Fishery Data Series No. 97-20

Abundance and Composition of the Northern Pike Population in Harding Lake, 1996

by

Stafford M. Roach

September 1997

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. All others must be defined in the text at first mention, as well as in the titles or footnotes of tables and in figures or figure captions.

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

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

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. 97-20

ABUNDANCE AND COMPOSITION OF THE NORTHERN PIKE POPULATION IN HARDING LAKE, 1996

by

Stafford M. Roach
Division of Sport Fish, Fairbanks

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

September 1997

Development and publication of this manuscript were partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-12, Job No. R-3-4(c).

The Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or a group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Distribution is to state and local publication distribution centers, libraries and individuals and, on request, to other libraries, agencies, and individuals. This publication has undergone editorial and peer review.

Stafford M. Roach
Alaska Department of Fish and Game, Division of Sport Fish, Region III,
1300 College Road, Fairbanks, AK 99701-1599,USA

This document should be cited as:
Roach, S. M. 1997. Abundance and composition of the northern pike population in Harding Lake, 1997. Alaska Department of Fish and Game, Fishery Data Series No. 97-20, Anchorage.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

In 1996, estimated abundance of northern pike *Esox lucius* within Harding Lake was 3,377 fish (SE = 915) for northern pike ≥ 300 mm FL, 2,576 fish (SE = 698) for northern pike ≥á450 mm FL, and 319 fish (SE = 86) for northern pike ≥ 625 mm FL. Estimated density of northern pike ≥ 300 mm FL was 3.4 (SE = 0.04) fish per hectare. The estimated proportion was 0.24 (SE = 0.07) for northern pike from 300 to 449 mm FL; 0.67 (SE = 0.13) for northern pike from 450 to 624 mm FL; and, 0.09 (SE = 0.04) for northern pike ≥ 625 mm FL. In 1996, estimated recruitment (abundance of age-5 fish) was 781 northern pike (SE = 212). Estimated abundance was 533 fish (SE = 144) for northern pike < age-5 and 2,844 fish (SE = 771) for northern pike > age-5. The mean error in assigning the proper incremental ages from the scales of 112 northern pike recaptured in 1996 from 1995 was -0.40 years (Z = 4.04; $P < 0.01$); 0.18 years (Z = 1.12; $P = 0.26$) for 22 northern pike that were ≤ age-5 in 1996; and -0.54 years (Z = 4.78; $P < 0.01$) for 90 northern pike ≥ age-6 in 1996. The estimated average percent error of the scale reader in reproducing the same age twice from a Harding Lake northern pike scale in 1996 was 3.4%. For Harding Lake northern pike, indirect estimated values for maximum sustainable yield was 298 fish, for the number of northern pike spawners needed to produce maximum sustainable yield 2,134, and for the carrying capacity of Harding Lake 4,268 spawning size northern pike (≥ 450 mm FL).

Key Words: Northern pike, *Esox lucius*, population abundance, age composition, length composition, Harding Lake, maximum sustainable yield, mark-recapture.

INTRODUCTION

The Alaska Department of Fish and Game 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 obtain estimates of maximum sustainable yield (MSY) have included estimates of abundance, length composition, age composition, mortality, recruitment, and movements of northern pike within selected lakes and wetland complexes in AYK.

Objectives to estimate abundance and length and age composition of Harding Lake northern pike began in 1990. An indirect estimate of sustainable yield for northern pike in Harding Lake based on methods in Ricker (1975) and Gulland (1983) was determined by Pearse and Hansen (1993) from four years of northern pike studies (Burkholder 1991; Skaugstad and Burkholder 1992; Pearse 1994). The indirect method of relating natural mortality and carrying capacity to MSY was used because population data were available for only four years. However, to directly estimate sustainable yield using the methods described by Pearse and Hansen (1993), three estimates of surplus production are needed, but many more preferred.

1996 RESEARCH OBJECTIVES

Working toward the goal of estimating surplus production and evaluating the current status of the stock, a northern pike mark-recapture experiment was conducted in Harding Lake in 1996. The research objectives were to:

1. estimate population abundance of northern pike ≥ 300 mm fork length (FL)[1] in Harding Lake such that this estimate is within 25% of the actual value 95% of the time; and,

---

[1] Four critical fork lengths are referred to in this report: 300 mm is the length that northern pike begin to recruit to the sampling gear, 450 mm is considered the smallest length of fully recruited spawners, 625 mm is the minimum size limit that can be legally harvested, and 725 mm and greater is a length category reported in the state wide harvest survey, which managers use to monitor the catch of large northern pike.

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

DESCRIPTION OF FISHERY

In 1991, northern pike fishing in Harding Lake was restricted by regulation to June 1 through March 31; northern pike fishing with spears or bows and arrows was prohibited; and minimum size limit for northern pike harvested was set at 26 inches (~625 mm FL). These restrictions were designed to eliminate the harvest of northern pike during the time of spawning and reduce the harvest of smaller northern pike. The intent was to prevent a harvest level that is not sustainable and to help in rebuilding the population while allowing a limited recreational fishery. The minimum size limit allows northern pike two years of spawning before reaching the legal size for harvest. In addition, it was believed that these regulations would restrict harvest to 15% of northern pike ≥ 300 mm FL, which was considered an acceptable level of harvest.

Estimated sport fishing effort at Harding Lake increased from 1,707 angler-days in 1984 to about 5,000 from 1991 through 1994 and 6,743 in 1995 (Table 1; Mills 1985, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994; Howe et al. 1995, 1996). Limited opportunities for fishing along the road system of the Tanana Valley and an increased angler demand for northern pike probably contributed to the increasing angler effort at Harding Lake. Despite the rise in angler effort, harvest has remained relatively low since 1992 compared to 1984 through 1991 (Table 1). Harvest estimates have varied from 341 in 1992 to 2,092 northern pike in 1988. Estimates of abundance for northern pike (≥ 300 mm FL) have ranged from 2,308 (SE = 563) in 1991 to 3,768 (SE = 432) in 1993 (Table 2; Burkholder 1991; Skaugstad and Burkholder 1992; Pearse 1994; Roach 1996).

DESCRIPTION OF STUDY AREA

Harding Lake is the largest road-accessible lake in the Tanana River drainage (Figure 1) with a surface area of 1,000 ha, a maximum depth of 43 m, a surface elevation of 217 m, and a shoreline circumference of 12.4 km. Harding Lake is located 54 km (69 km by road) southeast of Fairbanks, Alaska near the confluence of the Salcha and Tanana rivers. It is a circular lake with a prominent point along the southern shore and a small point along the northern shore. There are two inlets; the east inlet, which drains a 2,580 ha basin to the east of Harding Lake and enters the northeast corner of the lake, and the Little Harding Lake inlet that enters the southwest corner. There are no outlets from Harding Lake (Figure 2).

LaPerriere (1975) and Nakao (1980) described Harding Lake as oligotrophic. Most of the lake is in an open-water zone with almost all marginal vegetation (emergent grasses) found along the north and northeast shores in water < 1 m deep. However, more than half of shallow water (< 3 m depth) in north and northeast areas of the lake is free of vegetation. There are some deep beds of *Potamageton* sp. and *Chara* sp. located sporadically at about the 5 m contour. The littoral zone (the area from zero depth to the outer margin of the deep vegetation) comprises less than 33% of the surface area of the lake. Furthermore, there are large areas within this zone that are free of vegetation. Doxey (1991) hypothesized that macrophytes are not able to colonize large areas of the littoral zone within the lake because of wave action, freeze-down, and ice-

Table 1.-Estimated angler days expended, numbers (SE in parenthesis when available) of northern pike harvested and caught, and catches per angler day and harvests per catch in Harding Lake, 1984-1995 summarized by all northern pike and northern pike > 725 mm FL.

		Number Harvested				Number Caught		Catch/Angler Day		Harvest/Catch	
Year	Angler Days	All		> 725 mm		All	> 725 mm	All	> 725 mm	All	> 725 mm
1984	1,707	766		-		-	-	-	-	-	-
1985	-	-		-		-	-	-	-	-	-
1986	2,064	673		-		-	-	-	-	-	-
1987	5,125	1,886		-		-	-	-	-	-	-
1988	3,256	2,092		-		-	-	-	-	-	-
1989	4,935	1,764		-		-	-	-	-	-	-
1990	3,895	591		-		3,629	-	0.93	-	0.16	-
1991	5,155	1,888[a]	(1,007)	401	(220)	5,071	476	0.98	0.09	0.37	0.84
1992	5,068	341	(128)	100	(34)	3,400	424	0.67	0.08	0.10	0.24
1993	4,885	391	(145)	238	(100)	6,041	619	1.24	0.13	0.06	0.38
1994	4,913	539	(197)	179	(72)	5,559	995	1.13	0.20	0.10	0.18
1995	6,743	502	(124)	87	(34)	3,852	753	0.57	0.11	0.13	0.11
Average	4,341	1,039		201		4,592	653	0.92	0.12	0.15	0.35

[a] The imprecision of this estimate of harvest was attributed to an extraordinarily large harvest reported by three respondents to the state wide harvest survey (Alaska Department of Fish and Game memorandum from Mike Mills to Cal Skaugstad dated November 2, 1992). The actual harvest was most likely much smaller.

