiment, the 1997 experiment was designed to increase catch rates by lengthening the experiment, adding hoop traps as an additional capture method, and sampling during the cooler hours of the day to enable the use of more gear and longer soaks. Catch rates were higher and the resulting estimate of abundance was more precise.

OBJECTIVES

Volkmar Lake

The research objectives for the 2000 Volkmar Lake northern pike mark-recapture experiment were to:

1) estimate the abundance of northern pike ≥ 300 mm FL in Volkmar Lake such that the estimate would be within 25% of the actual value 95% of the time; and,

2) estimate the age and length composition of the northern pike population ≥ 300 mm FL in Volkmar Lake such that the estimates of proportions would be within 5 percentage points of the actual value 95% of the time.

Minto Lakes

The research objectives for the 2000 Minto Flats northern pike mark-recapture experiment were to:

1) estimate the population abundance of northern pike ≥ 400 mm FL in Minto Flats Area I such that the estimate would be within 25% of the actual value 90% of the time; and,

2) estimate the age and length composition of the northern pike population ≥ 400 mm FL in Minto Flats Area I such that the estimates of proportions would be within 5 percentage points of the actual value 95% of the time.

STUDY AREAS

VOLKMAR LAKE

Volkmar Lake is a remote 373 ha lake within the Tanana River Drainage located approximately 25 km northeast of Delta Junction (Figures 1 and 2). The lake is accessible during the open water season by float equipped aircraft and air boats. Snowmachines and ski-equipped aircraft provide a means of access during the winter. Volkmar Lake is at an elevation of 326 m, has a maximum depth of 12.8 m, and a shoreline circumference of 8.2 km. The lake has two small inlets and an ill-defined outlet that drains westerly through wetlands toward the Goodpaster River. Near shore waters are shallow, and beds of aquatic vegetation providing spawning and rearing substrate for northern pike. Volkmar Lake is typically ice-free from late May to early October and spawning of northern pike generally coincides with the beginning of the ice-free period and continues for up to two weeks into late May. Other fish species present in the lake include humpback whitefish *Coregonus pidschian*, least cisco *C. sardinella*, and slimy sculpin *Cottus cognatus*.

MINTO FLATS STUDY AREA

Minto Flats is located approximately 50 km west of Fairbanks, Alaska within the Tanana River drainage (Figure 1). It is a 200,000 ha area of marsh and lakes interconnected by numerous sloughs and five rivers: the Chatanika, Goldstream, Tatalina, Tolovana, and Tanana (Figure 3). Except for the Tanana River, these rivers are slow flowing and meandering. The Tanana River is a large glacial river that delineates the southern border of the flats and is the primary water source for Swanneck and Grassy sloughs. The lakes of Minto Flats are generally shallow and contain large areas of dense aquatic vegetation. Summer habitat for northern pike in Minto Flats covers approximately 6,000 ha (Holmes and Pearse 1987). Investigators, however, identified the Minto Lakes area[1] of Minto Flats as a primary northern pike spawning and summer feeding area.

DESCRIPTION OF NORTHERN PIKE FISHERIES

Volkmar Lake

The popularity of Volkmar Lake as a recreational area increased during the 1980s because of land disposals around the lake by the State of Alaska, improved winter access from new snow-machine trails and roads in the Delta Agricultural Project, and increased summer and winter use by cabin owners around the lake and on the nearby Goodpaster River. From 1981 through 1992, estimated annual fishing effort averaged 494 angler-days, with a range of 129 to 1,052 (Mills 1982-1993). For the same period, the estimated harvest averaged 415 northern pike, ranged from 84 (1990) to 777 (1982), and with a success rate of 0.8 fish harvested per angler-day (Mills 1982-1993). Estimates of catch, harvest, and effort have not been reported for Volkmar Lake in

[1]This area is also referred to in some reports as Minto Flats Area I, which includes the lakes, channels, and sloughs that empty into the Chatanika River by way of Goldstream Creek (see Figure 2).

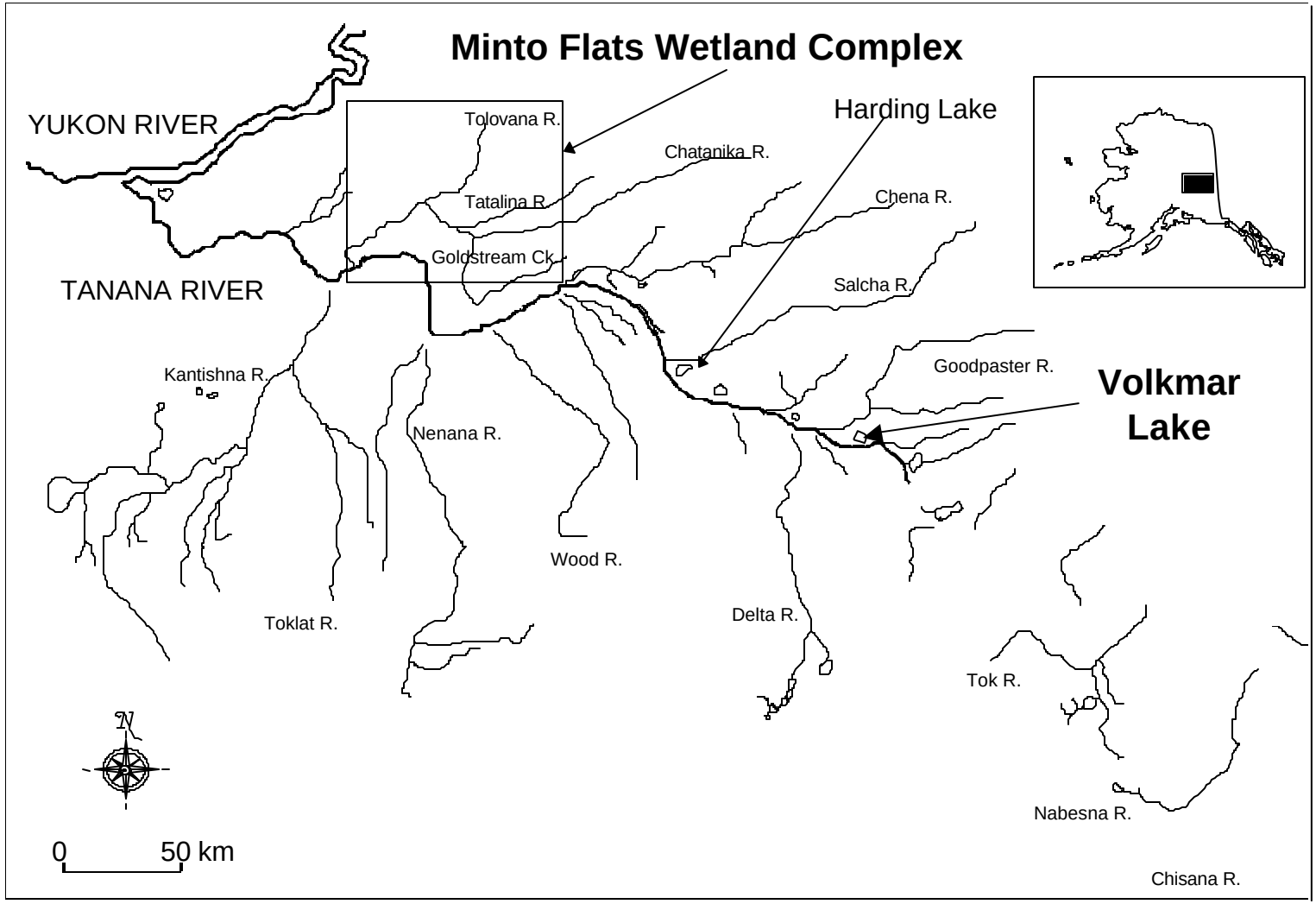

Figure 1.-The Tanana River drainage.

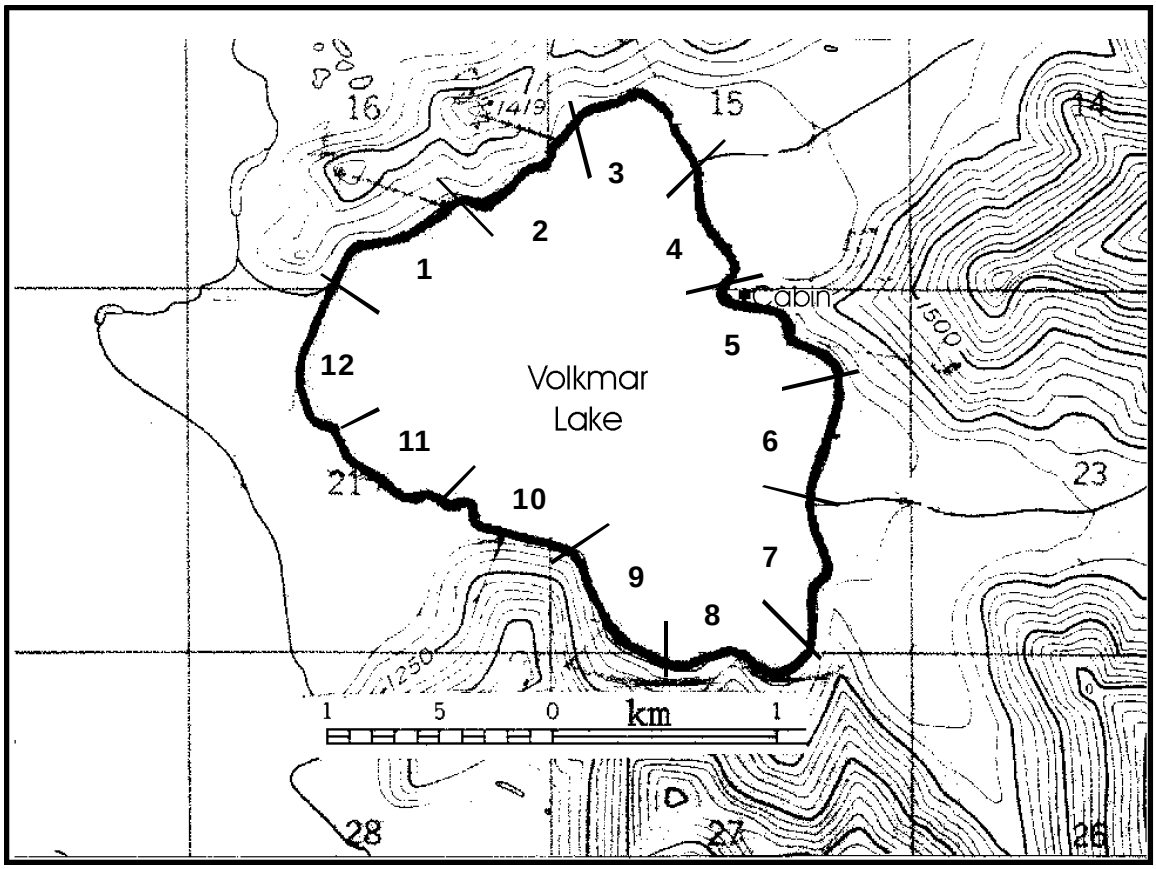

Figure 2.-Volkmar Lake study area.

