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ABSTRACT

Populations of northern pike *Esox lucius* in Volkmar, George, T, and East Twin lakes in interior Alaska were studied during spawning in the spring of 1992. Multiple mark and recapture events were used to estimate the abundance of northern pike. Abundance was estimated to have been 3,888 fish > 299 millimeters fork length in Volkmar Lake in 1992 (SE = 572; 14.2 fish per hectare). Abundance of northern pike > 299 millimeters fork length in George Lake in 1992 was estimated at 9,309 fish (SE = 750; 5.1 fish per hectare). The abundance of northern pike > 299 millimeters fork length in T Lake in 1992 was estimated to have been 782 fish (SE = 75; 4.9 fish per hectare). The estimated abundance of northern pike in East Twin Lake > 299 millimeters fork length was 7,449 fish (SE = 768; 14.2 fish per hectare). Populations of northern pike in Volkmar, George, and East Twin lakes were composed primarily of stock-sized fish, while quality-sized fish predominated in the population in T Lake. It was the objective in 1992 to obtain an estimate of age composition only for northern pike in East Twin Lake; 61 percent of the northern pike sampled at East Twin Lake were age 5 or younger. Data collected since the inception of northern pike research in Volkmar, George, and T lakes is summarized. Handling mortality, for content and condition factors were determined in Volkmar and George lakes. Condition factor was not correlated with fat content in Volkmar Lake. Mortality of seined fish held up to 10 days in George Lake was insignificant (not 10%).

KEY WORDS: Northern pike, *Esox lucius*, Volkmar Lake, George Lake, T Lake, East Twin Lake, abundance, mark-recapture, length composition.

INTRODUCTION

Background

Northern pike *Esox lucius* are popular with sport anglers in Alaska. An estimated 89,777 northern pike were caught statewide during 1991, of which 29,611 (33%) were harvested (kept) according to Mills (1992). Excluding anadromous and saltwater species, northern pike ranked third in preference (following rainbow trout *Oncorhynchus mykiss* and Arctic grayling *Thymallus arcticus*) of freshwater fish both caught and harvested during 1991. In the Arctic-Yukon-Kuskokwim region (AYK) during 1991, where the highest percentage (70%) of the statewide harvest occurred (20,771), northern pike ranked fourth of fish recreationally caught as well as harvested among all species. These harvests of northern pike in the AYK region have averaged about 15,700 fish between 1977 and 1991, with a harvest range from 11,661 to 20,771, and have accounted for 75% to 90% of the statewide harvest of northern pike on an annual basis.

Within AYK, harvest of northern pike from waters of the Tanana River drainage comprised 60% (12,476 fish) of the regional harvest during 1991. Harding, George, East Twin, and Volkmar lakes, in that order, are the most popular lakes fished for northern pike in the Tanana River drainage, and accounted for 35% (4,342 fish) of the total drainage harvest during 1991.

Periodic distribution, initial assessment of stocks, and creel surveys of northern pike in the Tanana River drainage were conducted from 1971 to 1984 (Cheney 1972; Peckham 1972-1985). Research conducted at Volkmar Lake in 1985 (Peckham 1986) provided the first estimate of northern pike abundance and composition in Alaska. Research conducted from 1986 through 1992 has provided additional estimates of abundance, along with information on catch-per-unit of sampling effort (CPUE), catchability, sampling methods, and life history of northern pike in Harding, George, East Twin, Volkmar, and T lakes (Peckham and Bernard 1987; Clark et al. 1988; Clark 1988; Clark and Gregory 1988; Timmons and Pearse 1989; Burkholder 1991; Pearse 1990, 1991; Pearse and Hansen 1992a, 1992b; and, Skaugstad and Burkholder 1992). This report documents research conducted in 1992 concerning the abundance, and composition of the populations of northern pike in Volkmar, George, T, and East Twin lakes.

Study Area Descriptions

Volkmar Lake:

Volkmar Lake (64°07'N, 145°11'W) is a remote 273 ha (675 ac) 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. Snow machines 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 mid-May to early October, and spawning activity of northern pike generally coincides with the

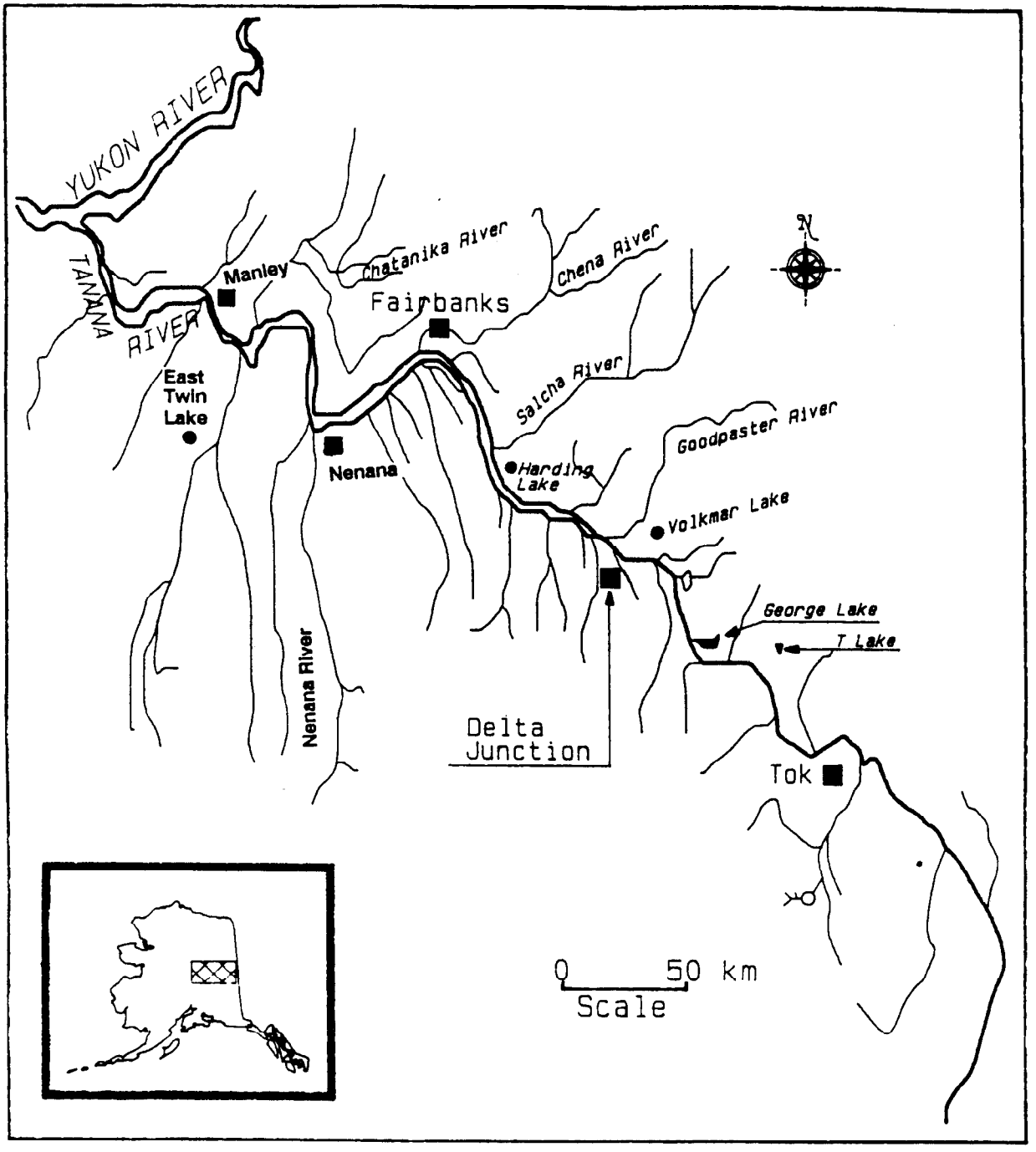

Figure 1. Tanana River study areas.

beginning of the ice-free period 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*.

The popularity of Volkmar Lake as a recreational area continues to grow because of recent land disposals around the lake by the State, improved winter access from new snow machine trails and roads in the Delta Agricultural Project, and increased summer and winter use by cabin owners around the lake and on the nearby Goodpaster River. For the period 1981 through 1991, estimated annual fishing effort averaged 484 angler-days (range 129 to 1,052; Mills 1991), as described in Appendix A. This equates to an estimated fishing pressure averaging 1.8 angler-days per hectare. For the same period, the estimated harvest averaged 432 northern pike, ranging from 84 (1990) to a high of 777 (1982), with a success of 0.9 northern pike per angler-day kept. In 1991, of 907 northern pike under 30 inches total length (TL, 720 mm fork length [FL]) caught in Volkmar Lake, 461 (51%) were retained (Mills 1992). All northern pike over 30 inches caught (104) were kept. The component of the catch 30 inches and longer comprised 10% of the total catch (565). Recreational fishing occurs year-round.

The research program on northern pike in Volkmar Lake began in 1985, with initial efforts focused on obtaining an abundance estimate. In 1986, several gear types and deployment techniques were evaluated to identify a non-lethal, efficient sampling method 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). Results of subsequent investigations have been reported upon by Clark and Gregory (1988); Timmons and Pearse (1989); Pearse (1990, 1991); and, Pearse and Clark (1992).

George Lake:

George Lake (63°47′N, 144°31′W) is a semi-remote 1,823 ha (4,505 ac) 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 then the outlet, George Creek. Although George Creek is navigable, it is shallow, requiring a conventional boat powered with a jet unit, an outboard equipped with a lift device, or an airboat. Snow machines 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, and a navigable outlet, George Creek, which flows to the south into the Tanana River. Near-shore waters are 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 early-June. Anglers at George Lake target northern pike, although other fish species are present including Arctic grayling, burbot *Lota lota*, humpback whitefish, least cisco, round whitefish *Prosopium cylindraceum*, longnose suckers *Catostomus catostomus*, and slimy sculpin. For the period 1981 through 1991, estimated annual fishing effort averaged 1,163 angler-days (range 557 to

1,957; Mills 1991), as described in Appendix A. This equates to an estimated fishing pressure that averaged 0.6 angler day per ha. For the same period, the estimated harvest averaged 1,722 northern pike, with a range of from 882 (1989) to 3,076 (1986) fish, with a success of 1.5 northern pike per angler-day kept. In 1991, of 4,684 northern pike under 30 in TL caught in George Lake, 1,086 (23%) were retained (Mills 1992). Of the 476 northern pike over 30 inches TL reportedly caught, 178 (37%) were kept. The component of the catch 30 inches and longer TL comprised 6% of the total estimated catch (4,996). Recreational fishing occurs year-round. Northern pike investigations in George Lake began in the early 1970's with limited composition sampling that included both Department caught and angler-harvested fish (Peckham 1972-1986). The current research program on northern pike began in 1986 with an assessment of efficient capture gear and sampling locations (Peckham and Bernard 1987). The abundance and composition of the northern pike population in this lake have been estimated annually since 1987 (Clark et al. 1988; Timmons and Pearse 1989; and, Pearse 1990, 1991).

T Lake:

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 ac) 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 late May. Other fish species in the lake include burbot, humpback whitefish, and least cisco.

Fishing pressure is believed to be low, but exploitation rates are high, compared with other area waters (Appendix A). Life history and abundance studies of northern pike have been conducted annually since 1986 (Peckham and Bernard 1987; Clark 1988; Timmons and Pearse 1989; and, Pearse 1990, 1991).

East Twin Lake:

East Twin Lake (63° 26'N, 150° 39'W) is a remote fly-in lake located approximately 139 km southwest of Fairbanks (Figure 1). The 526 ha lake lies at an elevation of 211 m, has a maximum depth of 13.7 m, and a shoreline circumference of 7.9 km. The lake has three small inlets and an outlet that possibly flows during flood events from the north shore into the Kantishna River to the east. Nearshore waters are shallow with beds of aquatic vegetation providing spawning and rearing substrate for northern pike. East Twin Lake is typically ice-free from mid-May to mid-October, and spawning of northern pike is believed to coincide with the beginning of the near-shore ice-free period and continues for up to two weeks into late-May. Other fish species in the lake include burbot (reported but unconfirmed), humpback whitefish, and least cisco.

East Twin Lake has supported a fly-in fishery for northern pike for many years, with anecdotal reports of good success in catching large fish dating back over 30 years. The sport fishery has been characterized by both winter

and summer harvests, and by limited exploitation from commercial sport fishing guides (Bill Lambert, Guide, pers comm.). The current level of subsistence harvest is undocumented, but is believed to be minimal. Over the years, numerous trophy fish certificates (for fish over 15 lbs or 6.8 kg) have been issued for northern pike reportedly harvested in this lake. The size and age composition of the harvest is undocumented. For the period 1983 through 1991, estimated annual fishing effort averaged 463 angler-days (range 76 to 1,035; Mills 1991), as described in Appendix A. This is equivalent to an estimated annual fishing pressure of 0.9 angler day per ha. For the same period, the estimated harvest averaged 411 northern pike, ranging from zero (likely below the actual harvest in 1990) to a high of 839 northern pike in 1983, with a success of 0.9 northern pike per angler-day kept. In 1991, of 3,063 northern pike under 30 inches TL caught in East Twin Lake, 595 (19%) were retained (Mills 1992). And of those over 30 inches TL estimated to have been captured (253), 30 (12%) were kept. The component of the catch 30 inches and longer TL comprised 8% of the total estimated catch (3,316). Recreational fishing occurs year-round.

Stock assessment of the northern pike population in East Twin Lake was initiated during the 1992 field season. Previous investigations have been limited, and reflect brief sampling to collect age and growth data relative to the fish species present, and limnological parameters (Alt 1969; Cheney 1972; and, Hallberg 1984).

Study Goals and Objectives

The goal of the northern pike research program in Tanana drainage lakes is to accurately estimate the ranges of population abundance and length composition in selected waterbodies over several years. These data, along with estimates of sport harvest, recruitment, and mortality will assist the development of techniques necessary to balance recreational demands with surplus production in Alaskan northern pike populations. Results to date include estimates of northern pike abundance, length, sex, and age compositions, survival, and recruitment for the northern pike populations in Volkmar, George, and T lakes (Pearse 1991). An improved understanding of age structure, growth, sex composition, and population dynamics of northern pike stocks has resulted from this program. Estimates of sustainable yield will be reported upon in another document.

The specific objectives for 1992, Project: F-10-8, Job R-3-4 (c) were to:

1. estimate the population abundance of northern pike (300 mm FL and longer) in Volkmar, George, T, and East Twin lakes;

2. estimate the length composition of the northern pike populations (300 mm FL and longer) in Volkmar, George, T, and East Twin lakes; and,

3. estimate the age composition of the northern pike population in East Twin Lake.

This report also presents historic estimates of abundance by size-class, density, length composition, and harvest of the northern pike populations in

these waters. The collection of age-related data was limited to all fish sampled in East Twin Lake during 1992, and only recaptures of northern pike tagged in prior years in the remaining waterbodies. See Pearse (1991) for historic age-related data for the other waterbodies investigated in prior years, Pearse and Hansen (1992) for analyses and discussion of error in age assessment, and Pearse and Clark (1992) for a discussion of movement behavior of northern pike in lakes.

METHODS

Study Design

Population sampling and multiple capture-recapture experiments for closed populations of northern pike were conducted in the four study lakes (Volkmar, George, T, and East Twin) in early June during 1992. Prior experience indicated that population studies of northern pike in interior Alaskan lakes are best conducted during and immediately after the spawning period, which coincides with spring ice melt in the area's lakes and normally occurs during mid to late May. Northern pike concentrate in near-shore waters at this time to spawn and later feed, and low water temperatures minimize temperature-sensitive handling injuries (Peckham and Bernard 1987; Clark 1988; and, Pearse and Clark 1992). Daily peaks in activity, as reflected by both observation of fish activity and catch of ripe or feeding fish in gill nets and seines, normally occurs during mid-day, generally between 1000 and 2000 hours. Sampling efforts were therefore focused to include this peak period of daily near-shore activity (within 100 m of the shoreline).