Table 2.-Abundance and SE of northern pike ≥ 300 mm FL and ≥ 450 mm FL in Harding Lake by year.

	≥ 300 mm		≥ 450 mm	
Year	Abundance	SE	Abundance	SE
1990[a]	-	-	1,283	145
1991	2,308	563	1,527	313
1992	2,868	353	1,496	160
1993	3,768	432	2,749	307
1994[b]	-	-	-	-
1995	2,338	411	1,554	170

[a] Abundance was not estimated for northern pike < 450 mm FL in 1990 due to the absence of recaptured northern pike < 450 mm FL.

[b] Abundance was not estimated in 1994.

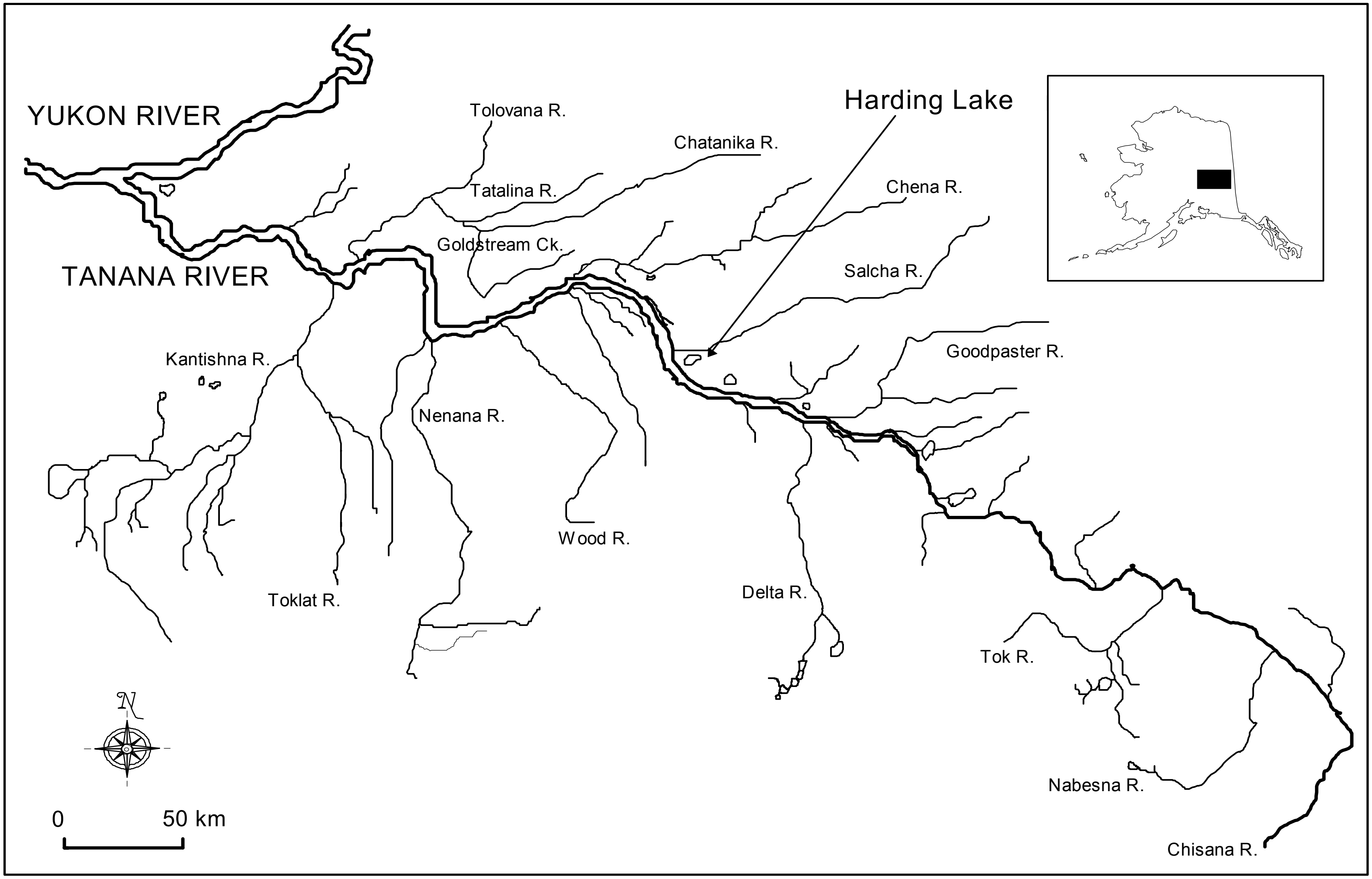

Figure 1.-Tanana River drainage.

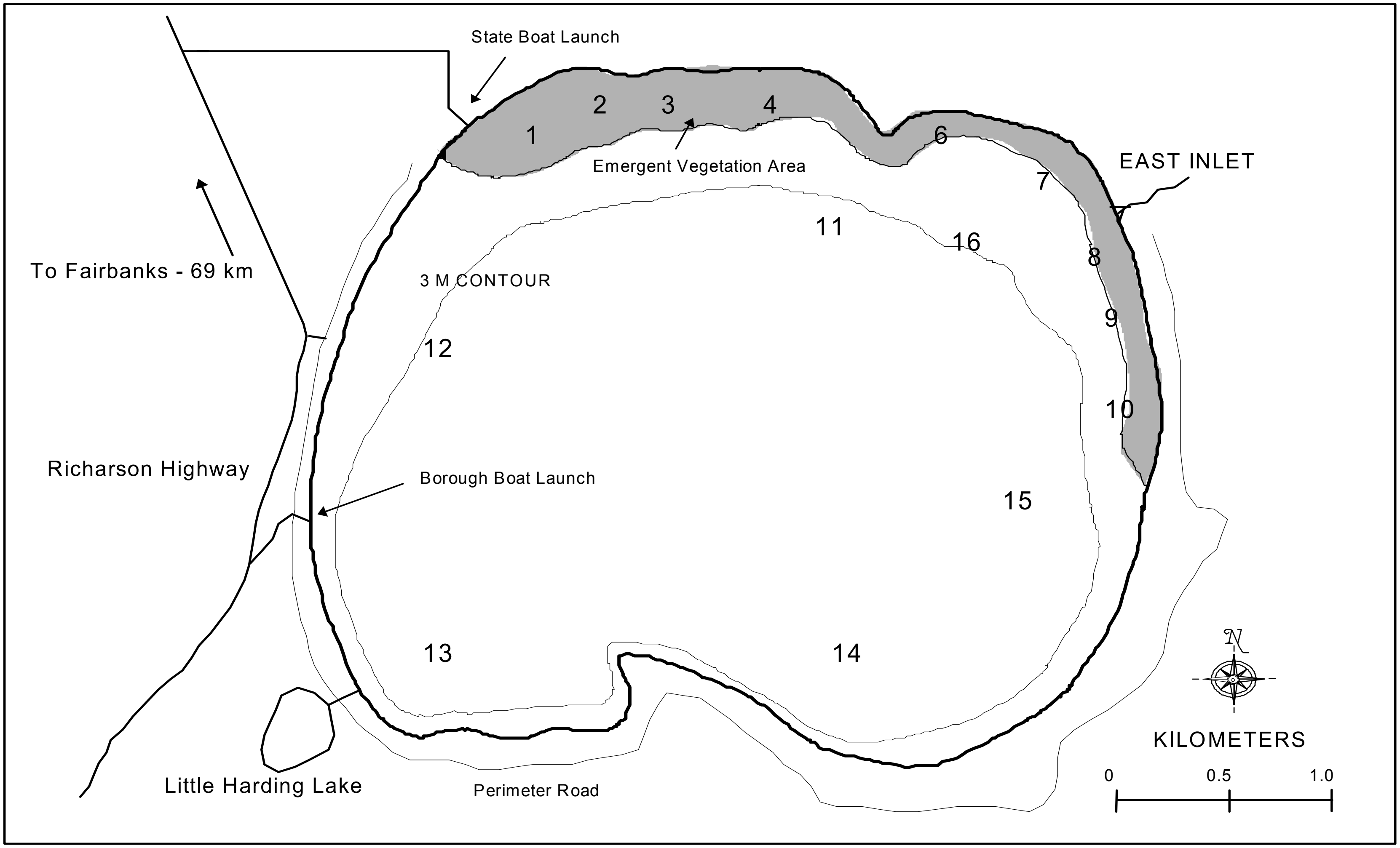

Figure 2.-Harding Lake with sampling sections (1 - 16) indicated, which were used for capture probability and movement analysis.

