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ABUNDANCE AND AGE, SEX, AND LENGTH COMPOSITION OF THE NORTHERN PIKE POPULATIONS OF GEORGE, VOLKMAR, AND T LAKES, 1989[1]

By

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ABSTRACT

Populations of northern pike *Esox lucius* in George, Volkmar, and T Lakes in interior Alaska, were studied during spawning in the spring, 1989. Abundance (over 299 millimeters fork length), was estimated at 25,466 (14/hectare) for George Lake. The two-season estimate of 1988 abundance in Volkmar Lake was 2,766 (10/hectare), and was the lowest abundance estimate since 1986. The abundance and population composition of northern pike in T Lake was not estimated in 1989. The sex composition of northern pike in George Lake indicated females (54 percent) outnumbered males (26 percent) and "sex unknowns" (20 percent), and females had higher growth rates, and lived longer than males. The length composition of northern pike in Volkmar Lake reflected poor recruitment and fewer large fish than in previous years. The length composition of northern pike in George Lake reflected increased recruitment and cohort strength between years. Survival rates declined in Volkmar Lake (from 71 percent to 36 percent) and in George Lake (from 79 percent to 70 percent) for age 5 through age 8 northern pike. Recruitment of age 5 northern pike increased in George Lake and decreased in Volkmar Lake.

KEY WORDS: Northern pike, *Esox lucius*, Volkmar Lake, T Lake, George Lake, Alaska, abundance, sampling methods, mark-recapture, growth, length-at-age, age composition, sex composition, survival rates, recruitment.

INTRODUCTION

Background

Northern pike *Esox lucius* are popular with sport anglers in interior Alaska. According to current estimates of recreational fisheries harvest in interior Alaska, northern pike rank fifth for all species and third for indigenous stocks (Mills 1988). Harvests of northern pike in interior Alaska averaged about 15,000 fish between 1977 and 1987 (ranging from 11,600 to 19,000), with more recent harvests at about 14,200 fish (Mills 1988). Interior Alaska accounts for 75% to 90% of the statewide harvest of northern pike on an annual basis, with waters of the Tanana River drainage accounting for about 65% of the regional harvest. George and Volkmar lakes are among the most popular fishing areas for northern pike in the Tanana River drainage. A third lake, T Lake, receives an unknown, but probably low, level of fishing pressure.

Periodic distribution, stock assessment, and creel surveys of northern pike resources and fisheries of the Tanana River drainage were conducted from 1971 to 1984 (Peckham 1972-1985). Research conducted at Volkmar Lake in 1985 (Peckham 1986) provided the first estimate of northern pike abundance in Alaska. Research conducted from 1986 through 1988 provided additional estimates of abundance, along with information on catch-per-unit of effort (CPUE), catchability, and life history of northern pike in Volkmar, T, and George lakes (Peckham and Bernard 1987, Clark et al. 1988, Clark 1988, Clark and Gregory 1988, Timmons and Pearse 1989). This report documents research conducted in 1989 concerning the abundance and age, sex, and length compositions of the populations of northern pike in these waters.

Study Area Descriptions

Volkmar Lake (64°07'30"N, 145°11'W) is a remote 273 ha (675 a) lake located approximately 25 km northeast of the town of Delta Junction (Figure 1). The lake is accessible during the open water season by float-equipped aircraft. Snowmachines and ski-equipped aircraft provide access during the winter. Volkmar Lake lies at an elevation of 326 m and has a maximum depth of 12.8 m. The lake has two small inlets and an ill-defined outlet that drains westerly through wetlands toward the Goodpaster River. Near shore waters are shallow with beds of aquatic vegetation providing spawning and rearing substrate for northern pike. Volkmar Lake is typically ice-free from late May to early October, and spawning of northern pike generally coincides with the beginning of the ice-free period in mid-May and continues for up to two weeks into early June. Other fish species present include humpback whitefish *Coregonus pidschian*, least cisco *Coregonus sardinella*, and slimy sculpin *Cottus cognatus*.

Fishing pressure in Volkmar Lake for northern pike is moderate, ranging from one to two angler days annually per ha. The popularity of Volkmar Lake is growing because of recent land disposals around the lake by the State, improved winter access from new snowmachine trails and roads in the Delta Agricultural Project, and increased summer and winter use by cabin owners around the lake and on the nearby Goodpaster River. Since 1977, harvest of northern pike in Volkmar Lake has been reported in the statewide angler survey

in only three of twelve years. In 1981, 648 northern pike were harvested during 458 days of fishing; 777 northern pike were harvested during 546 days of fishing in 1982; and 430 northern pike were harvested during 430 days of fishing in 1983 (Mills 1982, 1983, 1984). An estimated 503 northern pike were harvested in Volkmar Lake during 1985, 657 during 1986, 224 during 1987, and 255 during 1988 (Mills, pers. commun. 1990[1]).

The research program on northern pike in Volkmar Lake began in 1985 with initial efforts centered on obtaining an abundance estimate. Abundance of northern pike over 449 mm in June 1985 was 4,020 fish (SE = 250; Peckham 1986). Abundance of northern pike in Volkmar Lake over 299 mm was 8,053 fish (SE = 2,341) in June 1986 (Peckham and Bernard 1987) and 6,998 fish (SE = 1,278) in May 1987 (Clark and Gregory 1988). Densities in 1986 and 1987 were 29.5 and 25.6 fish per ha, respectively. In 1986, gear types were evaluated to identify a non-lethal, efficient sampling gear for the capture of northern pike. Seines proved to be the most effective capture gear of those evaluated (gill nets, various trap and fyke nets, and seines) for study of this northern pike population (Peckham and Bernard 1987).

T Lake (63°48′N, 143°53′W) is a remote fly-in lake located approximately 18 km north of Dot Lake village along the Alaska Highway (Figure 1). The 158 ha (390 a) lake lies at an elevation of 434 m and has a maximum depth of 17 m. The lake has two small inlets and an intermittent outlet that flows from the northeast corner into Billy Creek, a tributary of the Tanana River to the south. Near shore waters are shallow with beds of aquatic vegetation providing spawning and rearing substrate for northern pike. T Lake is typically ice-free from mid-May to early October, and spawning of northern pike generally coincides with the beginning of the ice-free period and continues for up to two weeks, into early June. Other fish species in the lake include burbot *Lota lota*, humpback whitefish, and least cisco.

Fishing pressure, although not reported to date in Mills' statewide harvest surveys', is believed to be light to moderate compared with other area waters. Life history and abundance studies of northern pike have been conducted annually since 1986 (Clark 1988, Timmons and Pearse 1989).

George Lake (63°47′N, 144°31′W) is a semi-remote 1,823 ha (4,505 a) lake located approximately 8 km northeast of the Tanana River and the Alaska Highway about 45 km southeast of the town of Delta Junction (Figure 1). The lake is accessible during the open water season by either float-equipped aircraft or boat via the Tanana River and George Creek, the outlet. Although George Creek is navigable by boat, it is shallow, requiring a boat powered with a jet unit or an outboard equipped with a lift device. Snowmachines and ski-equipped aircraft provide winter access.

George Lake lies at an elevation of 389 m and has a maximum depth of 11 m. The lake has one major inlet, six smaller inlets, a navigable outlet, George Creek, which flows to the south into the Tanana River. Near shore waters are

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[1] Mike Mills. 1990. Personal Communication. ADFG, Division of Sport Fish, RTS Section, 333 Raspberry Rd., Anchorage, Ak 99518.