Unlike the separate mark and recapture events performed within or between previous yearly sampling experiments (Pearse 1991; Appendix B), multiple mark-recapture events were conducted on a daily basis in all waterbodies during 1992. In Volkmar Lake, sampling of the northern pike population continued for an 8-day period (2 June to 9 June); in George Lake, sampling continued for an 11-day period (8 June to 18 June); in T Lake, sampling was conducted for a 6-day period (1 June to 6 June); and in East Twin Lake, sampling lasted for the 5-day period from 6 June to 10 June. The timing of sampling events for all waterbodies was generally delayed 10 to 14 days from the timing of previous years due to cold weather and the resultant lateness of the breakup in 1992.

The Schnabel multiple census method (Ricker 1975, pp. 96-100) of estimating abundance was used to estimate the minimum sample size (number of northern pike to mark, examine, and recapture) during the field activity in all lakes. The minimum sample size was achieved (and hence field sampling was soon terminated) when the relative precision (RP) of the abundance estimate was less than or equal to the objective criteria ($\pm$ 25%). Recording length from all fish sampled more than adequately met sample sizes deemed necessary (Thompson 1987) to estimate the length composition, a series of multinomial proportions.

The respective lakes were divided into sampling areas to ensure uniform sampling effort, and to allow for later testing of movement of marked fish between areas of release and recapture (Figures 2 to 5). The rationale behind establishing the size of the individual sampling areas was derived from the results of data collected in the Volkmar Lake telemetry study conducted during

a similar time frame in 1991 (Pearse and Clark 1992). The median distance moved during single nightly periods for the radio-tagged northern pike (642 m), was divided into the circumference of Volkmar Lake (8,200 m) which resulted in 13 uniform sampling areas. The areas were labeled consecutively in a clockwise fashion from a randomly selected starting point. Lakes T and East Twin were similarly divided into 650 m zones (T = 9 zones, 6,038 m; East Twin = 12 zones, 7,900 m). George Lake was divided into six, 5,200 m zones, as the sampling methodology for this large waterbody was planned originally to include a two-event Petersen estimator with a four-day mixing period (hiatus). Based upon the telemetry data gathered in Volkmar Lake, marked northern pike were expected to move that median distance during the four day hiatus if they behaved in a similar fashion. However, due to the relative lateness of the sampling event and good initial catch rates, George Lake was instead sampled continuously up to four times per zone each day to spread out sampling effort and generate a multiple census estimator.

Fish were captured in Volkmar, George, and East Twin 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. Seines were normally set in water less than 2 m deep in known spawning and feeding areas, usually within 100 m of the shore. Gill nets were used in T Lake to capture northern pike because of previous limited success with seines (Pearse 1990). Six-panel 46 m gill nets, both floating and sinking, with two-each panels of 25, 38, and 51 mm bar mesh multifilament netting dyed green, were set in spawning areas. Up to nine nets were employed by a two-person crew during peak daily fish activity periods. Frequent gill net checks (hourly) minimized handling mortality (for additional gear specifications and gear fishing patterns see Peckham and Bernard 1987).

Data Collection

Hauls or sets were numbered sequentially through the experiment, regardless of success of capture. Location of each haul or set was recorded on lake maps (Figures 2 to 5), with a separate map used each sampling day.

Past studies have shown that subsamples of length, sex, and age measurements from northern pike captured can be biased toward larger fish (Clark 1988). Therefore, each fish captured (including within-season recaptures) during daily sampling events was measured for FL to the nearest mm, sex was recorded if determined, and scale samples were taken. Northern pike were released at least 100 m offshore in the approximate middle of the respective zone of capture to allow natural mixing behavior to occur.

All captured northern pike were examined for tags. All fish were examined for evidence of fin clips and/or opercle punches, as fish captured in these long-term population studies have been double-marked to aid in detecting within and between year tag loss. Marking codes used in all lakes during 1992, plus those from prior sampling events, are detailed in Appendix C. Untagged northern pike judged to be in a healthy condition were released after being marked with a grey Floy FD-68B internal anchor tag (Floy Tag & Mfg., Inc., Seattle, WA.) inserted posteriorly at the left base of the dorsal fin during all sampling events. The 1992 double mark (anal clip, Option 5 = 8)

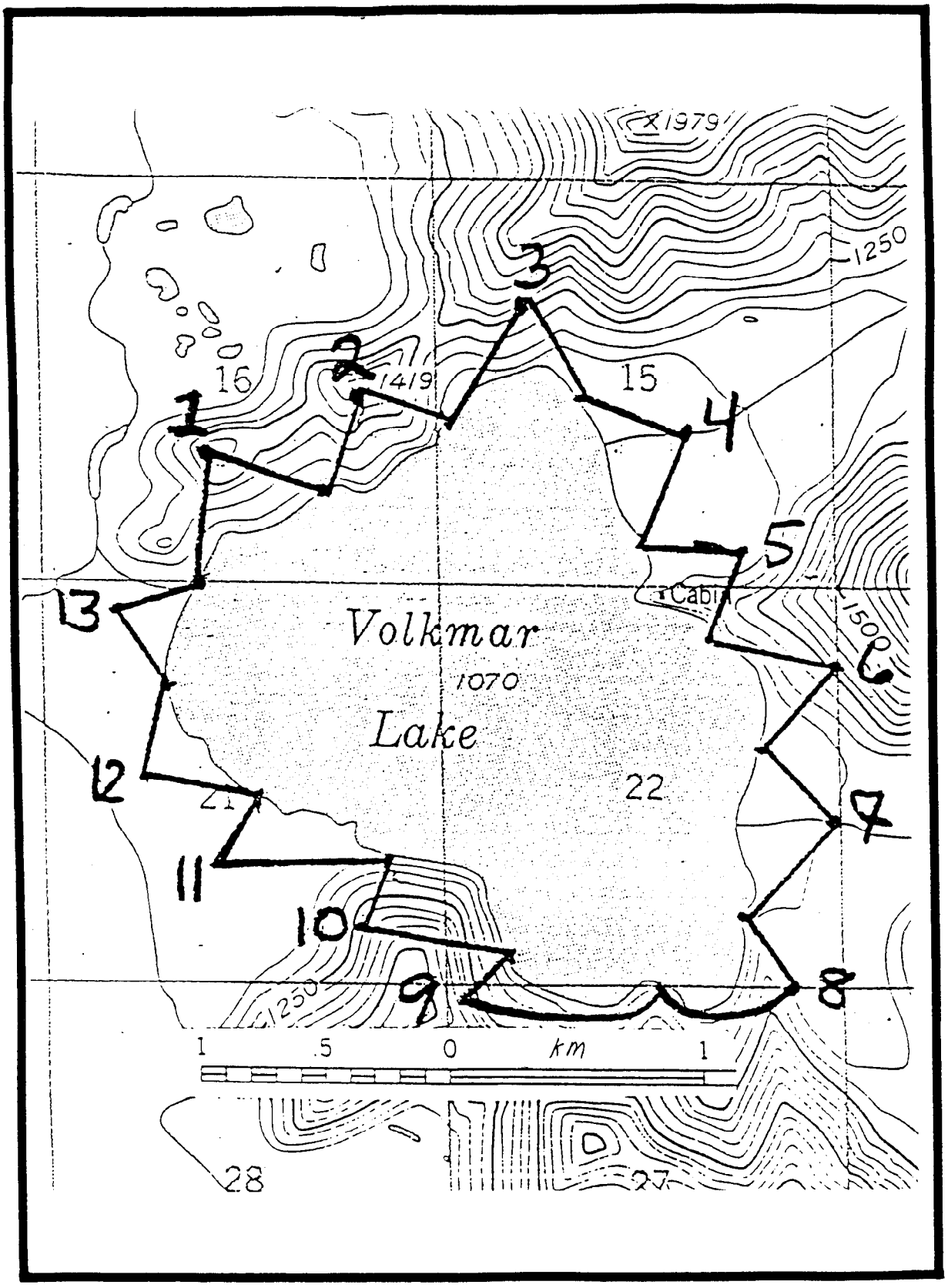

Figure 2. Volkmar Lake study area.

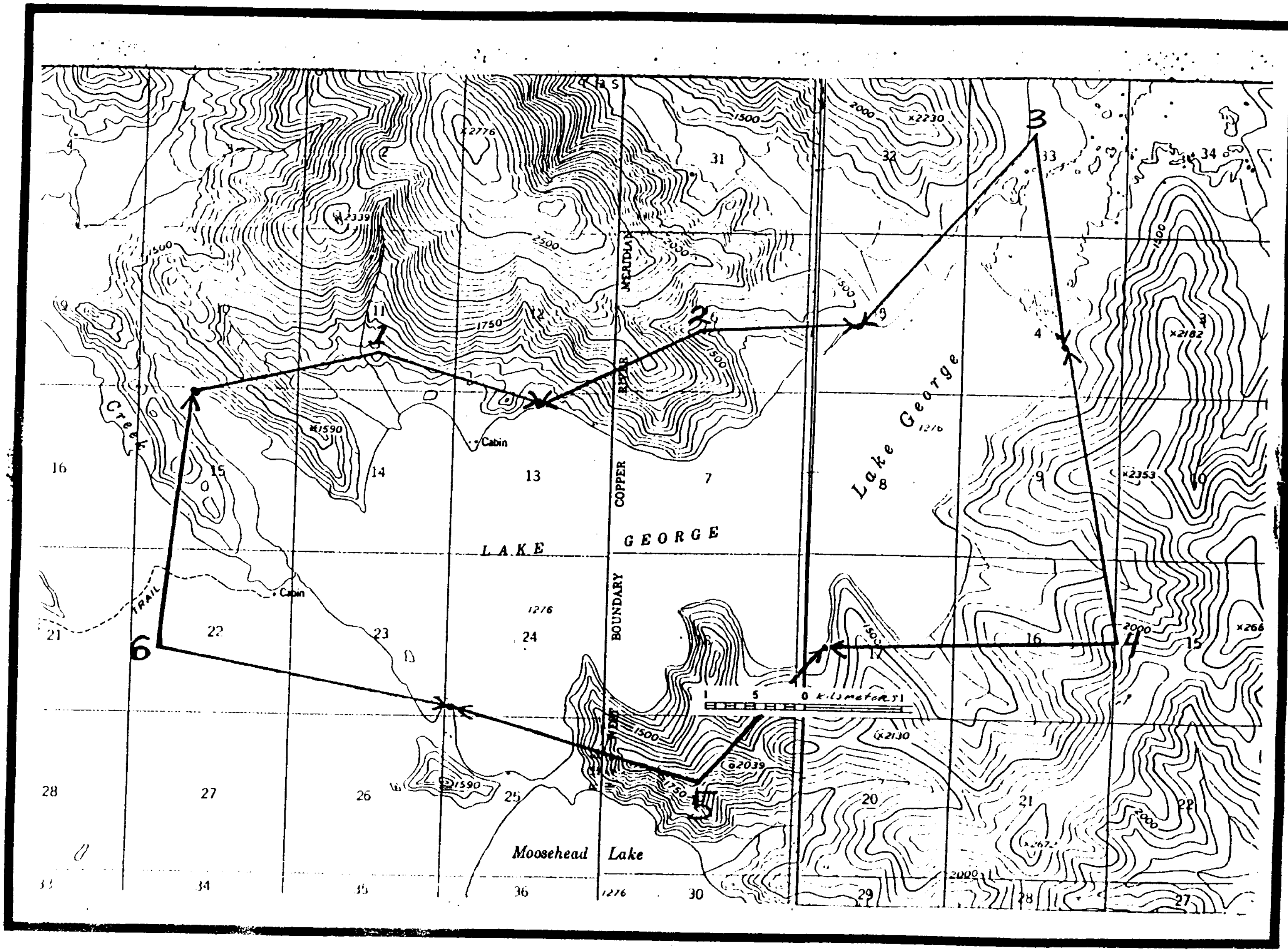

Figure 3. George Lake study area.

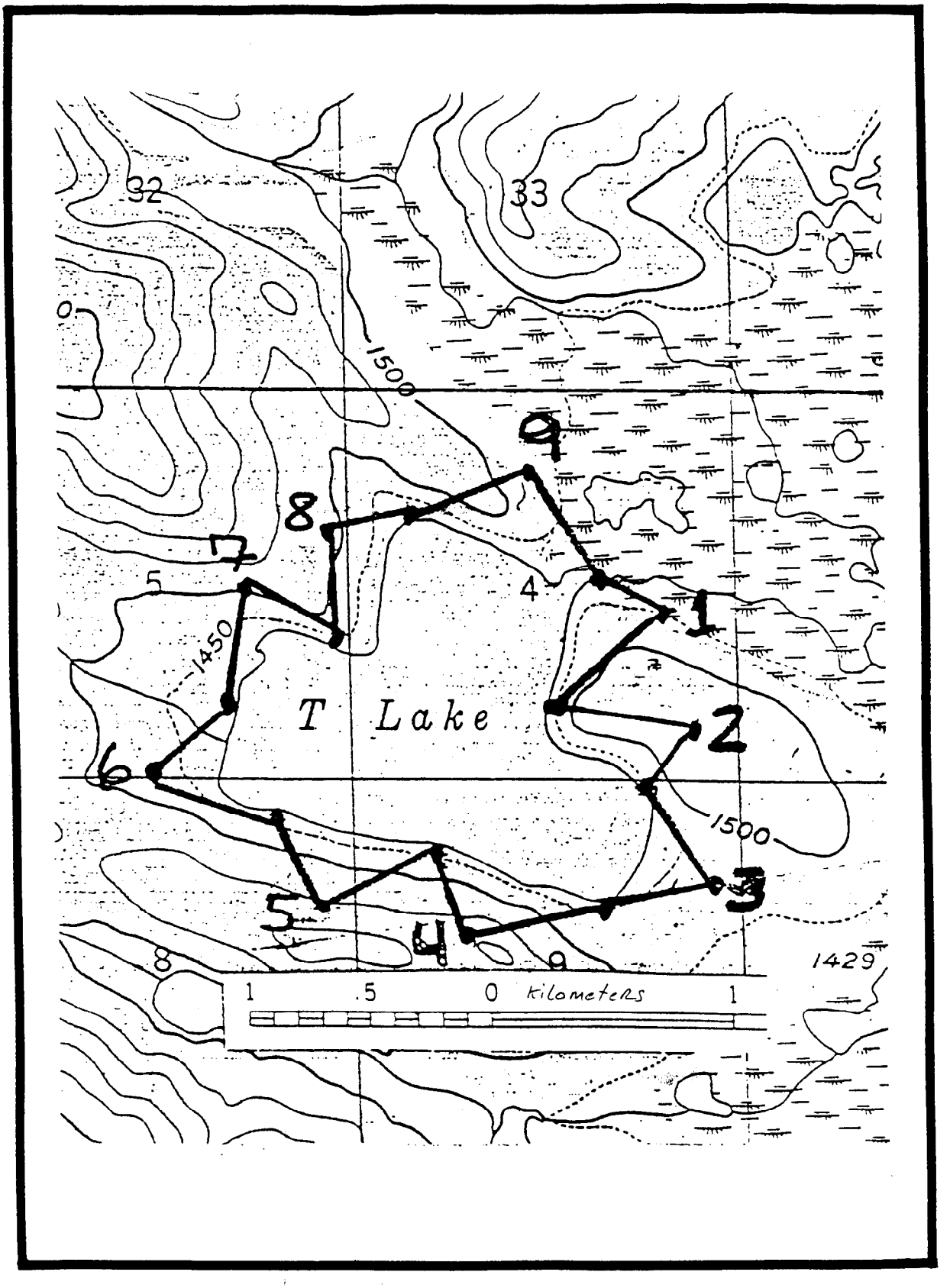

Figure 4. T Lake study area.