6

scouring. Emergent vegetation comprises less than 10% of the surface area. Shallow areas are composed of sand, sand and gravel, or silt and the deeper areas loose organic and clay sediments (Nakao 1980). In addition to northern pike, indigenous fish species that are found in Harding Lake are burbot *Lota lota*, least cisco *Coregonus sardinella*, and slimy sculpin *Cottus cognatus*. Introduced species include lake trout *Salvelinus namaycush* and Arctic char *S. alpinus*.

Access to Harding Lake is by three roads from the Richardson Highway; one that leads to a State of Alaska boat launch, and two that lead to a North Star Borough boat launch. Salchacket Drive, a perimeter road, encircles approximately three fourths of the lake (Figure 2). Approximately 75% of the shoreline is ringed by private cabins, homes, and other human development. Docks, rafts, and boatlifts dot the inhabited areas of the shoreline in the summertime. There is a State of Alaska campground on the northwestern shoreline near the State boat launch with a channel, swimming beach, campsites, parking, athletic fields, and some undeveloped areas for hiking and unstructured outdoor recreation.

METHODS

Methods for 1996 were similar to those used in 1993 (Pearse 1994) and 1995 (Roach 1996) due to the relative success of these two mark-recapture experiments compared to experiments in previous years. The 1993 and 1995 mark-recapture sampling took place in late May and early June, two to three weeks later than in other years and contrary to previous years, length distributions between marking and capture events were similar. In addition, Pearse (1994) concluded, from recapture to capture (R/C) ratios, from three sections of Harding Lake, that fish marked in the 1993 sample mixed completely with unmarked fish between events or that there was equal probability of capture for northern pike throughout the lake. Furthermore, the Harding Lake northern pike radio-telemetry study (Roach 1993) indicated that by June, Harding Lake northern pike are distributed more uniformly by sex and length compared to May and unlike northern pike in other Interior lakes, Harding Lake northern pike remain in shallow water (< 3 m) during late May and early June. Based on these studies, the 1996 mark-recapture experiment was scheduled for late May and early June. The marking event (May 28 - May 31) and recapture event (June 4 - June 6) took four and three days to complete with a three-day hiatus between events (June 1 - June 3). Data files for both events were archived (Appendix A1).

SAMPLING TECHNIQUES

Harding Lake was divided into 15 sections to examine movement, test for differences in catchability, and help insure uniform sampling effort (Figure 2). Two methods were used to capture northern pike, one in sections of emergent vegetation and the other in sections of open water.

Two crews of three individuals each used gill nets and backpack electrofishing to sample sections of emergent vegetation. In sections one through four, one set consisted of four gill nets set within the emergent vegetation, parallel to shore, parallel to each other, and spaced about 10 m apart. Northern pike were actively moved into the nets by electroshocking and splashing. At the completion of each set and after captured fish were sampled, gill nets were pulled parallel to shore a distance equal to the length of the gill nets and the process repeated. In sections six through ten, sets were similar to sections one through four except one or two gill nets were used instead of four, and the nets were placed at the outer margin of the emergent vegetation instead of within the emergent vegetation. In this manner sampling effort uniformly covered areas of emergent vegetation. All healthy northern pike were released immediately after data collection approximately 25 m from the capture site and in the opposite direction from the next set.

A crew of two individuals set gill nets from a boat in sections of open water. These gill nets were deployed at the beginning of the day perpendicular to shore and checked a minimum of once every hour. All healthy northern pike were released immediately after data collection 50 to 100 m from the capture site.

All data from northern pike captured during the mark-recapture experiment were recorded on ADF&G Tagging Length Mark-Sense Form, Version 1.0. A new form was used for each set with the date, area, and set number recorded on the description line. Locations of each set were recorded on a map each day. Scales for age determination were mounted directly to gummed cards at the time of sampling. A new gummed card was used for each set with the corresponding mark-sense litho-code, date, and waterbody recorded on the back. All crew members were aware of the importance of thoroughly examining all northern pike for Floy tags, recent tagging wounds, and recent fin clips and the importance of accurately recording data. All crew members performed these tasks appropriately.

During the marking event, all northern pike ≥ 300 mm FL that were captured were measured for length, a scale removed for age determination, examined for tags, and sex determined. Length was measured and recorded to the nearest millimeter FL. A minimum of two scales was taken from the preferred zone 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 uniquely numbered Floy FD-68 internal anchor tag inserted at the left base of the dorsal fin. Northern pike killed during sampling were not tagged but all other data were recorded and the fate (K) clearly noted in the blank space after the length on the mark-sense form. When possible, the sex of each northern pike was determined by the presence of milt or eggs and recorded.

During the recapture event, the same data collection procedures were used as during the marking event except northern pike without Floy tags were not given a new Floy tag, but instead, both the left and right side of the dorsal fin were examined closely for recent tag wounds and the left and right pelvic fins examined closely for recent clips, and then the right pelvic fin, instead of the left, was slightly clipped. Tag loss (TL) was clearly noted in the blank space after the tag number on the mark-sense forms for northern pike without a Floy tag but with a recent tag wound or recent left pelvic fin clip. Recapture (RC) was clearly noted on the mark-sense form for known recaptures from the marking event. Northern pike were not sampled more than once during the recaptured event. Northern pike already sampled during the recapture event were identified by the presence of a recent right pelvic fin clip.

Upon completion of field work, 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) according to criteria established by Williams (1955), and Casselman (1967). Since scale collection was after or near the time of annulus formation, growth beyond the last annulus was only considered an additional year when the distance from the last annulus to the edge was fairly parallel in the lateral to posterior direction and there were more than eight circuli on the anterior edge of the scale.

ABUNDANCE

Investigators estimated abundance using a Petersen mark-recapture experiment (Seber 1982). The assumptions of the experiment 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 completely between the marking and recapture events;
3) marking of northern pike did not affect their probability of capture in the recapture event;
4) northern pike did not lose their mark between events; and,
5) all marked northern pike were reported when recovered in the recapture event.

The validity of assumption 1 was inferred because northern pike movement into or from Harding Lake was unlikely. Mortality and growth, which may contribute to the violation of assumption 1, were assumed negligible because of the short duration of the experiment (ten days from beginning to end). The validity of assumptions 2 and 3 was evaluated with a series of statistical tests designed to detect unequal catchability by area and by size of fish (Appendix B1 and B2). 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. 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 for all northern pike. Floy tag numbers used for this mark-recapture experiment were archived (Appendix C1).

To reduce bias from unequal catchability by area the lake was divided into two areas. Abundance of northern pike was estimated from the number of northern pike marked, examined for marks, and recaptured for each area of the lake and summed. The Chapman estimator (Seber 1982) was used for each area:

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

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:

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

LENGTH AND AGE COMPOSITION

Length composition of northern pike ≥ 300 mm was estimated for each area stratum and adjusted for differential capture probability by length when necessary. Length proportions were estimated for each of two size groups. It was necessary to adjust the length proportions according to the ratio of total abundance in each group to minimize bias. Length composition data were archived (Appendix C2).

The proportion and the variance estimator approximated by the delta method used when adjustments were needed was:

$$\hat{p}_k = \sum_i \frac{\hat{N}_i}{\hat{N}} \hat{p}_{ik}, \text{ and} \quad (3)$$

$$\hat{V}[\hat{p}_k] \approx \sum_i (\hat{p}_{ik} - \hat{p}_k)^2 \frac{\hat{V}[\hat{N}_i]}{\hat{N}^2} + \sum_i \left(\frac{\hat{N}_i}{\hat{N}}\right)^2 \hat{V}[\hat{p}_{ik}] \quad (4)$$

where: $\hat{N}_i$ = the abundance of northern pike in stratum *i*;

$\hat{N}$ = total abundance of northern pike; and,

$\hat{p}_{ik}$ = the proportion of northern pike in stratum *i* that were of length or age class *k*.

The proportion and variance estimator used when no adjustments were needed was:

$$\hat{p}_k = \frac{n_k}{n}, \text{ and} \quad (5)$$

$$\hat{V}[\hat{p}_k] = \frac{\hat{p}_k(1-\hat{p}_k)}{n-1} \quad (6)$$

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

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

n = the number of northern pike sampled that were measured.

