**Fishery Data Series No. 98-14**

# Abundance and Composition of the Northern Pike Population in Harding Lake, 1997

**by**
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**July 1998**

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

## Symbols and Abbreviations

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**Weights and measures (metric)**

| | |
|---|---|
| centimeter | cm |
| deciliter | dL |
| gram | g |
| hectare | ha |
| kilogram | kg |
| kilometer | km |
| liter | L |
| meter | m |
| 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, $\chi^2$, 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. 98-14*

# ABUNDANCE AND COMPOSITION OF THE NORTHERN PIKE POPULATION IN HARDING LAKE, 1997

by

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# ABSTRACT

In 1997, estimated abundance of northern pike *Esox lucius* within Harding Lake was 1,780 fish (SE = 323) for northern pike ≥ 300 mm FL, 1,415 fish (SE = 257) for northern pike ≥ 450 mm FL, and 246 fish (SE = 45) for northern pike ≥ 625 mm FL. Estimated density of northern pike ≥ 300 mm FL was 1.78 (SE = 0.32) fish per hectare. The estimated proportion was 0.21 (SE = 0.05) for northern pike from 300 to 449 mm FL; 0.66 (SE = 0.09) for northern pike from 450 to 624 mm FL; and, 0.14 (SE = 0.05) for northern pike ≥ 625 mm FL. In 1997, estimated recruitment (abundance of age-5 fish) was 377 northern pike (SE = 68). Estimated abundance was 421 fish (SE = 76) for northern pike < age-5 and 982 fish (SE = 180) for northern pike > age-5. The mean error in assigning the proper incremental age from the scales of 89 northern pike recaptured in 1997 from 1996 was -0.72 years ($Z$ = 5.11; P < 0.01); -0.13 years ($Z$ = 0.39; P = 0.69) for 16 northern pike that were ≤ age-4 in 1996; and -0.85 years ($Z$ = 5.52; P < 0.01) for 73 northern pike ≥ age-5 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 1997 was 3.2%. For Harding Lake northern pike, indirect value for maximum sustainable yield was estimated as 484 fish, number of northern pike needed to produce maximum sustainable yield was estimated as 1,626 spawning size fish, and the carrying capacity of Harding Lake was estimated as 3,251 northern pike ≥ age-5.



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). Estimates of sustainable yield were updated in 1996 (Roach 1997). The indirect method of relating natural mortality and carrying capacity to MSY was used because population data were available for only four years. Eventually sustainable yield will be estimated using regression techniques described by Pearse and Hansen (1993). More than eight years of data are needed to use this method because of a five-year lag from egg deposition to full recruitment to the gear.

## 1997 RESEARCH OBJECTIVES

Working toward the goal of estimating surplus production and evaluating the current status of the stock, a mark-recapture experiment was conducted in Harding Lake in 1997. 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,

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 to a high of 6,743 in 1995 (Table 1; Mills 1985 - 1994; Howe et al. 1995 - 1997). 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 for all species at Harding Lake, harvest of northern pike 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 (Burkholder 1991; Skaugstad and Burkholder 1992; Pearse 1994; Roach 1996, 1997).

## 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,

[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.

**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, 1984-1996 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 |
| 1996 | 6,734 | 363 | | 115 | | 4,070 | 593 | 0.60 | 0.09 | 0.09 | 0.19 |
| Average | 4,540 | 983 | | 187 | | 4,517 | 643 | 0.88 | 0.12 | 0.15 | 0.33 |

[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.