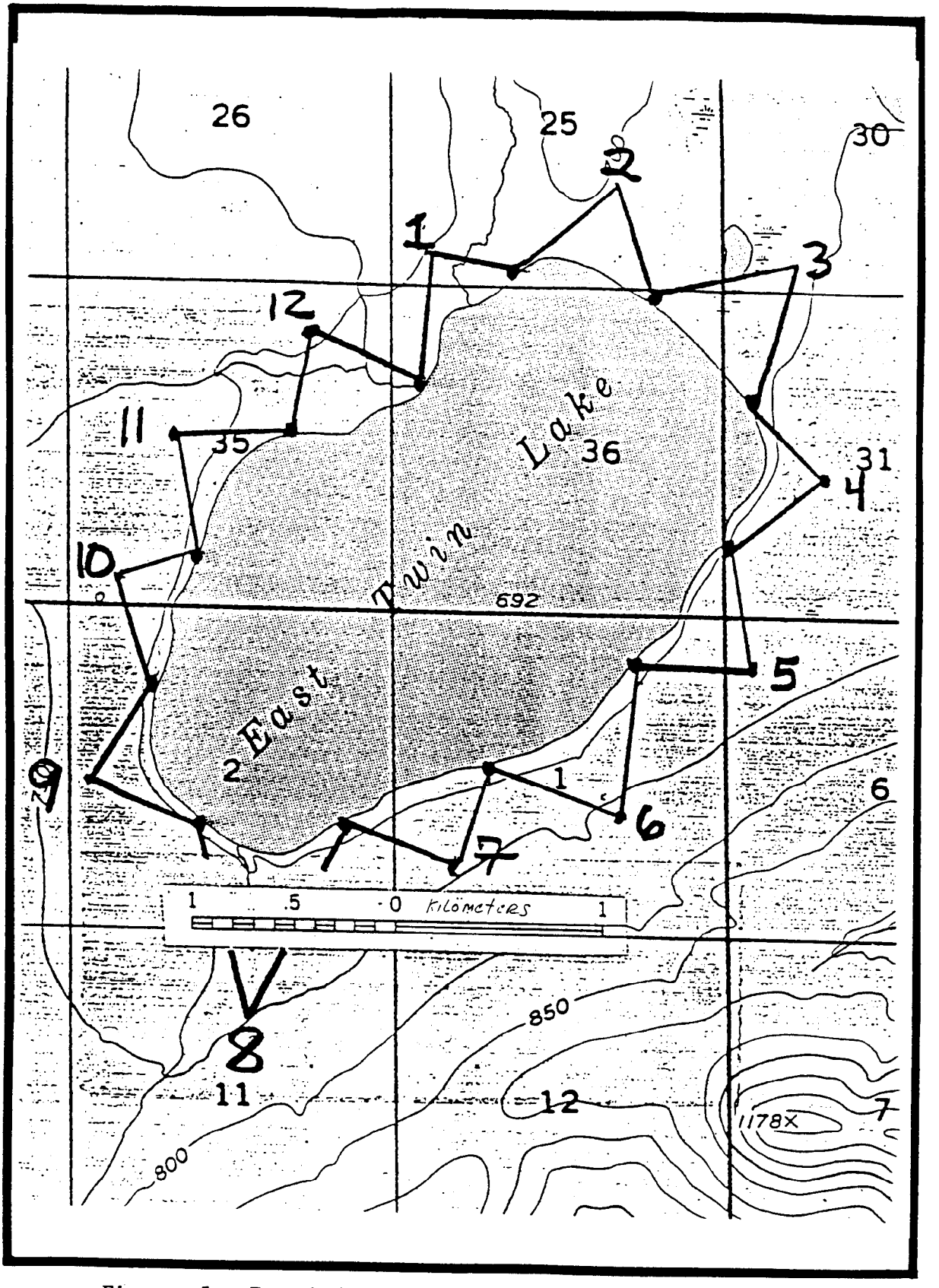

Figure 5. East Twin Lake study area.

was applied to all tagged fish to later estimate the rate of tag loss from each capture event. The importance of identifying all current and previous punches/fin clips (Appendix C) was stressed to field crews.

Scales were either removed from each fish captured (East Twin Lake), or only from northern pike marked in prior years (Volkmar, George, and T lakes). A minimum of three 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 then placed either in individual coin envelopes marked with the appropriate mark-sense form litho-code and sample number (Volkmar, George, and T lakes), or mounted directly on gummed cards (East Twin Lake). Scales placed in coin envelopes were later removed in the laboratory, cleaned, and two non-regenerated scales per fish 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 one minute. Scales were read on a microfiche reader (32x) and ages recorded in accordance with age identification criteria established by Williams (1955) and Casselman (1967). Because experience has shown that the formation of scale annuli in Alaskan stocks of northern pike generally coincides with or closely follows the sampling period in late May, ages were assigned with regard to counts of circuli or scales. In the case of individually excessive circuli plus growth (> 8 circuli since last annulus), a year was added to the count of annuli. A more detailed analysis of age interpretation based upon several body structures (scales, cleithra, and vertebrae) collected prior to the 1992 sampling program was presented by Pearse and Hansen (1992). Only the age composition of northern pike captured in East Twin Lake is reported in this document. 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.

Data Analysis

Abundance Estimation:

During the respective capture-recapture experiments, the preliminary estimates of abundance and RP of northern pike were estimated during the sampling process using the Chapman modification of the Schnabel mark/recapture population estimator (Ricker 1975) as follows:

$$\hat{N} = \frac{\Sigma(C_t M_t)}{\Sigma R_t + 1}; \text{ and,} \qquad (1)$$

$$\hat{V}[1/N] = \frac{\Sigma R_t}{(\Sigma C_t M_t)^2}; \qquad (2)$$

From the delta method:

$$\hat{V}[N] \approx V \left[\frac{1}{N}\right] \hat{N}^4$$

where:

C_t = total sample taken on day t;

M_t = total marked fish at large at the start of the day t (or other interval), i.e. the number previously marked less any previous mortalities; and,

R_t = number of fish recaptured in the sample C_t.

These confidence intervals were used to calculate the RP of the estimate as:

$$RP = \frac{1.96 * SE\,[\hat{N}]}{\hat{N}} * 100 \qquad (3)$$

Subsequent to database collection and editing, the 10 August, 1992 version of computer program CAPTURE was employed along with other statistical tests to interactively develop the Maximum Likelihood Estimator (MLE) of northern pike abundance (N), its approximate standard error, and infer the quality of the estimate. The underlying logic and statistical process of program CAPTURE is described in Otis et al. (1978), and White et al. (1978). White et al. (1982) further elaborated upon the use and applications of the program.

Estimation of population abundance using capture-recapture methods normally requires that four assumptions be met. The first assumption involves closure of the population while the estimation process is being conducted. Closure is normally divided into two components: geographic closure or boundaries that limit the fish population, and demographic closure to birth, immigration, death, and emigration. The assumption of closure was most likely met in all waterbodies due to the short period of sampling, and because no northern pike were observed entering or leaving the lakes studied that had outlets (George, T, and East Twin). The second assumption, that marked fish did not lose their marks between sampling events, was assured by double marking sampled fish and noting tag loss. Tag loss was minimal in this study. Careful data collection assured that all marked fish were noted upon both mark and recapture, which fulfilled this third assumption. The fourth assumption, that every fish has a constant and equal probability of capture on each trapping occasion, and that marking does not affect subsequent catchability of the animal, may not have been met. The focal point of Otis et al. (1978) was to relax assumption four, and they therefore developed program CAPTURE to partially accommodate situations involving unequal catchability of marked and recaptured fish. The authors admit the fourth assumption usually is not met in the real course of sampling events.

The various models developed for which abundance estimators are available in capture (10 August 1992 version) are as follows:

1. Model M_o: This is the most restrictive model and assumes capture probabilities to be constant through all sampling events, but does not allow capture probabilities to vary by individual

(heterogeneity), or provide for individual behavior (trap happy or shy).

2. Model M_b: Allows capture probabilities to vary due to behavioral response, but not due to heterogeneity or temporal variation (by sampling event). It assumes every unmarked fish in the population has the same probability of capture during each event, and every marked fish has the same probability of recapture for all events subsequent to marking.

3. Model M_t: Allows capture probabilities to vary only by time or sampling event, but does not allow heterogeneity of individual capture probabilities or behavioral response.

4. Model M_h: Allows heterogeneity but not behavioral response, and assumes each fish has its own unique capture probability which remains constant over all sampling events. Calculating population estimates by size, sex or age can apparently minimize heterogeneity of capture probabilities, if detected.

5. Model M_{bh}: Allows for both heterogeneity and trap response, and assumes each fish has its own unique pair of potential capture probabilities, referring to whether the fish is marked or unmarked, which remain constant over all sampling events.

In addition to the above, three other models have been conceptually developed to allow for time variation in capture probabilities (M_{th}, M_{tb}, and M_{tbh}).

Program CAPTURE neither directly accounts nor corrects specifically for size selectivity, if present (Dave Bernard, RTS, pers comm.). Model M_h was not indicated as the preferred estimator for the populations sampled in 1992. However, as a precaution dictated by prior estimates of stock abundance of northern pike populations in which size selectivity was frequently detected (Pearse 1991), two tests were done to determine if size selectivity occurred during the sampling events in 1992. Plots of cumulative distribution functions (CDF) of daily lengths of captured northern pike were visually examined to note potential size bias of a biological significance (spatial separation of the plots). In the second test, a chi-square statistic was used to test the null hypothesis of no difference between recapture probabilities by 100 mm length groups (300-399 mm, 400-499 mm, etc.) of marked fish. The outcome of these tests determined if the abundance estimates needed to be stratified into different length groups, and abundance estimated separately for each stratum using program CAPTURE. In addition, plots of the proportion of recaptured northern pike in the daily sample of captured fish (R/C ratio, Appendix D) versus the number of northern pike that were marked previous to the day's sampling event were examined to detect changes in catchability (trap shyness) brought upon by marking (Seber 1982, p. 145). A linear increase in the daily proportion of recaptured marked fish is expected to follow similar increases in the number of marked fish in the population prior to the event.

Based upon the combination of meeting the aforementioned assumptions, the output of program CAPTURE, and the results of additional tests for size selectivity described, the model was selected which best estimated the abundance of the respective population of northern pike. All authors suggest

caution is indicated when data are analyzed with program CAPTURE, as tests employed in the analysis and model selection are not independent and often have low power, especially for small populations. We feel that the populations and sample sizes we dealt with were sufficiently large enough to mitigate this problem.

Composition Estimation:

Estimates of abundance pertaining to length and age composition of sampled northern pike were used to apportion northern pike populations into the following categories:

1. "Small" (300-449 mm), "Medium" (450-749 mm), "Large" (750 mm and larger), and "All northern pike greater than 299 mm or 449 mm". This was done to facilitate annual comparisons among and between all lakes studied;

2. 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) FL classes;

3. Length frequency of the sampled northern pike; and,

4. Abundance by age (East Twin Lake only).

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

$$\hat{p}_j = n_j/n \tag{4}$$

where:

n - the number of fish sampled for information on age, length, or 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 proportion was calculated as:

$$\hat{V}[p_j] = \frac{\hat{p}_j(1 - \hat{p}_j)}{n - 1} \tag{5}$$

The estimated number of northern pike by length group was calculated as:

$$\hat{N}_j = \hat{p}_j \hat{N} \tag{6}$$

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

$$V[\hat{N}_j] = V[\hat{p}_j]\hat{N}^2 + V[\hat{N}]\hat{p}_j^2 - V[\hat{p}_j]V[\hat{N}] \quad (7)$$

Mean length-at-age by year reflects the mean value of summed lengths by age alone. Non overlapping 95% confidence intervals were used to detect differences between estimates of abundance or estimated proportions.

RESULTS AND DISCUSSION

Volkmar Lake

Abundance Estimation:

The estimated abundance of northern pike (> 299 mm FL) during early June was 3,888 fish (SE = 572, RP = 29%). Density was estimated to have been 14.2 northern pike per ha (Appendix E). The estimated abundance of northern pike > 449 mm was 2,542 fish (SE = 369, RP = 29%). The level of RP (29%) exceeded the criteria set forth in the operational plan (to be within 25% of the estimate) for the estimate of northern pike longer than 299 mm. Both estimates of abundance by size groups were statistically similar to those determined in 1991 (Appendix E).

After eight days of sampling, the in-season estimate of abundance (N = 3,837) was within 51 fish of that later suggested by program CAPTURE; the in-season estimate of RP (and hence SE) declined steadily from 61% on sampling day 3 to 29% on day 8.

As part of the model selection procedure, program CAPTURE used the daily capture history data as presented for Volkmar Lake in Appendix D. Included in Appendix F are the results of the model selection criteria, with the most appropriate model selected by CAPTURE having the maximum value. Although program CAPTURE selected model M_{tb} (time specific and behavioral response changes [trap shyness] in capture probabilities) first, and model M_{th} (time specific and heterogenetic changes in capture probabilities) second, the version of CAPTURE we used does not provide an estimator for either. Selected third was M_b, but the estimate of abundance (1,091, SE = 138) was believed to be an underestimate given we had handled over half of that number (592) of northern pike during the short sampling interval of eight days. We preferred M_t (N = 3,888) as it seemed reasonable given prior estimates of abundance and sport harvest, and closely approximated the traditional Schnabel estimate determined in-season. In addition, a traditional Petersen two-event estimate was also developed as all assumptions (mixing, size selectivity) were met. The estimated abundance (N = 3,258; SE = 538) was statistically similar to that developed by M_t, thus further supporting that later estimate.

Tests for gear selectivity among sampling events proved insignificant. The daily CDF plots of fish lengths were biologically identical (Figure 6), and the chi-square test statistic of recapture probabilities by length group was not significant ($\chi^2 = 2.64$, df = 4, P = 0.619). Daily proportions of

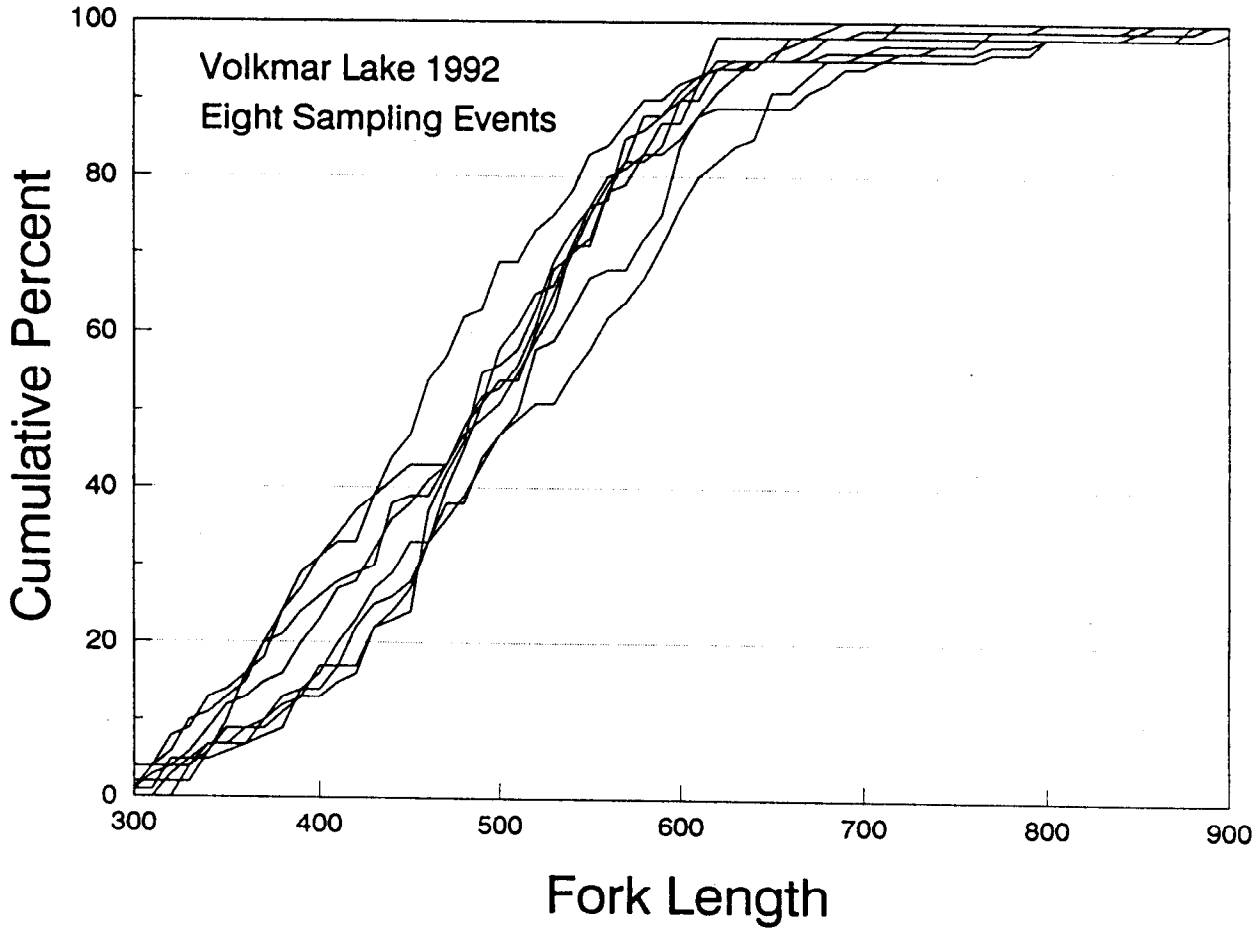

Figure 6. Daily cumulative length distribution frequencies of northern pike captured in Volkmar Lake, 1992.

recaptured fish appeared to increase in a linear fashion, as expected. However, program CAPTURE detected a slight decline in the estimated probability of capture of all fish by sampling occasion, probably leading to its selection of model M_{tb}. We reran program CAPTURE deleting the last two sampling days (six days total) to determine if data relevant to those events was affecting the model selection process and estimate of abundance. The model selection criteria remained unchanged, and the estimate of abundance using model M_t (3,449, SE = 587) remained statistically similar to that presented above. Declining catch rates during population sampling linked to movement and habitat preferences of northern pike in Volkmar Lake have been previously documented by Pearse and Clark (1992). No evidence of tag loss was observed during the sampling events.