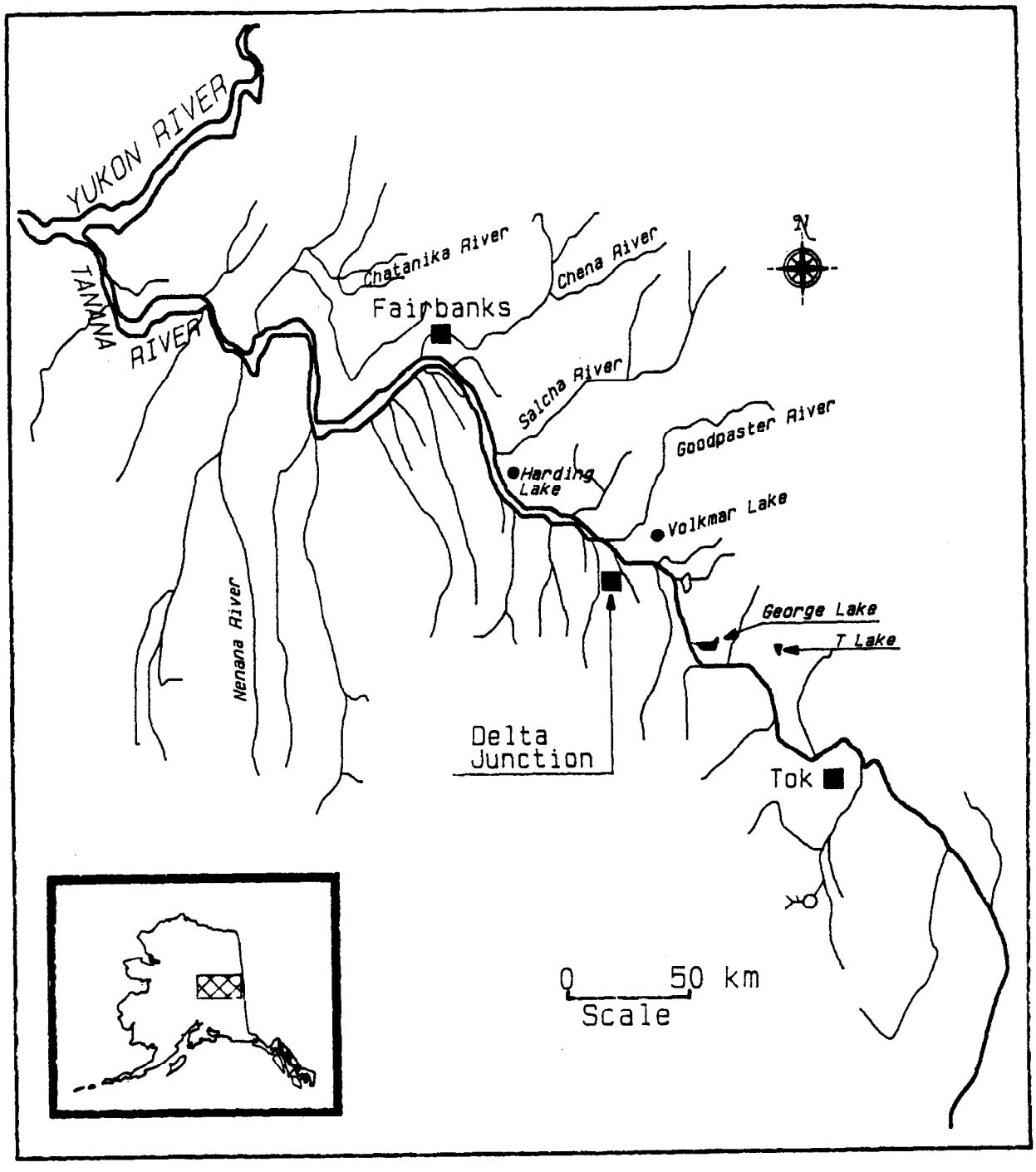

Figure 1. Location of Volkmar, T and George lakes, Alaska.

shallow with beds of aquatic vegetation providing spawning and rearing substrate for northern pike. George Lake is typically ice-free from late-May to mid-October, and spawning of northern pike generally coincides with the beginning of the ice-free period and continues for up to two weeks, into mid-June. Anglers at George Lake target northern pike, although other fish species are present including Arctic grayling *Thymallus arcticus*, burbot, humpback whitefish, least cisco, round whitefish *Prosopium cylindraceum*, longnose suckers *Catostomus catostomus*, and slimy sculpin.

Fishing pressure in George Lake for northern pike is moderate, ranging from 0.5 to 1.1 angler days annually per ha (Mills 1979-1989). Annual harvest of northern pike by recreational fishermen averaged 1,604 fish (0.88 per ha) from 1977 through 1983 and averaged 2,482 fish (1.36 per ha) from 1984 through 1986 (Mills 1979-1989). In 1986, the harvest of 3,076 northern pike (1.69 per ha) was the largest estimated for this lake. There were an estimated 2,229 (1.22 per ha) northern pike harvested in 1987 (Mills 1988) and 1,837 (1.01 per ha) northern pike harvested in 1988 (Mills 1989). Clark et al. (1988) estimated the abundance of northern pike over 299 mm FL in May 1987 to be 17,662 fish (SE = 2,105), or 9.69 fish per hectare. Timmons and Pearse (1989) estimated the abundance to be 23,381 (SE = 6,471) or 12.83 northern pike per hectare in May 1988.

Study Goals and Objectives

The goal of the project is the stock assessment and projection of sustainable yield and desirable stock composition ranges for northern pike stocks in George, Volkmar and T lakes. These assessments will be used to develop conservation regulations consistent with stock composition, harvest, and recreational use options as developed through the public management planning process for these stocks, as well as for stocks in other Alaskan lakes and rivers.

Specific objectives of the 1989 research program were to estimate:

1. abundance of northern pike (299 mm FL and longer) in Volkmar, T, and George lakes during May 1989; and,

2. sex, length, and age compositions of northern pike populations in each lake.

In addition, the program in 1989 addressed left-over objectives from 1988 (the F-10-4 contract), which were to estimate the abundance (299 mm FL and longer) and population composition of northern pike in Volkmar Lake during May 1988. These objectives were not achieved at the close of the F-10-4 contract, and consequently were addressed in the F-10-5 contract. The program in 1989 also addressed: mean length-at-age of the 1988 Volkmar Lake northern pike population; survival rates and recruitment rates of northern pike from 1985 to 1988 at Volkmar Lake; and, survival rates and recruitment of northern pike from 1987-1989 at George Lake.

METHODS

Study Design

Population sampling and mark-recapture experiments for northern pike were conducted in three lakes (George, T, and Volkmar) from mid-May to early June, 1989. Prior experience indicated that population studies of northern pike in interior Alaskan lakes are best conducted during the spawning period immediately following spring ice melt when northern pike are concentrated and low water temperatures minimize temperature-sensitive handling injuries (Peckham and Bernard 1987, Clark 1988). In George Lake during 1989, two discrete sampling events occurred: a six-day event (31 May to 5 June) and a four-day event (9 June to 12 June). In T and Volkmar lakes, instead of two distinct events, sampling was continuous from 18 May to 26 May in T Lake and from 19 May to 29 May in Volkmar Lake because of unanticipated low catches. Sample sizes were determined according to procedures in Robson and Regier (1964). An additional sampling event took place in T Lake between 20 August and 23 August in conjunction with other field activities at the lake. Fish were captured in all three lakes with a bag seine, 66 m long and 3 m deep with 25 mm square mesh, set from a boat and retrieved by hand to the shore by a crew of four or five. Gill nets and hook and line were also used in T Lake to capture northern pike because of limited success with seines (for additional gear specifications and gear fishing patterns see Peckham and Bernard 1987).

Data Collection

All age, sex, length, tag, and fins clipped were recorded on Tagging Length Version 1.0 mark-sense forms during the sampling process. As required, one or more new forms were processed for each seine haul or gill net set per day during which northern pike were successfully captured. Hauls or sets were numbered sequentially through the experiment, regardless of success of capture. Location of each haul or set was recorded on maps (Figures 2-4) with a separate map used each sampling day. Each lake was divided into parts for later hypothesis tests for mark-recapture experiments.

Because past studies have shown that subsamples of length, sex, and age measurements from northern pike taken in seines can be biased toward larger fish (Clark 1988), all fish captured in both events were measured for fork length to the nearest millimeter, sex recorded if determined, and scale samples were taken. Northern pike were released at least 100 m away from the capture location. Of all fish captured and released with marks, no more than 50% were taken in any one sampling area.

All captured northern pike were examined for tags and missing fins. Fish captured in this long-term study have been double marked to aid in detecting within and between year's tag loss. Marking codes used in all lakes during 1989, plus those from prior sampling events, are detailed in Appendix A1. Untagged northern pike judged to be in a healthy condition were released after being marked with a Floy FD-68 internal anchor tag inserted posteriorly at the base of the dorsal fin during all sampling events. A hole on the left opercle cover of each fish was created with a standard paper punch as a second mark. The importance of identifying all fin clips was stressed to field crews. When