Age composition of northern pike ≥ 300 mm was estimated for each group and adjusted according to the ratio of total abundance in each group to minimize bias. Although not directly tested, it was assumed that unequal movement and unequal catchability of northern pike by age was correlated with length. The age composition was calculated using the same equations for proportions and variances of the proportions as with length composition except ages were substituted for lengths. Age composition data were archived (Appendix C3).

Age Validation

Accuracy of age determinations from scales captured during the 1996 mark-recapture experiment was tested indirectly. Scales from northern pike tagged in previous years that were recaptured during the experiment were used to determine the relative accuracy of age determination. The mean error in assigning the correct incremental age from scales of these northern pike was used as a measure of bias. The mean error was determined for ages of all northern pike, northern pike ≤ age-5, and northern pike > age-5 because this age is the age of full recruitment into the spawning stock (Pearse and Hansen 1993). The Wilcoxon Signed-Rank Test was used to determine significance of the bias (Conover 1980). Probabilities of a Type I error (α) of 0.05 or lower were considered significant.

Error in assigning the correct incremental age for each fish was calculated as:

$$\text{ERROR} = \text{AGE}_{t+\Delta} - \text{AGE}_t - \Delta t \tag{7}$$

where: $\text{AGE}_{t+\Delta}$ = age assigned when fish was recaptured;

AGE_t = age assigned at earlier capture; and,

Δt = number of years elapsed from capture to recapture.

Mean error was calculated as the sum of all the errors divided by the number of fish recaptured.

Furthermore, to evaluate the precision in age determination, ages were determined twice for a random sample of 99 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 Harding Lake northern pike scale in 1996 was calculated as:

$$\text{APE} = \frac{\sum_{i=1}^{S}\left[\frac{\sum_{j=1}^{R}\frac{\left|x_{ij} - \overline{x}_i\right|}{\overline{x}_i}}{R}\right]}{S}\cdot 100 \tag{8}$$

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

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

R = total number of readings; and,

S = total number of scales in the sample.

APE provides a means to evaluate the reproducibility of ages within a year, but should not be considered independent of age (Laine et al. 1991).

MAXIMUM SUSTAINABLE YIELD

Surplus production was investigated using an indirect method adopted from Pearse and Hansen (1993) which was based upon the relationship of instantaneous rate of natural mortality (M), the intrinsic rate of population increase (r), and maximum recruitment (R_{MAX}) to the number of spawners (N_{MSY}) needed to produce maximum sustainable yield (Ricker 1975; Gulland 1983):

$$N_{msy} = \frac{R_{max}}{\frac{r}{2} + \left(1 - e^{-M}\right)}. \qquad (9)$$

Maximum recruitment was conservatively assumed to be the greatest observed number of age-5 northern pike in Harding Lake since 1990. Natural mortality (M) was calculated using the methods of Pearse and Hansen (1993). An indirect estimate for the intrinsic rate of population increase was then determined as 1.2 times M (Gulland 1983).

Following the calculations of (Ricker 1975; Gulland 1983), the carrying capacity of the environment (K) was determined as two times N_{MSY} and MSY as:

$$MSY = \frac{rK}{4}. \qquad (10)$$

RESULTS

Investigators handled 616 unique northern pike (≥ 300 mm FL) during the mark-recapture experiment. During the marking event, 304 northern pike were tagged and released alive. During the recapture event, 312 northern pike were examined for marks (one fish without length was ignored). Of these, 261 were unique and 51 were recaptured from the marking event. All northern pike were released alive and there was no observed tag loss. Investigators identified 193 northern pike with Floy tags from prior mark-recapture experiments (31.3% of unique northern pike handled).

ABUNDANCE

Estimated abundance of northern pike within Harding Lake was germane to fish ≥ 300 mm FL during late May and early June 1996. Recapture rates of northern pike within the study area were significantly different among three areas (sections 1, 2, 3, and 4; sections 6, 7, 8, 9, and 10; and sections 11, 12, 13, 14, 15, and 16; χ^2= 7.62; 2 df; P = 0.02). This bias was attributed to few large northern pike (≥ 600 mm FL) captured in sections 6, 7, 8, 9, and 10; and, an unequal capture probability for small northern pike (< 600 mm FL) between sections 1, 2, 3, 4, 11, 12, 13, 14, and 15; and, sections 6, 7, 8, 9, and 10 (Tables 3, 4). To minimize bias, fish were divided by size into two groups (small = fish < 600 and large = fish ≥ 600 mm FL). The Chapman estimator was chosen to estimate abundance of northern pike ≥ 600 mm FL.

The small group was divided into two areas (Area I = lake sections 1, 2, 3, 4, 11, 12, 13, 14, 15, and 16; and Area II = lake sections 6, 7, 8, 9, and 10). Dividing the small fish into two areas minimized the differences in catchability in each area by maximizing the differences in catchability between areas (χ^2= 15.49; 1 df; P < 0.01). The recapture rate (fish recaptured divided by fish examined for marks in the recapture event; R/C) for Area I was 0.06 and for Area

Table 3.–Recapture history of Harding Lake northern pike released with marks by size and area in 1996 (Area I = lake sections 1, 2, 3, 4, 11, 12, 13, 14, 15, and 16; and Area II = lake sections 6, 7, 8, 9, and 10).

	Northern Pike ≥ 600 mm FL			Northern Pike < 600 mm FL		
	Recaptured		Not	Recaptured		Not
Marked	Area I	Area II	Recaptured	Area I	Area II	Recaptured
Area I	20	1	70	4	5	94
Area II	0	1	11	4	16	78
Total	20	2	81	8	21	172

Table 4.-Numbers of Harding Lake northern pike ≥ 300 mm FL marked (M), examined for marks (C), recaptured with marks (R), capture probabilities, estimated abundances (N), and standard errors of estimated abundances SE[N] summarized by area and size of fish (small = fish < 600 mm FL and large = fish ≥ 600 mm FL).

Area	Size	M	C	R	R / C	R / M	$\hat{N}$	$SE[\hat{N}]$
I	Small	103	125	8	0.06	0.08	-	-
II	Small	98	81	21	0.26	0.21	-	-
I & II	Small	201	206	29	0.14	0.30	2,894	912
I & II	Large	103	106	22	0.21	0.21	483	77
I & II	Small & Large	304	312	51	0.16	0.17	3,377	915

II was 0.26. Comparison of areas where small northern pike were marked with areas where recaptured indicated movement between areas (Table 3). Nine of 29 recaptured small northern pike (31%) moved from one area stratum to another between events. In this situation the methodology outlined in Appendix B1 (Case IV) was followed, abundance estimates were calculated for each area stratum separately and summed using the Chapman estimator and for both area strata combined using the Darroch (1961) estimator. The Chapman estimate of abundance was not similar to the Darroch estimate (≈ 37% difference). This large difference and unequal movement between strata implied that mixing was not sufficient within each stratum, therefore, the Darroch estimator was chosen to estimate abundance of northern pike < 600 mm FL.

Estimated abundance of northern pike ≥á300 mm FL within Harding Lake was 3,377 fish (SE = 915; CV = 27%; Table 4). The upper and lower bounds of the 95% C.I. were 1,584 and 5,170 northern pike ≥á300 mm FL. Estimated abundance of northern pike ≥á450 mm FL was 2,576 fish (SE = 698). Estimated abundance of northern pike ≥á625 mm FL was 319 fish (SE = 86). Estimated density of northern pike ≥ 300 mm FL was 3.4 (SE = 0.04) fish per hectare.

LENGTH COMPOSITION

There was no significant difference between the length distributions of northern pike marked and northern pike recaptured within either the small (*D* = 0.10; P = 0.96; Figure 3) or large group (*D* = 0.16; P = 0.73; Figure 3). There was, however, a significant difference between the length distributions of northern pike marked and northern pike examined for marks during the recapture event within the small (*D* = 0.14; P = 0.04; Figure 3), but not the large group (*D* = 0.11; P = 0.51; Figure 3). This indicated that there was no size selectivity for either sampling event for the large group and size selectivity during the marking event but not the recapture event for the small group. To estimate length composition for the large group, fork lengths of northern pike captured during the marking and recapture events were pooled. For the small group, however, only the fork lengths of northern pike captured during the recapture event were used for length composition. Length composition was then adjusted by the abundances of each group.

Fork lengths measured from 616 northern pike ≥ 300 mm FL in Harding Lake ranged from 300 mm to 1,001 mm (mean = 550 mm; SE = 5 mm). The estimated abundance was 801 fish (SE = 217) for northern pike from 300 to 449 mm FL; 2,257 fish (SE = 612) for northern pike from 450 to 624 mm FL; and, 319 fish (SE = 86) for northern pike ≥ 625 mm FL (Figure 4). The estimated proportion was 0.24 (SE = 0.07) for northern pike from 300 to 449 mm FL; 0.67 (SE = 0.13) for northern pike from 450 to 624 mm FL; and, 0.09 (SE = 0.04) for northern pike ≥ 625 mm FL (Figure 4).