Composition Estimation:

The source for the 1992 estimates of composition was all unique fish examined in 1992, as size selectivity of the gear was not detected. The estimated 1992 abundance and proportion of northern pike in all size categories (Appendix E) were similar to that determined in 1991. The Small size category is mainly comprised of partially recruited northern pike. Fish in the Medium size range have predominated in all years. Medium and Large-sized northern pike consist primarily of fish fully recruited to the spawning population. In Volkmar Lake, male northern pike are generally absent from the Large size category (Pearse 1991).

Estimated RSDs (Appendix G) indicated the stock category predominated, with few if any captured in the memorable and above size groups. The 1992 composition is similar that detected in previous years, with the exception of 1988 and 1989, when recruitment failure was noted (Pearse 1991).

The length frequency distribution of sampled northern pike (sexes combined) is described in Appendix H. The distribution is similar to 1991. Approximately 50% of the fish sampled were shorter than 500 mm, and about 90% of the northern pike captured were less than 625 mm.

Of fish captured in 1992, none died through the normal course of sampling events, but 30 were selectively sacrificed to become part of the comparative condition factor study presented in the George Lake analysis.

George Lake

Abundance Estimation:

The estimated abundance of northern pike (> 299 mm) during early June was 9,309 fish (SE = 750, RP = 16%). Density was estimated to have been 5.1 northern pike per ha (Appendix E). The estimated abundance of northern pike > 449 mm was 7,001 fish (SE = 540, RP = 15%). The level of RP (16%) met the criteria set forth in the operational plan (to be within 25% of the estimate of northern pike greater than 299 mm). Both estimates of abundance by size groups were essentially lower than those determined in 1991, but were similar to those determined in 1990.

After 11 days of sampling, the in-season estimate of abundance (N = 9,136, Schnabel estimator) was within 173 fish of that later suggested by program

CAPTURE; the in-season estimate of RP (and hence SE) declined steadily from 78% on sampling day 3 to 15% on day 11. The criteria of RP was met by the end of sampling day 9 (20%).

As part of the model selection procedure, program CAPTURE used the daily capture history data as presented for George Lake in Appendix D. Included in Appendix F are the results of the model selection criteria, with the most appropriate model selected by CAPTURE having the maximum value. Program CAPTURE selected model M_t (time specific changes in capture probabilities) first, and model M_{th} (time specific and heterogenetic changes in capture probabilities) second; the version of CAPTURE we used does not provide an estimator for the latter. We accepted M_t with qualifications as described below.

Tests for gear selectivity among sampling events proved significant. The daily CDF plots of fish lengths were nearly identical (Figure 7), with the exception of captures from day 6 (of 11 days total). Substantially smaller northern pike were captured in this event (56 total including two recaptures, Appendix D), and therefore data relative to this event were ignored in developing the estimate of abundance. The chi-square test statistic of recapture probabilities by length group was tested and found to be significant ($\chi^2 = 15.017$, df = 4, $P < 0.005$); the data suggested the estimate of abundance be divided into two strata with the break at 500 mm. The database (minus sampling day six; 10 sampling days total) was divided into two files by fish length (those less than and including 500 mm, and those greater than 500 mm), and program CAPTURE was run on capture histories from each. The resultant stratified estimate (N = 10,098, SE = 1,037) was statistically similar to the unstratified estimate (N = 9,309, SE = 750), the latter was selected due to the lower SE. Daily proportions of recaptured fish did not appear to increase in a linear fashion, against expectations (R/C ratio, Appendix D), and tended to essentially stabilize after day 6. The cause is uncertain. Of 154 total northern pike recaptured, two (1.3%) had lost tags. This tag loss was accounted for in the final analysis of abundance.

Composition Estimation:

The source for the 1992 estimates of composition was all unique fish examined in 1992. Size selectivity of the gear was detected, but proved to be insignificant (see above). The estimated 1992 abundance and proportion of northern pike in the Small and Medium size categories (Appendix E) were not similar to that determined in 1991, and in fact indicated potential declines in the estimated abundance of northern pike in these categories. The estimated abundance of northern pike in the Large size category (N = 501, SE = 68) was essentially similar to that determined in 1991 (N = 443, SE = 65). The Small size category (300 to 449 mm) is mainly comprised of partially recruited northern pike. As in prior years, fish in the Medium size range predominated in George Lake. Medium and Large northern pike consist primarily of fish fully recruited to the spawning population. In George Lake, male northern pike are generally absent from the Large size category (Pearse 1991).

Estimated RSDs (Appendix G) indicated the stock category (300 to 525 mm) was dominant, with few captured in the memorable and above size groups. Declines were noted in the proportion and abundance of northern pike in the stock

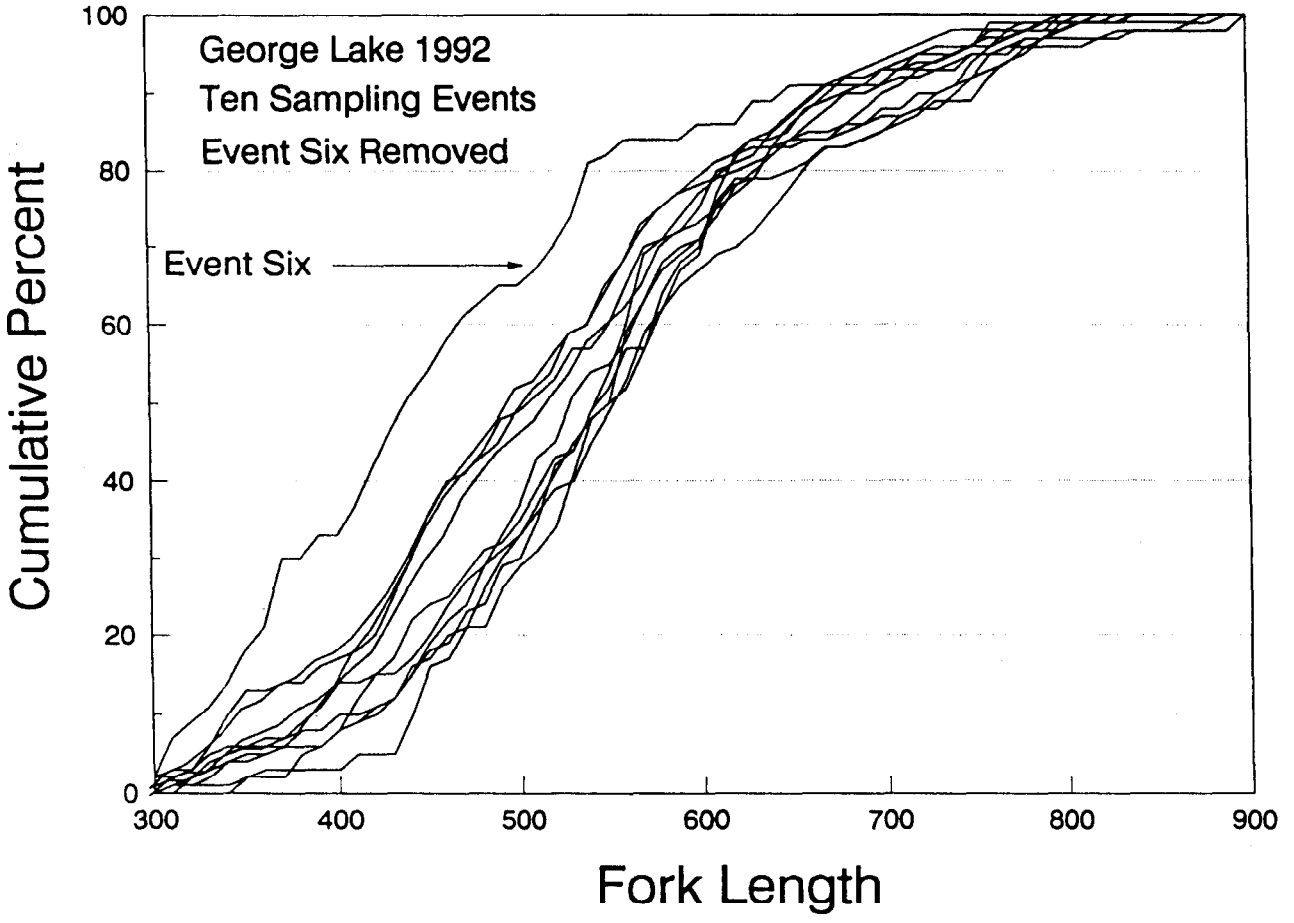

Figure 7. Daily cumulative length distribution frequencies of northern pike captured in George Lake, 1992.

category in 1992 compared with the 1991 estimate. Comparatively low levels of recruitment in 1992 were likely the cause.

The length frequency distribution of sampled northern pike (sexes combined) is described in Appendix I. The distribution is similar to 1991, with some reductions in percentages noted for certain size groups. Approximately 50% of the fish sampled were shorter than 525 mm, and about 90% of the northern pike captured were less than 700 mm in 1992. Whereas, 50% of the fish captured in 1991 were less than 500 mm, and 90% were less than 675 mm in 1991. The difference may indicate a slight reduction in the proportion of smaller northern pike in 1992.

Of fish captured in 1992, nine died through the normal course of sampling events, and 30 were selectively sacrificed to become part of the comparative condition factor study presented elsewhere in the George Lake analysis. No incidence of unhealthy northern pike was observed (Appendix L).

T Lake

Abundance Estimation:

The estimated abundance of northern pike (> 299 mm) in T Lake during early June was 782 fish (SE = 75, RP = 19%). Density was estimated to have been 4.9 northern pike per ha (Appendix E). The estimated abundance of northern pike > 449 mm was 707 fish (SE = 67, RP = 19%). The level of RP (19%) met the criteria set forth in the operational plan (to be within 25% of the estimate of northern pike greater than 299 mm). Both estimates of abundance by size groups were statistically greater than those determined in 1991.

After six days of sampling, the in-season estimate of abundance (N = 780, Schnabel estimator) came within two fish of that later suggested by program CAPTURE; the in-season estimate of RP (and hence SE) declined steadily from 92% on sampling day 2 to 22% on day 6. The criteria of RP was met by the end of sampling day 5 (25%).

As part of the model selection procedure, program CAPTURE used the daily capture history data as presented for T Lake in Appendix D. Also included are the results of the model selection criteria, with the most appropriate model selected by CAPTURE having the maximum value. Program CAPTURE selected model M_t (time specific changes in capture probabilities) first, and model M_{tb} (time specific and behavioral changes in capture probabilities) second; the version of CAPTURE we used does not provide an estimator for the latter. We accepted M_t with qualifications as described below.

Tests for gear selectivity among sampling events proved significant in one test. The daily CDF plots of fish lengths were biologically identical (Figure 8). However, the chi-square test statistic of recapture probabilities by length group was tested and found to be significant (χ^2 = 13.324, df = 4, P = 0.010); data suggested the estimate of abundance be divided into two strata with the break at 500 mm. As in the case of George Lake, the database was divided into two files by fish length (those less than and including 500 mm, and those greater than 500 mm), and program CAPTURE was run on each. The resultant stratified estimate (N = 876, SE = 118) was similar to the unstratified estimate (N = 782, SE = 75), the latter was selected due to the

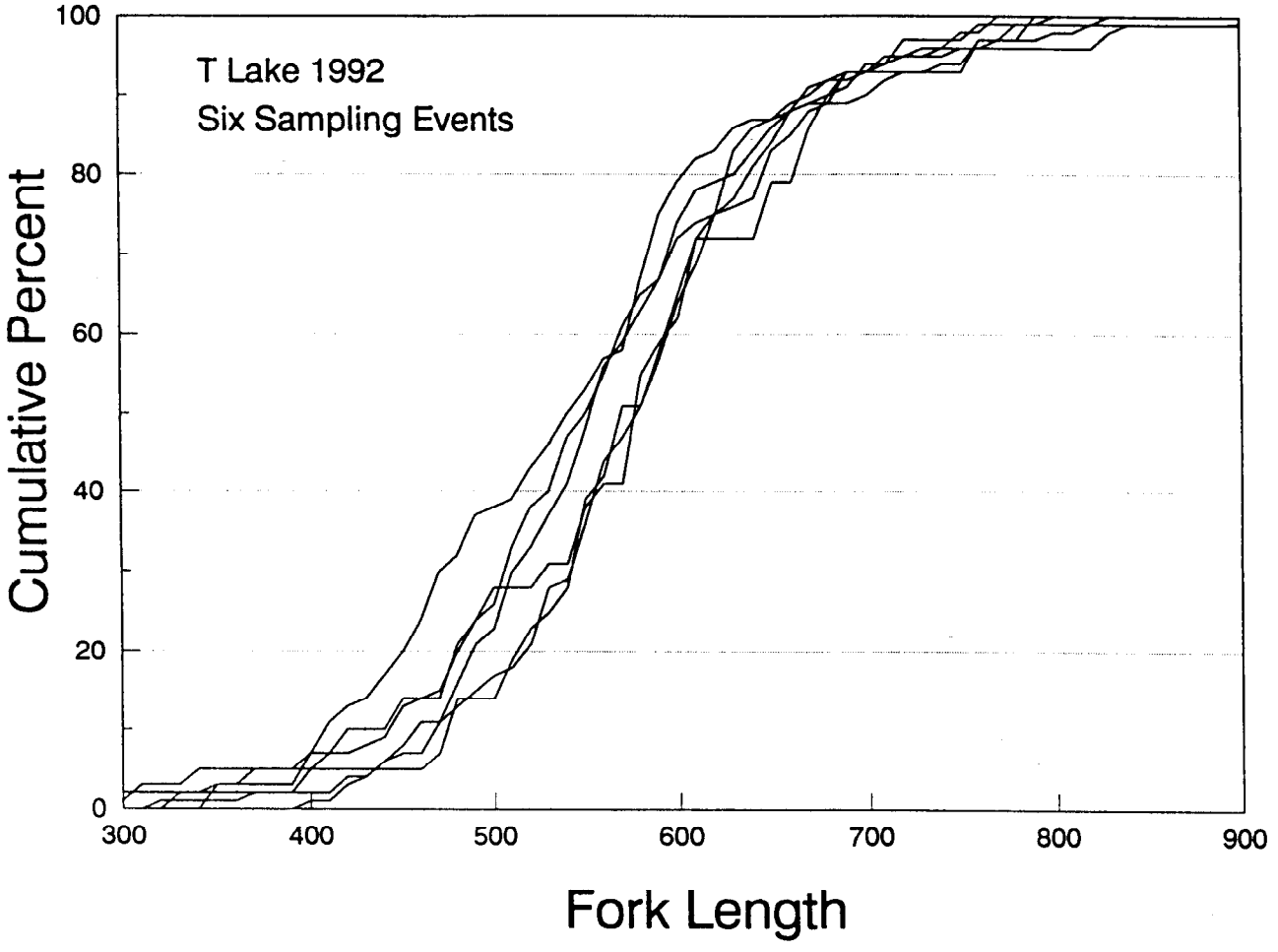

Figure 8. Daily cumulative length distribution frequencies of northern pike captured in T Lake, 1992.

lower SE. Daily proportions of recaptured fish increased in a normal linear fashion, as the R/C ratio (Appendix D) increased throughout the study. No tag loss was detected during the sampling program.