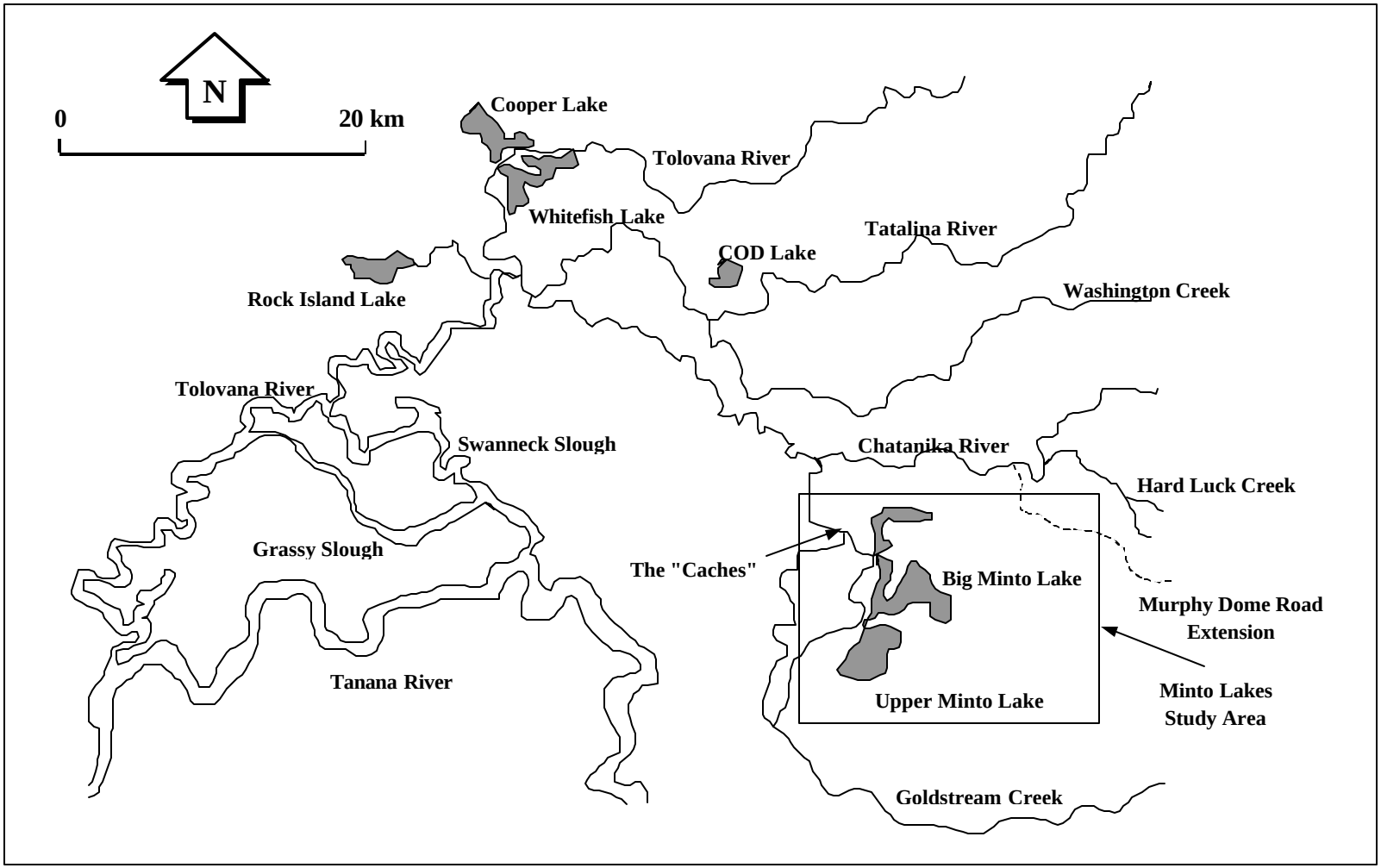

Figure 3.-The Minto Lakes study area.

annual Statewide Harvest Survey reports since 1992, and no reliable current information exists on the northern pike population or fishery.

Minto Flats

Minto Flats supported the largest sport fishery for northern pike in Alaska in 16 of the last 20 years (Mills 1979 - 1994; Howe et al. 1995, 1996, 2001a, b, c, d; Walker *In prep.*). From 1981-1984, the average sport harvest in Minto Flats was 2,279 northern pike. In 1985, however, a new sport fishery developed on a concentration of over-wintering northern pike in the Chatanika River. 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. Angler reports and limited creel survey sampling (Holmes and Burkholder 1988) indicated that a large proportion of the harvest from this new fishery was prespawning females.

Due to the suspected increased winter harvest of large female northern pike, which concentrate in few locations and are easily caught, ADF&G closed the Minto Flats winter sport fishery for northern pike by emergency order in January 1987. In the spring of 1988 the Alaska Board of Fisheries restricted the sport-fishing season to June 1 through October 14 and reduced the bag limit to five northern pike a day, only one of which can be over 30 inches TL (≈ 725 mm FL). Since the current regulations have been in effect, the estimated sport-fish harvest of northern pike in Minto Flats has fluctuated from 872 in 1989 to 8,438 in 1994 (Mills 1988 - 1994; Howe et al. 1995, 1996, 2000a; Table 1). In addition, estimated angler days fluctuated from 699 in 1989 to 6,267 in 1994. The 1994 estimates of harvest and effort are thought to be overestimates by the area managers. This fluctuation in effort and harvest, however, emphasizes the need for the capability of assessing the Minto Flats northern pike population.

A subsistence fishery for northern pike occurs near the present village site (New Minto) and at historically used sites in the eastern portions of Minto Flats (Andrews 1988). Gill nets are used to catch northern pike throughout the open-water period and hook-and-line techniques are primarily used to capture fish through the ice.

In December 1997, the Alaska Board of Fisheries adopted restrictions to ensure that the Minto Flats subsistence and sport-fishing harvest remain sustainable. Given the potential for the over harvest of overwintering northern pike, the board restricted subsistence and sport-fish anglers to the use of single hook within the Chatanika River overwintering area between the mouth of Goldstream Creek and the Murphy Dome Road Extension. The board also put in place measures to restrict the entire Minto Flats northern pike sport fishery to a daily bag and possession limit of one northern pike once the reported winter harvest from the Chatanika River overwintering area reaches 750 northern pike. Furthermore, the Chatanika overwintering area will be closed to subsistence fishing once the reported winter harvest from this area reaches 1,500 northern pike.

Table 1.- Estimated angler days expended; number of northern pike harvested and caught; and catch per angler day and harvest per catch in Minto Flats, 1978-1999 summarized by all northern pike and northern pike > 725 mm FL[a].

		Number Harvested		Number Caught		Catch/AnglerDay		Harvest/Catch	
Year	Angler Days	All	> 725 mm	All	> 725 mm	All	> 725 mm	All	> 725 mm
1978	3,640	3,300	-	-	-	-	-	-	-
1979	2,709	3,209	-	-	-	-	-	-	-
1980	2,727	3,909	-	-	-	-	-	-	-
1981	2,045	2,009	-	-	-	-	-	-	-
1982	1,791	1,886	-	-	-	-	-	-	-
1983	1,281	1,825	-	-	-	-	-	-	-
1984	1,829	1,960	-	-	-	-	-	-	-
1985	2,011	3,902	-	-	-	-	-	-	-
1986	3,318	3,621	-	-	-	-	-	-	-
1987	1,539	1,161	-	-	-	-	-	-	-
1988	1,564	1,128	-	-	-	-	-	-	-
1989	699	872	-	-	-	-	-	-	-
1990	932	1,182	-	3,967	-	4.3	-	0.3	-
1991	1,532	1,754	297	4,907	535	3.2	0.3	0.4	0.5
1992	2,401	1,247	131	5,765	808	2.4	0.3	0.2	0.2
1993	3,911	2,076	170	19,536	5,238	5.0	1.3	0.1	0.0
1994	6,267	8,438	1,943	47,248	5,408	7.5	0.9	0.2	0.4
1995	6,260	3,126	594	21,823	2,463	3.5	0.4	0.1	0.2
1996	3,973	2,078	659	12,495	1,408	3.1	0.4	0.2	0.5
1997	3,332	1,074	290	9,932	1,935	3.4	0.4	0.1	0.2
1998	1,414	731		4,105	N/A	2.9	N/A	0.2	N/A
1999	2,431	908		3,261		1.3		0.3	
Average	2,650	2,643	627	17,208	2,890	4.3	0.7	0.2	0.3

a Daily fishing regulations within Minto Flats are such that only one northern pike over 30 inches TL (≈725 mm FL) may be retained or in possession.

STUDY DESIGNS

Volkmar Lake

The Volkmar Lake northern pike study was designed to estimate abundance and length and age composition of northern pike using a multiple-mark and release experiment. The assumptions were that:

1) the population was closed (no change in the number or composition of northern pike during the experiment);
2) all northern pike had the same probability of capture during the marking event *or* the same probability of capture during the recapture event *or* marked and unmarked northern pike mixed thoroughly between the marking and recapture events;
3) marking of northern pike did not affect their probability of capture in subsequent samples;
4) northern pike did not lose their mark between events; and,
5) all marked northern pike were reported when recovered in subsequent samples.

The sampling design allowed the validity of these assumptions to be ensured or tested.

Sampling Design

Northern pike were captured in Volkmar Lake immediately following breakup. Sampling was scheduled during late May because northern pike are typically concentrated in near shore during this time. Past studies have indicated that catch-per-unit-effort of sampling gear is high at this time (Peckham and Bernard 1987; Clark 1988; Pearse 1990-1991; Pearse and Burkholder 1993; Hansen and Pearse 1995). The validity of assumption 1 was assumed because Volkmar Lake is a closed system with only one outlet that is negligible, and therefore movement of northern pike in or out of the lake is unlikely. Mortality and growth, which may contribute to the violation of assumption 1, was also negligible because of the short duration of the experiment.