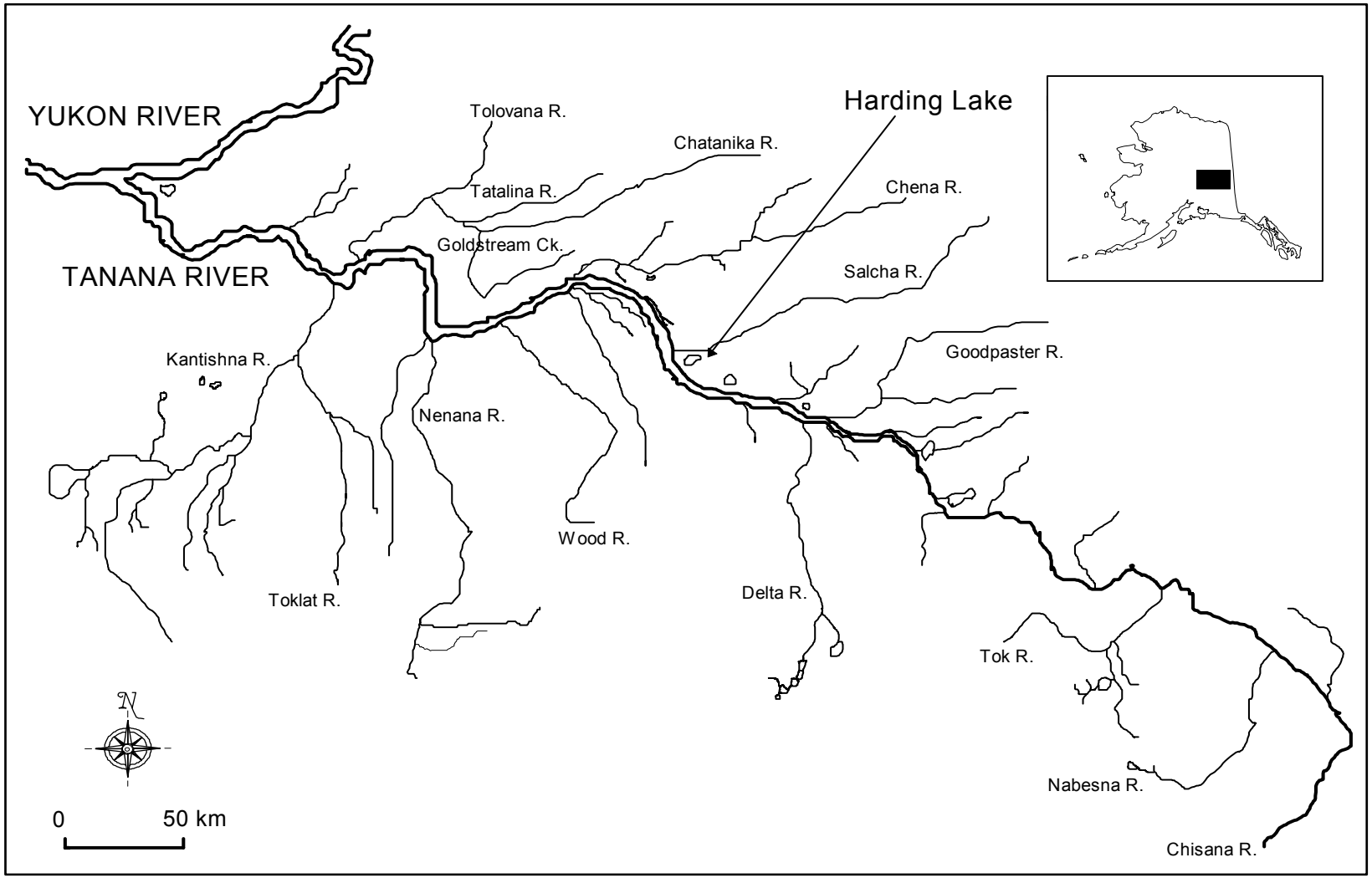


**Figure 1.-Tanana River drainage.**

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 the 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-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 shore 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 1997 were similar to those used in 1993 (Pearse 1994), 1995 (Roach 1996), and 1996 (Roach 1997). Based on the relative success of these studies, a two-event mark-recapture experiment was scheduled similarly in late May and early June of 1997. The Harding Lake northern pike radio-telemetry study (Roach 1993) indicated that Harding Lake northern pike are more uniformly distributed by sex and length in June compared to May. Therefore, to help ensure a uniform sample by sex and length during at least one of the sampling events, the recapture event took place in early June. Unlike northern pike in other Interior lakes, Harding Lake northern pike remain in shallow water (< 3 m) during late May and early June (Roach 1993) and are susceptible to in-shore sampling techniques during this time. The marking event

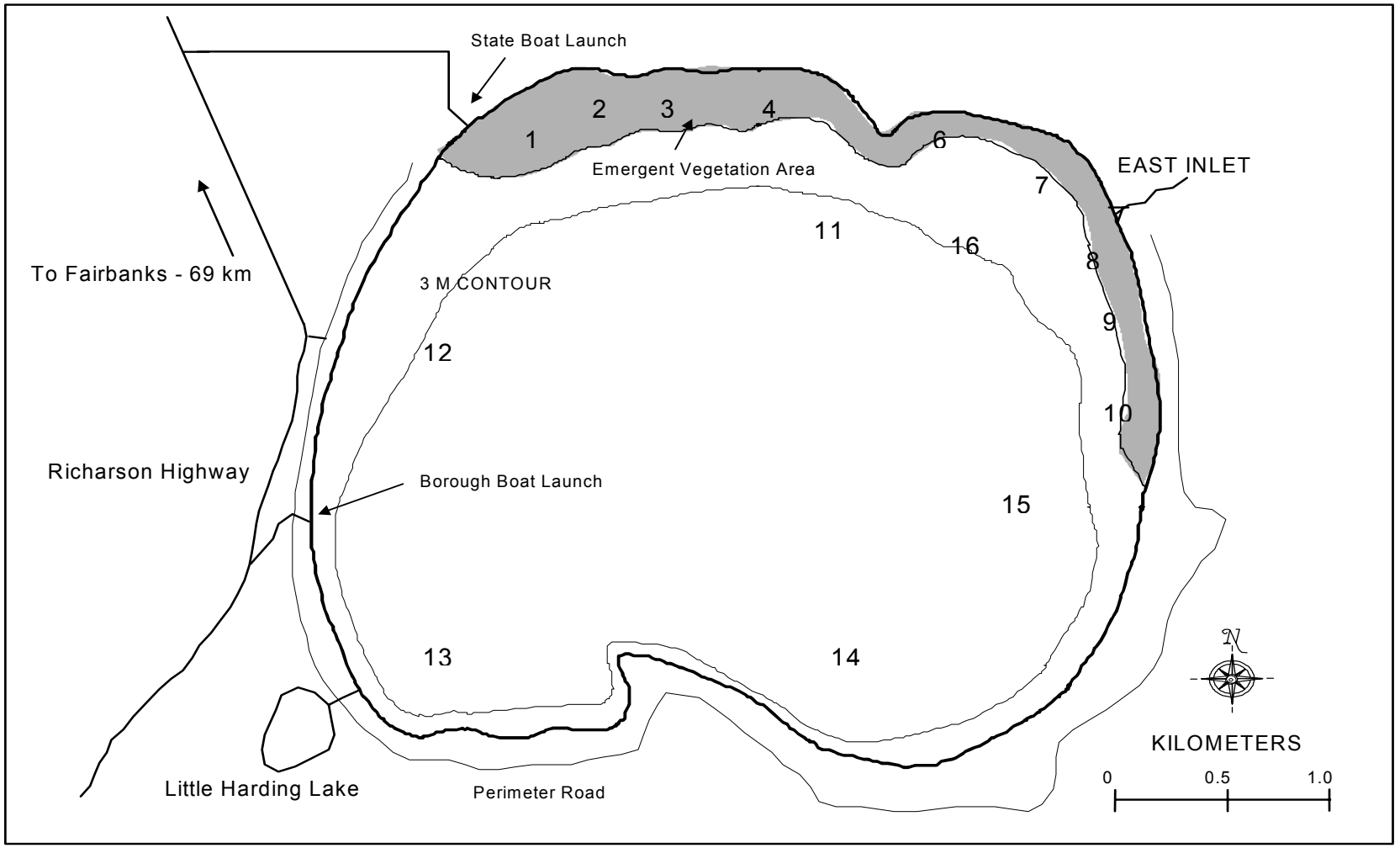


**Figure 2.-Harding Lake with sampling sections (1 - 16) indicated, which were used for capture probability and movement analysis.**

(May 27 - May 30) and recapture event (June 3 - June 5) took four and three days to complete with a three-day hiatus between events (May 31 - 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.

One 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 water body recorded on the back. All crewmembers 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 crewmembers performed these tasks appropriately.

During the marking event, all northern pike ≥ 300 mm FL that were captured were measured for length, examined for tags, two or more scales removed from each for age determination, and left pectoral fin slightly clipped. Length was measured and recorded to the nearest millimeter FL. Scales were 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. If a Floy tag was present, the color and number of the tag was 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.

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. Both the left and right side of the dorsal fin were examined closely for recent tag wounds and the left and right pectoral fins examined closely for recent clips, and then the right pectoral 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 recapture event. Northern pike already sampled during the recapture event were identified by the presence of a recent right pectoral fin clip.

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) according to criteria established by Williams (1955), and Casselman (1967). Because 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 for fish older than age-4. In cases of age-4 and younger fish, growth beyond the last annulus was generally always considered plus growth instead of an additional year.