AGE COMPOSITION

Using scales, investigators determined ages for 585 of 617 unique northern pike (≥ 300 mm FL) sampled during the mark-recapture experiment. Of scales collected during the marking event, ages were determined for 287 unique northern pike. Of scales collected during the recapture event, ages were determined for 298 unique northern pike. Investigators determined ages for 112 northern pike within the sample that were also aged in 1995. Of the 617 unique northern pike (≥ 300 mm FL) sampled, ages were not determined for 32 (scales were not taken or lost from 5 fish,

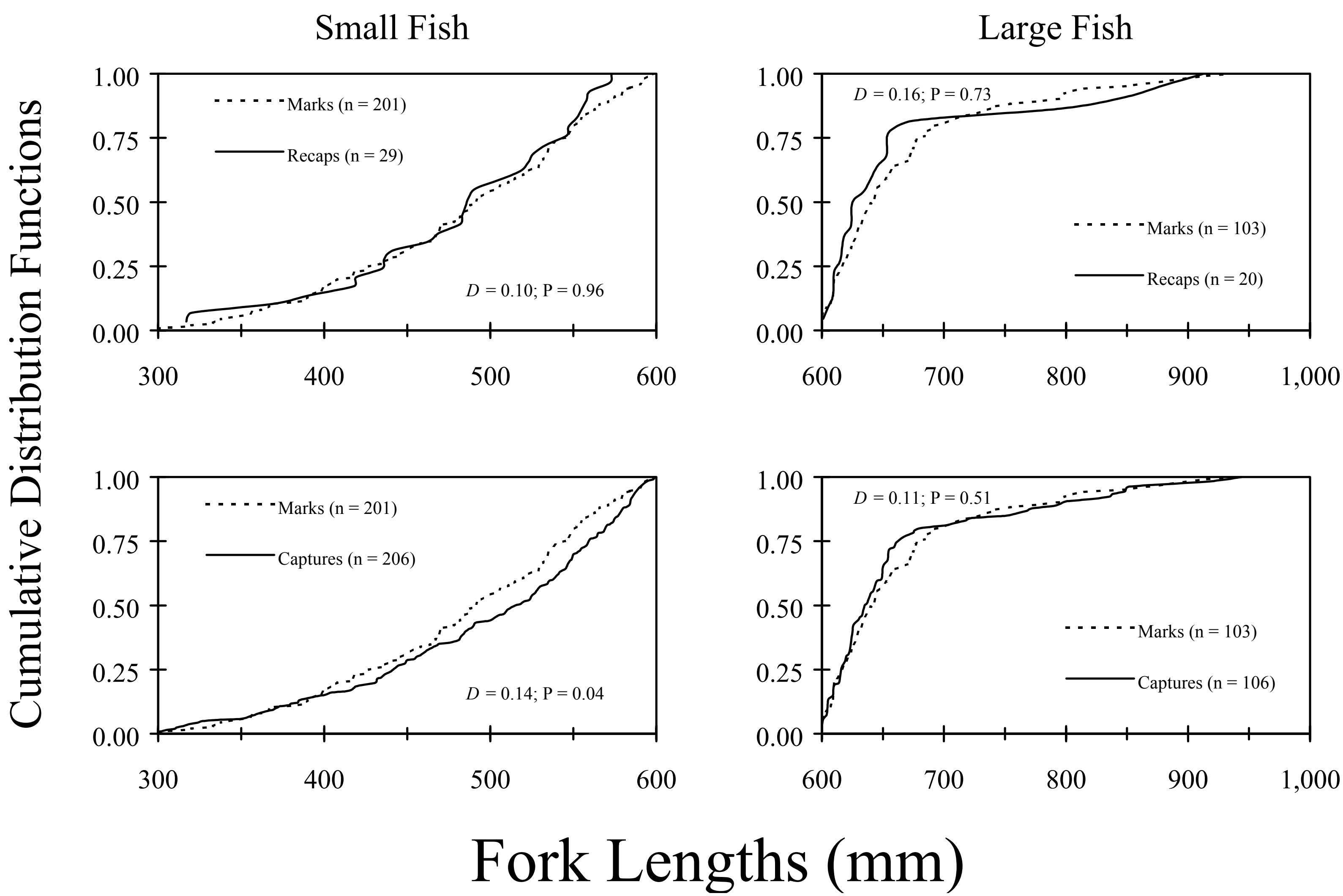

Figure 3.-Cumulative distribution functions of fork lengths of northern pike marked versus recaptured and marked versus examined for marks in Harding Lake by size group.

17

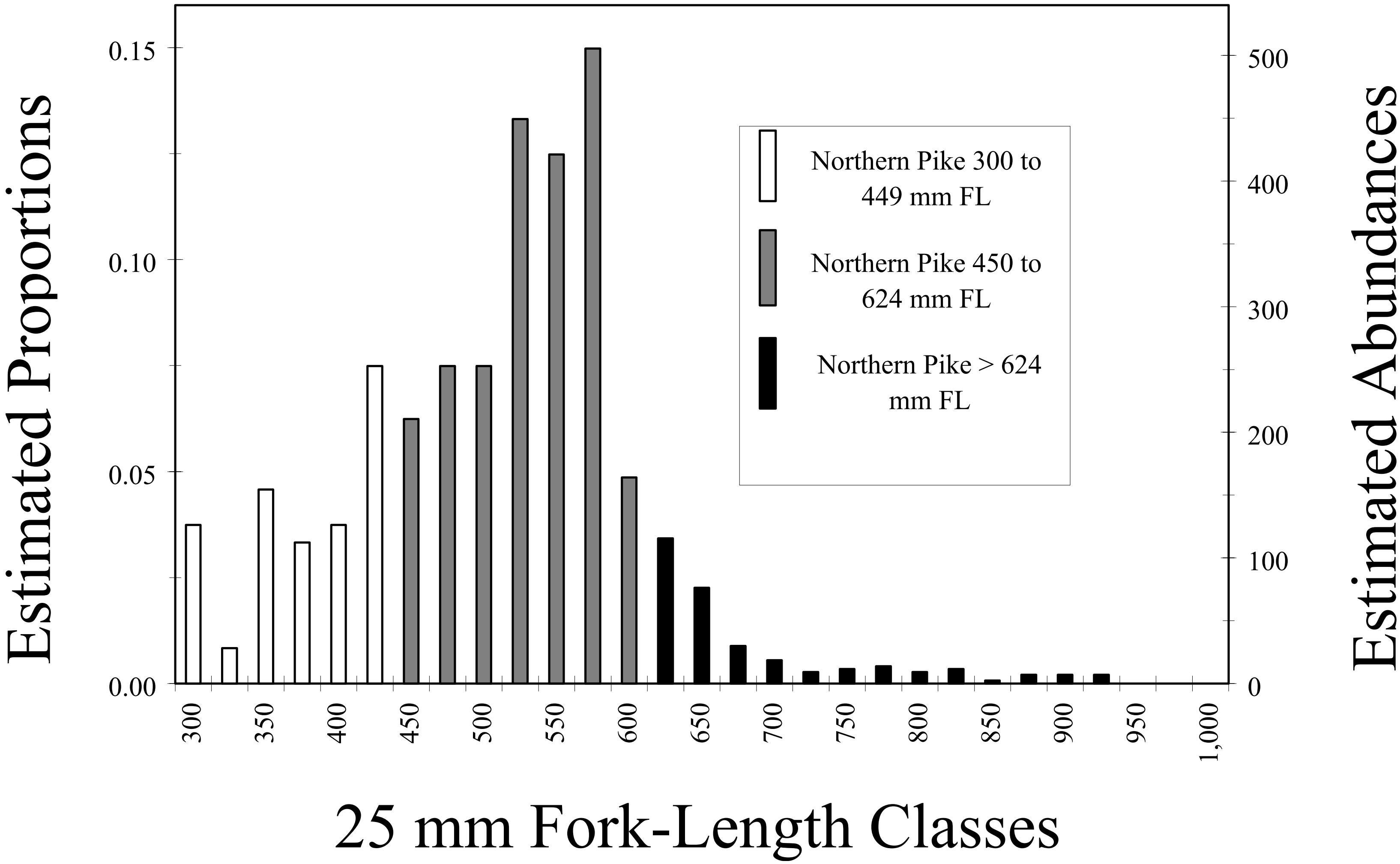

Figure 4.-Estimated proportions and abundances of northern pike ≥ 300 mm FL by 25-mm length classes within Harding Lake during late May and early June 1996 (adjusted for different capture probabilities by length).

not readable because of regeneration from 25 fish, and not readable because of poor acetate impression from 2 fish).