Composition Estimation:

The source for the 1992 estimates of composition was all unique fish examined in 1992. Size selectivity of the gear was detected, but an unstratified estimate of abundance was selected for the reasons presented above. As indicated in Appendix E, the estimated 1992 abundance and proportion of northern pike in the Small category (N = 74, SE = 15) was similar to that determined in 1991 (N = 40, SE = 9). The abundance of Medium sized northern pike (N = 665, SE = 66) was significantly greater from that determined in 1991 (N = 264, SE = 32), and in fact indicated an increase in the estimated abundance of northern pike in this category. The estimated abundance of northern pike in the Large size category (N = 42, SE = 11) was similar to that determined in 1991 (N = 24, SE = 7). The Small size category (300 to 449 mm) is mainly comprised of partially recruited northern pike. Unlike northern pike in other lakes studied, fish in T Lake probably do not recruit to the spawning population at as small a size or at as high a rate (Pearse 1991). Therefore, as in prior years, fish in the Medium size (> 449 mm) range predominated in T Lake. The increase in numbers of fish in this size category likely contributed to the increased estimate of abundance in 1992. Medium and Large northern pike consist primarily of fish fully recruited to the spawning population. In T Lake, male northern pike are generally absent from the Large size category (Pearse 1991).

Estimated RSDs (Appendix G) indicated the quality category (525 to 654 mm) was dominant, with few captured in the memorable and above size groups. The RSD composition as a proportion was essentially the same in 1992 as in 1991.

The length frequency distribution of sampled northern pike (sexes combined) is described in Appendix J. The distribution is similar to 1991, with some small changes in percentages. Approximately 50% of the fish sampled were smaller than 550 mm, and about 90% of the northern pike captured were less than 700 mm in 1992. Whereas, 50% of the fish captured in 1991 were less than 600 mm, and 90% were less than 750 mm in 1991.

Of fish captured in 1992, one died through the normal course of sampling events. All northern pike captured appeared healthy.

East Twin Lake

Abundance Estimation:

The sampling effort in 1992 lasted five days, and was the first intensive look at the northern pike population in this popular recreational waterbody. The abundance of northern pike (> 299 mm) in early June was estimated at 7,449 fish (SE = 768, RP = 20%; Table 1). Density was estimated to have been 14.2 northern pike per ha (Appendix E), identical to that estimated for Volkmar Lake which is a smaller waterbody. The estimated abundance of northern pike > 449 mm was 5,016 fish (SE = 522, RP = 20%). The level of RP met the

Table 1. Estimated age composition and cohort abundance of the northern pike populations (> 299 mm FL) in East Twin Lake, 1992.

Age	No. of Fish	Proportion	SE	Abundance	SE
2	2	0.002	0.001	13	10
3	89	0.080	0.008	597	86
4	239	0.215	0.012	1,604	189
5	346	0.312	0.014	2,322	261
6	210	0.189	0.012	1,409	169
7	94	0.085	0.008	631	90
8	63	0.057	0.007	423	67
9	37	0.033	0.005	248	47
10	23	0.021	0.004	154	35
11	2	0.002	0.001	13	10
12	3	0.003	0.002	20	12
13	1	0.001	0.001	7	7
18	1	0.001	0.001	7	7
Total	1,110	100		7,449	768

criteria set forth in the operational plan (to be within 25% of the estimate of northern pike greater than 299 mm).

After five days of sampling, the in-season estimate of abundance (N = 7,319, Schnabel estimator) came within 130 fish of that later suggested by program CAPTURE; the in-season estimate of RP (and hence SE) declined steadily from 85% as soon as sampling day 2 to 21% on day 6. The criteria of RP was nearly met by the end of sampling day 4 (27%), and was met on sampling day 5.

As part of the model selection procedure, program CAPTURE used the daily capture history data as presented for East Twin Lake in Appendix D. As for other lakes, included are the results of the model selection criteria, with the most appropriate model selected by CAPTURE having the maximum value. Program CAPTURE selected model M_{tbh} (time specific, behavior related, and heterogenetic changes in capture probabilities) first, and model M_t (time specific changes in capture probabilities) second; no current version of CAPTURE provides an estimator for M_{tbh}. We accepted M_t with qualifications as described below.

Tests for gear selectivity among sampling events proved insignificant in all tests. The daily CDF plots of fish lengths were biologically the same (Figure 9). In addition, the chi-square test statistic of recapture probabilities by length group was run and found to be insignificant ($\chi^2 = 0.273$, df = 4, $P > 0.05$); data suggested the estimate of abundance not be stratified on length. Daily proportions of recaptured fish increased in a normal linear fashion until day four, then stabilized at just over 10% for unknown reasons in day five (Appendix D). No tag loss was detected in this study.

Composition Estimation:

The source for the 1992 estimates of composition of northern pike in East Twin Lake was all unique fish examined in 1992. As indicated in Appendix E, the estimated proportion in 1992 of northern pike in the Small category was 0.33 (SE = 0.014), and was quite close to that estimated for Volkmar Lake (0.35, SE = 0.020). Medium-sized northern pike (N = 4,960, SE = 521) were dominant; their proportion (0.66, SE = 0.014) was also similar to that found in Volkmar Lake during 1992 (0.63, SE = 0.020). High proportions of northern pike in this size category likely indicates size at initial maturity occurs (and recruitment to our sampling gear) at a length within the lower bounds of the size category (> 449 mm), as opposed to the upper limits of the Small size category (< 449 mm). The estimated abundance of northern pike in the Large size category (N = 56, SE = 20) was disappointing given the reputation of this lake to provide "trophy" northern pike (> 15 lbs). Further sampling in 1993 is recommended to better define the abundance and proportion of these large northern pike and to determine if large fish in East Twin Lake were unavailable to the gear in 1992, due to the lateness of breakup and sampling described previously. Medium and Large northern pike consist primarily of fish fully recruited to the spawning population.

The age composition of northern pike sampled during 1992 in East Twin Lake, presented in Table 2, indicates fish between age 2 and age 18 were captured and age 5 northern pike dominated (0.31, SE = 0.014) the composition. Based upon age composition studies in other lakes (Pearse 1991), this is likely the

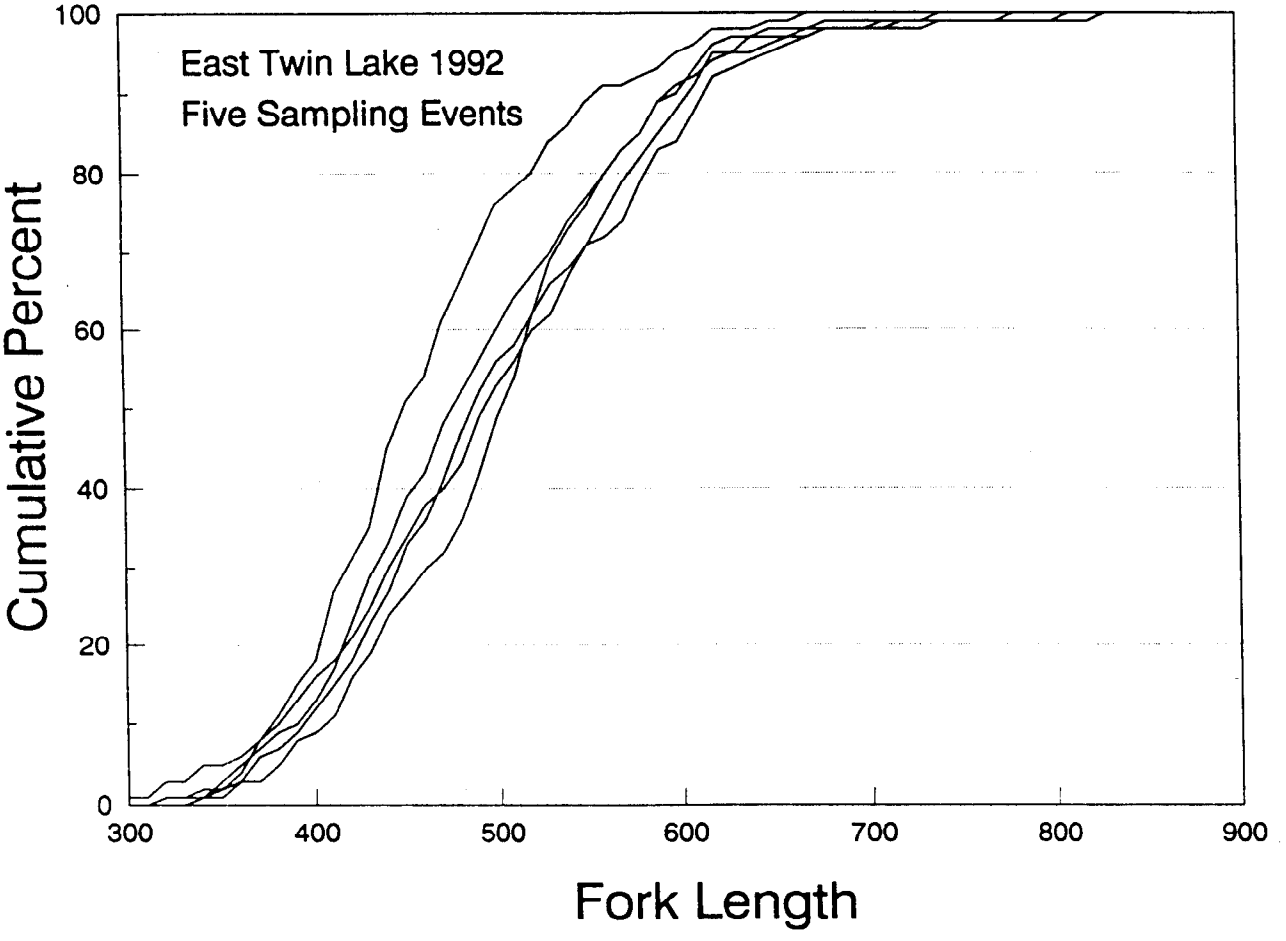

Figure 9. Daily cumulative length distribution frequencies of northern pike captured in East Twin Lake, 1992.

Table 2. Estimated length-at-age of northern pike (> 299 mm FL) in East Twin Lake, 1992.

Number of Fish	Age	Mean Length (mm)	SE
78[a]	---	511	10
2	2	320	< 1
89	3	381	4
239	4	428	3
346	5	487	3
210	6	519	4
94	7	564	6
63	8	606	6
37	9	632	11
23	10	616	15
2	11	729	49
3	12	706	72
1	13	785	___
1	18	1,140	___
Total 1,188			

[a] Includes northern pike for which age was not determined due to unreadable scales being taken.

age at which the majority of fish reach maturity. Sixty one percent of the northern pike were assigned age 5 or younger. Mean length-at-age estimates for age 5 fish (Table 2) are 487 mm. The largest fish captured measured 1,140 mm. The composition by age and mean length-at-age estimated for East Twin Lake is very similar to the average for similar data in Volkmar Lake for the period 1985 through 1991 (Pearse 1991).

Estimated RSDs (Appendix G) indicated the stock category (300 to 525 mm) was dominant, with none captured in the memorable and one in the trophy size categories. Again, this composition virtually mimics that estimated in 1992 for Volkmar Lake. A high percentage in the stock category is probably a good indicator of strong recruitment, but the database is too limited to predict future levels.

The length frequency distribution of sampled northern pike (sexes combined) is described in Appendix K. Approximately 55% of the fish sampled were shorter than 500 mm, and about 90% of the northern pike captured were less than 625 mm in 1992. The length composition was very similar to that determined for Volkmar Lake in 1992.

Of fish captured in 1992, none died through the normal course of sampling events. All fish captured appeared healthy, and had spawned by the time of sampling in early June.

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Appendix A

Appendix A. Recreational fishing effort, harvest, and exploitation of northern pike in Volkmar, George, and T lakes, 1977-1991.

Lake	Angler Days[a]	Angler Days Per Ha[a]	Harvest of Northern Pike[a]	Harvest Per Angler Day	Estimated Abundance of Northern Pike > 299 mm	Estimated Exploitation Rate if Harvested Fish were > 299 mm	Estimated Abundance of Northern Pike > 449 mm	Estimated Exploitation Rate if Harvested Fish were > 449 mm
Volkmar								
1981	458	1.7	648	1.4				
1982	546	2.0	777	1.4				
1983	270	1.0	430	1.6				
1984	436	1.6	428	1.0				
1985	711	2.6	503	0.7			4,020	0.13
1986	596	2.2	657	1.1	8,056	0.08	4,028	0.16
1987	472	1.7	224	0.5	6,932	0.03	4,230	0.05
1988	186	0.7	255	1.4	2,766	0.09	2,196	0.12
1989	466	1.7	180	0.4	1,330	0.14	1,115	0.16
1990	129	0.5	84	0.7	4,038	0.02	2,019	0.04
1991	1,052	3.9	565	0.5	4,510	0.13	2,509	0.23
Mean	484	1.8	432	0.9	4,605	0.08[b]	2,683	0.13[b]
George								
1977	854	0.5	1,227	1.4				
1978	1,271	0.7	1,392	1.1				
1979	903	0.5	2,018	2.2				
1980	1,057	0.6	1,395	1.3				
1981	1,351	0.7	2,236	1.7				
1982	989	0.5	1,635	1.7				
1983	860	0.5	1,322	1.5				
1984	557	0.3	1,700	3.1				
1985	1,127	0.6	2,670	2.4				
1986	1,957	1.1	3,076	1.6				
1987	1,467	0.8	2,229	1.5	17,662	0.13	8,495	0.26
1988	964	0.5	1,837	1.9	23,381	0.08	16,680	0.11
1989	610	0.3	882	1.4	25,466	0.03	12,606	0.07
1990	1,540	0.8	945	0.6	11,568	0.08	8,107	0.12
1991	1,931	1.1	1,264	0.7	15,944	0.08	10,939	0.12
Mean	1,163	0.6	1,722	1.5	18,804	0.08[c]	11,365	0.13[c]
T								
1989	67	0.4	60	0.9	298	0.20	271	0.22

-continued-

Appendix A. (Page 2 of 2).

Lake	Angler Days[a]	Angler Days Per Ha[a]	Harvest of Northern Pike[a]	Harvest Per Angler Day	Estimated Abundance of Northern Pike > 299 mm	Estimated Exploitation Rate if Harvested Fish were > 299 mm	Estimated Abundance of Northern Pike > 449 mm	Estimated Exploitation Rate if Harvested Fish were > 449 mm
East Twin								
1983	388	0.7	839	2.2				
1984	87	0.2	208	2.4				
1985	104	0.2	0	0.0				
1986	76	0.1	24	0.3				
1987	398	0.8	66	0.2				
1988	637	1.2	346	0.5				
1989	765	1.5	832	1.1				
1990	1,035	2.0	760	0.7				
1991	679	1.3	625	0.9	595	0.08	5,016	0.12
Mean	463	0.9	411	0.9				

[a] Data source: Mills 1979-1992, Mills pers comm. 1992.
[b] Includes 1986-1991 data only.
[c] Includes 1987-1991 data only.