The validity of assumption 2 was assured by the sampling design. The lake was divided into 12 sampling areas (Figure 2). Each sampling area included approximately 650 m of shoreline to ensure uniform sampling effort throughout the lake and to allow testing for movement of marked fish between areas. Each sampling area was sampled once each day. This sampling design proved successful in 1992 in Volkmar, George, T, and East Twin lakes (Pearse and Burkholder 1993). Sampling at Volkmar Lake began on May 18 and lasted 8 days. Each day was a separate marking event using the Schnabel multiple-census method (Ricker 1975).

The defined areas allowed for the evaluation of assumptions 2 and 3 with a series of consistency tests designed to detect unequal catchability and length selectivity. These tests included chi-square contingency table tests that compared catchability and proportions marked by area, inspection of movement, and two Kolmogorov-Smirnov two-sample tests that compared catchability by length. The results of these tests, in combination, determined methods to compensate, if necessary, for bias in the estimation of abundance from possible violations of assumptions 2 and 3. Probabilities of a Type I error (α) of 0.05 or lower were considered significant.

The validity of assumption 4 was insured by double marking (Floy tag and fin-clip) of each northern pike during the marking event. Tag loss was noted when a fish was recovered during the recapture event with a specific fin clip but without a Floy tag. In addition, Floy tag

placement was standardized, which enabled the fish handler to verify tag loss by locating recent tag wounds.

The validity of assumption 5 was insured by a thorough examination of fins for fin-clips and the recording of fin clips and Floy tag numbers whether the fish was believed to be a recaptured fish or not.

Minto Flats

The Minto Flats northern pike study was designed to estimate abundance and length and age composition of northern pike using a single-mark and release experiment. The assumptions were similar to those described above in the Volkmar Lake study design.

Sampling Design

The Minto Flats Area I northern pike mark-recapture experiment was designed to estimate abundance and composition germane to the area of Minto Flats that attracts the majority of sport fish anglers and during a time in which the population is vulnerable to sport harvest.

Since it was possible for northern pike to move out of or into Area I during the mark-recapture experiment the validity of assumption 1 was based upon completing the experiment during the time of least northern pike movement. The experiment was scheduled for the middle to late June. The northern pike radiotelemetry study indicated that during the open water period, Minto Flats Area I northern pike are least active from the middle of June until the middle of July (Roach 1998a). In support of little movement during the middle to late June, all northern pike recovered with marks in 1996 were recovered in the same area in which they were marked. Furthermore, in the 1997 study examination of areas where northern pike were marked with areas where the fish were recaptured indicated movement towards the center of the study area (Roach 1998b). This one-way movement suggests that there may have been movement into the study area but once within the study area all northern pike remained throughout the study. Mortality and growth, which may contribute to the violation of assumption 1, was considered to be negligible because of the short duration of the experiment.

The validity of assumption 2 was assured by the timing of the mark-recapture experiment and the sampling design. Investigators have reported biased estimates of composition when samples were collected in spring and fall in other systems. Casselman (1975) reported that male and female northern pike exhibit biannual peaks of availability to the gear, resulting in inherent sampling error. Males were relatively more abundant in spring and fall. He suggested that composition bias was related to differential timing of movements to spawning and overwintering areas by sex and not necessarily related to locality or method of capture. Neumann and Willis (1995) reported that males moved into and out of spawning areas faster than females and entered spawning areas first. A higher percentage of males were captured during the spawning period suggesting greater activity of males during this time. These studies suggest that northern pike are more likely to have the same probability of capture by length and sex after spawning, which further supports the idea of conducting this experiment during June.

Sampling in June during a time northern pike movements are minimal required a systematic sampling design. Minto Flats Area I was divided into 16 areas. Sampling was conducted by two crews of two individuals, with each crew responsible for sampling eight areas. Each area was systematically sampled such that sampling was not concentrated in a small portion of the area but evenly distributed throughout the area. Crews sampled two areas per day, and each area was sampled twice during each event. Originally, the marking event was scheduled for 8 June

through 15 June and the recapture event was scheduled for 22 June through 29 June, with a six-day hiatus between events. However, due to high water and subsequent low catches, the marking event ran continuously from 10 June through 29 June, and the recapture event ran from 17 August through 24 August. According to the radiotelemetry data northern pike movement into and out of the sampling area during this time is negligible (Roach 1998a).

The defined areas allowed the evaluation of assumptions 2 and 3 with a series of consistency tests designed to detect unequal catchability and length selectivity. These tests will included chi-square contingency table tests that compared catchability and proportions marked by area, inspection of movement, and two Kolmogorov-Smirnov two-sample tests that compared catchability by length. The results of these tests, in combination, determined methods to compensate for bias in the abundance estimation from possible violations of assumptions 2 and 3. Probabilities of a Type I error (α) of 0.05 or lower were considered significant.

The validity of assumption 4 was insured by double marking (Floy tag and fin-clip) of each northern pike during the marking event. Tag loss was noted when a fish was recovered during the recapture event with a specific fin clip but without a Floy tag. In addition, Floy tag placement was standardized, which enabled the fish handler to verify tag loss by locating recent tag wounds. The validity of assumption 5 was insured by a thorough examination of fins for fin-clips and the recording of fin clips and Floy tag numbers whether the fish was believed to be a recaptured fish or not.

METHODS

VOLKMAR LAKE

A crew of four people used a 100 m by 10 m beach seine with 25 mm square mesh and attached bag to capture northern pike. Extreme care was exercised to minimize mortalities by providing fresh water to the sampling tub periodically and by careful and prudent handling of fish. All northern pike were released in the same sampling area as captured. One seine haul in each of the twelve areas was completed once per day in order to distribute effort uniformly through the lake.

Data Collection

All data from northern pike captured during the Volkmar Lake mark-recapture experiment were recorded on ADF&G Tagging Length Mark-Sense Forms, Version 1.0. A new form was used for each area with the date, area, and set number recorded on the description line. Scales for age determination were mounted directly to gummed cards at the time of sampling. Gummed cards were labeled with the corresponding mark-sense litho-code, date, and location. The importance of thoroughly examining all northern pike for Floy tags, recent tagging wounds, and recent fin clips and accurately recording data was stressed to all crewmembers.

All northern pike ≥ 300 mm FL that were captured were measured for length, examined for a previous tag, if not tagged then tagged with a uniquely numbered Floy tag, and the upper caudal fin slightly clipped. Fork length was measured and recorded to the nearest millimeter. A minimum of two scales were taken from the preferred zone of each fish adjacent to but not on the lateral line above the pelvic fins, as described by Williams (1955), and mounted on gummed scale cards. Both the left and right side of the dorsal fin were examined for the presence of a Floy tag; and if present, the color and number of the tag recorded; or if not present, a new Floy FD-68 internal anchor tag inserted at the left base of the dorsal fin and the number recorded. Northern pike killed during the sampling procedure were not tagged, but all other data was

recorded and the fate (K) clearly noted in the blank space after the length on the mark-sense form. The sex of each northern pike was determined when possible by the presence of milt or eggs and recorded. Recaptures and fin-clips from previous years were noted on the mark-sense forms.

Data Reduction

Upon completion of fieldwork, collected northern pike scales were processed for age determination. Scale impressions were made on 20 mil acetate sheets using a Carver press at 241,315 kPa (35,000 psi) heated to 150 °C for 150 s from scales collected in the field on gummed cards. Ages were determined from scale impressions using a Micron 770 microfiche reader (32X) or equivalent according to criteria established by Williams (1955) and Casselman (1967). Ages were recorded on the mark-sense forms.

The project biologist edited all mark-sense forms twice for stray marks, incomplete marks, coding errors, and omissions. After editing, all mark-sense forms were sent to ADF&G, Research and Technical Services (RTS) for processing.

Upon completion, RTS returned data (DTA) files to the project biologist. The DTA files were also edited for coding errors, omissions, out-of-bounds lengths, and out-of-bounds tag numbers using Microsoft Excel. The corrected DTA files were archived with RTS. From the corrected DTA files, a database (DBF) file was created and merged into the Volkmar Lake northern pike historical DBF file.

Estimation of Abundance

The Volkmar Lake mark-recapture experiment data was analyzed using the program CAPTURE (Rexstad and Burnham 1991). This program helped perform an examination of the assumptions for multiple-sample abundance estimators. The underlying logic and statistical processes of program CAPTURE is described in Otis et al. (1978) and White et al. (1978, 1982), and was used successfully in estimation of abundance of northern pike in Volkmar Lake several times (Pearse 1990-1991; Pearse and Burkholder 1993; Hansen and Pearse 1995). Based upon the output of program CAPTURE, a model was selected which best estimated the abundance of the population of northern pike in Volkmar Lake.

Estimation of Length and Age Compositions

Length and age proportions and variances of proportions for northern pike in Volkmar Lake in 2000 that were ≥ 300 mm FL were estimated using:

$$\hat{p}_k = \frac{x_k}{n}, \text{ and} \tag{1}$$

$$\hat{V}\left[\hat{p}_k\right] = \frac{\hat{p}_k\left(1-\hat{p}_k\right)}{n-1} \tag{2}$$

where: $\hat{p}_k$ = the proportion of northern pike that were length or age *k*;

x_k = the number of northern pike sampled that were length or age *k*; and,

n = the number of northern pike that were measured for length or for which ages were determined.

Furthermore, to evaluate the precision in age determination ages were determined twice for a random sample of 100 scales taken during the experiment. The average percent error (Beamish and Fournier 1981) of the scale reader to reproduce the same age twice from a scale was calculated as:

$$APE = \frac{\sum_{i=1}^{S}\left[\frac{\sum_{j=1}^{R}\frac{\left|x_{ij}-\bar{x}_i\right|}{\bar{x}_i}}{R}\right]}{S}\cdot 100 \qquad (3)$$

where: x_{ij} = age determined from the j^{th} reading of the i^{th} scale;

$\bar{x}_i$ = average age determined from the i^{th} scale;

R = total number of readings; and,

S = total number of scales in the sample.