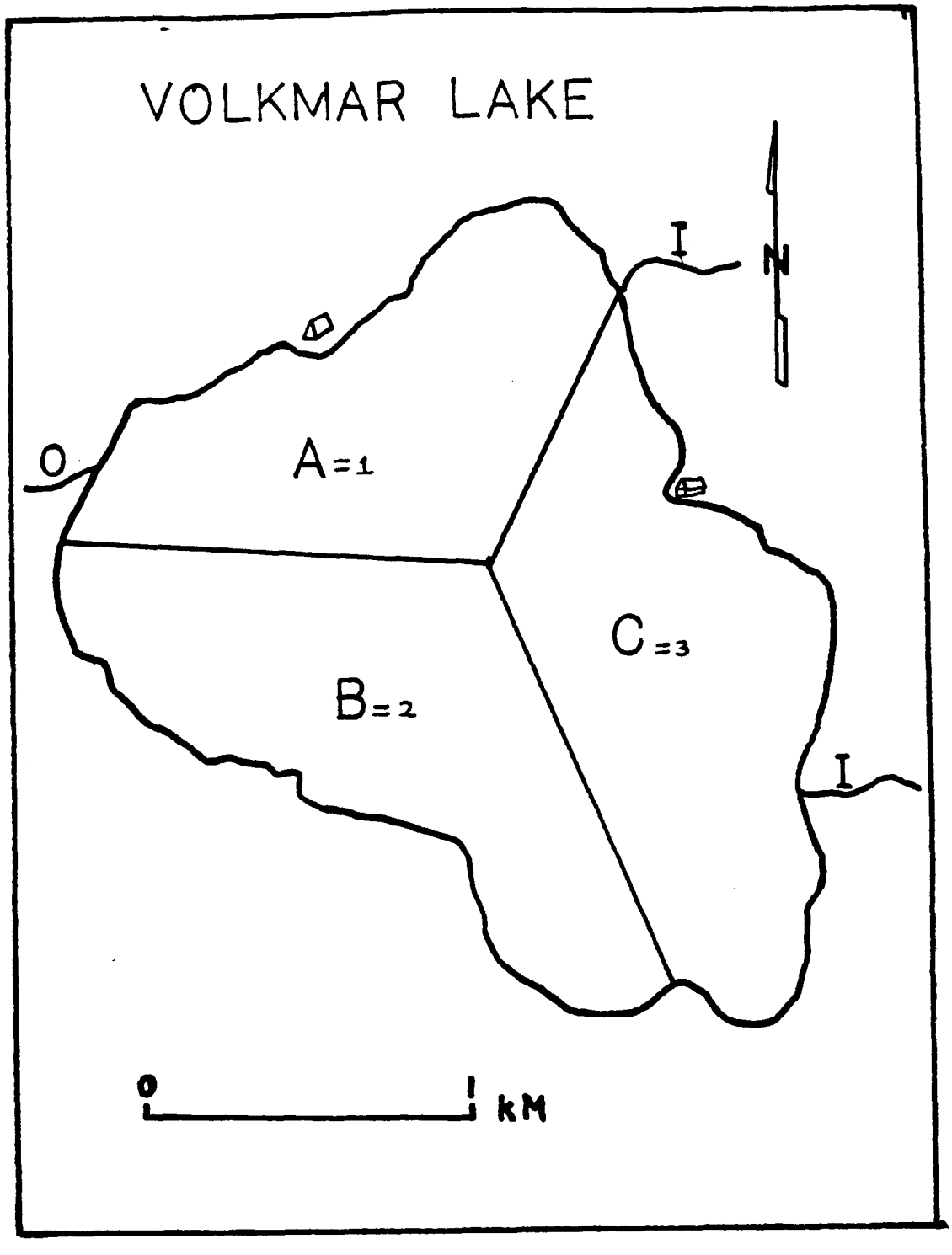

Figure 2. Sampling areas in Volkmar Lake, Alaska.

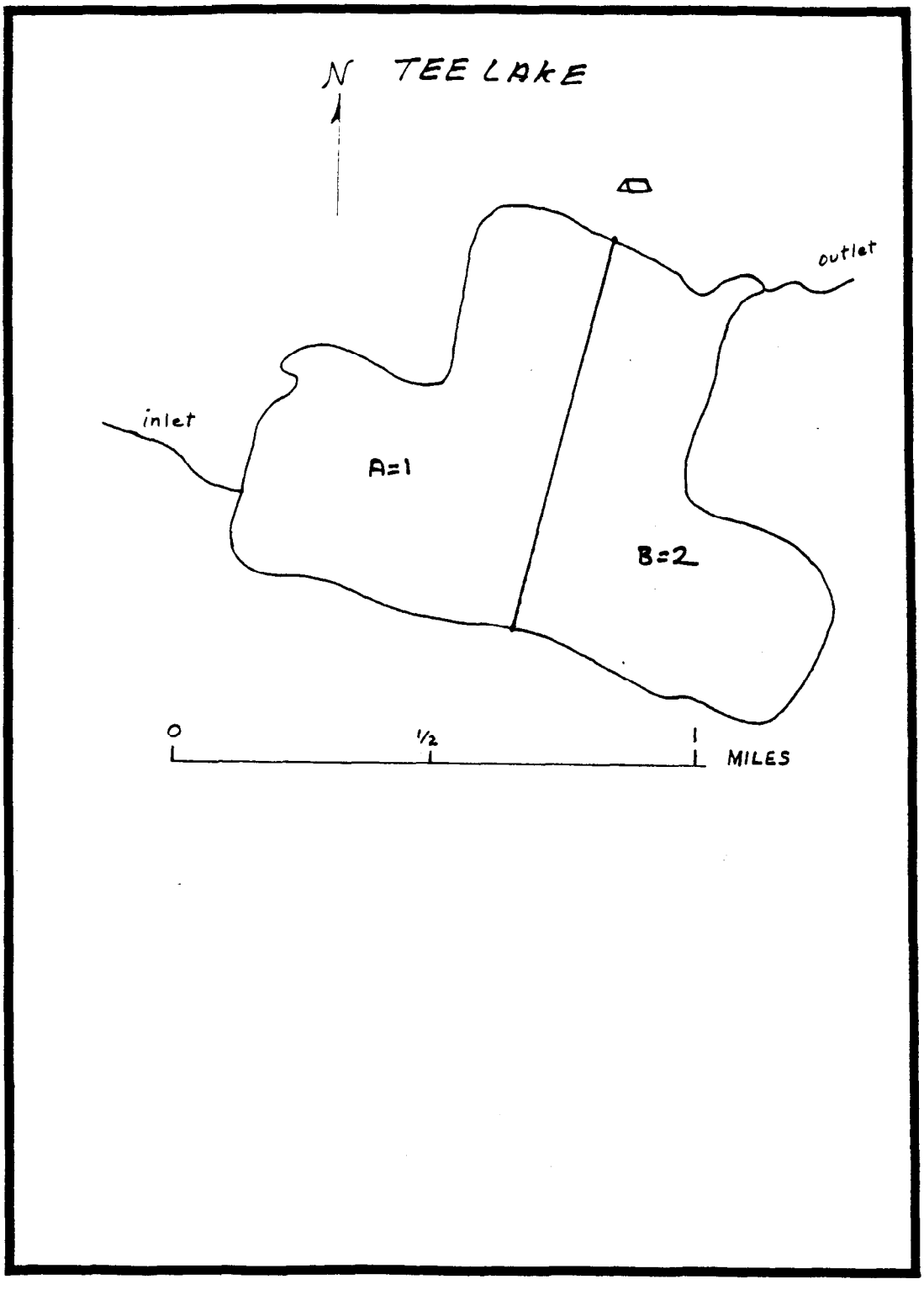

Figure 3. Sampling areas in T Lake, Alaska.