## ABUNDANCE

The mark-recapture experiment was designed to satisfy the assumptions of a Petersen mark-recapture experiment (Seber 1982). These 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 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 tested by comparing recapture rates and movements of fish between events with tests of

consistency designed to detect unequal catchability by area and by size of fish (Seber 1982). The validity of assumption 4 was ensured 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 ensured by a thorough examination of fins for fin-clips and recording Floy tag numbers for all northern pike. Floy tag numbers used for this mark-recapture experiment were archived (Appendix B1).

Tests indicated that assumption 2 was not valid for this experiment due to unequal mixing of fish, unequal catchability of fish, and non-uniform sampling during both events. By default, the Darroch estimator of abundance was used in place of the Petersen since this estimator does not require the validity of assumption 2 (Darroch 1961). The variances of capture and movement probabilities were estimated from the observed information matrix. The variance of estimated abundance was estimated using the delta method (Seber 1982).

## LENGTH AND AGE COMPOSITION

Length and age proportions and variances of proportions for northern pike ≥ 300 mm FL were estimated using:

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

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

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*;

$n$ = the number of northern pike that were measured for length or for which ages were determined; and,

$\hat{N}$ = estimated abundance.

For a given length or age class, abundance was estimated as $\hat{N}\hat{p}_k$ and the variance of abundance was estimated using Goodman's formula. Length and age composition data were archived (Appendices B2, B3).

## AGE VALIDATION

Accuracy of age determinations from scales captured during the 1997 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 ($\alpha$) of 0.05 or lower were considered significant.

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

$$\text{ERROR} = \text{AGE}_{t+\Delta} - \text{AGE}_t - \Delta t \tag{3}$$

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

$\text{AGE}_t$ = age assigned at earlier capture; and,

$\Delta t$ = 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 (APE; Beamish and Fournier 1981) of the scale reader to reproduce the same age twice from a Harding Lake northern pike scale in 1997 was calculated as:

$$\text{APE} = \frac{\sum_{i=1}^{S}\left[\frac{\sum_{j=1}^{R}\frac{\left|x_{ij}-\bar{x}_i\right|}{\bar{x}_i}}{R}\right]}{S}\cdot 100 \tag{4}$$

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.

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):

$$N_{MSY} = \frac{R_{MAX}}{\frac{r}{2} + \left(1 - e^{-M}\right)}. \tag{5}$$

Maximum recruitment was 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) and Gulland (1983), the carrying capacity of the environment (K) was determined as two times $N_{MSY}$ and MSY as:

$$MSY = \frac{rK}{4}. \quad (6)$$

# RESULTS

Of the 478 unique northern pike handled during the mark-recapture experiment, 228 were tagged and released alive during the marking event and 250 were examined for marks during the recapture event of which 45 were recaptures from the marking event (Appendix B4). There was no observed tag loss during the experiment, one northern pike was inadvertently killed, and 180 northern pike with Floy tags from prior mark-recapture experiments (38% of unique northern pike handled) were identified.

## ABUNDANCE

Estimated abundance of northern pike within Harding Lake was germane to fish ≥ 300 mm FL during late May and early June 1997. Since tag-recovery rates were variable by location, Harding Lake was divided into two areas in such a way that minimized the difference in recovery rates within each area but maximized the difference between the areas. Examination of areas where northern pike were marked with areas where the fish were recaptured indicated unequal movement between these two areas of the lake during the experiment. A comparison of the recovery history of fish marked in these two areas indicated significantly different mixing rates between the areas ($\chi^2 = 21.95$; 2 df; $P < 0.01$; Table 2). In addition, recapture rates were significantly different ($\chi^2 = 17.25$; 1 df; $P < 0.01$; Table 3), which suggests that along with unequal movement, all fish did not have a similar probability of capture during the marking event. Furthermore, significantly different proportions of fish marked in each area were recovered ($\chi^2 = 11.52$; 1 df; $P < 0.01$; Table 4). This also suggested that all fish did not have a similar probability of capture during the recapture event. These tests indicated that the conditions of Assumption 2 were not met and therefore the Darroch estimator was used to estimate abundance.

**Table 2.-Numbers of northern pike marked in areas A (sections 9, 10, and 16) and B (sections 1, 2, 3, 4, 6, 7, 8, 11, 12, 13, 14, and 15) and recovered in area A, area B, or not recovered.**

| Marking | Recovery History | | | |
|---|---|---|---|---|
| Area | A | B | Not Recovered | Total |
| A | 13 | 4 | 28 | 45 |
| B | 10 | 18 | 155 | 183 |
| Total | 23 | 22 | 183 | 228 |

**Table 3.-Numbers of marked and unmarked northern pike captured during the recapture event by areas A (sections 9, 10, and 16) and B (sections 1, 2, 3, 4, 6, 7, 8, 11, 12, 13, 14, and 15).**

| | Capture Area | | |
|---|---|---|---|
| Northern Pike | A | B | Total |
| Marked | 23 | 22 | 45 |
| Unmarked | 43 | 162 | 205 |
| Total | 66 | 184 | 250 |

**Table 4.-Numbers of marked northern pike recovered and not recovered during the recapture event by areas A (sections 9, 10, and 16) and B (sections 1, 2, 3, 4, 6, 7, 8, 11, 12, 13, 14, and 15).**

| | Marking Area | | |
|---|---|---|---|
| History | A | B | Total |
| Recovered | 17 | 28 | 45 |
| Not Recovered | 28 | 155 | 183 |
| Total | 45 | 183 | 228 |

Estimated abundance of northern pike ≥ 300 mm FL within Harding Lake was 1,780 fish (SE = 323; CV = 18%). The upper and lower bounds of the 95% C.I. were 1,146 and 2,414 northern pike ≥ 300 mm FL. Estimated abundance of northern pike ≥ 450 mm FL was 1,415 fish (SE = 259) and estimated abundance of northern pike ≥ 625 mm FL was 246 fish (SE = 51). Estimated density of northern pike ≥ 300 mm FL was 1.78 (SE = 0.32) fish per hectare.

## LENGTH COMPOSITION

There were no significant differences between the length distributions of fish marked and fish recaptured ($D = 0.09$; P = 0.88; Figure 3) or between the length distributions of fish marked and fish captured during the recapture event ($D = 0.05$; P = 0.85; Figure 3). This suggests that length selectivity was the same during both events, therefore, fork lengths from both events were pooled for estimating length composition.