The mean error in assigning the proper incremental ages from the scales of the 112 northern pike that were recaptured in 1996 from 1995 was -0.40 years ($Z = 4.04$; $P < 0.01$); 0.18 years ($Z = 1.12$; $P = 0.26$) for 22 northern pike that were ≤ age-5 in 1996; and -0.54 years ($Z = 4.78$; $P < 0.01$) for 90 northern pike ≥ age-6 in 1996 (Figure 5). Analysis by cohort was limited to northern pike ≤ age-5 in 1996 since there was not a significant bias in relative age determination for these fish. All cohorts ≥ age-6 were lumped into one group since there was significant bias in determining the older ages.

The estimated average percent error of the scale reader in reproducing the same age twice from a Harding Lake northern pike scale in 1996 was 3.4% (Figure 6).

The estimated abundances of Harding Lake northern pike ≥ 300 mm FL were 533 (SE = 144) prespawning-age fish (< age-5) and 2,844 (SE = 771) spawning-age fish (≥ age-5; Table 5). The estimated proportions of northern pike ≥ 300 mm FL were 0.16 (SE = 0.02) for prespawning-age fish (< age-5), and 0.84 (SE = 0.02) for spawning-age fish (≥ age-5; Table 5).

MAXIMUM SUSTAINABLE YIELD

For Harding Lake northern pike estimated MSY was 298 fish, N_{MSY} was 2,134 fully recruited fish, and K was 4,268 spawning size northern pike (≥ 450 mm FL).

DISCUSSION

In 1996, fewer northern pike ≥ 600 mm FL were captured in the northeast area of Harding Lake than in previous mark-recapture experiments. This along with a higher proportion of marked fish < 600 mm FL moving into the northeast area, than moving out during the experiment, complicated the estimation procedure. A simple Petersen was used to estimate abundance of fish ≥ 600 mm FL, but because of uneven movement of small fish a Darroch estimator with an inherently larger estimate of variance was needed to estimate abundance of fish < 600 mm FL. Northern pike typically move into and out of spawning areas differently by size and sex (Roach 1993; Neumann and Willis 1995). Inadvertently, the 1996 experiment occurred closer to the time of spawning than the 1993 or 1995 experiments because of ice conditions on the lake. Northern pike spawn near the time of ice-out, once shallow water temperatures warm to 4 - 12° C (McNarmara 1936; Clark 1950; Casselman and Lewis 1996). The spring of 1996 was unusual because ice prevented northern pike from moving into spawning areas as early as in 1993 and 1995. This pattern of unequal movement away from spawning areas during the experiment should be anticipated in those years when the ice on the lake is thick and melts slowly.

Once again age validation demonstrated the difficulty in determining ages from the scales of interior Alaska northern pike. Unlike northern pike in warmer climates (Laine et al. 1991), age determination of interior Alaska northern pike becomes increasingly difficult after age-5 (Roach 1996). This is attributed to inconsistent growth from one year to the next and little or no growth in some years after reaching maturity. Fortunately, the age considered as full recruitment to the gear (Pearse and Hansen 1993; Roach 1996) was determined with relative precision and accuracy, however, it was necessary to lump older fish into one group. Age validation must

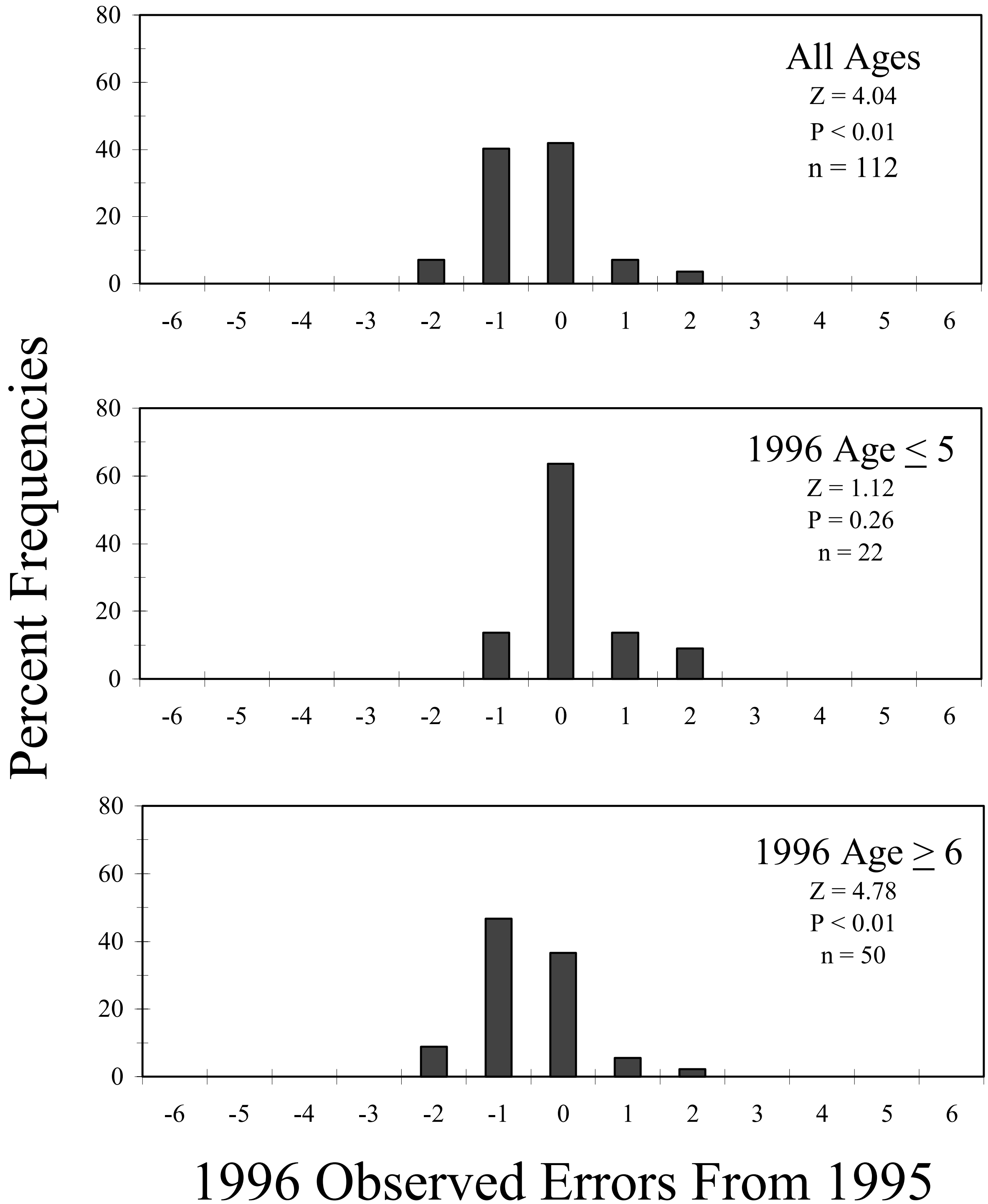

Figure 5.-Percent frequencies of observed errors in assigning the proper incremental ages to Harding Lake northern pike marked in 1995 and recaptured in 1996.

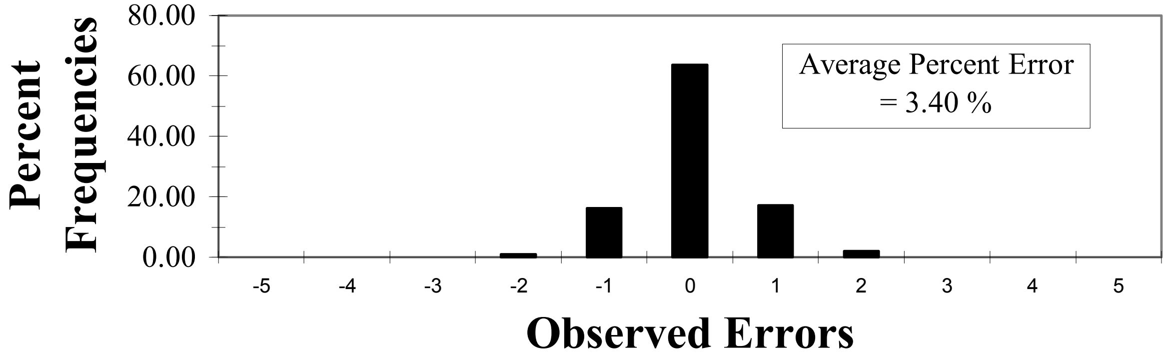

Figure 6.-Percent frequencies for observed errors in reproducing the same age twice from a Harding Lake northern pike scale in 1996.