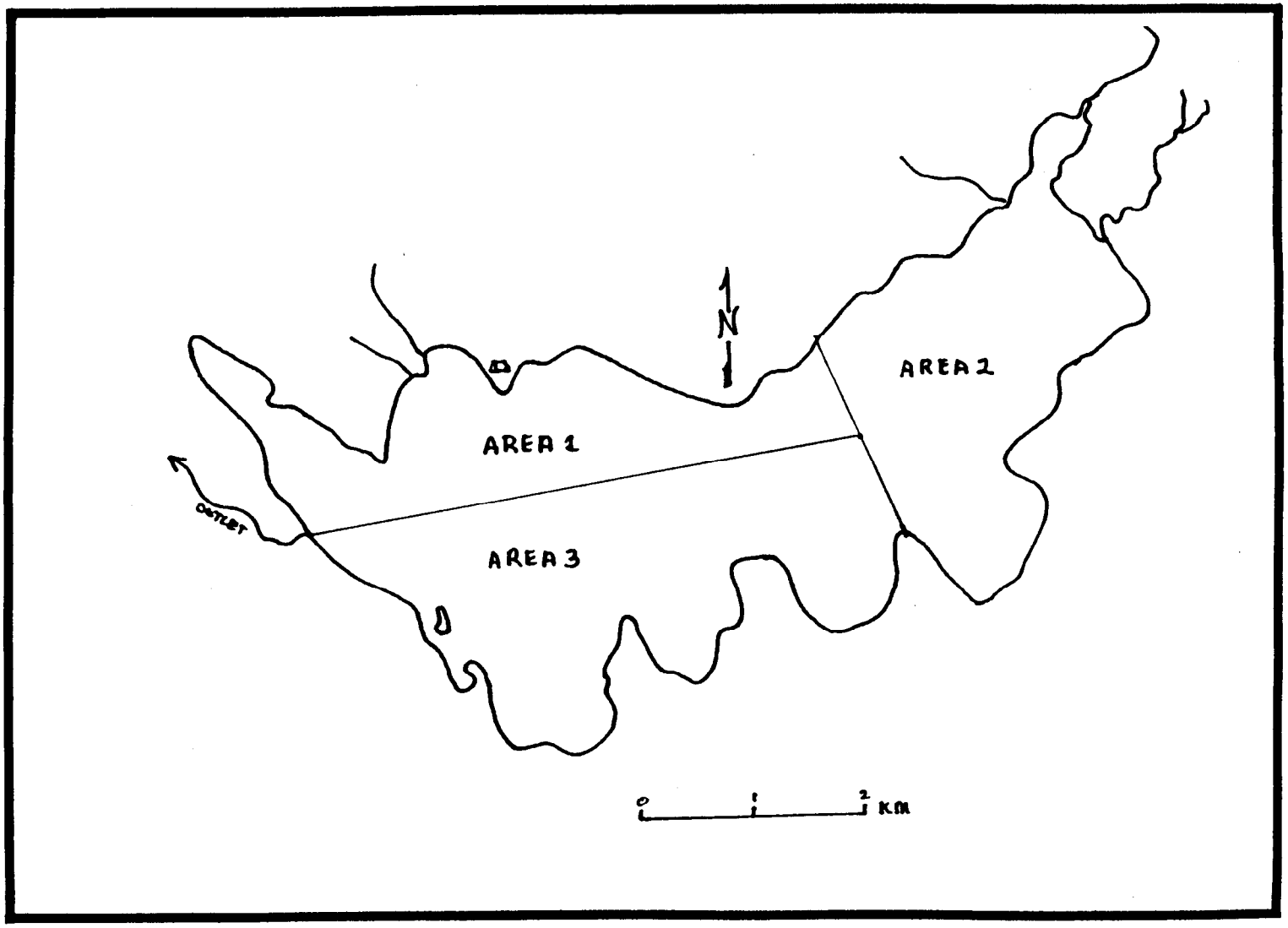

Figure 4. Sampling areas in George Lake, Alaska.

possible, the sex of each live fish was determined by the presence of sex products or by external characteristics as described in Casselman (1974). Fish for which sex could not be determined were recorded as neither male nor female.

Scales were removed from each live fish when first caught. A minimum of five scales were taken from the preferred zone adjacent to but not on the lateral line above the pelvic fins as described by Williams (1955). Scales were placed in individual coin envelopes marked with the appropriate mark-sense form litho code and sample number. Scales were removed from coin envelopes in the laboratory, cleaned, and two non-regenerated scales per fish were mounted on gummed cards. The cards were used to make scale impressions on 20 mil acetate sheets using a Carver press at 137,895 kPa (20,000 psi) heated to 93°C for 45 seconds. Scales were read on a Micron 770 microfiche reader and ages recorded in accordance with age identification criteria established by Williams (1955) and Cassleman (1967). Because experience has shown that the formation of scale annuli in Alaskan stocks of northern pike generally coincides with or closely follows our sampling period in late May during spawning, ages were assigned to match the observed annuli. In the case of excessive circuli plus growth, a year was added. All dead fish were dissected to verify sex and maturity through examination of the gonads. Scales, vertebrae, and cleithra were taken from each dead fish for later determination of age, and stomach contents were noted.

Data Analysis

Data collected for northern pike in Volkmar, T and George lakes were analyzed for abundance and age, sex and length compositions.

Abundance Estimation:

The modified Petersen mark/recapture population estimator (Chapman 1951), and the approximate variance of this estimate, as taken from Seber (1982), are:

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

$$\hat{V}[N] = \frac{\hat{N}(C-R)(M-R)}{(R+1)(R+2)}; \qquad (2)$$

where:

C = number of fish captured during recapture event;

M = number of fish marked during marking event; and,

R = number of fish recaptured during recapture event.

Assumptions necessary for the accurate use of this estimator are (Ricker 1975):

1. recruitment between sampling events (emigration, immigration, and growth) is negligible;

2. marking does not affect the later catchability of fish (no trap sensitivity or differential natural mortality);

3. fish do not lose their marks between sampling events;

4. all marked fish are reported when recaptured; and,

5. all fish have an equal probability of being marked and released during the first sampling event, or all fish have an equal probability of being captured during the second sampling event, or marked and unmarked fish mix completely between events.

Whenever size-selectivity of sampling gear was detected, the population was divided (stratified) into length groups, and abundance was estimated separately for each stratum (as suggested by Ricker 1975).

The above assumptions for the Petersen estimator are for a population closed to recruitment and mortality. Whenever a population was not so closed, a non-parametric test designed by Robson and Flick (1965) was used to detect and cull significant growth recruitment. Abundance was adjusted and estimated as:

$$\hat{N} = (M + 1)\,(\bar{u}_r + 1) - 1; \tag{3}$$

$$\bar{u}_r = \frac{\sum_{i=r}^{R} u_i}{a}; \tag{4}$$

$$\hat{V}[N] = (M + 1)^2\, V[\bar{u}_r]; \text{ and,} \tag{5}$$

$$V[\bar{u}_r] = \frac{\sum_{i=r}^{R} (u_i - \bar{u}_r)^2}{a(a - 1)} \tag{6}$$

where: u_i = the number of unmarked fish of length longer than the ith largest recaptured fish but shorter than the length of the $(i + 1)$th recaptured fish;

r = the order of the recaptured fish beyond whose length no significant growth recruitment occurred;

$\bar{u}_r$ = the mean of the u_i when $i \geq r$; and,

$a = R - r + 1$.

Composition Estimation:

Abundance estimates and data pertaining to sex, length, age composition were used to apportion northern pike populations into the following categories:

1. Relative Stock Densities (RSD; Gabelhouse 1984) in "stock" (300-524 mm), "quality" (525-654 mm), "preferred" (655-859 mm), "memorable" (860-1,079 mm), and "trophy" (> 1,079 mm) length classes;

2. length frequencies by sex;

3. estimated mean length at age; and,

4. age composition by sex.

When abundance estimates were not stratified due to size-selectivity in the sampling gear, composition estimates were calculated as follows:

$$p_j = n_j/n \tag{7}$$

where:

n = the number of fish sampled for information on age, length, and sex composition;

n_j = the number of sampled fish in group j; and,

p_j = the estimated fraction of the fish in group j.

The variance of the fraction was calculated as:

$$V[p_j] = \frac{p_j(1 - p_i)}{n - 1} \tag{8}$$

The estimated number of northern pike by group was:

$$\hat{N}_j = p_j \hat{N} \tag{9}$$

The variance for $\hat{N}_j$ was a sum of the exact variance of a product from Goodman (1960):

$$\hat{V}[\hat{N}_j] = V[p_j]\hat{N}^2 + V[\hat{N}]p_j^2 - V[p_j]V[\hat{N}]) \quad (10)$$

Whenever abundance estimates were stratified because of size selectivity in the sampling gear, estimates of length and age compositions were calculated as follows:

$$p_{ij} = n_{ij}/n_i \quad (11)$$

where:

n_i = the number sampled from stratum i in the mark-recapture experiment;

n_{ij} = the number sampled from stratum i that belong to group j; and,

p_{ij} = the estimated fraction of the fish in group j in stratum i.

Note that $\sum_j p_{ij} = 1$. The variance for p_{ij} is:

$$V[p_{ij}] = \frac{p_{ij}(1 - p_{ij})}{n_i - 1} \quad (12)$$

The estimated abundance of group j in the population (N_j) is

$$\hat{N}_j = \sum_i p_{ij} \hat{N}_i \quad (13)$$

where: N_i = the estimated abundance in stratum i of the mark-recapture experiment. The variance for N_j is a sum of the exact variance of a product from Goodman (1960):

$$\hat{V}[\hat{N}_j] = \sum_i (V[p_{ij}]\hat{N}_i^2 + V[\hat{N}_i]p_{ij}^2 - V[p_{ij}]V[\hat{N}_i]) \quad (14)$$

The estimated fraction of the population that belongs to group j (p_j) is:

$$\hat{p}_j = \hat{N}_j/\hat{N} \quad (15)$$

where: $N = \sum N_i$. The variance of the estimated fraction was approximated with the delta method (see Seber 1982):

$$V[p_j] \approx \sum_i V[p_{ij} \left[\frac{\hat{N}_i}{\hat{N}} \right]^2 + \frac{\sum_i \{V[\hat{N}_i] (p_{ij} - p_j)^2\}}{\hat{N}^2} \quad (16)$$

Length frequencies were compensated for the size selectivity of gear and for growth recruitment as described above.

Survival and Recruitment:

Survival rates and recruitment were calculated as by-products of the estimation of abundance for populations in Volkmar and George lakes. Age-specific survival rates were calculated as follows:

$$\hat{S}_t = \frac{\hat{N}_{t+1,y+1}}{\hat{N}_{t,y}} \qquad (17)$$

where: S_t = the survival rate of fish age t in year y to age t+1 one year later.