Fork lengths measured from 478 northern pike ≥ 300 mm FL in Harding Lake ranged from 305 mm to 1,005 mm (mean = 530 mm; SE = 5). The estimated abundance was 365 fish (SE = 72) for northern pike from 300 to 449 mm FL; 1,169 fish (SE = 215) for northern pike from 450 to 624 mm FL; and, 246 fish (SE = 51) for northern pike ≥ 625 mm FL (Figure 4). The estimated proportion was 0.21 (SE = 0.016) for northern pike from 300 to 449 mm FL; 0.66 (SE = 0.019) for northern pike from 450 to 624 mm FL; and, 0.14 (SE = 0.014) for northern pike ≥ 625 mm FL (Figure 4).

## AGE COMPOSITION

Using scales, investigators determined ages for 402 of 478 unique northern pike (≥ 300 mm FL) sampled during the mark-recapture experiment. Scales were not taken or lost from 49 fish, were not readable because of regeneration from 23 fish, and were not readable because of poor acetate impression from 4 fish. Of scales collected during the marking event, ages were determined for 210 unique northern pike. Of scales collected during the recapture event, ages were determined for 192 unique northern pike. Investigators determined ages for 89 northern pike within the sample that were also aged in 1996.

The mean error in assigning the proper incremental ages from the scales of the 89 northern pike that were recaptured in 1997 from 1996 was -0.72 years ($Z = 5.11$; P < 0.01); -0.13 years ($Z = 0.39$; P = 0.69) for 16 northern pike that were ≤ age-4 in 1996; and -0.85 years ($Z = 5.52$; P < 0.01) for 73 northern pike ≥ age-5 in 1996 (Figure 5). Analysis by cohort was limited to northern pike ≤ age-5 in 1997 because there was not a significant bias in relative age determination for these fish. All cohorts ≥ age-6 were lumped into one group because 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 1997 was 3.2% (Figure 6).

The estimated abundances of Harding Lake northern pike ≥ 300 mm FL were 421 (SE = 83) prespawning-age fish (< age-5) and 1,359 (SE = 249) spawning-age fish (≥ age-5; Table 5). The estimated proportions of northern pike ≥ 300 mm FL were 0.24 (SE = 0.019) for prespawning-age fish (< age-5), and 0.76 (SE = 0.019) for spawning-age fish (≥ age-5; Table 5).

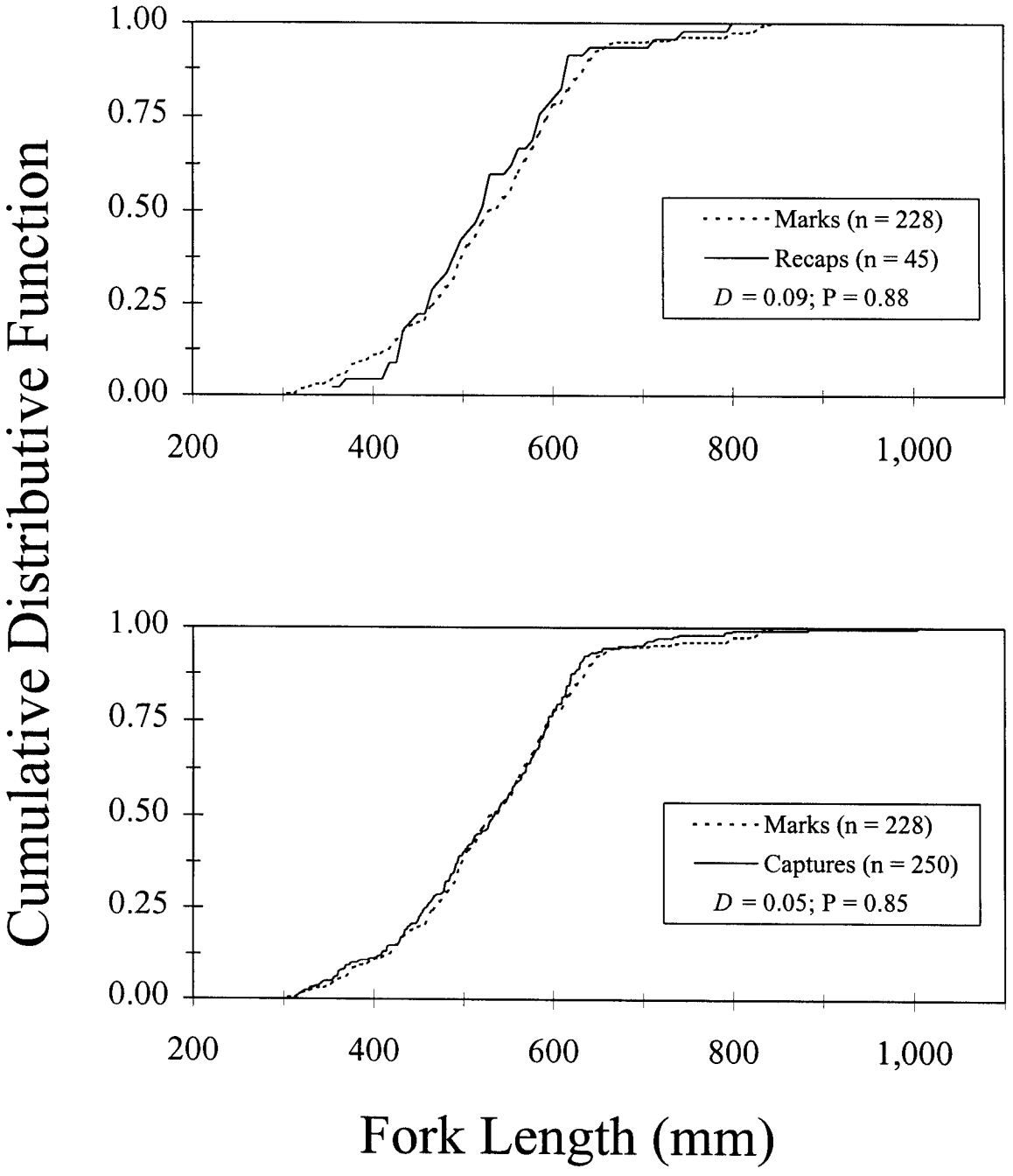


**Figure 3.–Cumulative distributive functions of fork lengths of northern pike marked versus recaptured and marked versus captured in Harding Lake, 1997.**