MINTO LAKES

A systematic method was used to sample northern pike in Minto Lakes. The marking event was carried out from 8 June through 29 June and the recapture event from 17 August through 24 August. The study area was composed of seven sections (001, 002, 003, 004, 013, 023, 033), which were subdivided into 16 subsections (indicated by the number following the hyphenated section number in Figure 4) to examine movement, test for differences in catchability, and help insure uniform sampling effort (Figure 4). Generally, sampling took place between 1000 and 1800 hours each day, but after the 18^{th} day of the mark event, crews worked 2-4 hours a day longer in an effort to increase catches. There were five to six passes through each subsection for the marking event and two passes through each subsection for the recapture event. Two crews of two individuals systematically sampled two subsections per day such that sampling was not concentrated in a small portion of the area but evenly distributed. Each crew fished four hoop traps, moving them at the beginning and end of each workday. Due to the unusually high water in the study area, the hoop traps were less effective in capturing fish than in previous years. Therefore, sampling was supplemented with gillnets starting on the fourteenth day of the marking event, and were used throughout the recapture event. When not tending the hoop traps each crew typically fished two to three gill nets but never more gill nets than would allow fish to be sampled and checked within one hour. Each area was sampled evenly and as uniformly as possible by moving the gill nets to new sites within the area throughout the workday. All healthy northern pike were released immediately after data collection, 50 to 100 m from the capture site.

Data Collection

Data collection procedures were identical to those used in the Volkmar Lake northern pike experiment described above. All files used for data analysis of northern pike in the Minto Flats northern pike experiment are listed in Appendix A1.

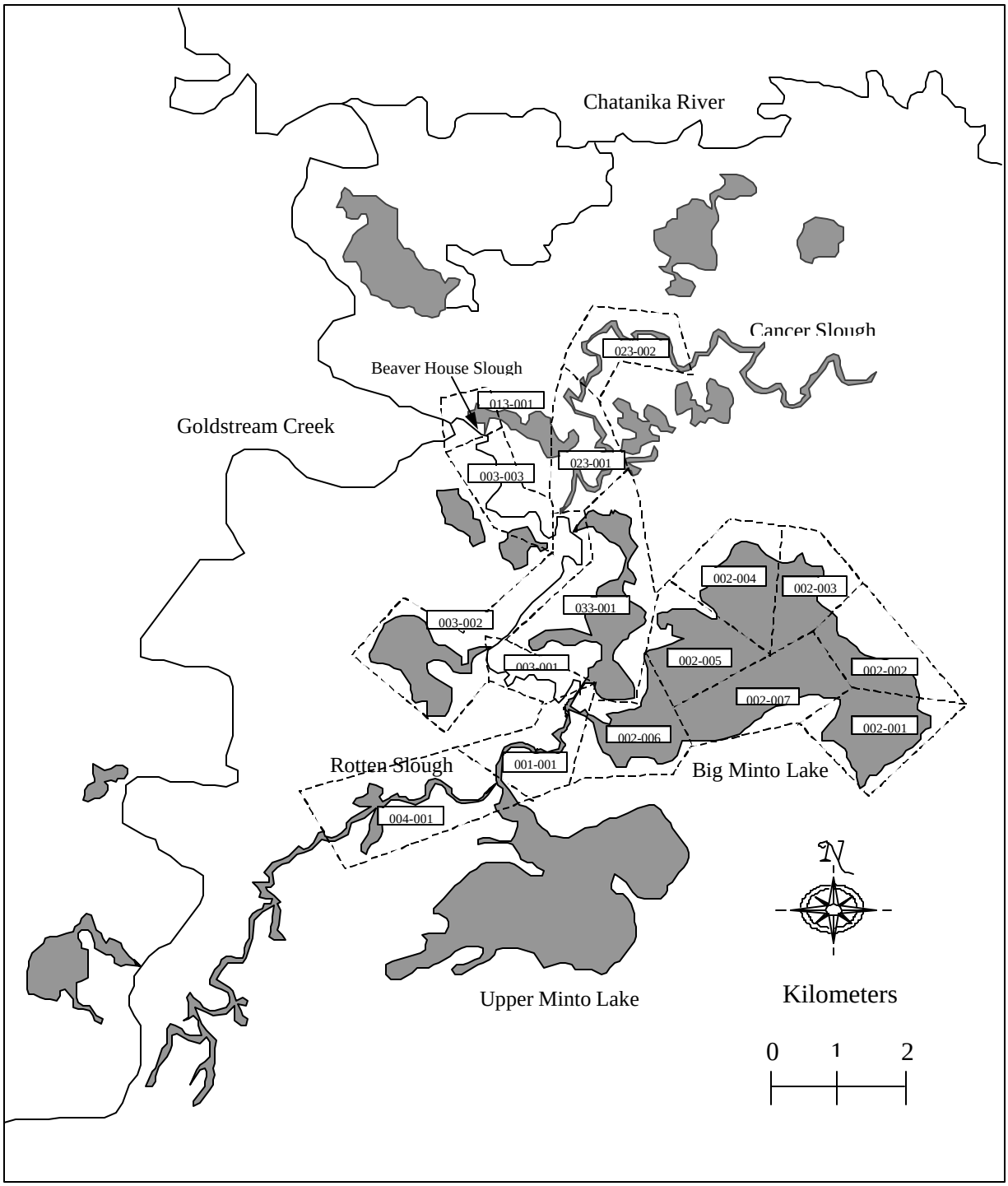

Figure 4.-Minto Lakes study area with designated sampling areas indicated with dashed lines.

Estimation of Abundance

Abundance was estimated using a two-sample Petersen mark-recapture experiment (Seber 1982), which has the identical assumptions described for the Volkmar Lake experiment.

The validity of assumption 1 was inferred from information gained from a two-year radiotelemetry study of northern pike movements within the study area and from examination of the movements of marked fish during the experiment. The radiotelemetry study indicated that little movement of radio-tagged fish occurred between the middle of June and the end of August. In the case that assumption 1 was violated by a one way change in numbers (either an increase or a decrease in the number of fish but not both) and other assumptions were valid, the estimate of abundance would be germane either to the marking event or the recapture event but not both. Growth, which may have contributed to the violation of assumption 1, likely occurred. This was addressed by conducting a Kologorov-Smirnov test for length distributions of northern pike sampled by event to look for significant differences, which would determine whether or not stratification of the abundance estimate by length was necessary. The validity of assumption 2 and 3 was evaluated with tests of consistency designed to detect unequal catchability by area and by size of fish (Seber 1982). The validity of assumption 4 was insured by double marking (Floy tag and fin-clip) each northern pike during the marking event. Tag loss was noted when a fish was recovered during the recapture event with the specific fin clip but without a Floy tag. In addition, Floy tag placement was standardized, which enabled the fish handler to verify tag loss by locating recent tag wounds. A thorough examination of fins for fin-clips and the recording of fin clips and Floy tag numbers for all northern pike insured the validity of assumption 5. Information on Floy tag numbers used for this mark-recapture experiment were archived (Appendix B1).

Estimated abundance of northern pike was calculated from the number of northern pike marked, examined for marks, and recaptured. The Chapman estimator (Seber 1982) was used:

$$\hat{N} = \frac{(M+1)(C+1)}{R+1} - 1 \qquad (4)$$

where:

- M = the number of northern pike marked and released alive during the marking event;
- C = the number of northern pike examined for marks during the recapture event;
- R = the number of northern pike recaptured during the recapture event; and,
- $\hat{N}$ = estimated abundance of northern pike at the time of marking.

Variance of the abundance estimate (Seber 1982) was estimated as:

$$\hat{V}\left[\hat{N}\right] = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)}. \qquad (5)$$

Estimation of Length and Age Compositions

Length and age proportions of northern pike ≥ 400 mm FL were estimated for the Minto Lakes study area. The proportion and variance estimators used were identical to those previously

described. Age composition was estimated using the same equations for proportions and variances of proportions used to estimate length composition except ages were substituted for lengths. Length composition data was archived (Appendix B3).

RESULTS

VOLKMAR LAKE

Abundance

A total of 236 unique northern pike were sampled over eight days. Of these 236 fish, 14 were subsequently recaptured. There was no observed tag loss or immediate mortalities during the experiment, and 10 northern pike with Floy tags from prior mark-recapture experiments (4% of unique northern pike handled) were identified.

Analysis of the data indicated that there may have been an effect on sampling from behavior and time but no effect from heterogeneity in probability of capture. This suggested using model M_t or M_t Chao to estimate abundance (Appendix C1). M_t Chao was chosen because it is more robust when capture probabilities and sample sizes are low. This model allowed for different sampling effort over time but assumed that northern pike were selected at each occasion with equal probability.

The estimated abundance of northern pike ≥ 300 mm FL in Volkmar Lake in 2000 was 1,491 fish (SE = 369), and the estimated abundance of northern pike ≥ 450 mm FL was 615 fish (SE = 161). The 95% profile-likelihood bounds were 950 and 2,442 northern pike ≥ 300 mm FL, and density was estimated to be 6.1 northern pike ≥ 300 mm FL per ha.

Inspection of the cumulative distribution of length of sampled northern pike suggested potential problems with size-selectivity among sampling events (Figure 5). An Anderson-Darling K-sample test was performed on the daily cumulative length distributions, which determined that the length distribution of fish during the first day of sampling was significantly different than it was for the other seven days. However, when we removed samples caught the first day from the analysis, the estimate of abundance did not change significantly, which suggested there was only negligible effect from the difference in lengths. The first day was left in the analysis.

Length and Age Composition

In 2000, the estimated abundance of northern pike ≥ 450 mm FL was 615 fish (or 37% of the estimate for fish ≥ 300 mm FL; Figure 6) compared to 2,318 fish (or 83% of the estimate for fish ≥ 300 mm FL) in 1994 (Hansen and Pearse 1995).

Ages determined from 230 northern pike showed that 18% of the northern pike sampled in Volkmar Lake in 2000 were age-5 (Figure 7). Northern pike ≥ age-7 constituted 18% of the sample. In 1994, age-5 northern pike sampled in Volkmar Lake composed 27% of the sample, and 29% of the northern pike sampled were ≥ age-7 (Hansen and Pearse 1995). In 2000, the average percent error in observing the same age twice from a Volkmar Lake northern pike scale was 6.1% (Figure 8). Of the 100 scales aged twice for validation, 53 were assigned the same age during the second reading. The mean error in assigning the proper incremental age from these scales was 0.83 years.