The variance of S_t was approximated with the delta method (see Seber 1982, pp.7-9):

$$V[S_t] \approx S_t^2 \left[\frac{\hat{V}[N_{t+1,y+1}]}{\hat{N}^2_{t+1,y+1}} + \frac{\hat{V}[N_{t,y}]}{\hat{N}^2_{t,y}} \right] \qquad (18)$$

Age-specific survival rates were estimated for northern pike ages 5 through 9.

Survival rates for northern pike fully recruited to the sampling gear (age 5) were also calculated. Inspection of modes in length frequency of samples taken this and past years, and analysis of size-selectivity in sampling gear indicated that fish of age 5 are fully recruited. Therefore, estimated abundance of all fish of ages 5 through 8 in year y and all fish of ages 6 through 9 in year y+1 were used in equations similar to (17-18) to estimate survival rate and its variance. Numbers by age group were not summed to estimate abundance, but compositions (p_i) data were redefined into two groups (ages 5 through 8 vs. ages 4 and younger in year y and ages 6 through 9 vs. ages 5 and younger in year y+1), and abundance estimates were partitioned into these two groups with Equations 11-16.

RESULTS

Volkmar Lake

Abundance of northern pike in 1989 in Volkmar Lake was not estimated as planned because catchability of fish in seines declined before the end of the first sampling event. Of the 607 northern pike captured in the ten-day sampling event, 198 had been marked in previous years and 92 were captured and recaptured at least once within the ten-day period. No fish died during sampling. Without a mark-recapture experiment in 1989 to gauge size-selectivity of sampling gear, no means were available to ensure accurate estimates of compositions that were directly or indirectly based on length.

Therefore, no compositions were estimated. In the sample, the female to male sex ratio was 2.8 to 1.

Estimated abundance of northern pike in May 1988 was 2,766 (SE = 177). Since only one sampling event was conducted in 1988 (Timmons and Pearse 1989), information collected in 1989 was used as the second sampling event (Table 1). The population was stratified to minimize any effect of size-selectivity of sampling gear in 1988 and to facilitate the culling of recruits from samples taken in 1989. Estimated density of northern pike in 1988 was 10 per ha (4.1 per a).

Estimates of length and age compositions and RSD for 1988 showed a population of small, young fish near the size and age of recruitment to the sampling gear. In 1988, northern pike in the stock category were most abundant (48%), with few pike in the memorable (> 860 mm) and above categories (Table 2). The population appeared normally distributed (Figure 5). Mean length-at-age (sexes combined) for the 1988 sampling event indicates estimated mean lengths-at-age increased significantly through age 7; there was a slight but insignificant increase in the point estimate from age 7 to 8 (Table 3). The sex-combined age composition and cohort abundance for the 1988 sampling event suggests northern pike in Volkmar Lake fully recruit to the gear (seines) by age 5 at a mean length of 517 mm (Table 3). Some northern pike recruit as early as age 2; the oldest northern pike aged was 12 years old. An estimated 56% of the total population (2,766), and 75% of the fully recruited population (2,078) was comprised of age 5 and 6 fish; an estimated 19% of the total 1988 Volkmar lake northern pike population was age 7 and older. The sex composition in May 1988 was not determined, due to the low number of the sampled fish (56 out of 478) that were assigned sex, and to a variable sex proportion by length strata.

Estimated annual grouped-cohort survival rates from 1985 to 1988 for northern pike (sexes combined) in Volkmar Lake show a steady decline from 1985, dropping from 71% between 1985 and 1986 to 36% between 1987 and 1988 for age 5 through 8 northern pike (Table 4). Recruitment, established as the estimated abundance of the age 5 cohort for a given year, increased from 1,238 in 1985 to 1,914 in 1987, and then fell to 781 northern pike in 1988.

T Lake

Abundance of northern pike and composition of the population in T Lake for 1989 could not be estimated due to insufficient numbers of fish captured. Eighty-seven unique northern pike over 299 mm were captured in May of 1989. Seventy-nine were released unharmed, six were sacrificed and two died from handling. Without a mark-recapture experiment with which to measure any size-selectivity in sampling gear, there was no way to ensure accurate estimates of any compositions based directly or indirectly on the size of northern pike, therefore no compositions were estimated. Between 18 May and 22 May, 26 (30%) of the fish were caught with seines; between 23 May and 26 May an additional 61 (70%) were caught with gill nets, including the two that died from handling. Of the 87 captured, 65 (76%) had been tagged in prior years' sampling events. Abundance of northern pike in 1989 will be estimated with a two-year Petersen estimator as a byproduct of the 1990 sampling event.

Table 1. Components of the 1988 Volkmar Lake abundance estimate.[a]

Fork Length (mm)	No. Captured 1989	No. Recaptured 1989	No. Released 1988	$\hat{n}$ 1988	$\hat{SE}[n]$ 1988	$\bar{u}_r$	$V[\bar{u}_r]$
300-525	244	14	230	1,478[b]	127	6.5	42.9
526-675	262	48	198	1,068[c]	118	–	–
676-1,000	101	18	40	220[c]	33	–	–
Total	607	80	468	2,766	177		

[a] Source: Pat Hansen, Sport Fish Research and Technical Services unit.
[b] Petersen estimate with Robson and Flick (1965) correction.
[c] Petersen estimate.

Table 2. Relative Stock Densities (RSD), expressed as percentages, of northern pike in Volkmar, T, and George lakes in 1986, 1987, 1988, and 1989.[a]

	1986		1987		1988		1989	
	RSD	SE	RSD	SE	RSD	SE	RSD	SE
Volkmar Lake[b]								
Stock	58.7	0.5	66.0	0.6	48.2	3.2	-	-
Quality	33.8	0.5	27.3	0.3	38.3	3.0	-	-
Preferred	6.9	0.3	6.1	0.3	12.8	1.4	-	-
Memorable	0.6	0.1	0.6	0.9	0.7	0.3	-	-
Trophy	0.0		0.0		0.0	-	-	-
T Lake[b]								
Stock	13.4	1.6	39.8	2.9	37.3	3.0	-	-
Quality	44.3	2.4	26.7	2.6	34.7	2.9	-	-
Preferred	40.9	2.3	31.7	2.8	25.8	2.7	-	-
Memorable	1.4	0.5	1.8	0.8	2.2	0.9	-	-
Trophy	0.0		0.0		0.0		-	-
George Lake								
Stock	69.3	2.4	74.3	1.6	64.2	1.5	60.0	1.4
Quality	22.1	2.2	20.9	1.5	26.5	1.4	32.6	1.3
Preferred	8.3	1.5	4.7	0.8	8.9	0.9	7.2	0.7
Memorable	0.3	0.3	0.0		0.4	0.2	0.2	0.1
Trophy	0.0		0.0		0.0		0.0	0.0

[a] Stock = 300-524 mm, quality = 525-654 mm, preferred = 655-859 mm, memorable = 860-1,079 mm, and trophy = 1,080 mm and larger.

[b] Estimates of abundance were not available for Volkmar and T Lakes in 1989.

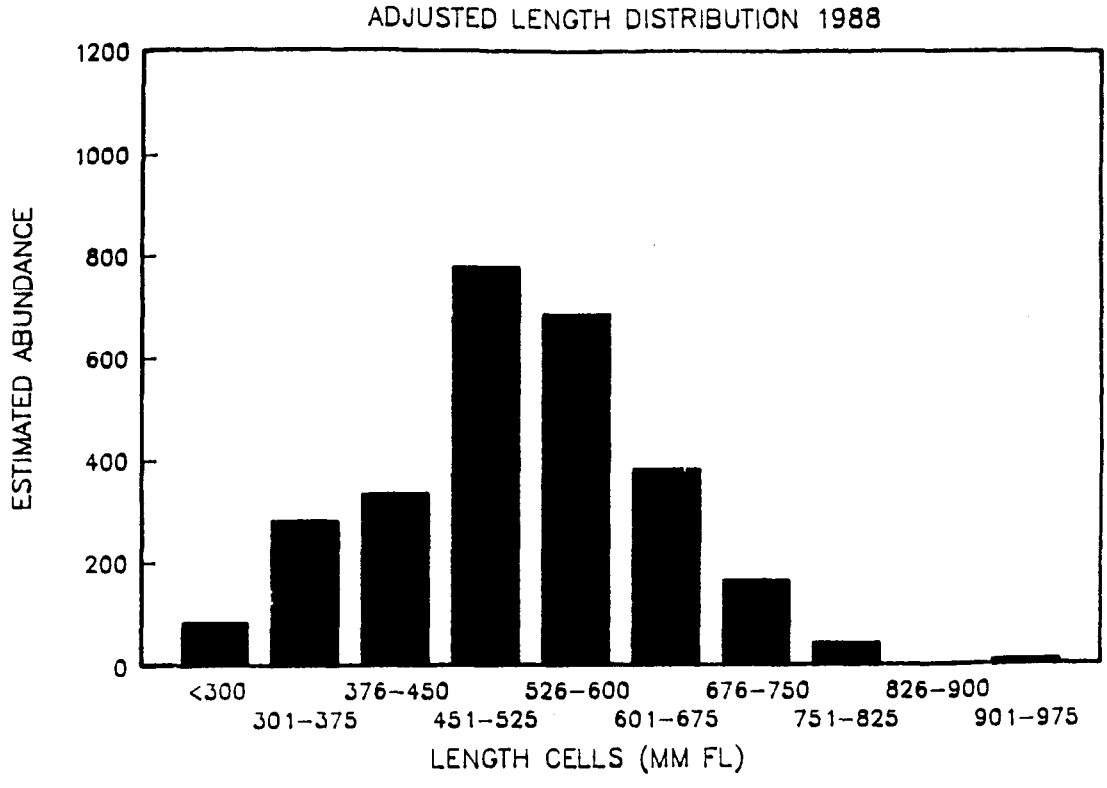

Figure 5. Adjusted length frequency distribution of northern pike in Volkmar Lake, 1988.