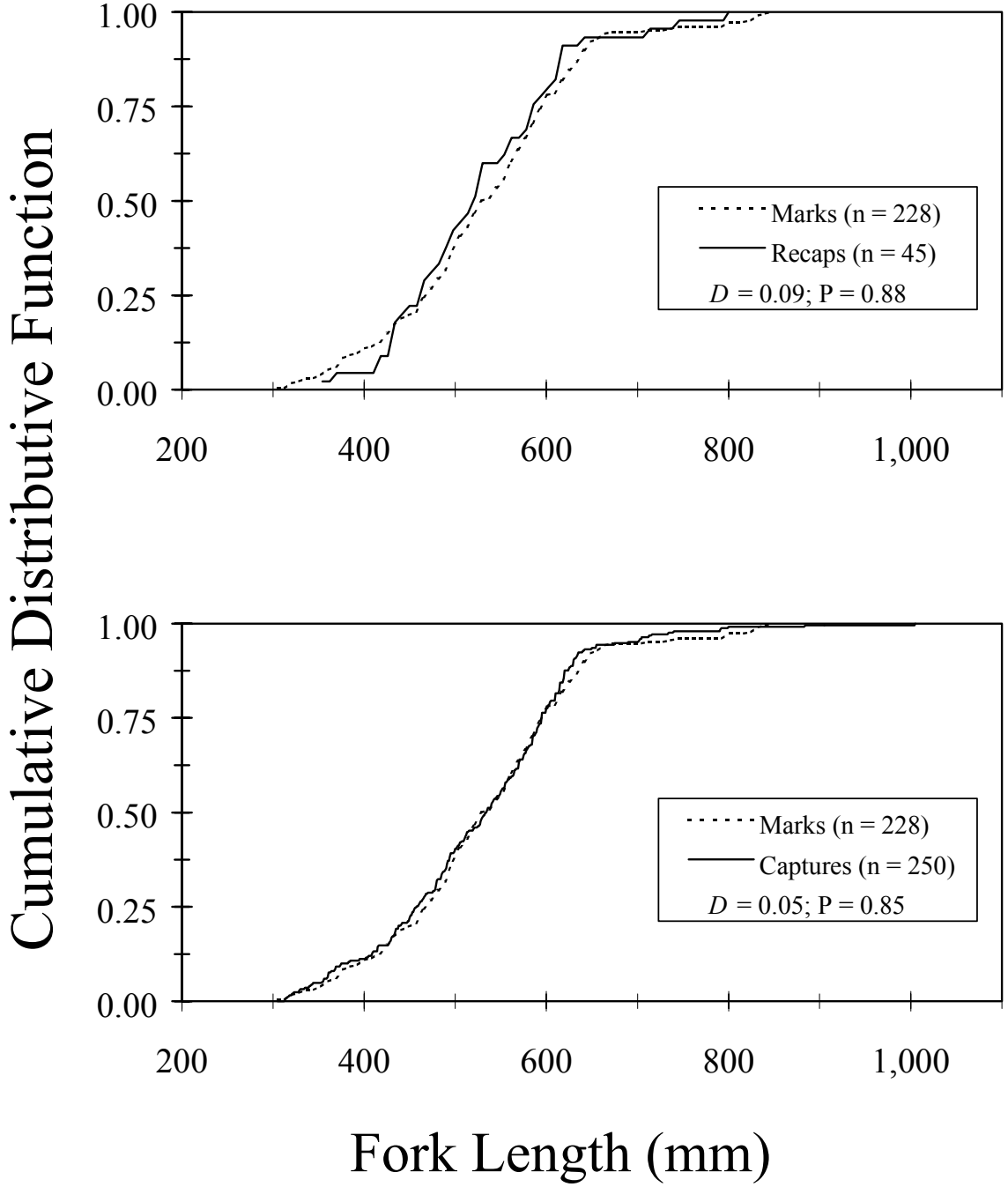


**Figure 3.–Cumulative distributive functions of fork lengths of northern pike marked versus recaptured and marked versus captured in Harding Lake, 1997.**

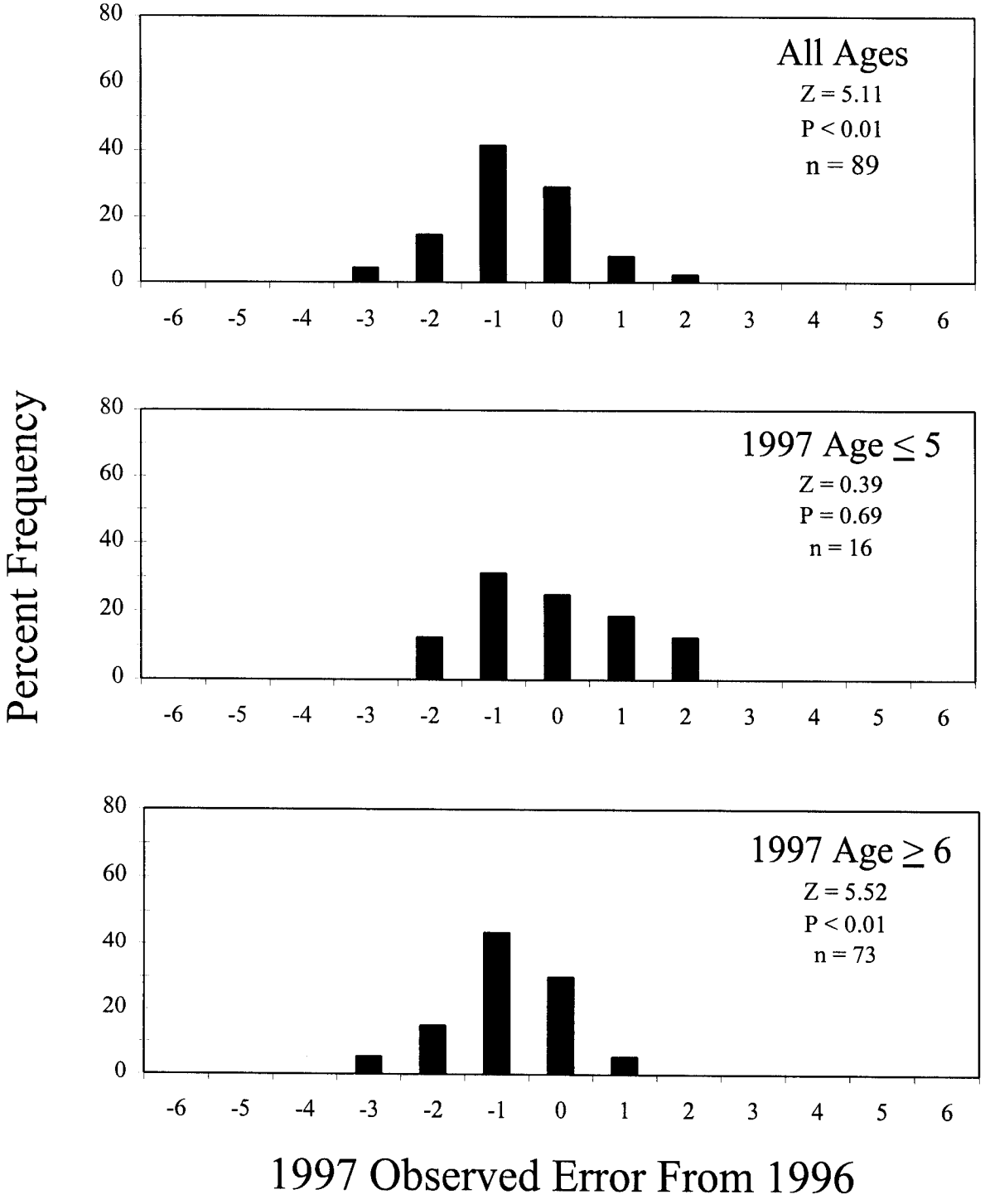


**Figure 5.-Percent frequencies of observed errors in assigning the proper incremental ages to Harding Lake northern pike marked in 1996 and recaptured in 1997.**