Table 5.-Estimated proportions (p), abundances (N), and standard errors of estimates (SE) of Harding Lake northern pike that were ≥ 300 mm in early late May and early June 1996 by age (adjusted for different capture probabilities by length).

		Proportions		Abundances	
Ages	n	p'	SE[p']	N'	SE[N']
1	-	-	-	-	-
2	-	-	-	-	-
3	17	0.07	0.02	244	66
4	21	0.09	0.02	289	78
5	57	0.23	0.03	781	212
≥ 6	302	0.61	0.03	2,063	560

continue as one component of northern pike stock assessment to safeguard against the misuse of age data.

Current Harding Lake northern pike regulations have not contributed to a long-term change in abundance during the study period from 1991 to 1996 (Figure 7), but have been sufficient in allowing a yearly harvest between 10% (SE = 4%; 1992) and 19% (SE = 5%; 1995) of the yearly average abundance of northern pike ≥ 300 mm FL. Given the relatively high number of angler days at Harding Lake (Table 1), the 26 inch TL (~625 mm FL) minimum size limit has resulted in a recruitment fishery. A large number of Harding Lake northern pike are harvested in the first season after recruiting into minimum legal length. Current management of Harding Lake northern pike has the effect of increasing abundance of northern pike < 625 mm FL, maintaining abundance of spawners (northern pike ≥ 450 mm FL), and maintaining harvest levels; but reducing the abundance of northern pike ≥ 625 mm FL and the average length of northern pike harvested.

Given that the abundance of Harding Lake northern pike has not increased significantly during the study period, at minimum the regulations should remain in place that protects Harding Lake northern pike < 625 mm FL and all northern pike in Harding Lake during the time of spawning. In addition, Harding Lake northern pike should be monitored closely through continued population assessment with particular attention to a decrease in abundance or an increase in harvest. Furthermore, if managers desire the current population of northern pike to increase in numbers or desire a greater average length in the harvest, consideration may need to be given to regulations that would reduce the current harvest level. For the Harding Lake northern pike population, harvest should not be diverted to fish < 625 mm FL. Catch and release information suggests that, due to the level of abundance, effort, and angler success, Harding Lake northern pike < 625 mm FL are vulnerable to over exploitation if opened to harvest.

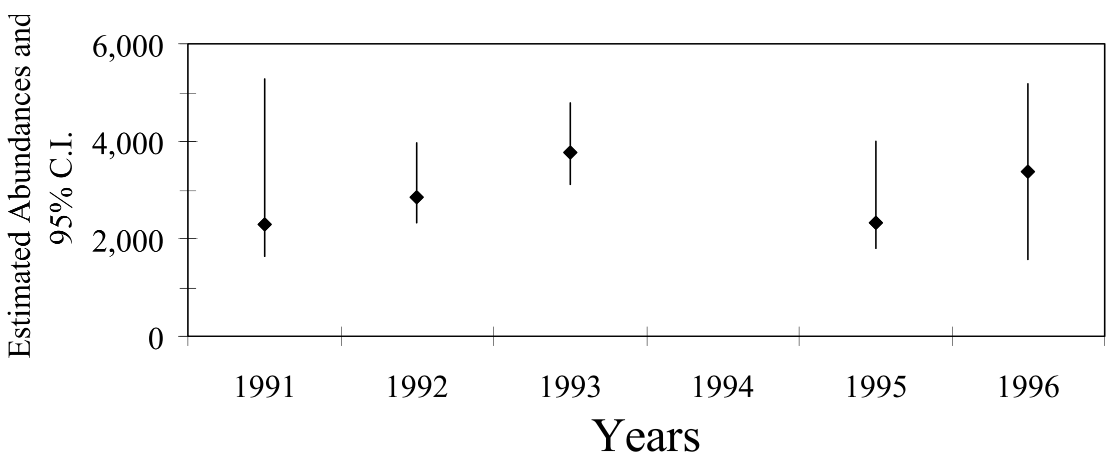

Figure 7.-Estimated abundances of Harding Lake northern pike ≥ 300 mm FL and 95% confidence intervals by year.

ACKNOWLEDGMENTS

The author appreciates the help and comments from those who reviewed and edited this report as well as its operational plan, Peggy Merritt as research coordinator, Jerry Hallberg for fisheries management concerns, Mike Wallendorf for biometric review, and Sara Case for the preparations necessary for publication. Thanks is also given to Fred Andersen and Peggy Merritt for supervisory support and encouragement. Additionally, a special thanks go to those who helped collect the data: Nancy Klemm, Margo Kramer, Peggy Merritt, Gary Pearse, Brendan Scanlan, Corey Schwanke, Lisa Stuby, and Tom Taube. The U. S. Fish and Wildlife Service provided partial funding for this study through the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under project F-10-12, Job 3-2(c).

LITERATURE CITED

Beamish, J. R. and D. A. Fournier. 1981. A method for comparing the precision of a set of age determinations. Canadian Journal of Fisheries and Aquatic Sciences 38:982-983.

Burkholder, A. 1991. Abundance and composition of northern pike, Harding Lake, 1990. Alaska Department of Fish and Game, Fishery Data Series Number 91-9, Anchorage.

Casselman, J. M. 1967. Age and growth of northern pike, *Esox lucius* Linnaeus, of the Upper St. Lawrence River. M. S. Thesis. University of Guelph.

Casselman, J. M. and C. A. Lewis. 1996. Habitat requirements of northern pike (*Esox lucius*). Canadian Journal of Fisheries and Aquatic Sciences 53:161-174.

Clark, C. F. 1950. Observations on the spawning habits of the northern pike, *Esox lucius*, in northwest Ohio. Copeia 4:285-288.

Conover, W. J. 1980. Practical nonparametric statistics. John Wiley and Sons. New York, N. Y.

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

Doxey, M. 1991. A history of fisheries assessments and stocking programs in Harding Lake, Alaska, 1939-1989. Fishery Manuscript Number 91-2, Anchorage.

Gulland, J. A. 1983. Fish stock assessment: A manual of basic methods. John Wiley and Sons, Inc., New York.

Howe, A. L., G. Fidler, and M. J. Mills. 1995. Harvest, catch, and participation in Alaska sport fisheries during 1994. Alaska Department of Fish and Game, Fishery Data Series Number 95-24, Anchorage.

Howe, A. L., G. Fidler, A. E. Bingham, and M. J. Mills. 1996. Harvest, catch, and participation in Alaska sport fisheries during 1995. Alaska Department of Fish and Game, Fishery Data Series Number 96-32, Anchorage.

Laine, A. O., W. T. Momot, and P. A. Ryan. 1991. Accuracy of using scales and cleithra for aging northern pike from an oligotrophic Ontario lake. North American Journal of Fisheries Management 11:220-225.

LaPerriere, J. D. 1975. Evaluation of the trophic types of several Alaskan Lakes by assessment of the benthic fauna. Institute of Water Resources, University of Alaska, Report IWR-63.

McNamara, F. 1936. Breeding and food habits of the pikes, *Esox lucius* and *Esox vermiculatus*. Transactions of the American Fisheries Society 66:372-373.

Mills, M. J. 1985. Alaska statewide sport fish harvest studies (1984). Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1984-1985, Project F-9-17, 26(SW-I-A), Juneau.

Mills, M. J. 1986. Alaska statewide sport fish harvest studies (1985). Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1985-1986, Project F-10-1, 27(RT-2), Juneau.

LITERATURE CITED (Continued)

Mills, M. J. 1987. Alaska statewide sport fisheries harvest report (1986). Alaska Department of Fish and Game, Fishery Data Series Number 2, Juneau.

Mills, M. J. 1988. Alaska statewide sport fisheries harvest report (1987). Alaska Department of Fish and Game, Fishery Data Series Number 52, Juneau.

Mills, M. J. 1989. Alaska statewide sport fisheries harvest report (1988). Alaska Department of Fish and Game, Fishery Data Series Number 122, Juneau.

Mills, M. J. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series Number 90-44, Anchorage.

Mills, M. J. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series Number 91-58, Anchorage.

Mills, M. J. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series Number 92-40, Anchorage.

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series Number 93-42, Anchorage.

Mills, M. J. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series Number 94-28, Anchorage.

Nakao, K. 1980. Climatic changes in the Interior Alaska. Faculty of Science, Hokkaido University, Report of the Alaskan Paleolimnology Research Project-1977/78/79.

Neumann, R. M. and D. W. Willis. 1995. Seasonal variation in gill-net sample indexes for northern pike collected from a glacial prairie lake. North American Journal of Fisheries Management 15:838-844.