Table 3. Length-age composition of northern pike (> 299 mm) in Volkmar Lake in 1989.

Age	n	Mean Length At Age Length	SE	Proportion	SE	Estimated Abundance	SE
All Fish							
2	2	318	13	<0.01	<0.01	12	10
3	27	362	12	0.06	0.01	167	37
4	82	441	8	0.18	0.02	509	67
5	126	517	6	0.28	0.02	782	80
6	125	569	6	0.28	0.02	775	77
7	53	624	13	0.12	0.01	329	44
8	18	642	23	0.04	0.01	112	25
9	5	627	25	0.01	<0.01	31	12
10	7	737	38	0.02	0.01	43	15
11	0	-	-	0.00	0.00	0	0
12	1	972	-	<0.01	<0.01	6	6
13	0	-	-	0.00	0.00	0	0
14	0	-	-	0.00	0.00	0	0
15	0	-	-	0.00	0.00	0	0
Total	446			1.00		2,766	177

Table 4. Estimates of grouped-cohort survival rates and recruitment in Volkmar Lake, 1985-1988.

Year	Year Classes	Age	N	SE[a]	Survival[b] Rate	SE	Recruitment	SE
1985	1977-80	5-8	3,280	220	---	---	1,238	137
	1976-79	6-9	2,419	184	---	---		
1986	1978-81	5-8	3,448	507	---	---	1,357	375
	1977-80	6-9	2,334	358	0.71	0.12		
1987	1979-82	5-8	3,474	383	---	---	1,914	340
	1978-81	6-9	1,678	179	0.49	0.09		
1988	1980-83	5-8	1,997	121	---	---	781	80
	1979-82	6-9	1,247	92	0.36	0.05		

[a] Maximum estimated standard error (SE) due to underestimated covariance between estimated cohort abundances. Variances summed across cohorts.

[b] Derived by dividing the abundance of given year classes by the abundance of those same year classes a year earlier.

In 1988, to validate methods of determining age of northern pike, an experiment was initiated in T Lake. Of 257 tagged northern pike released that year, 148 (58%) were injected with oxytetracycline to implant the bony structures (otoliths, cliethra, and vertebrae) with a fluorescing age-dependent mark to permit subsequent known age determination (per methods described by McFarlane and Beamish 1987). Of those marked, 39 (26%) were recaptured in 1989; six were autopsied and age structures collected for subsequent examination. After cursory examination of structures with Ultra Violet (UV) light, no marks were visible under a 30x microscope. However, more in-depth examination of the structures is needed and will be performed in the near future following the collection of additional samples

George Lake

The estimated abundance of northern pike over 299 mm FL in George Lake was 25,466 (SE = 3,157), a density of 14 northern pike/ha (5.7/a). During the first sampling event, 1,234 unique northern pike were captured and released. After a three-day hiatus in sampling, 1,195 northern pike were captured and examined (57 were recaptures from the first event). Less than 6% of recaptured fish had lost their tags. Since fractions of northern pike with marks captured during the second sampling event were not significantly different among the three lake sampling areas (χ^2 = 0.27, df = 2, 0.95 < 0.98), it was concluded that marked fish mixed completely between sampling events or probabilities of capture during the first sampling event were the same throughout the lake. Comparison of the length distribution of fish marked during the first sampling event with the length distribution of fish recaptured during the second showed that size-selectivity in the sampling gear during the second sampling event was negligible (Kolmogorov-Smirnov two-sample test, D = 0.13, n = 1,292, P = 0.32). However, the length distribution of all fish captured during the second sampling event was significantly different than the length distribution from the first event (Kolmogorov-Smirnov two-sample test, D = 0.06, n = 2,429, P = 0.03), indicating size-selectivity in the sampling gear during the first event. Therefore, all compositions were estimated with data collected during the second sampling event.

Northern pike in the stock category of RSD were most abundant (60%), with decreasing proportions noted for quality (33%) and preferred (7%) categories. Few fish fell into the memorable and trophy (<1%) classifications. Those fish classified as female (n = 663) showed a length frequency peak around 525 mm; males (n = 318) showed a peak between 400 mm and 425 mm; all sexes (n = 1,222), including "sex unknown", had lengths that ranged from 275 mm to 850 mm with a peak around 475 mm (Figure 6).

The population was comprised of primarily females (13,817; 54%), which outnumbered males (6,627; 26%), and those unclassified northern pike identified as "sex unknown" (5,022; 20%; Table 5). Females ranged in age from 2 through 13 with a peak at age 5 (27%; Table 5), while males ranged from age 2 through 8 and peaked at age 4 (36%). For sexes combined, including "sex unknown" fish, ages ranged from 2 through 13, with a peak at age 4 (28%). Table 6 also contains statistics on cohort abundance, which reflects age-group proportions of the population estimate, by both sex and sexes combined.

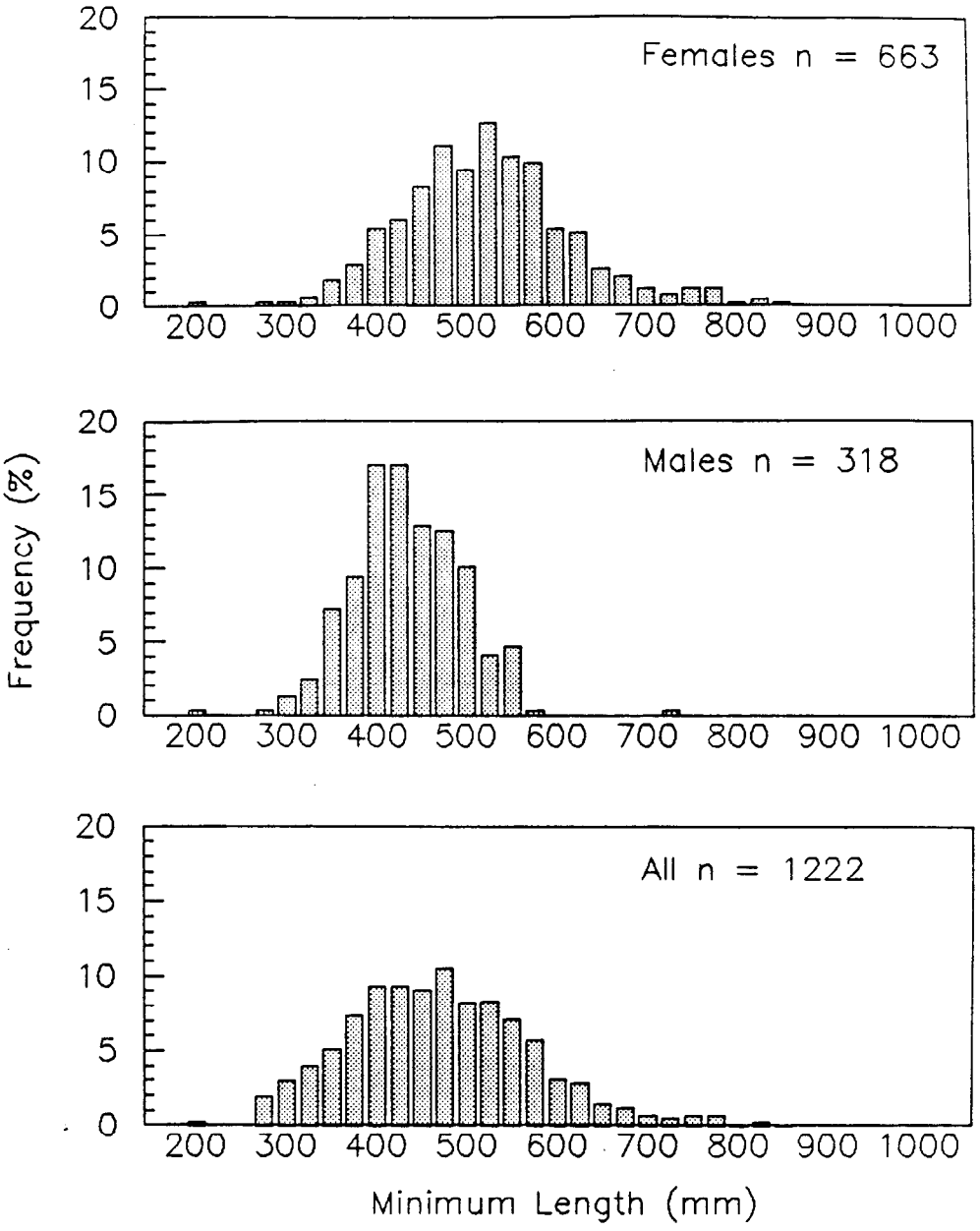

Figure 6. Length frequency distribution of northern pike in George Lake, 1989.