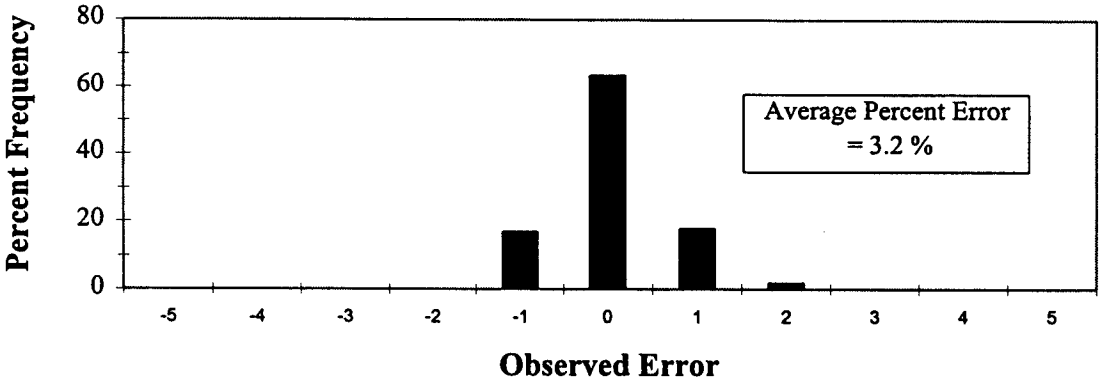


**Figure 6.-Percent frequencies for observed errors in reproducing the same age twice from a Harding Lake northern pike scale in 1997.**

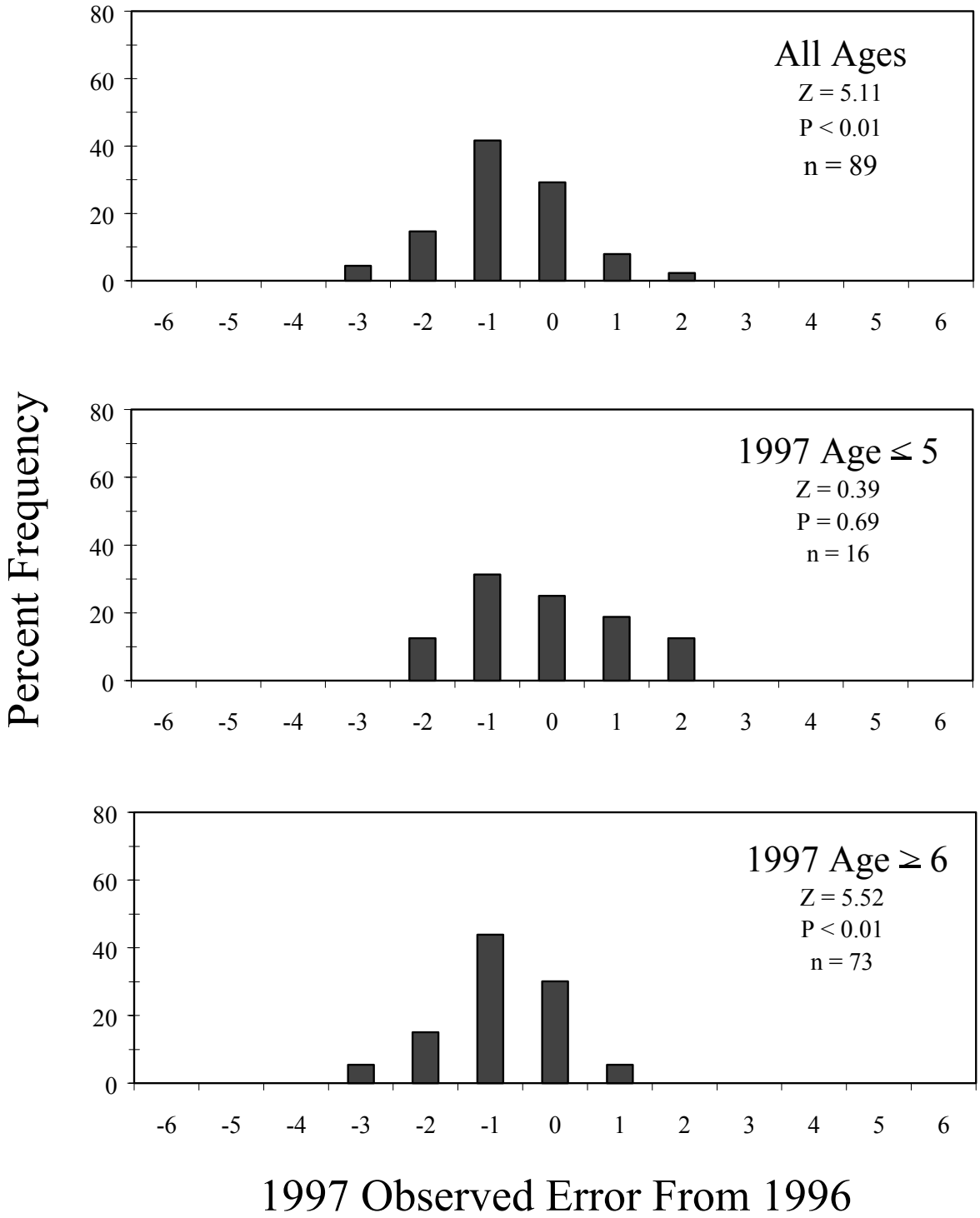


**Figure 5.-Percent frequencies of observed errors in assigning the proper incremental ages to Harding Lake northern pike marked in 1996 and recaptured in 1997.**