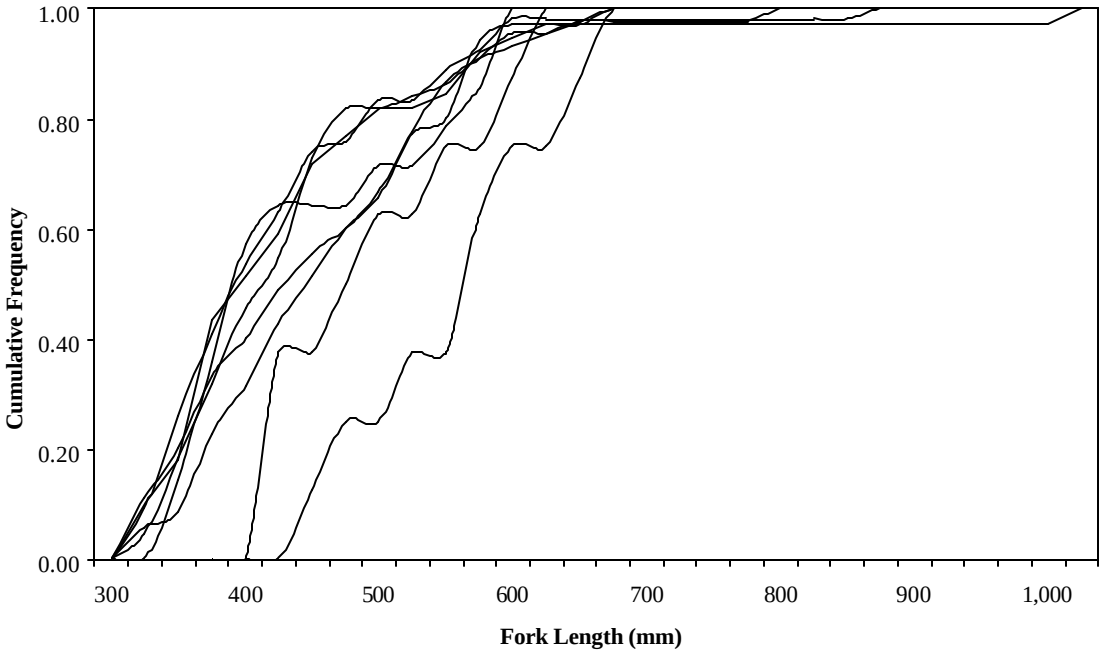

Figure 5.-Cumulative length frequency distribution of northern pike captured in Volkmar Lake, 2000 by event.

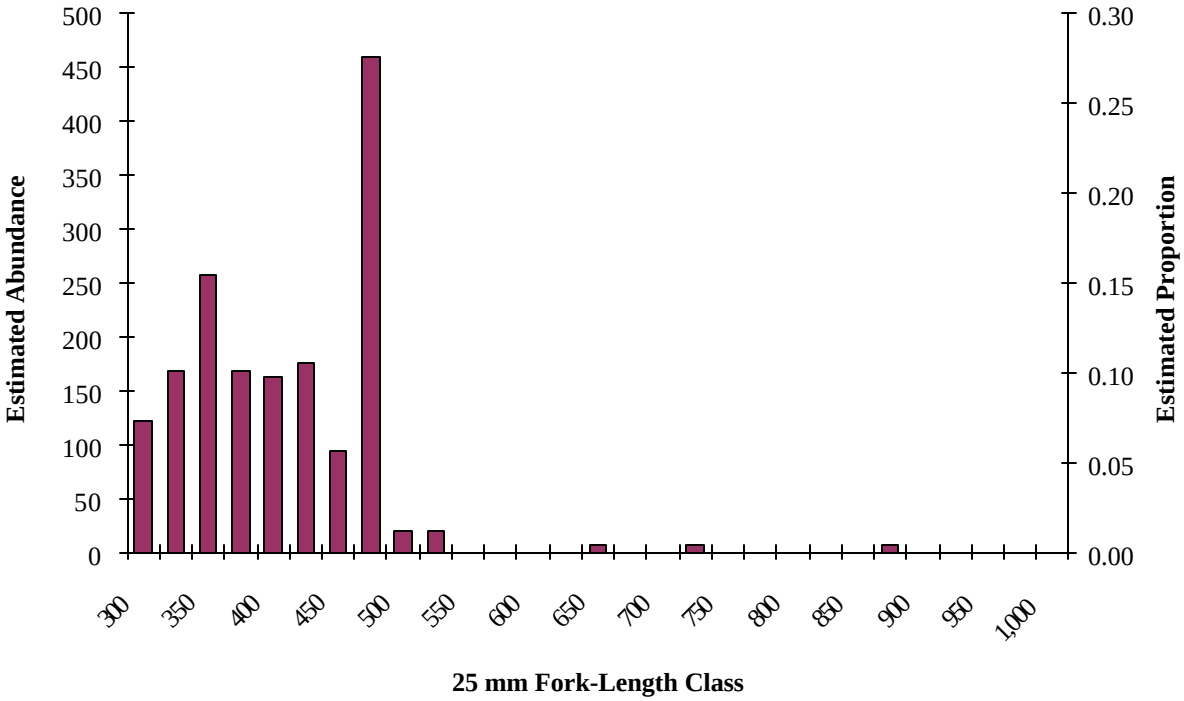

Figure 6.-Estimated abundances and proportions of northern pike ³ 300 mm FL in Volkmar Lake, 2000.

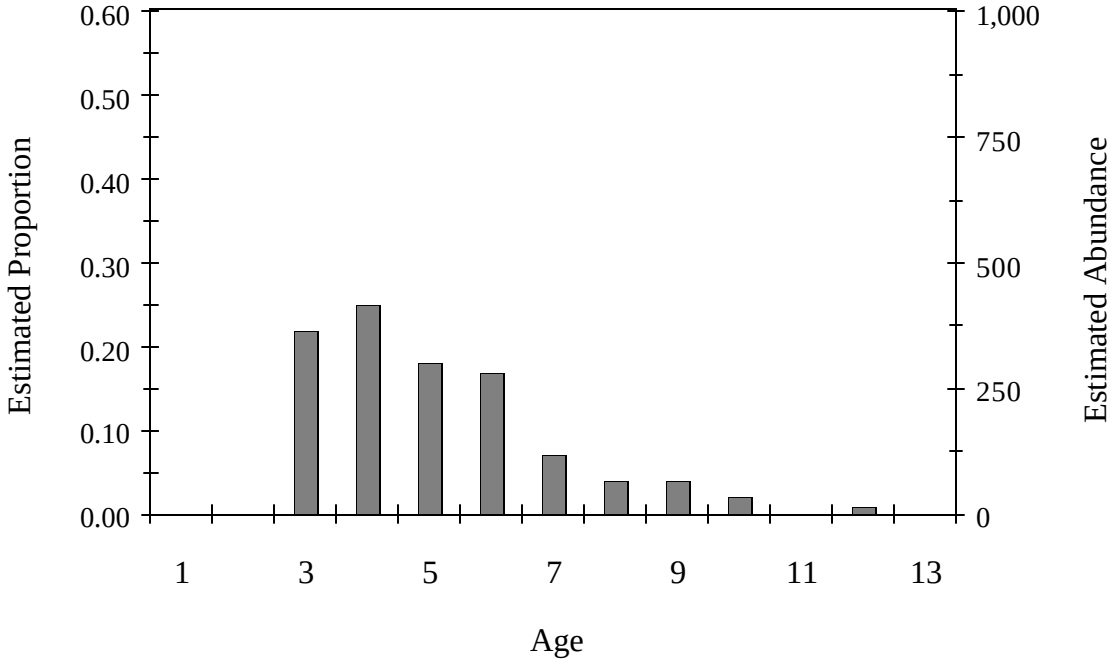

Figure 7.-Estimate proportions and abundances of northern pike ³ 300 mm FL by ages in Volkmar Lake during late May, 2000.

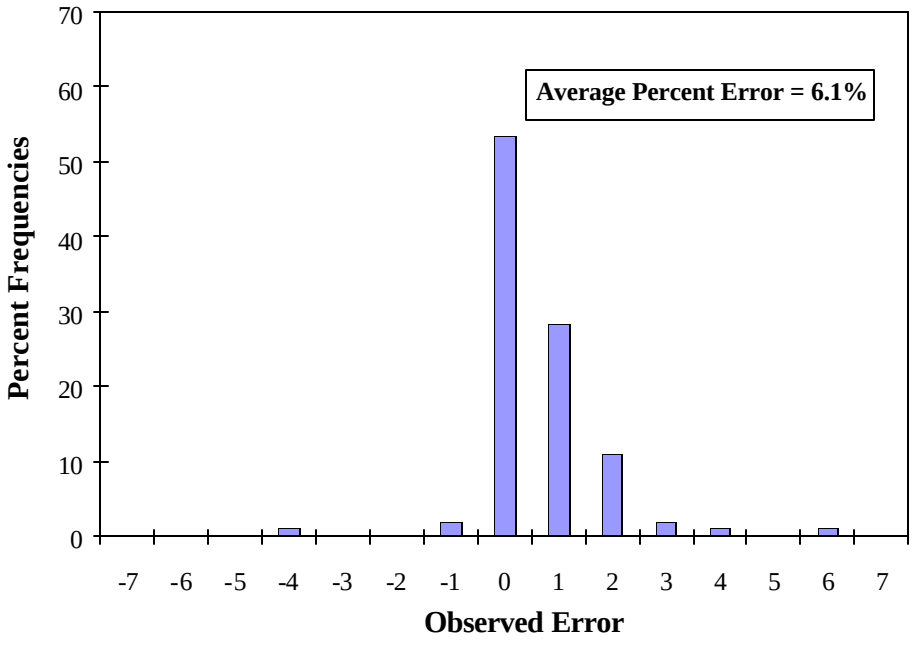

Figure 8.-Percent frequencies for observed errors in observing the same age twice from a Volkmar Lake northern pike scale in 2000 (n = 100).

MINTO LAKES

Abundance

Due to high water and subsequent low catch rates, the experiment was extended. This resulted in a longer than anticipated hiatus between events. The marking event was conducted from 8 June through 29 June, and the recapture event was conducted from 17 August through 24 August. The resultant hiatus between events was 49 days. Of the 879 unique northern pike ≥ 300 mm FL handled during this mark-recapture experiment, 525 were tagged and released alive during the marking event of which 17 were subsequently recaptured, and 354 new fish were captured during the second event. There was no observed tag loss during the experiment, nine northern pike were inadvertently killed, and 67 northern pike with Floy tags from prior mark-recapture experiments (8% of unique northern pike handled) were identified. The smallest northern pike recaptured in 2000 was 612 mm FL. The estimate of abundance was germane only to northern pike ≥ 600 mm FL. Of 343 unique northern pike ≥ 600 mm FL sampled during the first event 17 were subsequently recaptured, and 278 new northern pike ≥ 600 mm FL were examined for marks in the second event (Appendix B4).

Examination of areas where northern pike were marked with areas where the fish were recaptured indicated movement from the outer margins (sections 001, 004, and 013; Area A) towards the center (sections 002, 003, 023, and 033; Area B) of the study area (Figures 4 and 9). This movement pattern is similar to that observed by Roach (1997; 1998a) in previous experiments, and suggested that there may have been immigration into the study area but probably no emigration out of the study area. This pattern of movement was also supported with information obtained using radiotelemetry (Roach 1998b). The radiotelemtry study also suggested that northern pike in Minto Lakes do not begin mass movements out of the study area until September.