APPENDIX B

Appendix B. Sampling dates and abundance estimate types for Volkmar, George, T, and East Twin lakes, 1985-1992.

		Dates	Type Estimate	Comments
Volkmer Lake:				
1985	Mark Event	5/31-6/6	Stratified Petersen (> 449 mm FL)	No recaps < 450 mm.
	Recapture Event	6/17-6/19	(1) 450 - 699 mm	Gear selectivity for large
	11-day hiatus		(2) > 699 mm	fish with gill nets noted.
1986	Mark Event	6/3-6/6	Stratified Petersen	Gear selectivity occurred for
	Recapture Event	6/16-6/19	(1) < 450 mm	large fish with gill nets
	10-day hiatus		(2) 450-749 mm	(also seines/traps used;
			(3) > 750 mm	not selective).
1987	Mark Event	5/19-5/25	Stratified Petersen	Beach seine used
	Recapture Event	5/27-5/29	(1) 300-549 mm (Darroch)	(some gillnetting).
	2-day hiatus		(2) 550-645 mm (Darroch)	Sampling gears selective
			(3) > 650 mm (Petersen)	for large fish.
				Large fish (3) didn't mix.
1988	Mark Event 1988	5/23-5/31	Two-Season Stratified Petersen	Seines used from this year on.
	Recapture Event	1989	(1) 300-525 mm (Robson/Flick)	Insufficient fish captured to
			(2) 526-675 mm (Petersen)	do a within-season estimate.
			(3) > 676 mm (Petersen)	
1989	Mark Event 1989	5/19-5/29	Two-Season Petersen	Insufficient captures during 1989
	Recapture Event	1990	(Robson/Flick)	for within-season estimates.
				Case IV B for composition estimates.
1990	Mark Event	5/16-5/19	Unstratified Petersen	Case IV B for composition estimates.
	Recapture Event	5/22-5/24		
	3-day hiatus			
1991	Mark Event	5/20-5/25	Petersen	Case IV B for composition estimates.
	Recapture Event	5/28-5/30		
	3-day hiatus			
1992	Capture-Recap-	6/2-6/9	m_t (Program Capture)	
	ture Event		Unstratified	

-continued-

Appendix B. (Page 2 of 3).

		Dates	Type Estimate	Comments
"T" Lake:				
1986	Mark Event Recapture Event 10 day hiatus	5/30-6/1 6/11-6/12	Stratified Petersen (> 450 mm FL) (1) 450-749 (2) 750 -->	No recaps < 450 mm. Gill nets size selective for large fish. Mixing okay.
1987	Mark Event Recapture Event 3-day hiatus	5/27-5/29 6/1-6/3	Petersen (1) 300-449 mm (2) 450-745 mm (3) 750 --> mm	Mix okay; no length bias (stratified to simplify comparison between years only).
1988	Mark Event Recapture Event 2-day hiatus	5/18-5/21 5/23-5/28	Petersen	Mixing sufficient, no size bias detected.
1989	Mark Event Recapture Event	5/18-5/26 1990	2 season Petersen (Robson/Flick)	1990 Recap event. Insufficient captures to do 1988 estimate.
1990	Mark Event Recapture Event 1-day hiatus	5/18 5/20-5/21	Petersen	Case II Composition estimate.
1991	Mark Event Recapture Event	5/20-5/21 5/24-5/25	Stratified Petersen By Area	Composition weighted by area abundance and summed across area strata
1992	Capture-Recapture Event	6/1-6/6	m_t (Program Capture) Unstratified	
George Lake:				
1987	Mark Event Recapture Event 14-day hiatus	6/2-6/9 6/23-6/29	Darroch	Unequal mixing/mark probabilities. 5 strata for composition estimate using 2nd event data.
1988	Mark Event Recapture Event 3-day hiatus	5/24-5/28 6/1-6/4	Darroch	Unequal mixing/mark probabilities. Size selectivity during 1st event = 2nd event for composition.

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Appendix B. (Page 3 of 3).

	Dates		Type Estimate	Comments
1989	Mark Event	5/31-6/5	Petersen	Case II composition estimate.
	Recapture Event	6/9-6/12		
	4-day hiatus			
1990	Mark Event	5/25-5/29	Minimum Petersen	Case II composition estimate.
	Recapture Event	6/1-6/3	(stratified by area)	
	2-day hiatus		(1) area 1 & 3	Fish failed to mix between lake area.
			(2) area 2	
1991	Mark Event	5/24-5/26	Petersen	Case I for composition estimates.
	Recapture Event	5/30-6/05		
	3-day hiatus			
1992	Capture-Recapture Event	6/8-6/18	m_t (Program Capture) Unstratified	
East Twin:				
1992	Capture-Recapture Event	6/6-6/10	m_t (Program Capture) Unstratified	

APPENDIX C

Appendix C. Fin clips and tags assigned to northern pike in Volkmar, George, T, and East Twin lakes, 1983-1992.

Year	Tag Series[c]	Color[a]	Fin Clips[b]	Comments
George Lake				
<1983	Jaw Tags		None	
1983	16197 - 16206	Red	None	
1984	16221 - 16305	Red	None	
1985	No Sampling			
1986	3000, 4000 series	Yellow	004	Coded LV in original data.
	17000 series	Red		
1987	20000, 30000 series	White		
	17715		008	Most tagged fish given 008; when ran out of tags, gave 002; a few tagged fish given 002.
	17836 - 17999	Red	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	
1990	55000 - 55999	Blue	Option 5 = 1	Right opercle punch
	56000 - 57179	Blue	Same	
1991	54001 - 54998	Blue	Option 5 = 4	Dorsal fin clip
	57200 - 57999	Blue	Same	
	58000 - 58597	Blue	Same	
1992	07000 - 08843	Grey	Option 5 = 8	Anal fin clip
Volkmar Lake				
1983	16189 - 16196	Red	None	
	174 - 214	Blue		
1984	16207 - 16347	Red	None	
1985	16431 - 17568	Red	None	
1986	3000, 4000 series	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 series	Red	Many odd combos	
	20400 - 20454	White		

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Appendix C. (Page 2 of 2).

Year	Tag Series	Color[a]	Fin Clips[b]	Comments
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
1990	50000 - 50516	Blue	Option 5 - 1	Right opercle punch
1991	50517 - 50999	Blue	Option 5 - 4	Dorsal fin clip
	51000 - 51307	Blue	Same	
1992	03003 - 03442	Grey	Option 5 - 8	Anal fin clip
T Lake				
1986	3247 - 3618	Yellow	002 004 032	002 - accidental wrong clip; 004 - Mark Run; 032 - Recap Run.
1987	17569 - 17834	Red	008	
1988	99000 - 99139	Green	064	
1989	20000 - 20017	Green	Option 5 - 2	Left opercle punch
	20050 - 20058	Green	Same	
1990	59000 - 59055	Blue	Option 5 - 1	Right opercle punch
	59100 - 59126	Blue	Same	
1991	59250 - 59299	Blue	Option 5 - 4	Dorsal fin clip
	59344,59346-7	Blue	Same	
	59349	Blue	Same*	
1992	06000 - 06109	Grey	Option 5 - 8	Anal fin clip
East Twin				
1992	00000 - 01198	Grey	Option 5 - 8	Anal fin clip

[a] Color Codes: 01 - Not Checked, 02 - Yellow, 03 - Green, 04 - White, 05 - Red, 06 - Blue, 08 - Grey.

[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, Option 5 - 1 - Right opercle punch, Option 5 - 8 - Anal fin clip.

[c] Tag series may not indicate the total number of tags applied.

APPENDIX D

Appendix D. Number of northern pike marked and recaptured by event in Volkmar, George, T, and East Twin lakes, 1992.

Event	Fish Caught (C)	Newly Caught	Tags at Start of Daily Event (M)	Recaptured[a] (R)	Recapture Rate % (R/M)	Ratio (R/C) %
T Lake:						
1	56	56	0	0		0.0
2	73	70	56	3	5.4	4.1
3	73	56	126	17	13.5	23.3
4	87	72	182	15	8.2	17.2
5	71	50	254	21	8.3	29.6
6	29	14	304	15	4.9	51.7
Total			318	71		
East Twin Lake:						
1	154	154	0	0		
2	172	169	154	3	1.9	1.7
3	361	343	323	18	5.6	5.0
4	290	260	666	30	4.5	10.3
5	293	262	926	31	3.3	10.6
Total			1,188	82		
Volkmar Lake:						
1	112	112	0	0		
2	78	76	112	2	1.8	2.6
3	82	79	188	3	1.6	3.7
4	100	94	267	6	2.2	6.0
5	86	75	361	11	3.0	12.8
6	49	42	436	7	1.6	14.3
7	55	49	478	6	1.3	10.9
8	76	65	527	11	2.1	14.5
Total			592	45		
George Lake:						
1	40	40	0	0		
2	181	181	40	0	0.0	0.0
3	188	185	221	3	1.4	1.6
4	92	82	406	10	2.5	10.9
5	120	114	488	6	1.2	5.0
6 [b]	56	54	602	2	0.3	3.6
7	116	100	656	16	2.4	13.8
8	180	162	756	18	2.4	10.0
9	366	325	918	41	4.5	11.2
10	267	239	1,243	28	2.3	10.5
11	216	186	1,482	30	2.0	13.9
Total			1,668	154		

[a] No necessarily unique fish.
[b] Day 6 data removed in final analysis due to size bias in that event.

APPENDIX E

Appendix E. Abundance and density of various size groups of northern pike (> 299 mm FL) in Volkmar, George, T, and East Twin lakes, 1985-1992.

Lake/ Year	Small (300-449 mm) Abundance Estimate	SE	Small (300-449 mm) Proportion Estimate	SE	Medium (450-749 mm) Abundance Estimate	SE	Medium (450-749 mm) Proportion Estimate	SE	Large (Larger than 749 mm) Abundance Estimate	SE	Large (Larger than 749 mm) Proportion Estimate	SE	All (Larger than 299 mm) Abundance Estimate	SE	All (Larger than 299 mm) Density (Fish/Ha)	All (Larger than 449 mm) Abundance Estimate	SE	All (Larger than 449 mm) Proportion Estimate	SE	All (Larger than 449 mm) Density (Fish/Ha)
Volkmar																				
1985	---	---	---	---	3,732	201	---	---	288	24	---	---	---	---	---	4,020	250	---	---	15
1986	4,028	2,266	0.50	0.006	3,891	584	0.48	0.006	137	65	0.02	0.001	8,056	2,915	29.5	4,028	587	0.50	0.006	14.8
1987	2,703	641	0.39	0.006	4,118	634	0.59	0.006	111	22	0.02	0.002	6,932	1,542	25.4	4,230	634	0.61	0.006	15.5
1988	570	64	0.21	0.008	2,135	147	0.77	0.008	61	19	0.02	0.003	2,766	177	10.1	2,196	148	0.79	0.008	8.0
1989	215	43	0.16	0.010	974	177	0.73	0.012	141	30	0.11	0.008	1,330	240	4.9	1,115	179	0.84	0.010	4.1
1990	2,019	372	0.50	0.026	1,866	346	0.46	0.026	153	48	0.04	0.010	4,038	714	14.8	2,019	349	0.50	0.028	7.4
1991	2,001	253	0.44	0.018	2,276	285	0.51	0.018	233	46	0.05	0.008	4,510	541	16.5	2,509	289	0.56	0.020	9.2
1992	1,346	212	0.35	0.020	2,450	368	0.63	0.02	92	28	0.02	0.006	3,888	572	14.2	2,542	369	0.65	0.021	9.3
George																				
1987	9,167	978	0.52	0.004	8,195	1,031	0.46	0.004	300	342	0.02	0.001	17,662	2,105	9.7	8,495	1,086	0.48	0.004	4.7
1988	8,264	2,310	0.35	0.003	14,705	4,083	0.63	0.003	412	145	0.02	0.001	23,381	6,471	12.8	15,117	4,086	0.65	0.003	9.1
1989	13,112	1,710	0.51	0.003	11,845	1,471	0.47	0.003	509	67	0.02	0.001	25,466	3,157	14.0	12,354	1,473	0.49	0.003	6.9
1990	3,461	412	0.30	0.004	7,946	891	0.69	0.004	161	43	0.01	0.001	11,568	1,277	6.3	8,107	892	0.70	0.004	4.4
1991	5,005	473	0.31	0.009	10,496	957	0.66	0.009	443	65	0.03	0.003	15,944	1,436	8.7	10,939	959	0.69	0.009	6.0
1992	2,308	214	0.25	0.011	6,500	536	0.70	0.012	501	68	0.05	0.006	9,309	750	5.1	7,001	540	0.75	0.013	3.8
T																				
1986	---	---	---	---	412	37	---	---	42	5	---	---	---	---	---	454	37	---	---	2.9
1987	107	18	0.17	0.015	452	53	0.73	0.018	64	13	0.10	0.012	623	70	3.9	516	54	0.83	0.015	3.3
1988	73	12	0.16	0.017	350	34	0.75	0.020	42	9	0.09	0.013	465	43	2.9	392	35	0.84	0.017	2.5
1989	27	9	0.09	0.017	247	25	0.83	0.022	24	9	0.08	0.016	298	31	1.9	271	27	0.91	0.017	1.7

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Appendix E. (Page 2 of 2).

Lake/ Year	Small (300-449 mm) Abundance Estimate	SE	Small (300-449 mm) Proportion Estimate	SE	Medium (450-749 mm) Abundance Estimate	SE	Medium (450-749 mm) Proportion Estimate	SE	Large (Larger than 749 mm) Abundance Estimate	SE	Large (Larger than 749 mm) Proportion Estimate	SE	All (Larger than 299 mm) Abundance Estimate	SE	All (Larger than 299 mm) Density (Fish/Ha)	All (Larger than 449 mm) Abundance Estimate	SE	All (Larger than 449 mm) Proportion Estimate	SE	All (Larger than 449 mm) Density (Fish/Ha)
T (Cont'd)																				
1990	46	12	0.13	0.018	286	37	0.82	0.020	15	7	0.04	0.011	347	42	2.2	301	38	0.87	0.018	1.9
1991	40	9	0.12	0.025	264	32	0.81	0.030	24	7	0.07	0.020	328	54	2.1	288	33	0.88	0.036	1.8
1992	74	15	0.10	0.017	665	66	0.85	0.020	42	11	0.05	0.013	782	75	4.9	707	67	0.90	0.023	4.5
East Twin																				
1992	2,433	270	0.33	0.014	4,960	521	0.66	0.014	56	20	0.01	0.003	7,449	768	14.2	5,016	522	0.67	0.014	9.5

Appendix F

Appendix F. Model selection criteria used by program CAPTURE, 1992.

Model Lake Criteria[a]	M_o	M_h	M_b	M_{bh}	M_t	M_{th}	M_{tb}	M_{tbh}
Volkmar	0.14	0.00	0.54	0.29	<u>0.30</u>	0.55	1.00	0.41
George	0.13	0.00	0.01	0.02	<u>1.00</u>	0.78	0.32	0.22
T	0.20	0.00	0.62	0.10	<u>1.00</u>	0.81	0.90	0.54
East Twin	0.69	0.66	0.04	0.00	<u>0.90</u>	0.70	0.55	1.00

[a] Model selected by CAPTURE has maximum value. Model selected by authors is underlined, justification found in text.

APPENDIX G

Appendix G. Percent RSDs and abundance of northern pike (> 299 mm FL) in Volkmar, George, T, and East Twin lakes, 1986-1992.