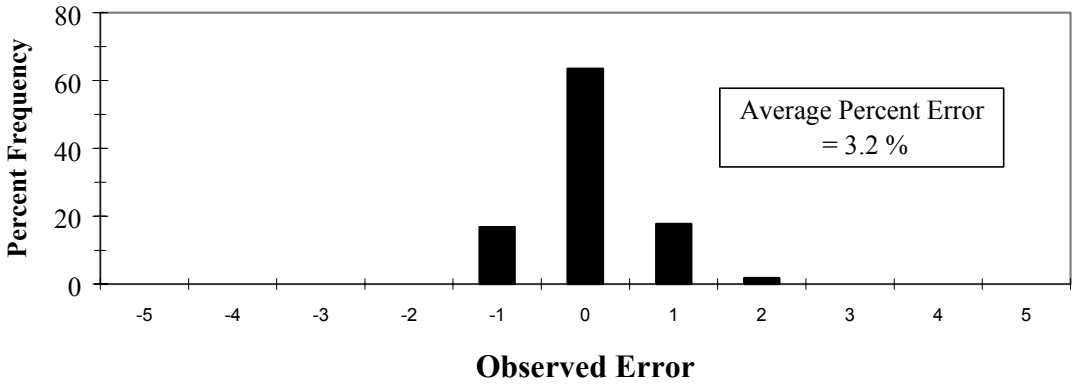


**Figure 6.-Percent frequencies for observed errors in reproducing the same age twice from a Harding Lake northern pike scale in 1997.**

**Table 5.-Estimated proportions (p), abundances (N), and standard errors of estimates (SE) of Harding Lake northern pike that were ≥ 300 mm in late May and early June 1997 by age.**

| | | Proportion | | Abundance | |
|---|---|---|---|---|---|
| Age | n | P | SE[p] | N | SE[N] |
| 1 | - | - | - | - | - |
| 2 | 8 | 0.02 | 0.006 | 35 | 13 |
| 3 | 34 | 0.08 | 0.012 | 151 | 35 |
| 4 | 53 | 0.13 | 0.015 | 235 | 50 |
| 5 | 85 | 0.21 | 0.018 | 377 | 75 |
| ≥ 6 | 222 | 0.56 | 0.022 | 982 | 183 |

### MAXIMUM SUSTAINABLE YIELD AND EXPLOITATION

From estimates of harvest (1990 – 1996) and abundance of northern pike ≥ age-5 and estimates of age-5 recruits (1990 – 1993 and 1995 –1997) average natural mortality (M) of Harding Lake northern pike ≥ age-5 was estimated as 0.37 and the intrinsic rate of increase (r) as 0.59. The greatest number of recruits observed from 1990 to 1997 was 982 in 1993, which was considered an estimate of maximum recruitment ($R_{MAX}$). Using these values, maximum sustainable yield (MSY) was estimated as 484 fish, the number of spawners needed to produce MSY ($N_{MSY}$) as 1,626 fish, and the carrying capacity of the lake (K) as 3,251 fish ≥ age-5.

## DISCUSSION

Similar to 1996, the Darroch estimator was needed to estimate abundance of Harding Lake northern pike in 1997 because none of the "or" conditions of Assumption 2 were met for a simple Petersen model. In 1996, this was attributed to the late melt-off of winter ice, which resulted in the unequal distribution and movement of fish occurring by size at the time of the experiment instead of earlier in May. In 1997, although the distribution and movement of fish by size was similar, sampling was not uniform during either event. A greater proportion of northern pike in area A (section 9, 10, and 16) compared to the rest of the lake was sampled during both events. To help in solving both problems and increasing the likelihood of satisfying at least one of the "or" conditions, the recapture event should ideally be scheduled during the first week in June and a greater proportion of sampling effort should be expended in other areas of the lake compared to Area A. Even though both estimators are unbiased, satisfying at least one "or" condition enables the use of the Petersen estimator that is inherently more precise.

Once again age validation demonstrated the difficulty in determining age 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 of full recruitment to the gear (age-5; Pearse and Hansen 1993; Roach 1996; Roach 1997) was determined with relative precision and accuracy, however, it was necessary to lump older fish into one group. Age validation must continue as one component of northern pike stock assessment to safeguard against the misuse of age data.

The current Harding Lake regulations have the effect of providing a yearly harvest between 10% (SE = 4%; 1992) and 19% (SE = 5%; 1995) of the yearly average abundance of northern pike ≥ 300 mm FL but do not provide for increasing the stock as initially desired. 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 in which some years there are more legal-size fish harvested than are present at the beginning of the fishing season. This type of fishery results in a reduction of the average length of fish harvested and a reduction in the abundance of fish greater than the minimum size limit. Even though this harvest regime may be sustainable, and perhaps desirable, the current abundance level should be evaluated with regard to the initial

management goal of increasing abundance. Population assessment of Harding Lake northern pike should continue and particular attention should be given to a decrease in abundance or an increase in harvest.

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## 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.

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.

Howe, A. L., G. Fidler, C. Olnes, A. E. Bingham, and M. J. Mills. 1997. Harvest, catch, and participation in Alaska sport fisheries during 1996. Alaska Department of Fish and Game, Fishery Data Series Number 97-29, 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.

# LITERATURE CITED (Continued)


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.

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.

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, Anchorage.

Roach, S. M. 1997. Abundance and composition of the northern pike population in Harding Lake, 1996. Alaska Department of Fish and Game, Fishery Data Series Number 97-20, Anchorage.

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

# LITERATURE CITED (Continued)

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, 1997.**

| Data file[a] | Description |
|---|---|
| U189BLAA.DTA | Population and marking data for Harding Lake northern pike captured during the marking event, May 27 through May 30, 1997. |
| U189BLBA.DTA | Population and recapture data for Harding Lake northern pike captured during the recapture event, June 3 through June 5, 1997. |

[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 Harding Lake northern pike mark-recapture experiments by year and color, 1990-1997.**

| Year | Tag Color | | |
|---|---|---|---|
| | 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 | |
| 1997 | | | 4,425-4,774 |