Table 5. Sex-length-age composition of northern pike (> 299 mm) in George Lake in 1989.

Age	Mean Length At Age Length	SE	n	Proportion	SE	Estimated Abundance	SE
Females							
2	317	18	1	<0.01	<0.01	57	57
3	413	4	25	0.10	<0.01	1,433	325
4	468	3	56	0.23	0.02	3,211	552
5	529	3	65	0.27	0.03	3,727	614
6	571	4	34	0.14	0.03	1,949	395
7	612	5	30	0.12	0.02	1,720	364
8	643	7	14	0.06	0.02	803	231
9	719	8	10	0.04	0.02	573	191
10	766	28	1	<0.01	0.01	57	57
11	806	20	2	0.01	<0.01	115	82
12	846	21	2	0.01	0.01	115	82
13	801	28	1	<0.01	0.01	57	57
Total			241			13,817	1,750
Males							
2	307	18	1	<0.01	0.01	43	43
3	421	5	18	0.12	0.03	770	198
4	439	3	56	0.36	0.04	2,394	407
5	470	3	43	0.28	0.04	1,838	340
6	501	5	21	0.14	0.03	898	217
7	532	6	13	0.08	0.02	556	164
8	544	13	3	0.02	0.01	128	75
Total			155			6,627	881
All Fish[a]							
2	324	5	13	0.03	0.01	672	201
3	384	2	84	0.17	0.02	4,339	688
4	444	2	140	0.28	0.02	7,232	1033
5	500	2	118	0.24	0.02	6,095	899
6	542	3	62	0.13	0.01	3,203	548
7	588	4	43	0.09	0.01	2,221	423
8	625	6	17	0.03	0.01	878	235
9	718	8	10	0.02	0.01	517	173
10	766	28	1	<0.01	<0.01	52	52
11	806	20	2	<0.01	<0.01	103	74
12	846	21	2	<0.01	<0.01	103	74
13	801	28	1	<0.01	<0.01	52	52
Total			493			25,466	3,157

[a] Includes females, males, and "sex unknown fish".

Table 6. Estimates of grouped-cohort survival rates and recruitment in George Lake, 1985-1988.

Year	Year Classes	Age	n	SE	Survival Rate	SE	Recruitment	SE
1987	1979-82	5-8	7,998	999	---	---	3,832	520
	1978-81	6-9	5,061	662	---	---	---	---
1988	1980-83	5-8	9,691	2,708	---	---	3,681	1,055
	1979-82	6-9	6,328	1,783	0.79	0.24		
1989	1981-84	5-8	12,397	1,639	---	---	6,095	899
	1980-83	6-9	6818	984	0.70	0.22		

Survival rates for the 1979-82 year classes (age 5 through 8) were estimated at 0.79 (SE = 0.24) between 1987 and 1988 (Table 6). Survival for the 1980-83 cohorts was estimated at 0.70 (SE = 0.22) between 1988 and 1989. Recruitment (the estimated annual abundance of age 5 northern pike) was similar from 1987 to 1988 (3,832 fish in 1987 and 3,681 fish in 1988), then rose markedly from 3,681 fish in 1988 to an estimated 6,095 northern pike in 1989.

DISCUSSION

Sampling Methods

Sampling of northern pike in interior Alaskan waters continues to be successful for most annual events. Timing of spawning appears to critically affect sampling success, as was the was case during the spring 1989 sampling events in both Volkmar and T lakes. In Volkmar Lake, even though sampling was conducted immediately (within two days) following breakup (some ice remained on the lake), capture rates declined rapidly as sampling progressed. Determining the sex of captured fish was difficult since most fish were in post-spawning condition. Similar timing produced similar results at T Lake.

Volkmar and T lakes are accessible only by float-equipped aircraft or helicopter during the desired sampling period, therefore some open water is required for logistic support with the current method (float plane). Overflights of these two lakes prior to breakup in 1989, and in other years, have indicated that some pre-breakup spawning probably occurs along shore margins subject to early melt. That, and factors that contribute to a rapid rise in surface water temperatures (bright sunlight, warm air temperatures, calm winds), are believed to quickly warm the spawning areas and stratify the lake, thus abbreviating the spawning period compared to cooler, more prolonged breakups. Catch success with the use of seines or gill nets is dependent upon either good concentrations of spawning northern pike or fish movement in nettable areas, generally less than 2 m deep. Apparently, northern pike in lakes often disperse to depths or unnettable areas after reproducing to rest and feed, and thus escape capture. Not only does availability affect catch success, but it may affect the mixing of marked and unmarked northern pike, which in turn complicates estimation of abundance and composition. By sampling earlier (during breakup) within one season, or by conducting the mark-recapture experiment over two spawning events, the problems of fish availability, accurate sex identification, and incomplete mixing may be minimized. The effectiveness (cost/data quality) of this method (two-season Petersen versus a single season Petersen estimate) and the biometric adjustments necessary to correct for between-year growth recruitment and mortality require evaluation.

Volkmar Lake

Abundance of northern pike (>299 mm FL) in Volkmar Lake has steadily declined since 1986. Peckham and Bernard (1987) estimated the abundance in June 1986 at 8,053 (SE = 2,341), and Clark and Gregory (1988) estimated the abundance in

May 1987 to be 6,998 (SE = 1,278). The estimate for May of 1988 was 2,767 (SE = 177).

The composition of the population has also changed. Sex composition estimates are not available for 1988. However, Clark and Gregory (1988) noted a decline between 1985 and 1987 of medium-sized (450-749 mm) males and large (>749 mm) females, but saw an increase of medium-sized females. Sex-dependent data for Alaskan northern pike must be evaluated with caution, however, as classification of live fish is probably dependent upon investigator experience and proximity to the spawning event, and therefore is subject to error.

Clark and Gregory (1988) described length frequency peaks for the northern pike population of between 500 mm and 599 mm for the years 1983 to 1986. In 1987, the length frequency flattened, with weak bimodal peaks approximately between 275 mm to 375 mm and again between 500 mm and 600 mm. The 1988 length frequency (Figure 5) peaked between 450 mm and 600 mm, with few fish below 300 mm and above 750 mm. Approximately 54% of the 1988 population was between 450 mm and 600 mm, compared with 49% in 1985, 45% in 1986, and 35% in 1987. The apparent higher percentage in 1988 is due to a lower abundance of fish in smaller and larger length groups compared with other years. Relative Stock Density of length group proportions have also changed between 1986 and 1988 (Table 2). Stock percentage has declined from 58.7% to 48.2%; quality rose from 33.8% to 38.8%; preferred rose from 6.9% to 12.8%; memorable percentages remained low but stable at 0.7%; and, no fish were captured in the trophy category. This reflects a length composition "clumping" in the middle size ranges in 1988, compared with previous years.

Cohort abundance estimates, available for the years 1985-1987 (Clark and Timmons 1988) and for 1988 (Table 3), indicate that the abundance of northern pike over ages 5 (fully recruited) dropped from 4,020 in 1985 to 2,078 in 1988. Estimates of abundance for northern pike age 5 through 8 (Table 4), though not tested for statistically significant differences, indicate decreased survival rates (71% to 36%) between 1985 and 1988. There are no known environmental changes that have accounted for such a decline. The reported sport harvest for those years (Mills, pers. comm.[2]), was 503 (1985), 657 (1986), 224 (1987), and 255 (1988). The magnitude of the reported harvest, in light of the estimated recruitment, is unlikely to have caused the entire population decrease. The reported harvest, which averaged 0.83 fish per angler day for these years, does not directly reflect the size and age composition of the catch, but could, if applied to fish of ages 5 and older, account for the decline in their abundance and the decrease in survival rates through increases in fishing mortality. The accuracy of harvest estimates for Volkmar Lake is unknown. Delayed hooking mortality is unknown, but has been reported by other authors to reach 11% (Falk and Gillman 1975). If anglers in Volkmar Lake individually caught and released ten or more northern pike per day, kept one, and released one that died through handling, then fishing mortality could easily be twice that reported in the estimated harvest. This could have contributed to the decline of the larger and older

[2] Mike Mills. 1990. Personal Communication. ADFG, Division of Sport Fish, RTS Section, 333 Raspberry Rd., Anchorage, Ak 99518.

portion of the northern pike population. In addition, Volkmar Lake, along with other area northern pike waters, supports an increasingly popular winter ice fishery employing hand-held lines, closely attended set-lines, and spears. The legal through-ice combination of up to two lines (with a single hook per line), plus the concurrent option to selectively spear large, hungry (female) northern pike, may have also accounted for the decline of those large, old fish.