Pearse, G. A. 1994. Abundance and composition of the northern pike populations in Volkmar, T, East Twin, and Harding Lakes. Alaska Department of Fish and Game, Fishery Data Series Number 94-23, Anchorage.

Pearse, G. A., and P. A. Hansen. 1993. Estimates of sustainable yield for the northern pike populations in George, Volkmar, T, and Harding Lakes. Alaska Department of Fish and Game, Fishery Manuscript Number 93-1, Anchorage.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada No. 191. 382 pp.

Roach, S. M. 1993. Movements and distributions of radio-tagged northern pike in Harding Lake. Alaska Department of Fish and Game, Fishery Data Series Number 93-12, Anchorage.

Roach, S. M. 1996. Abundance and composition of the northern pike population in Harding Lake, 1995. Alaska Department of Fish and Game, Fishery Data Series Number 96-8.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. Charles Griffin and Co., Ltd. London, U.K.

Skaugstad, C., and A. Burkholder. 1992. Abundance and age-length composition of northern pike in Harding Lake, 1991-92. Alaska Department of Fish and Game, Fishery Data Series Number 92-54, Anchorage.

Williams, J. E. 1955. Determination of age from the scales of northern pike, (*Esox lucius* L.). Doctoral Dissertation series Publication Number 12:668. Ann Arbour, Michigan: University Microfilms.

APPENDIX A

Data File Listing

Appendix A1.-Data files used to estimate parameters of the Harding Lake northern pike populations, 1996.

Data file[a]	Description
U1890LA6.DTA	Population and marking data for Harding Lake northern pike captured during the marking event, May 28 through May 31, 1996.
U1890LB6.DTA	Population and recapture data for Harding Lake northern pike captured during the recapture event, June 4 through June 6, 1996.

[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

Statistical Methodology

Appendix B1.-Methodology to compensate for bias due to unequal catchability by lake section .

Case	Result of χ^2 Test[a]	Inspection of Fish Movement[b]	Inferred Cause
I[c]	Fail to reject H_o	No movement between sections	There is no differential capture probability by lake section or marked fish completely mixed with unmarked fish within each lake section.
II[d]	Fail to reject H_o	Movement between sections	There is no differential capture probability by lake section or marked fish completely mixed with unmarked fish across lake sections.
III[e]	Reject H_o	No movement between sections	There is differential capture probability by lake section or marked fish did not mix completely with unmarked fish within at least one lake section.
IV[f]	Reject H_o	Movement between sections	There is differential capture probability by lake section or marked fish did not mix completely with unmarked fish across lake sections.

[a] The chi-squared test compares the frequency of marked fish recaptured during the second event in each lake section with the frequency of unmarked fish examined in the second event in each lake section. H_o for this test is: capture probability of fish in the first event is the same in all lake sections.

[b] Inspection of fish movement is a visual comparison of the frequency of marked fish recaptured in the second event that moved from one lake section to another with the frequency of unmarked fish examined in the second event in each lake section.

[c] Case I: Calculate one unstratified abundance estimate using the Chapman estimator (Seber 1982).

[d] Case II: Calculate one unstratified abundance estimate using the Chapman estimator (Seber 1982).

[e] Case III: Completely stratify the experiment by lake section, calculate abundance estimates for each using the Chapman estimator (Seber 1982)., and sum abundance estimates.

[f] Case IV: Completely stratify the experiment by lake section. Calculate abundance estimates for each using the Chapman estimator (Seber 1982) and sum estimates. Calculate abundance with the partially stratified model of Darroch (1961) and compare with the sum of the Chapman estimates. If estimates are dissimilar, discard the sum of the Chapman estimates and use the Darroch estimate as the estimate of abundance. If estimates are similar, discard the estimate with the largest variance.

Appendix B2.- Methodologies to compensate for bias due to unequal catchability by length.

Case	Result of First K-S Test[a]	Result of second K-S test[b]	Inferred Cause
I[c]	Fail to reject H_o	Fail to reject H_o	There is no size-selectivity during either sampling event.
II[d]	Fail to reject H_o	Reject H_o	There is no size-selectivity during the second sampling event, but there is during the first sampling event.
III[e]	Reject H_o	Fail to reject H_o	There is size-selectivity during both sampling events.
IV[f]	Reject H_o	Reject H_o	There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.

[a] The first K-S (Kolmogorov-Smirnov) test is on the lengths of fish marked during the first event versus the lengths of fish recaptured during the second event. H_o for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish recaptured during the second event.

[b] The second K-S test is on the lengths of fish marked during the first event versus the lengths of fish captured during the second event. H_o for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish sampled during the second event.

[c] Case I: Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling events for size and age composition estimates.

[d] Case II: Calculate one unstratified abundance estimate, and only use lengths and ages from the second sampling event to estimate size and age composition.

[e] Case III: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Pool lengths and ages from both sampling events and adjust composition estimates for differential capture probabilities.

[f] Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Also calculate a single abundance estimate without stratification.

Case IVa: If stratified and unstratified estimates are dissimilar, discard unstratified estimate and use lengths and ages from second event and adjust these estimates for differential capture probabilities.

Case IVb: If stratified and unstratified estimates are similar, discard estimate with largest variance. Use lengths and ages from first sampling event to directly estimate size and age compositions.

APPENDIX C

Historical Data Summaries

Appendix C1.-Floy tag numbers used for Harding Lake northern pike mark-recapture experiments by year and color, 1990-1996.

	Tag Color		
Year	White	Blue	Gray
1990		62,765-62,999	
		63,550-63,984	
1991		64,000-64,099	
		64,400-64,415	
		64,700-64,999	
1992	351-900		
	1,001-1,053		
1993			48,000-48,868
1994			
1995			40,000-40,783
1996		53,000-53,271	
		53,750-53,894	

Appendix C2.-Sample sizes (adjusted for unequal capture probabilities by area and length), estimated abundances, and standard errors by length category for Harding Lake northern pike, 1995 and 1996.

	1995			1996		
Length	n′	N′	SE′	n′	N′	SE′
300-324	23	101	18	16	126	34
325-349	23	77	13	3	28	8
350-374	23	77	14	19	155	42
375-399	33	94	16	14	112	30
400-424	32	75	13	16	126	34
425-449	53	119	21	31	253	69
450-474	32	115	20	26	211	57
475-499	52	138	24	31	253	69
500-524	72	203	36	31	253	69
525-549	60	154	27	55	450	122
550-574	88	283	50	52	421	114
575-599	101	250	44	62	506	137
600-624	74	190	33	20	164	44
625-649	64	143	25	14	116	31
650-674	37	83	15	9	76	21
675-699	24	62	11	4	30	8
700-724	20	42	8	2	18	5
725-749	13	28	5	1	9	3
750-774	8	20	4	1	12	3
775-799	4	10	2	2	14	4
800-824	8	20	3	1	9	3
825-849	3	5	1	1	12	3
850-874	2	3	1	0	2	1
875-899	2	6	1	1	7	2
900-924	7	27	5	1	7	2
925-949	0	0	0	1	7	2
950-974	2	7	1	0	0	0
975-999	1	3	0	0	0	0
>1,000	1	3	0	0	0	0
Totals	862	2,338	411	600	2,366	444

Appendix C3.-Sample sizes, estimated abundances, and standard errors by age for Harding Lake northern pike ≥ 300 mm FL, 1990-1996.

	1990[a]			1991[a]			1992[a]			1993[a]			1994[b]		
Age	n	N	SE	n	N	SE	n	N	SE	n	N	SE	n	N	SE
2	1	11	11	---	---	---	---	---	---	16	71	19	---	---	---
3	15	160	48	11	126	56	51	538	111	128	571	80	---	---	---
4	47	484	106	15	171	72	87	892	164	254	1,134	143	---	---	---
5	88	657	125	30	343	131	75	609	97	220	982	126	---	---	---
≥ 6	324	973	140	192	1,668	482	133	829	174	226	1,007	185	---	---	---
Totals	475	2,285	---	248	2,308	---	519	2,868	---	581	3,765	---	---	---	---

-continued-

Appendix C3.-Continued.

33

	1995[c]			1996		
Age	n′[d]	N′	SE′	n′[d]	N′	SE′
2	5	15	3	-	-	-
3	46	185	32	29	244	66
4	128	431	76	34	289	78
5	225	704	124	92	781	212
≥ 6	357	1,003	177	242	2,063	560
Totals	761	2,338	441	397	3,377	916

a From Pearse (1994).

b Data was not collected in 1994.

c From Roach (1996).

d Sample sizes adjusted for unequal capture probabilities by area and length.