Lake	1986 RSD[a]	1986 SE	1986 Abundance	1986 SE	1987 RSD[a]	1987 SE	1987 Abundance	1987 SE	1988 RSD[a]	1988 SE	1988 Abundance	1988 SE
Volkmar												
Stock	59	12.0	4,719	2,269	65	4.2	4,496	1,056	48	2.3	1,316	106
Quality	34	2.7	2,730	413	28	4.2	1,976	317	39	2.3	1,080	94
Preferred	7	0.8	562	91	6	0.9	412	64	12	1.6	352	49
Memorable	1	0.3	45	23	1	0.2	48	12	1	0.4	18	11
Trophy	0	---	---	---	0	---	---	---	0	---	---	---
Total	100		8,056	2,915	100		6,932	1,542	100		2,766	177
George			[b]									
Stock	69	2.4	---	---	74	1.6	13,123	1,589	64	1.5	15,011	4,168
Quality	23	2.2	---	---	21	1.5	3,709	514	27	1.4	6,196	1,743
Preferred	8	1.5	---	---	5	0.8	830	172	9	0.9	2,081	610
Memorable	0	---	---	---	0	---	---	---	0	---	---	---
Trophy	0	---	---	---	0	---	---	---	0	---	---	---
Total	100				100		17,662	2,105	100		23,381	6,471
T			[c]									
Stock	14	1.6	---	---	40	2.9	248	33	37	3.0	173	21
Quality	44	2.4	---	---	27	2.6	166	25	35	2.9	161	20
Preferred	41	2.3	---	---	31	2.8	197	28	26	2.7	120	17
Memorable	1	0.5	---	---	2	0.8	11	5	2	0.9	10	4
Trophy	0	---	---	---	0	---	---	---	0	---	---	---
Total	100				100		623	70	100		465	43

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Appendix G. (Page 2 of 3).

Lake	1989 RSD[a]	1989 SE	1989 Abundance	1989 SE	1990 RSD[a]	1990 SE	1990 Abundance	1990 SE	1991 RSD[a]	1991 SE	1991 Abundance	1991 SE
Volkmar												
Stock	36	1.8	481	90	66	2.5	2,674	483	65	1.8	2,939	361
Quality	44	1.9	581	107	25	2.3	1,026	203	25	1.6	1,141	155
Preferred	19	1.5	247	49	8	1.4	327	81	8	1.0	350	61
Memorable	2	0.5	21	7	< 1	0.3	11	11	2	0.5	80	24
Trophy	0	---	---	---	0	---	---	---	0	---	---	---
Total	100		1,330	285	100		4,038		100		4,510	541
George												
Stock	60	1.4	15,280	1,915	62	1.4	7,172	808	58	1.0	9,252	847
Quality	33	1.3	8,302	1,074	31	1.4	3,551	424	30	0.9	4,826	458
Preferred	7	0.7	1,834	287	7	0.8	833	130	11	0.6	1,835	193
Memorable	0	---	---	---	0	---	---	---	1	0.1	31	14
Trophy	0	---	---	---	0	---	---	---	0	---	---	---
Total	100		25,466	3,137	100		11,567	1,277	100		15,944	1,436
T												
Stock	30	4.9	88	17	30	4.3	103	19	27	3.4	89	15
Quality	53	5.3	159	23	50	4.7	174	27	49	3.8	160	23
Preferred	16	3.9	47	13	20	3.8	70	16	23	3.2	75	13
Memorable	1	1.3	3	3	0	---	---	---	1	0.8	4	3
Trophy	0	---	---	---	0	---	---	---	0	---	---	---
Total	100		298	32	100		347	42	100		328	54

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Appendix G. (Page 3 of 3).

Lake	1992 RSD[a]	SE	Abundance	SE
Volkmar				
Stock	62	2.0	2,424	365
Quality	32	1.9	1,241	197
Preferred	5	0.9	197	45
Memorable	< 1	0.3	26	14
Trophy	0	---	---	---
Total	100		3,888	572
George				
Stock	48	1.3	4,492	382
Quality	36	1.3	3,413	299
Preferred	15	0.9	1,378	141
Memorable	< 1	0.1	26	13
Trophy	0	---	---	---
Total	100		9,309	750
T				
Stock	34	2.7	263	33
Quality	49	2.8	382	43
Preferred	16	2.1	132	21
Memorable	< 1	0.4	5	4
Trophy	0	---	---	---
Total	100		782	75
East Twin				
Stock	65	1.4	4,847	510
Quality	31	1.3	2,358	263
Preferred	3	0.5	238	45
Memorable	0	---	---	---
Trophy	< 1	0.1	6	6
Total	100		7,449	768

[a] Stock = 300-524 mm, quality = 525-654 mm, preferred = 655-899 mm, memorable = 860-1,079 mm, and trophy = 1,080 mm and larger (Clark 1988).

[b] Abundance unavailable; RSD's reflect sampled fish only.

[c] As above.

APPENDIX H

Appendix H. Length frequency of all northern pike sampled in Volkmar Lake, 1985-1992.

Length Class (mm)	1985		1986		1987		1988	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
< - 249	66	5.3	5	0.3	6	0.5	6	1.2
250 - 274	7	0.6	20	1.2	42	3.8	1	0.2
275 - 299	13	1.0	67	4.1	82	7.4	5	1.0
300 - 324	13	1.0	57	3.5	65	5.8	11	2.2
325 - 349	15	1.2	49	3.0	61	5.5	16	3.3
350 - 374	24	1.9	40	2.4	63	5.7	18	3.7
375 - 399	14	1.1	49	3.0	58	5.2	23	4.7
400 - 424	24	1.9	58	3.5	52	4.7	13	2.7
425 - 449	32	2.6	76	4.6	36	3.2	21	4.3
450 - 474	43	3.4	63	3.8	60	5.4	33	6.7
475 - 499	69	5.5	61	3.7	64	5.8	45	9.2
500 - 524	91	7.3	89	5.4	72	6.5	48	9.8
525 - 549	114	9.1	112	6.8	60	5.4	56	11.4
550 - 574	163	13.0	178	10.8	64	5.8	38	7.8
575 - 599	134	10.7	237	14.4	78	7.0	40	8.2
600 - 624	105	8.4	187	11.3	69	6.2	30	6.1
625 - 649	48	3.8	94	5.7	48	4.3	16	3.3
650 - 674	40	3.2	76	4.6	34	3.1	28	5.7
675 - 699	32	2.6	33	2.0	32	2.9	8	1.6
700 - 724	37	3.0	24	1.5	29	2.6	15	3.1
725 - 749	29	2.3	23	1.4	15	1.3	8	1.6
750 - 774	19	1.5	8	0.5	5	0.4	3	0.6
775 - 799	18	1.4	7	0.4	3	0.3	4	0.8
800 - 824	19	1.5	8	0.5	2	0.2	1	0.2
825 - 849	26	2.1	6	0.4	3	0.3	0	0.0
850 - 874	27	2.2	4	0.2	3	0.3	0	0.0
875 - 899	12	1.0	6	0.4	0	0.0	0	0.0
900 - 924	10	0.8	7	0.4	1	0.1	0	0.0
925 - 949	3	0.2	2	0.1	1	0.1	1	0.2
950 - 974	4	0.3	1	0.1	1	0.1	2	0.4
975 - 999	1	0.1	0	0.0	0	0.0	0	0.0
1,000 -1,024	0	0.0	2	0.1	0	0.0	0	0.0
> 1,024	0	0.0	0	0.0	4	0.4	0	0.0
Total	1,252	100.0	1,649	100.0	1,113	100.0	490	100.0

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Appendix H. (Page 2 of 2).

Length Class (mm)	1989		1990		1991		1992	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
< - 249	7	1.0	7	2.0	0	0	0	0.0
250 - 274	6	0.8	22	6.2	2	0.2	0	0.0
275 - 299	8	1.1	41	11.6	2	0.2	0	0.0
300 - 324	16	2.2	50	14.1	89	8.8	23	3.9
325 - 349	14	2.0	56	15.8	75	7.4	31	5.2
350 - 374	16	2.2	40	11.3	77	7.6	29	4.9
375 - 399	13	1.8	20	5.6	102	10.1	42	7.1
400 - 424	15	2.1	30	8.5	94	9.3	33	5.6
425 - 449	37	5.2	12	3.4	55	5.5	47	7.9
450 - 474	40	5.6	10	2.8	60	5.9	56	9.5
475 - 499	53	7.4	12	3.4	60	5.9	57	9.6
500 - 524	47	6.6	11	3.1	66	6.5	51	8.6
525 - 549	70	9.8	3	0.8	43	4.3	57	9.6
550 - 574	83	11.7	6	1.7	55	5.5	46	7.8
575 - 599	73	10.3	11	3.1	50	5.0	44	7.4
600 - 624	38	5.3	11	3.1	45	4.5	32	5.4
625 - 649	30	4.2	6	1.7	34	3.4	9	1.5
650 - 674	22	3.1	0	0.0	16	1.6	7	1.2
675 - 699	15	2.1	1	0.3	14	1.4	8	1.4
700 - 724	25	3.5	0	0.0	9	0.9	5	0.8
725 - 749	11	1.5	1	0.3	11	1.1	1	0.2
750 - 774	13	1.8	0	0.0	8	0.8	4	0.7
775 - 799	22	3.1	1	0.3	8	0.8	0	0.0
800 - 824	17	2.4	1	0.3	9	0.9	3	0.5
825 - 849	5	0.7	0	0.0	3	0.3	2	0.3
850 - 874	10	1.4	1	0.3	10	1.0	1	0.2
875 - 899	2	0.3	0	0.0	5	0.5	2	0.3
900 - 924	0	0.0	0	0.0	2	0.2	1	0.2
925 - 949	2	0.3	1	0.3	3	0.3	1	0.2
950 - 974	0	0.0	0	0.0	1	0.1	0	0.0
975 - 999	2	0.3	0	0.0	1	0.1	0	0.0
1,000 -1,024	0	0.0	0	0.0	0	0.0	0	0.0
> 1,024	0	0.0	0	0.0	0	0.0	0	0.0
Total	712	100.0	354	100.0	1,009	100.0	592	100.0

APPENDIX I

Appendix I. Length frequency of all northern pike sampled in George Lake, 1987-1992.

Length Class (mm)	1987 Males No. of Fish	1987 Males Percent	1987 Females No. of Fish	1987 Females Percent	1987 All Fish No. of Fish	1987 All Fish Percent	1988 Males No. of Fish	1988 Males Percent	1988 Females No. of Fish	1988 Females Percent	1988 All Fish No. of Fish	1988 All Fish Percent
< 249	0	0.0	0	0.0	0	0.0	1	0.1	3	0.3	6	0.3
250 - 274	1	0.3	0	0.0	9	1.1	0	0.0	0	0.0	0	0.0
275 - 299	6	2.1	3	0.9	40	5.1	0	0.0	0	0.0	0	0.0
300 - 324	29	10.0	10	3.1	60	7.6	1	0.1	0	0.0	13	0.6
325 - 349	37	12.7	26	8.0	72	9.1	7	0.7	0	0.0	63	2.8
350 - 374	25	8.6	16	4.9	46	5.8	28	2.8	1	0.1	73	3.3
375 - 399	26	8.9	23	7.1	59	7.4	38	3.8	5	0.5	72	3.2
400 - 424	37	12.7	26	8.0	72	9.1	72	7.2	19	1.9	116	5.2
425 - 449	30	10.3	19	5.8	60	7.6	123	12.3	41	4.2	182	8.2
450 - 474	22	7.6	23	7.1	60	7.6	158	15.8	64	6.5	240	10.8
475 - 499	24	8.2	34	10.4	69	8.7	167	16.7	76	7.7	253	11.4
500 - 524	18	6.2	24	7.4	57	7.2	117	11.7	104	10.6	231	10.4
525 - 549	13	4.5	25	7.7	44	5.6	100	10.0	99	10.1	204	9.2
550 - 574	11	3.8	20	6.1	35	4.4	75	7.5	89	9.1	167	7.5
575 - 599	4	1.4	20	6.1	33	4.2	56	5.6	82	8.4	141	6.4
600 - 624	6	2.1	13	4.0	21	2.7	27	2.7	82	8.4	111	5.0
625 - 649	1	0.3	11	3.4	15	1.9	12	1.2	69	7.0	82	3.7
650 - 674	0	0.0	11	3.4	13	1.6	5	0.5	60	6.1	66	3.0
675 - 699	1	0.3	6	1.8	7	0.9	6	0.6	65	6.6	71	3.2
700 - 724	0	0.0	3	0.9	4	0.5	0	0.0	36	3.7	36	1.6
725 - 749	0	0.0	3	0.9	3	0.4	2	0.2	33	3.4	35	1.6
750 - 774	0	0.0	4	1.2	5	0.6	1	0.1	16	1.6	17	0.8
775 - 799	0	0.0	3	0.9	5	0.6	2	0.2	16	1.6	18	0.8
800 - 824	0	0.0	1	0.3	1	0.1	0	0.0	6	0.6	6	0.3
825 - 849	0	0.0	1	0.3	1	0.1	0	0.0	6	0.6	6	0.3
850 - 874	0	0.0	1	0.3	1	0.1	0	0.0	5	0.5	5	0.2
875 - 899	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	1	0.0
900 - 924	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	1	0.0
925 - 949	0	0.0	0	0.0	0	0.0	0	0.0	2	0.2	2	0.1
950 - 974	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	1	0.0
975 - 999	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
>999	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	291	100.0	998	100.0	326	100.0	982	100.0	792	100.0	2,219	100.0

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Appendix I. (Page 2 of 3).

Length Class (mm)	1989 Males No. of Fish	1989 Males Percent	1989 Females No. of Fish	1989 Females Percent	1989 All Fish No. of Fish	1989 All Fish Percent	1990 Males No. of Fish	1990 Males Percent	1990 Females No. of Fish	1990 Females Percent	1990 All Fish No. of Fish	1990 All Fish Percent
< 249	3	0.4	3	0.2	6	0.2	0	0.0	1	0.3	6	0.3
250 - 274	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
275 - 299	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
300 - 324	0	0.0	1	0.1	15	0.6	0	0.0	0	0.0	4	0.2
325 - 349	5	0.6	6	0.5	51	2.1	1	0.4	1	0.3	35	1.5
350 - 374	13	1.6	5	0.4	74	3.0	3	1.3	0	0.0	30	1.3
375 - 399	26	3.3	10	0.8	94	3.9	11	4.7	0	0.0	49	2.1
400 - 424	51	6.4	28	2.2	122	5.0	15	6.5	0	0.0	80	3.4
425 - 449	69	8.7	39	3.1	157	6.5	38	16.4	2	0.6	172	7.2
450 - 474	112	14.1	67	5.3	209	8.6	44	19.0	4	1.3	243	10.2
475 - 499	118	14.9	73	15.8	219	9.0	38	16.4	7	2.2	242	10.2
500 - 524	102	12.9	101	8.0	225	9.2	19	8.2	9	2.9	226	9.5
525 - 549	109	13.7	125	9.9	249	10.2	18	7.8	13	4.1	211	8.9
550 - 574	80	10.1	124	9.8	213	8.8	14	6.0	10	3.2	199	8.4
575 - 599	46	5.8	154	12.2	205	8.4	13	5.6	26	8.3	206	8.7
600 - 624	36	4.5	139	11.0	177	7.3	7	3.0	33	10.5	174	7.3
625 - 649	11	1.4	107	8.5	121	5.0	5	2.2	34	10.8	119	5.0
650 - 674	8	1.0	77	6.1	88	3.6	2	0.9	35	11.1	117	4.9
675 - 699	0	0.0	54	4.3	55	2.3	2	0.9	36	11.4	101	4.2
700 - 724	1	0.1	51	4.0	52	2.1	0	0.0	25	7.9	53	2.2
725 - 749	1	0.1	27	2.1	28	1.2	2	0.9	28	8.9	39	1.6
750 - 774	1	0.1	24	1.9	25	1.0	0	0.0	18	5.7	25	1.1
775 - 799	1	0.1	13	1.0	14	0.6	0	0.0	12	3.8	21	0.9
800 - 824	0	0.0	13	1.0	13	0.5	0	0.0	11	3.5	15	0.6
825 - 849	0	0.0	13	1.0	13	0.5	0	0.0	3	1.0	5	0.2
850 - 874	0	0.0	2	0.2	2	0.5	0	0.0	2	0.6	2	0.1
875 - 899	0	0.0	6	0.5	6	0.1	0	0.0	2	0.6	2	0.1
900 - 924	0	0.0	1	0.1	1	0.2	0	0.0	3	1.0	3	0.1
925 - 949	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
950 - 974	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.0
975 - 999	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
> 999	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	793	100.0	1,263	100.0	2,434	100.0	232	100.0	315	100.0	2,380	100.0

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Appendix I. (Page 3 of 3).