A comparison of the recovery history of fish marked in Area A and Area B indicated mixing between the areas (c^2 = 2.95; 1 df; P = 0.23; Table 2). In addition, there were also no significant differences in recapture rates (c^2 = 1.99; 1 df; P = 0.16; Table 3) between the center (R/C = 0.05) and outer margins (R/C = 0.09) of the study area. These results suggest that fish from both areas had the same probability of capture during the first event. A comparison of the probability of capture during the second event shows that a relatively constant proportion of fish marked in each area were recovered (c^2 = 1.89; 1 df; P = 0.32; Table 4). This suggested that fish marked in the outer margins of the study area did not move out of the study area.

Results from a Kolmogorov-Smirnov goodness of fit test indicated significant differences between the length distributions of fish marked during the first event and fish captured during the second event (D = 0.03; P = 0.01; Figure 10) and between the length distributions of fish marked and fish recaptured (D = 0.01; P = 0.00). Under circumstances when growth is minimal, this would suggest that there was length selectivity during the second event and the status of length selectivity during the first event was not known. However, there was no significant difference between the length distributions of fish captured during the second event and fish recaptured (D = 0.01; P = 0.92; Figure 10). This, along with the long hiatus, suggested that differences in distribution of length were due to growth and that the same population of fish was sampled during both events.

Given the conditions that there may have been only one-way movement into the study area, that sampling during the second event was uniform, and that there was no difference in length

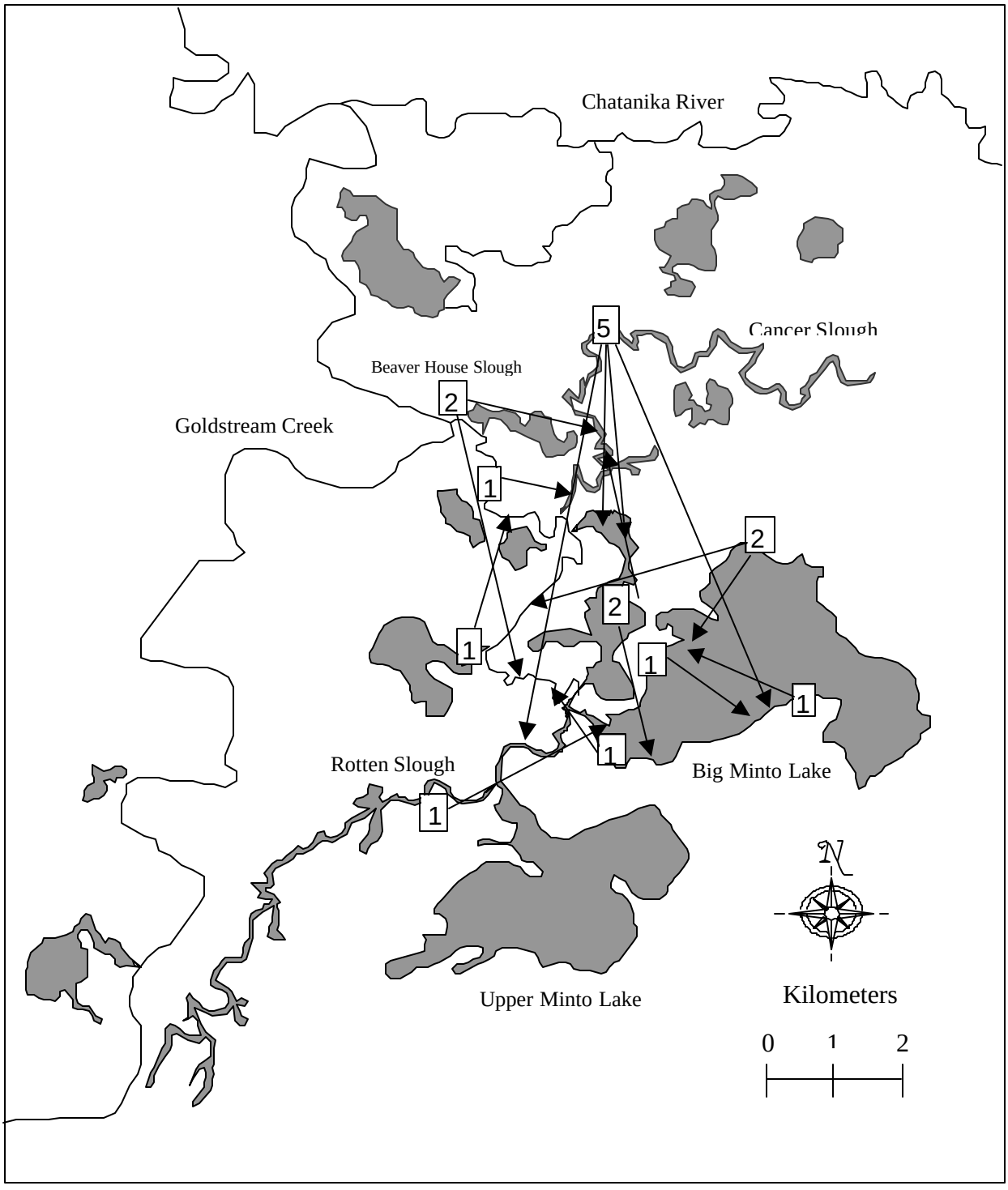

Figure 9.-Minto Lakes study area with number of recaptures indicated by location of marking (numbered box) and location of recovery (location of arrow).

Table 2.-Numbers of northern pike marked in areas A (sections 001, 004, and 013) and B (sections 002, 003, 023, and 033) and recovered in area A, area B, or not recovered.

Marking	Recovery History			
Area	A	B	Not Recovered	Total
A	9	1	216	226
B	5	2	110	117
Total	10	7	326	343

Table 3.-Numbers of marked and unmarked northern pike captured during the recapture event by areas A (sections 001, 004, and 013) and B (sections 002, 003, 023, and 033).

	Capture Area		
Northern Pike	A	B	Total
Marked	10	7	17
Unmarked	108	153	261
Total	118	160	278

Table 4.-Numbers of marked northern pike recovered and not recovered during the recapture event by areas A (sections 001, 004, and 013) and B (sections 002, 003, 023, and 033).

	Marking Area		
History	A	B	Total
Recovered	14	3	17
Not Recovered	216	110	326
Total	230	113	343

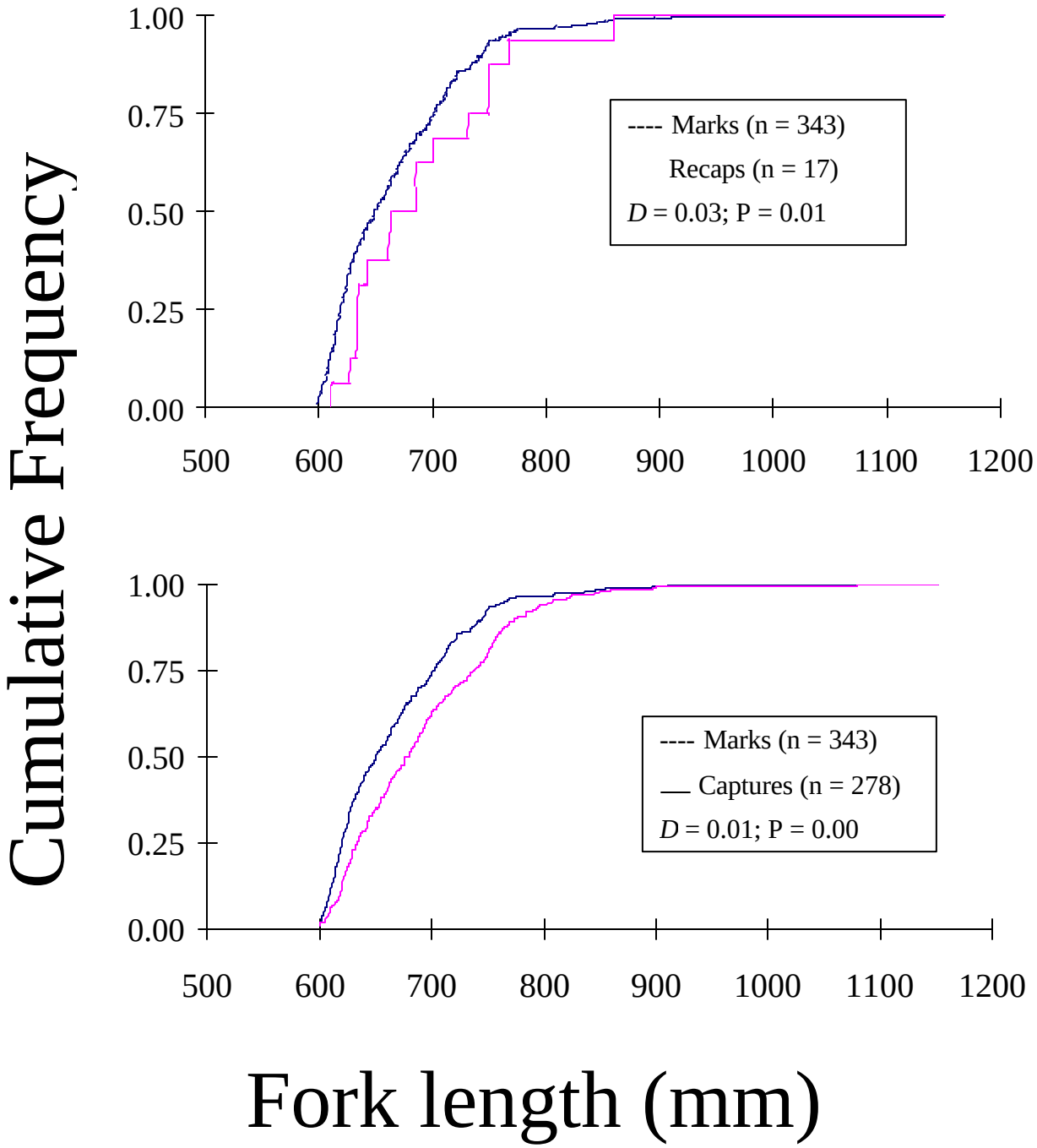

Figure 10.- Cumulative length frequency of northern pike marked versus recaptured and marked versus captured in Minto Lakes in 2000.

selectivity between events, abundance at the time of the second event was estimated using the unstratified Chapman estimator based on the hypergeometric probability distribution. Estimated abundance of northern pike within Minto Lakes was germane to fish ≥ 600 mm FL (middle August to late August 2000; this estimate is probably also valid for the time of the first event also). Estimated abundance of northern pike ≥ 600 mm FL within Minto Lakes was 5,331 fish (SE = 1,152; CV = 22%). The confidence interval around the estimate of abundance was 3,074 and 7,588 northern pike ≥ 600 mm FL. For comparison estimates of abundance for Minto Lakes northern pike germane to fish ≥ 600 mm FL in 1996 was 7,616 fish (SE = 883), and in 1997 3,251 fish (SE = 174; Figure 11).