Between 1986 and 1988, the abundance of northern pike younger than age 5 and greater than 299 mm also declined substantially from 3,983 in 1986, to 3,306 in 1987, and then to 688 in 1988. This decrease in pre-age 5 abundance indicates either a severe recruitment failure of unknown cause, an undocumented, but normal "pulsing" of population abundance due to periodically strong year classes, or less likely, gross estimation errors of cohort abundance for the years encompassing the study. Regardless of cause, the overall result of an annually increasing total mortality, in combination with variable then diminishing recruitment, has been a decline in abundance and a marked change in the composition of northern pike in Volkmar Lake since 1985. Based upon the release of marked fish in 1989, and their recapture as part of a successful two-event mark-recapture experiment conducted in May of 1990, estimates of abundance and composition for 1989 and 1990 will be developed along with further insights into the northern pike population dynamics of this lake in a report currently in preparation.

T Lake

Sampling of northern pike in T Lake was relatively unsuccessful as sample size goals were not met. However, based upon the release of marked northern pike in 1989, and their subsequent recapture as part of a successful two-event mark-recapture experiment conducted in May of 1990, estimates of abundance and composition for 1989 and 1990 will be developed along with further insights into the northern pike population dynamics of this lake in a report currently being prepared.

George Lake

The estimated abundance of northern pike in 1989 in George Lake (25,466, SE = 3,157), is the highest estimate of the three years (1987-1989) for which estimates are available. The 1987 estimate of 17,662 (SE = 2,105) (Clark et al. 1988) was followed by a population increase in 1988 to 23,381 (SE = 6,471; Timmons and Pearse 1989).

The estimated percentage of female northern pike in the George Lake population has ranged from 63% in 1986 (Clark et al. 1988) to 48% in 1989 (Table 5). Male percentages have varied from 46% in 1987 to 31% in 1989. This apparent decline in female and male percentages is probably a result of the current method of assigning sex criteria to live fish and does not reflect the actual sex composition. Starting with the 1989 field season, sex was determined only for live northern pike for which a positive sex identification could be established. This was done to accurately determine future estimates of length and age at maturity by sex. Therefore, of the 20% of the northern pike classified as "unknown" sex, an unknown percentage is comprised of a mixture

of northern pike for which sex identification is difficult: spawned-out males or immature males and females. This difficulty has been informally demonstrated in prior years by comparing pre- and post-autopsy estimates of sex. The accuracy of these estimates has often proven to be examiner-dependent. Post-spawning females can be identified with a fair degree of certainty.

The length composition of the George Lake northern pike population is changing. Historic RSD percentages (Table 2) indicate that the percentage (and hence abundance) of stock size (300-525 mm) fish decreased from a preceding three-year average of 69% to 60%, however this decrease was not tested for significance. Quality fish rose from a 23% average to 32.6%; proportions of fish in preferred and memorable categories remained stable at 7.2% and 0.2%, respectively. Again, in 1989 there were no trophy (>1,080 mm) northern pike captured in George Lake. The 1989 northern pike length frequency in George Lake (Figure 6) displayed similar sex-dependent peaks in length (males peak lower than females) as in prior years (Peckham and Bernard 1987, Clark et al. 1988, Timmons and Pearse 1989). There has been a tendency for these modes to shift upward slightly in length; such a shift could result from the advancing age of the strong year classes contributing to the peak. Bimodal peaks were evident in 1987 for both sexes, and in 1989 for George Lake females. The 1989 length frequency (sexes combined) reflects a lower abundance of fish 300 mm to 400 mm, as well as a slight decline for those northern pike above 575 mm. Mean length-at-age data from 1989 (Table 5) indicate that females generally are longer at a given age than males, as has been reported previously by Peckham and Bernard (1987), Clark et al. (1988), and Timmons and Pearse (1989). For most age classes under age 10, mean length-at-age by sex has apparently decreased since 1986. Factors such as density-dependent growth (higher density being positively correlated with slower growth), or the refinement of techniques to determine age, may account for this phenomenon.

Three age classes (ages 4, 5, 6) comprised 65% of the 1989 sex-combined George Lake northern pike population (Table 5). This slightly exceeds, for these same age groups, a value of 59% in 1988, and equals the 64% determined for the 1987 population (Clark et al. 1988, Timmons and Pearse 1989). The strongest male cohort in 1988 and 1989 was age 4; the strongest female cohort was age 4 in 1988 and age 5 in 1989. Northern pike appear to fully recruit by those respective ages in George Lake. The percentage of age 3 northern pike (all sexes) fell from 24% in 1987 to 20% in 1988 to 17% in 1989. Northern pike age 7 and greater (sexes combined) have comprised less than 15% of the population since 1987.

Factors contributing to the recent increase in the George Lake northern pike population (from 17,662 in 1987 to 25,466 in 1988) are reflected in the estimates of survival rates and recruitment (Table 6). The abundance of ages 5 through 8 northern pike increased by 55% between 1987 and 1989, due in part to the recruitment of age 5 fish during those three years and good survival rates for the fully recruited age groups. The decline in the estimated sport fishery harvest from 3,076 in 1986 to 1,837 in 1988 supported the population increase.

The direct effect, in terms of numbers, of variable seasonal fishing mortality upon the George Lake northern pike population abundance, composition, and recruitment estimates has not been fully evaluated. There has certainly been a contribution, but the net effect of reduced estimated fishing mortality upon total mortality, and hence survival, requires further examination in light of the unknown ability of the George Lake northern pike population to continue to support the popular sport fishery during and immediately after the spring spawning event. This time period is critical to northern pike that are recovering from the stress of overwintering and reproduction and are therefore especially vulnerable to handling and harvest.

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APPENDIX A

Appendix A1. Fins clipped and tag numbers used to mark northern pike in Volkmar, T, and George lakes 1983-1989.

Year	Tag Series	Color[a]	Fin Clips[b]	Comments
Volkmar Lake				
1983	16189 - 16196	Red	None	
	174 - 214	Blue		
1984	16207 - 16347	Red	None	
1985	16431 - 17568	Red	None	
1986	3000, 4000	Yellow	016, 032	032 = fish >499 mm; mostly untagged fish during marking run; mostly tagged fish during recap run. 016 = fish <500 mm; most tagged. Odd 16000, 17000 series tags from previous years.
	16000, 17000	Red	Many odd combos	
	20400 - 20454	White		
1987	25000 - 26037	White	008	
			Many odd combos	
1988	98000 - 98355	Green	064	
			Many odd combos	
1989	21000 - 21383	Green	Option 5 = 2	Left opercle punch
T Lake				
1986	3247 - 3618	Yellow	002	002 = accidental wrong clip; 004 = Mark Run; 032 = Recap Run.
			004	
			032	
1987	17569 - 17834	Red	008	
1988	99000 - 99139	Green	064	
1989	20000 - 20017	Green	Option 5 = 2	Left opercle punch
	20050 - 20058	Green	Same	
George Lake				
<1983	Jaw Tags		None	
1983	16197 - 16206	Red	None	
1984	16221 - 16305	Red	None	
1985	No Sampling			
1986	3000, 4000,	Yellow	004	Coded LV in original data.
	17000	Red		

-(Continued)-

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Year	Tag Series	Color[a]	Fin Clips[b]	Comments
1987	20000, 30000	White		
	17715		008	Most tagged fish
	17836 - 17999	Red	002	given 008; when ran out of tags, gave 002; a few tagged fish given 002.
1988	62000 - 62356	White	064	
	96000 - 97999	Green		
1989	20300 - 20999	Green	Option 5 = 2	Left opercle punch
	23000 - 23599	Green	Same	
	24000 - 24999	Green	Same	

[a] Color Codes: 01 = Not Checked, 02 = Yellow, 03 = Green, 04 = White, 05 = Red, 06 = Blue.

[b] Fin Clip Codes: 001 = Adipose, 002 = R. Pelvic (Ventral), 004 = L. Pelvic (Ventral), 008 = R. Pectoral, 016 = L. Pectoral, 032 = U. Caudal, 064 = L. Caudal, Option 5 = 2 = Left opercle punch.