**Appendix B2.–Sample sizes, estimated abundances, and standard errors by length category for Harding Lake northern pike, 1995 – 1997 (adjustments made for unequal capture probabilities in 1995 and 1996).**

| | 1995 | | | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|---|---|---|
| Length | n | $\hat{N}$ | SE | n | $\hat{N}$ | SE | n | $\hat{N}$ | SE |
| 300-324 | 23 | 101 | 18 | 16 | 126 | 34 | 10 | 37 | 12 |
| 325-349 | 23 | 77 | 13 | 3 | 28 | 8 | 10 | 37 | 12 |
| 350-374 | 23 | 77 | 14 | 19 | 155 | 42 | 22 | 82 | 21 |
| 375-399 | 33 | 94 | 16 | 14 | 112 | 30 | 9 | 34 | 11 |
| 400-424 | 32 | 75 | 13 | 16 | 126 | 34 | 20 | 74 | 19 |
| 425-449 | 53 | 119 | 21 | 31 | 253 | 69 | 27 | 101 | 24 |
| 450-474 | 32 | 115 | 20 | 26 | 211 | 57 | 37 | 138 | 31 |
| 475-499 | 52 | 138 | 24 | 31 | 253 | 69 | 50 | 186 | 40 |
| 500-524 | 72 | 203 | 36 | 31 | 253 | 69 | 38 | 142 | 32 |
| 525-549 | 60 | 154 | 27 | 55 | 450 | 122 | 36 | 134 | 30 |
| 550-574 | 88 | 283 | 50 | 52 | 421 | 114 | 49 | 182 | 39 |
| 575-599 | 101 | 250 | 44 | 62 | 506 | 137 | 60 | 223 | 47 |
| 600-624 | 74 | 190 | 33 | 20 | 164 | 44 | 44 | 164 | 36 |
| 625-649 | 64 | 143 | 25 | 14 | 116 | 31 | 31 | 115 | 27 |
| 650-674 | 37 | 83 | 15 | 9 | 76 | 21 | 9 | 34 | 11 |
| 675-699 | 24 | 62 | 11 | 4 | 30 | 8 | 2 | 7 | 5 |
| 700-724 | 20 | 42 | 8 | 2 | 18 | 5 | 6 | 22 | 9 |
| 725-749 | 13 | 28 | 5 | 1 | 9 | 3 | 4 | 15 | 7 |
| 750-774 | 8 | 20 | 4 | 1 | 12 | 3 | 0 | 0 | 0 |
| 775-799 | 4 | 10 | 2 | 2 | 14 | 4 | 4 | 15 | 7 |
| 800-824 | 8 | 20 | 3 | 1 | 9 | 3 | 3 | 11 | 6 |
| 825-849 | 3 | 5 | 1 | 1 | 12 | 3 | 5 | 19 | 8 |
| 850-874 | 2 | 3 | 1 | 0 | 2 | 1 | 0 | 0 | 0 |
| 875-899 | 2 | 6 | 1 | 1 | 7 | 2 | 1 | 4 | 3 |
| 900-924 | 7 | 27 | 5 | 1 | 7 | 2 | - | - | - |
| 925-949 | - | - | - | 1 | 7 | 2 | - | - | - |
| 950-974 | 2 | 7 | 1 | - | - | - | - | - | - |
| 975-999 | 1 | 3 | 0 | - | - | - | - | - | - |
| 1,000-1,024 | 1 | 3 | 0 | - | - | - | 1 | 4 | 3 |
| 1,025-1,049 | - | - | - | - | - | - | - | - | - |
| > 1,050 | - | - | - | - | - | - | - | - | - |
| Totals | 862 | 2,338 | - | 600 | 3,377 | - | 478 | 1,780 | - |

**Appendix B3.–Sample sizes, estimated abundances, and standard errors by age for Harding Lake northern pike ≥ 300 mm FL, 1990-1997 (adjustments made for unequal capture probabilities in 1995 and 1996).**

| | 1990[a] | | | 1991[a] | | | 1992[a] | | | 1993[a] | | | 1994[b] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | n | $\hat{N}$ | SE | n | $\hat{N}$ | SE | n | $\hat{N}$ | SE | n | $\hat{N}$ | SE | n | $\hat{N}$ | 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 B3.–Continued.**

| | 1995[c] | | | 1996[d] | | | 1997 | | |
|---|---|---|---|---|---|---|---|---|---|
| Age | n | $\hat{N}$ | SE | n | $\hat{N}$ | SE | n | $\hat{N}$ | SE |
| 2 | 5 | 15 | 3 | - | - | - | 8 | 35 | 13 |
| 3 | 46 | 185 | 32 | 29 | 244 | 66 | 34 | 151 | 35 |
| 4 | 128 | 431 | 76 | 34 | 289 | 78 | 53 | 235 | 50 |
| 5 | 225 | 704 | 124 | 92 | 781 | 212 | 85 | 377 | 75 |
| ≥ 6 | 357 | 1,003 | 177 | 242 | 2,063 | 560 | 222 | 982 | 183 |
| Totals | 761 | 2,338 | --- | 397 | 3,377 | 916 | 402 | 1,780 | --- |

a From Pearse (1994).

b Data were not collected in 1994.

c From Roach (1996).

d From Roach (1997).

**Appendix B4.–Number of northern pike ≥ 300 mm FL marked (M), examined for marks (C), and recaptured with marks (R) by section during Harding Lake two-event mark-recapture experiments, 1995 - 1997.**

| Section | 1995 | | | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|---|---|---|
| | M | C | R | M | C | R | M | C | R |
| 1 | 45 | 56 | 7 | 48 | 46 | 6 | 23 | 26 | 3 |
| 2 | 22 | 15 | 1 | 10 | 9 | 0 | 0 | 2 | 0 |
| 3 | 5 | 3 | 0 | 1 | 10 | 1 | 0 | 0 | 0 |
| 4 | 116 | 46 | 18 | 55 | 50 | 7 | 62 | 54 | 8 |
| 6 | 3 | 5 | 2 | 0 | 5 | 2 | 5 | 0 | 0 |
| 7 | 28 | 15 | 3 | 8 | 19 | 4 | 4 | 8 | 1 |
| 8 | 32 | 53 | 15 | 24 | 19 | 3 | 45 | 19 | 3 |
| 9 | 60 | 71 | 25 | 45 | 33 | 9 | 21 | 27 | 11 |
| 10 | 15 | 32 | 10 | 33 | 15 | 5 | 17 | 24 | 7 |
| 11 | 1 | 9 | 3 | 11 | 0 | 0 | 0 | 0 | 0 |
| 12 | 3 | 4 | 1 | 1 | 0 | 0 | 0 | 1 | 0 |
| 13 | 31 | 37 | 3 | 23 | 26 | 1 | 11 | 18 | 1 |
| 14 | 34 | 25 | 4 | 14 | 25 | 3 | 3 | 31 | 4 |
| 15 | 25 | 15 | 5 | 5 | 13 | 2 | 30 | 25 | 2 |
| 16 | 26 | 26 | 8 | 26 | 43 | 8 | 7 | 15 | 5 |
| Totals | 446 | 412 | 105 | 304 | 313 | 51 | 228 | 250 | 45 |