Length and Age Composition

In 2000, fork lengths of sampled fish ranged from 612 mm to 1,151 mm. Of the 879 unique northern pike (≥ 400 mm FL) sampled during the Minto Lakes mark-recapture experiment, age was determined for 100 fish. Ages determined for northern pike (70 from the marking event and 30 from the recapture event) ranged from age-2 to age-11. For 11 of these northern pike, age had been determined previous to 2000. The mean error in assigning the proper incremental age from these scales was 0.95 years ($Z = 4.73$; $P < 0.01$); and the estimated average percent error of the scale reader in observing the same age twice from the same scale in 1997 was 6.8% (Figure 12). Of the 100 Minto Lakes northern pike ≥ 400 mm FL aged in 2000, an estimated 24% (SE = 1.9%) were age-6 (Figure 13).

DISCUSSION

VOLKMAR LAKE

The estimate of abundance for northern pike ≥ 300 mm FL in Volkmar Lake in 2000 of 1,668 fish (SE =418) is considerably lower than the 5-year average of estimated abundances from 1990 through 1994 of 3,881 fish (Hansen and Pearse 1995). In 1994, the estimated abundance of northern pike ≥ 300 mm FL in Volkmar Lake was 2,810 fish (SE = 302), and of northern pike ≥ 450 mm FL was 2,318 fish (SE= 236). The average age and average length of the population were down from previous estimates as well.

The environmental conditions in Volkmar Lake observed during the experiment appeared to be favorable for northern pike production. Adequate amounts of aquatic vegetation for spawning and juvenile cover were present, and there also appeared to be large numbers of humpback whitefish and least cisco (adults and juveniles) for food. It seems unlikely that the reduction of northern pike in Volkmar Lake can be attributed to a lack of available habitat or forage. In addition, the Statewide Harvest Survey estimates do not reflect an increase in effort, harvest, or catch in Volkmar Lake since the regulation was changed in 1997. Due to difficulty of accessing Volkmar Lake, sport fishing effort for northern pike in the summer months is probably low and restricted primarily to landowners with access to aircraft.

Anecdotal information from two landowners present on the lake during the experiment in 2000 supported the idea that the winter northern pike fishery through the ice in the spring was popular at Volkmar Lake in the 1990s, before the harvest regulation was changed from five fish to one fish per day in 1997. From 1991 through 1997, the number of icehouse permits issued for Volkmar Lake averaged nine per year, with highs of 12 in the winters of 1992-93 and 1993-94 (N. L. Greiner, Alaska Department of Fish and Game, Fairbanks, personal communication).

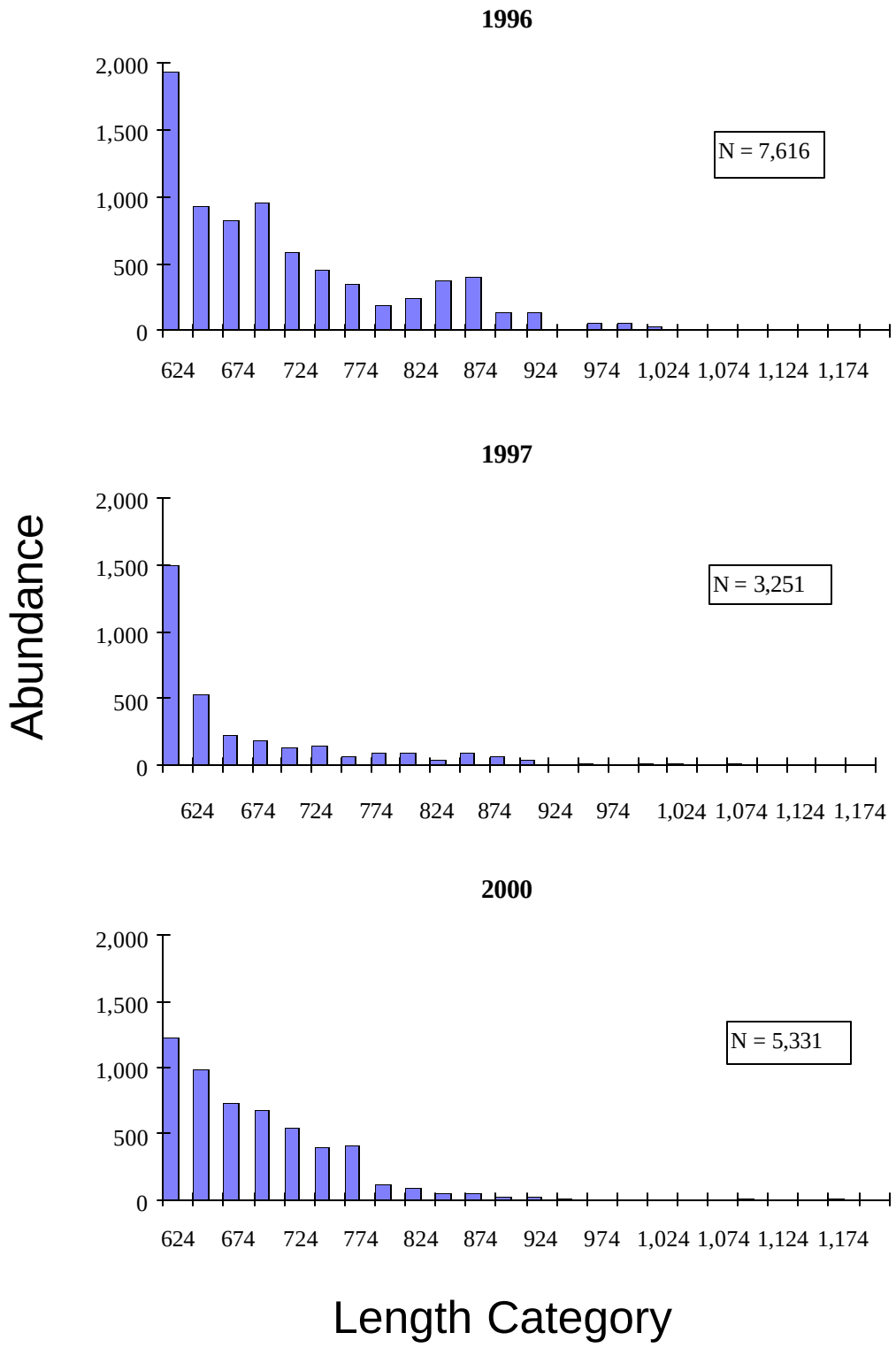

Figure 11.-Abundance of northern pike ≥ 600 mm FL in Minto Lakes in 1996, 1997, and 2000.

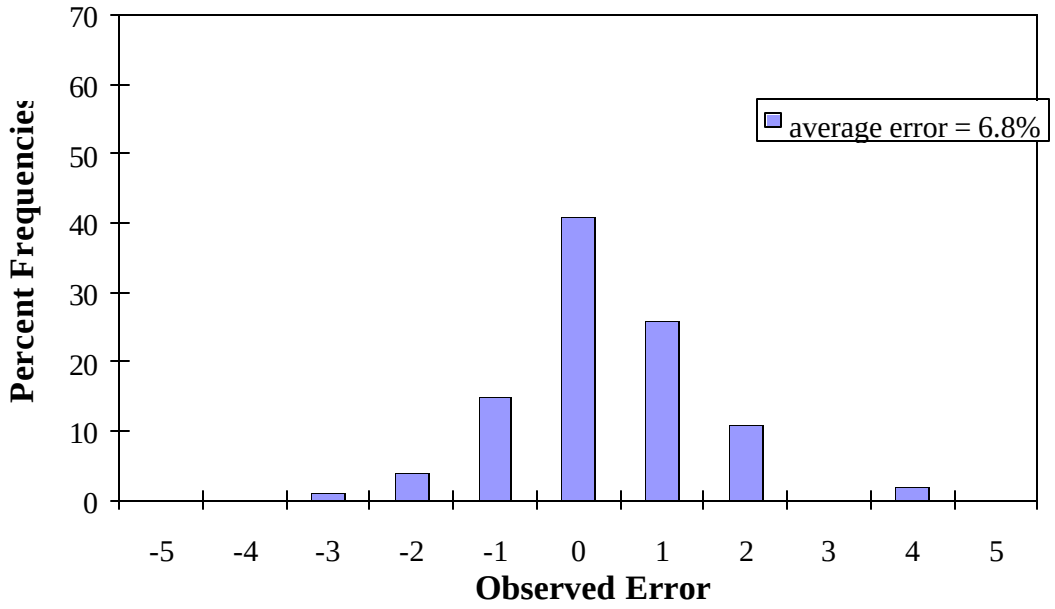

Figure 12.-Percent frequencies for observed errors in observing the same age twice from a Minto Lakes northern pike scale in 2000 (n = 100).

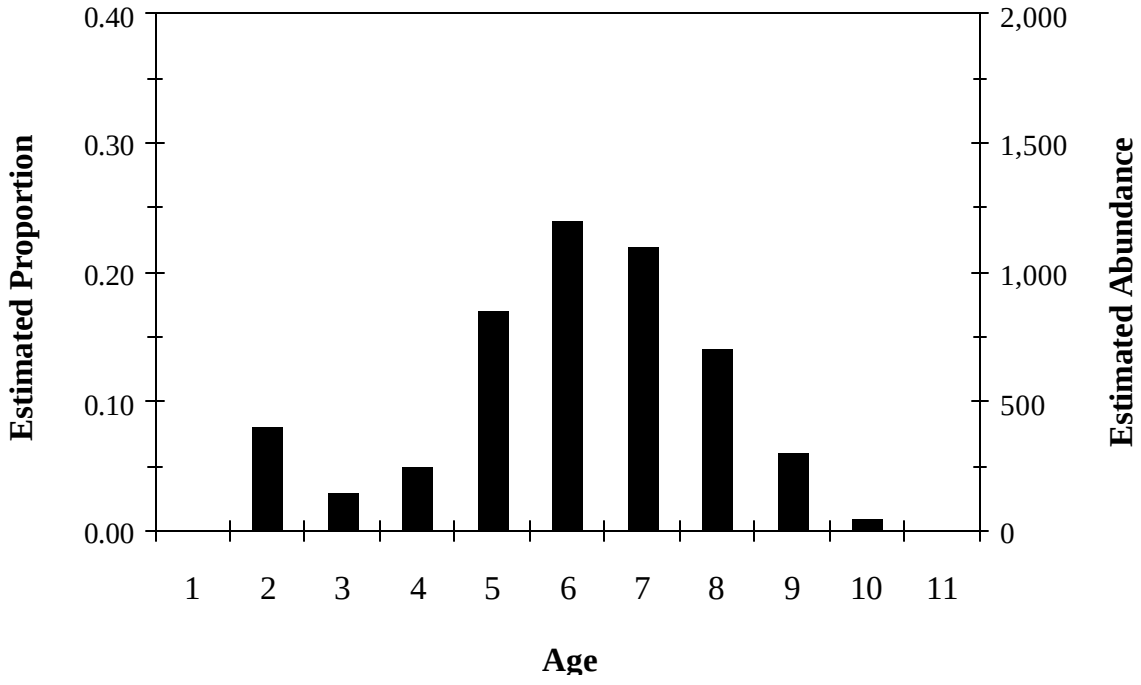

Figure 13.-Estimated proportions and abundances of northern pike ^{3} 600 mm FL by ages within Minto Lakes during late June 2000.

Typically, ice fishing for northern pike is efficient in catching larger northern pike, probably a high proportion of prespawning females, and due to the difficulty of accessing Volkmar Lake in the summer, most of the harvest of northern pike during the 1990s can probably attributed to the winter fishery. In 2000-2001, only two icehouse permits were issued. This decrease in winter fishing effort is probably reflective of the regulation change.

Even though the abundance estimate and proportion of large fish in Volkmar Lake is lower than it was in the 1980s and 1990s, there is evidence to suggest that both of these characteristics will increase in the near future. The environmental conditions are favorable, there is a large abundance of small northern pike, and harvest has decreased. These conditions may help increase the size and survival of adult fish, which in turn, may result in an increase in production. To better evaluate the effects of the regulation change on the abundance of northern pike in Volkmar Lake, abundance and composition assessment may be needed within the next three years. This would coincide with the time that fish born during and soon after the regulation change will become recruited to the sampling gear.

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Considerably higher water in 2000 compared to 1996 and 1997 contributed to decreased effectiveness of sampling gear and consequently low catches. Sampling sites in 1996 and 1997 where hoop traps completely blocked off sloughs and caught fish moving in both directions were ineffective in 2000 because the water was one two three feet deeper and fish could swim by or over the traps. In 1996 and 1997, water flowed from the study area out into Goldstream Creek and then into the Chatanika River (Figure 3) at the time of sampling. In 2000, however, high water from the Chatanika River flowed into the study area throughout the summer, flooding areas within the Minto Lakes area and effectively increasing the area used by the fish. Extending the duration of the experiment was necessary to sample sufficient numbers of fish to calculate a reasonable estimate of abundance.

The dearth of small fish recaptured in 2000 as compared to 1996 and 1997 is probably due to the high water, which enabled fish to avoid being captured. It is likely, however, that this high water event was beneficial to smaller northern pike by providing increased cover and protection from predators. There may be an increase in abundance of northern pike in this study area when age-0 fish from 2000 become fully recruited to sampling gear in 2005 because of the high water event.

The Minto Lakes area has been described as having fewer large northern pike than other populations in the Yukon and Tanana drainages (Alt 1968; Roach 1998a). However, the size of the northern pike in the Minto Lakes is comparable to other populations. Craig (1996) reported, based on length-at-age data from 25 circumpolar populations of northern pike, that the ultimate length (L_∞) for these populations was approximately 725 mm FL for male northern pike and 1,050 mm FL for female northern pike. In 2000, 32% of the abundance estimate of northern pike ≥ 600 mm FL was composed of fish ≥ 725 mm FL, and the largest fish sampled was 1,151 mm FL. Information on abundance of northern pike ≥ 600 mm FL obtained from this study suggests that that the northern pike population in the Minto Flats area is stable and that current regulations are adequate. As long as the fishery for northern pike in Minto Flats remains one of the most important northern pike fisheries in the state, the northern pike population should be investigated on a three to five year schedule for abundance and composition so that trends in population characteristics can be monitored.

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APPENDIX A
DATA FILE LISTING

Appendix A1.-Data files used to estimate parameters of the Minto Lakes and Volkmar Lake northern pike populations, 2000.

Data file[a]	Description
U001401L012000.DTA	Population and marking data for Minto Lakes northern pike captured during the marking event, 8 June through 29 June 2000.
U001401L022000.DTA	Population and recapture data for Minto Lakes northern pike captured during the recapture event, 17 August through 24 August 2000.
U001200L012000.DTA	Population and capture data for Volkmar Lake northern pike sampled in all events, 25 May through 1 June 2000.

[a] Data files were archived at and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.

APPENDIX B

HISTORICAL DATA SUMMARIES

Appendix B1.-Floy tag numbers used for Minto Flats northern pike mark-recapture experiments by year and color, 1988-2000.

Year	Tag Color			
	Green	White	Blue	Gray
1988	89,000-89,045	45,500-45,547		
		49,000-49,822		
		56,000-57,999		
		58,221-58,999		
1989	5,000-5,432			
	7,000-7,344			
1990			60,000-62,764	
			75,000-75,238	
1991			77,000-78,492	
			79,000-79,991	
1994				15,000-17,059
				17,450-17,784
1995				9,719-9,735
				53,700-53,749
1996				41,000-41,989
1997				42,000-42,999
				44,000-44,060
2000				45,275-45,324
				45,450-45,572
				46,000-46,297

Appendix B2.-Floy tag numbers used for Volkmar Lake northern pike mark-recapture experiments by year and color, 1987-2000.

	Tag Color			
Year	Green	White	Blue	Gray
1987		25,000-26,037		
1988	98,000-98,355			
1989	21,000-21,383			
1990			50,000-50,516	
1991			50,517-50,999	
			51,000-51,307	
1992				3,003-3,442
1993				3,450-3,924
1994				3,450-3,924
2000				53,050-53,199
				53,300-53,327

Appendix B3.- Sample sizes, estimated abundances, and standard errors by length category for Minto Lakes northern pike, 1997 and 2000.

Fork Length (mm)	1997			2000		
	n	$\hat{N}$	SE	n	$\hat{N}$	SE
600-624	207	1,496	159	141	1,222	277
625-649	74	535	57	114	988	227
650-674	31	224	24	85	737	173
675-699	26	188	20	78	676	160
700-724	19	137	15	63	546	132
725-749	20	145	15	46	399	101
750-774	9	65	7	47	407	102
775-799	13	94	10	13	113	37
800-824	12	87	9	10	87	31
825-849	6	43	5	5	43	20
850-874	13	94	10	6	52	22
875-899	10	72	8	2	17	12
900-924	5	36	4	2	17	12
925-949	0	0	0	1	9	8
950-974	1	7	1	0	0	0
975-999	0	0	0	0	0	0
1,000-1,024	1	7	1	0	0	0
1,025-1,049	2	14	2	0	0	0
1,050-1,074	0	0	0	0	0	0
1,075-1,099	1	7	1	1	9	8
1,100-1,149	0	0	0	0	0	0
1,150-1,174	0	0	0	1	9	8
Totals	450	3,251	348	615	5,331	1,332

Appendix B4.-Number of northern pike ≥ 400 mm FL marked (M), examined for marks (C), and recaptured with marks (R) by section during Minto Lakes two-event mark-recapture experiments in 1996, 1997 and 2000 (germane only to fish ≥ 600 mm FL for 2000).

Section	1996			1997			2000		
	M	C	R	M	C	R	M	C	R
1	30	38	1	68	184	4	18	26	1
2	165	244	3	214	357	26	129	139	6
3	48	128	1	244	354	21	62	74	5
4	16	27	0	40	179	3	12	5	0
13	39	47	1	135	56	2	30	8	0
23	22	70	1	137	199	13	70	19	3
33	12	18	0	46	91	6	22	7	2
Totals	332	572	7	884	16,546	75	343	278	17

APPENDIX C

MODEL SELECTION TESTS FROM PROGRAM CAPTURE

Appendix C1.-Model selection tests from program CAPTURE (Volkmar Lake 2000).

VOLKMAR LAKE 2000

Model Selection Tests from Program Capture

1. Test for heterogeneity of trapping probabilities in population.

Null hypothesis of model M(o) vs. alternate hypothesis of model M(h)

Expected values too small. Test not performed.

2. Test for behavioral response after initial capture.

Null hypothesis of model M(o) vs. alternate hypothesis of model M(b)

Test failed. Failure criterion = -270

3. Test for time specific variation in trapping probabilities.

Null hypothesis of model M(o) vs. alternate hypothesis of model M(t)

Chi-square value = 168.067 degrees of freedom = 7

Probability of larger value – 0.00000

4. Goodness of fit test of model M(h)

Null hypothesis of model M(h) vs. alternate hypothesis of not model M(h)

Chi-square value = 151.521 degrees of freedom = 7

Probability of larger value – 0.00000

Test model M(h) by frequency of capture

(frequencies less than 2t are not calculated.)

-continued-

Number of captures	Chi-square	d.f.	Probability
1	139.798	7	0.000

5. Goodness of fit test of model M(b)

Null hypothesis of model M(b) vs. alternate hypothesis of not model M(b)

Chi-square value = 9.670 degrees of freedom = 6

Probability of larger value – 0.13925

5a. Contribution of first capture homogeneity across time.

Test failed. Failure criterion = -270

5b. Contribution of recapture homogeneity across time

Chi-square value = 9.670 degrees of freedom = 5

Probability of larger value – 0.13925

6. Goodness of fit test of model M(t)

Null hypothesis of model M(t) vs. alternate hypothesis of not model M(t)

Chi-square value = 109.723 degrees of freedom = 112

Probability of larger value – 0.54756

7. Test for behavioral response in presence of heterogeneity.

Null hypothesis of model M(h) vs. alternate hypothesis of model M(bh)

Chi-square value = 148.851 degrees of freedom = 11

Probability of larger value – 0.00000

Appendix C1.-Page 3 of 3.

Model selection criteria. Model selected has maximum value.

Model	M(0)	M(h)	M(bh)	M(t)	M(th)	M(tb)	M(tbh)
Criteria	0.72	0.66	0.03	0.00	1.00	0.83	1.00