Length Class (mm)	1991 All Fish No. of Fish	1991 All Fish Percent	1992 All Fish No. of Fish	1992 All Fish Percent
< 249	7	0.3	0	0.0
250 - 274	0	0	0	0.0
275 - 299	0	0	0	0.0
300 - 324	76	2.9	32	2.2
325 - 349	126	4.9	56	3.9
350 - 374	141	5.4	41	2.9
375 - 399	118	4.5	35	2.4
400 - 424	139	5.4	79	5.5
425 - 449	213	8.2	112	7.8
450 - 474	212	8.2	119	8.3
475 - 499	213	8.2	113	7.9
500 - 524	265	10.2	104	7.3
525 - 549	211	8.1	115	8.0
550 - 574	183	7.0	156	10.9
575 - 599	140	5.4	95	6.6
600 - 624	146	5.6	85	5.9
625 - 649	82	3.2	57	4.0
650 - 674	79	3.0	65	4.5
675 - 699	78	3.0	25	1.7
700 - 724	50	1.9	35	2.4
725 - 749	46	1.8	31	2.2
750 - 774	34	1.3	29	2.0
775 - 799	23	0.9	21	1.5
800 - 824	6	0.2	16	1.1
825 - 849	3	0.1	6	0.4
850 - 874	2	0.1	3	0.2
875 - 899	3	0.1	2	0.1
900 - 924	0	0.0	0	0.0
925 - 949	1	0.0	0	0.0
950 - 974	0	0.0	0	0.0
975 - 999	0	0.0	0	0.0
> 999	0	0.0	0	0.0
Total	2,597	100.0	1,432	100.0

APPENDIX J

Appendix J. Length frequency of all northern pike sampled in T Lake, 1986-1992.

Length Class (mm)	1986 Males No. of Fish	1986 Males Percent	1986 Females No. of Fish	1986 Females Percent	1986 All Fish No. of Fish	1986 All Fish Percent	1987 Males No. of Fish	1987 Males Percent	1987 Females No. of Fish	1987 Females Percent	1987 All Fish No. of Fish	1987 All Fish Percent
< 249	0	0.0	0	0.0	1	0.3	0	0.0	0	0.0	6	1.9
250 - 274	0	0.0	0	0.0	1	0.3	0	0.0	0	0.0	0	0.0
275 - 299	0	0.0	0	0.0	2	0.5	0	0.0	0	0.0	0	0.0
300 - 324	1	0.7	0	0.0	3	0.8	4	4.3	0	0.0	10	3.2
325 - 349	4	3.0	0	0.0	6	1.6	7	7.6	4	2.4	12	3.8
350 - 374	2	1.5	0	0.0	4	1.0	4	4.3	0	0.0	7	2.2
375 - 399	1	0.7	0	0.0	3	0.8	2	2.2	1	0.6	4	1.3
400 - 424	6	4.4	0	0.0	7	1.8	5	5.4	1	0.6	8	2.6
425 - 449	5	3.7	2	1.2	9	2.4	2	2.2	4	2.4	8	2.6
450 - 474	4	3.0	0	0.0	6	1.6	8	8.7	5	3.0	15	4.8
475 - 499	3	2.2	3	1.7	11	2.9	16	17.4	7	4.1	25	8.0
500 - 524	5	3.7	3	1.7	10	2.6	12	13.0	8	4.7	21	6.7
525 - 549	9	6.7	4	2.3	17	4.5	7	7.6	6	3.6	16	5.1
550 - 574	12	8.9	7	4.1	21	5.5	3	3.3	7	4.1	12	3.8
575 - 599	16	11.9	12	7.0	28	7.3	6	6.5	9	5.3	19	6.1
600 - 624	22	16.3	12	7.0	40	10.5	7	7.6	6	3.6	13	4.2
625 - 649	21	15.6	11	6.4	43	11.3	3	3.3	10	5.9	15	4.8
650 - 674	15	11.1	24	14.0	42	11.0	2	2.2	14	8.3	17	5.4
675 - 699	3	2.2	20	11.6	26	6.8	1	1.1	19	11.2	24	7.7
700 - 724	3	2.2	16	9.3	24	6.3	3	3.3	15	8.9	21	6.7
725 - 749	3	2.2	20	11.6	30	7.9	0	0.0	15	8.9	16	5.1
750 - 774	0	0.0	13	7.6	17	4.5	0	0.0	9	5.3	10	3.2
775 - 799	0	0.0	9	5.2	11	2.9	0	0.0	5	3.0	7	2.2
800 - 824	0	0.0	4	2.3	7	1.8	0	0.0	10	5.9	11	3.5
825 - 849	0	0.0	5	2.9	5	1.3	0	0.0	4	2.4	5	1.6
850 - 874	0	0.0	2	1.2	2	0.5	0	0.0	3	1.8	4	1.3
875 - 899	0	0.0	3	1.7	3	0.8	0	0.0	3	1.8	3	1.0
900 - 924	0	0.0	1	1.6	1	0.3	0	0.0	1	0.6	1	0.3
925 - 949	0	0.0	0	0.0	0	0.0	0	0.0	2	1.2	2	0.6
950 - 974	0	0.0	0	0.0	0	0.0	0	0.0	1	0.6	1	0.3
975 - 999	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
1,000-1,024	0	0.0	1	0.6	1	0.3	0	0.0	0	0.0	0	0.0
> 1,024	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	135	100.0	172	100.0	381	100.0	92	100.0	169	100.0	313	100.0

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Appendix J. (Page 2 of 3).

Length Class (mm)	1988 Males No. of Fish	1988 Males Percent	1988 Females No. of Fish	1988 Females Percent	1988 All Fish No. of Fish	1988 All Fish Percent	1989 Males No. of Fish	1989 Males Percent	1989 Females No. of Fish	1989 Females Percent	1989 All Fish No. of Fish	1989 All Fish Percent
< 249	0	0.0	0	0.0	45	15.1	0	0.0	0	0.0	0	0.0
250 - 274	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
275 - 299	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
300 - 324	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
325 - 349	6	4.7	0	0.0	7	2.3	0	0.0	0	0.0	3	3.3
350 - 374	8	6.2	0	0.0	8	2.7	2	5.4	0	0.0	3	3.3
375 - 399	5	3.9	0	0.0	5	1.7	0	0.0	0	0.0	1	1.1
400 - 424	3	2.3	0	0.0	4	1.3	0	0.0	0	0.0	1	1.1
425 - 449	5	3.9	2	1.8	7	2.3	0	0.0	0	0.0	0	0.0
450 - 474	8	6.2	2	1.8	12	4.0	0	0.0	0	0.0	1	1.1
475 - 499	8	6.2	4	3.5	13	4.3	2	5.4	0	0.0	4	4.4
500 - 524	14	10.9	1	0.9	16	5.4	2	5.4	0	0.0	5	5.6
525 - 549	16	12.4	6	5.3	22	7.4	4	10.8	4	14.3	10	11.1
550 - 574	17	13.2	6	5.3	23	7.7	6	16.2	0	0.0	12	13.3
575 - 599	8	6.2	12	10.6	22	7.4	2	5.4	2	7.1	6	6.7
600 - 624	9	7.0	7	6.2	16	5.4	4	10.8	4	14.3	9	10.0
625 - 649	6	4.7	9	8.0	16	5.4	9	24.3	0	0.0	10	11.1
650 - 674	6	4.7	6	5.3	13	4.3	2	5.4	7	25.0	9	10.0
675 - 699	6	4.7	9	8.0	16	5.4	1	2.7	0	0.0	1	1.1
700 - 724	2	1.6	14	12.4	17	5.7	0	0.0	2	7.1	2	2.2
725 - 749	1	0.8	10	8.8	11	3.7	1	2.7	2	7.1	3	3.3
750 - 774	1	0.8	6	5.3	6	2.0	0	0.0	2	7.1	3	3.3
775 - 799	0	0.0	3	2.7	3	1.0	0	0.0	0	0.0	0	0.0
800 - 824	0	0.0	3	2.7	3	1.0	0	0.0	2	7.1	2	2.2
825 - 849	0	0.0	1	0.9	2	0.7	1	2.7	1	3.6	2	2.2
850 - 874	0	0.0	5	4.4	5	1.7	1	2.7	1	3.6	2	2.2
875 - 899	0	0.0	3	2.7	3	1.0	0	0.0	0	0.0	0	0.0
900 - 924	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
925 - 949	0	0.0	3	2.7	3	1.0	0	0.0	1	3.6	1	0.0
950 - 974	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.1
975 - 999	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
1,000-1,024	0	0.0	1	0.9	1	0.3	0	0.0	0	0.0	0	0.0
> 1,024	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	129	100.0	113	100.0	299	100.0	37	100.0	28	100.0	90	100.0

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Appendix J. (Page 3 of 3).

Length Class (mm)	1990 Males No. of Fish	1990 Males Percent	1990 Females No. of Fish	1990 Females Percent	1990 All Fish No. of Fish	1990 All Fish Percent	1991 All Fish No. of Fish	1991 All Fish Percent	1992 All Fish No. of Fish	1992 All Fish Percent
< 249	0	0.0	1	1.3	1	0.5	1	0.7	0	0.0
250 - 274	0	0.0	0	0.0	0	0.0	0	0	0	0.0
275 - 299	0	0.0	0	0.0	0	0.0	2	1.3	0	0.0
300 - 324	0	0.0	0	0.0	2	1.0	4	2.6	2	0.6
325 - 349	2	2.4	0	0.0	3	1.4	5	3.3	3	1.0
350 - 374	0	0.0	0	0.0	1	0.5	2	1.3	3	1.0
375 - 399	3	3.6	0	0.0	3	1.4	0	0	1	0.3
400 - 424	1	1.2	1	1.3	4	1.9	5	3.3	11	3.5
425 - 449	1	1.2	0	0.0	4	1.9	3	2.0	10	3.2
450 - 474	7	8.4	0	0.0	11	5.3	9	6.0	19	6.0
475 - 499	5	6.0	3	3.9	13	6.3	6	4.0	28	8.9
500 - 524	5	6.0	1	1.3	6	2.9	10	6.6	29	9.2
525 - 549	4	4.8	2	2.6	6	2.9	5	3.3	30	9.5
550 - 574	9	10.8	2	2.6	13	6.3	21	13.9	34	10.8
575 - 599	22	26.5	7	9.2	35	16.9	7	4.6	37	11.7
600 - 624	13	15.7	8	10.5	30	14.5	6	4.0	29	9.2
625 - 649	4	4.8	5	6.6	14	6.8	19	12.6	17	5.4
650 - 674	0	0.0	9	11.8	11	5.3	13	8.6	20	6.3
675 - 699	1	1.2	11	14.5	14	6.8	10	6.6	11	3.5
700 - 724	2	2.4	7	9.2	11	5.3	7	4.6	11	3.5
725 - 749	1	1.2	4	5.3	6	2.9	3	2.0	3	1.0
750 - 774	1	1.2	3	3.9	5	2.4	3	2.0	7	2.2
775 - 799	0	0.0	4	5.3	4	1.9	1	0.7	2	0.6
800 - 824	0	0.0	3	3.9	3	1.4	5	3.3	3	1.0
825 - 849	1	1.2	1	1.3	2	1.0	2	1.3	3	1.0
850 - 874	1	1.2	2	2.6	3	1.4	2	1.3	0	0.0
875 - 899	0	0.0	1	1.3	1	0.5	0	0.0	0	0.0
900 - 924	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
925 - 949	0	0.0	0	0.0	0	0.0	0	0.0	2	0.6
950 - 974	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
975 - 999	0	0.0	1	1.3	1	0.5	0	0.0	0	0.0
1,000-1,024	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
> 1,024	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	83	100.0	76	100.0	207	100.0	151	100.0	315	100.0

APPENDIX K

Appendix K. Length frequency of all northern pike sampled in East Twin Lake, 1992.

Length Class (mm)	No. of Fish	Percent
300 - 324	11	0.9
325 - 349	10	0.8
350 - 374	60	5.1
375 - 399	66	5.6
400 - 424	111	9.3
425 - 449	130	10.9
450 - 474	135	11.4
475 - 499	128	10.8
500 - 524	122	10.3
525 - 549	100	8.4
550 - 574	82	6.9
575 - 599	86	7.2
600 - 624	82	6.9
625 - 649	23	1.9
650 - 674	15	1.3
675 - 699	8	0.7
700 - 724	5	0.4
725 - 774	5	0.4
775 - 799	4	0.3
800 - 824	1	0.1
825 - 1124	1	0.1
1125 -	1	0.1
Total	1,188	100

APPENDIX L

Appendix L. Evaluation of handling mortality associated with seines for northern pike in George Lake.

INTRODUCTION

In 1991 Department staff working on the stock assessment of northern pike project at George Lake observed some northern pike that they considered to be in poor condition. These fish were reported to be "post spawners, very thin, weak, covered with leeches, and lacking slime". Fish that were seined and held for a period of 15 days as part of the catch and release study (Burkholder 1992) had a mortality rate of 31.5%. In contrast, northern pike caught by hook and line in 1991 looked healthier than those captured by seine, and their mortality rate at the end of the experiment was substantially less (6.1%). Aerial and boat surveys were conducted to look for dead northern pike. Few dead fish were found suggesting that the mortality of the seined fish held in the catch and release study was not representative of the mortality of seined fish that were released in George Lake. In an effort to further investigate handling mortality associated with seining, the holding experiment was repeated in 1992 and indices of well being were estimated and compared for various treatment groups of northern pike.

The specific objectives of this study were to:

1. test the hypothesis that there was no significant (α = 0.10) mortality ($\leq$10%) suffered by northern pike caught once with seines and held in George Lake for 15 days;

2. test the hypothesis that the condition factors of northern pike from the following five sample groups were not significantly different;

   a) caught once with a seine in George Lake in 1986;
   b) caught once with a seine in George Lake in 1991;
   c) caught once with a seine in George Lake in 1992;
   d) caught once with hook and line gear in George Lake in 1992;
   e) caught once with a seine in Volkmar Lake in 1992; and,

3. test the hypothesis that there was no significant differences between percent body fat content of northern pike captured with seines in George Lake and Volkmar Lake in 1992.

METHODS

Handling Mortality

To test the hypothesis that there was no significant mortality (>10%) suffered by northern pike caught once with seines in George Lake, equal numbers of fish (20) from 300-449, 450-599, and 600-749 mm fork length (FL) intervals were captured throughout George Lake and held in an enclosure for 8 to 10 days.

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The enclosure was then checked at least twice per day to determine the number of mortalities. The enclosure had a surface area of approximately 400 m^2, maximum depth of 1.25 m, and was constructed out of conduit panels.

All fish used in this experiment were examined for fin clips and tags to ensure that they had not been previously captured. Before being released into the holding enclosure each fish was tagged with a individually numbered Floy anchor tag, measured to the nearest mm FL, weighed to the nearest 10 g with a Chatillion 860-H scale, and received a partial upper caudal fin clip. This information was recorded onto Tagging-Length mark-sense forms (Version 1.0). In addition time and location of capture and time of release into the holding enclosure was also noted. Determination of sex by external characteristics was considered to be unreliable and therefore not recorded. It was assumed that the fish used in this experiment were post spawners. All surviving fish were released at the end of the experiment.

Sixty northern pike captured by hook and line were also released into the holding enclosure. Handling and data recording procedures were the same as those used for the fish that were seined. The only differences between the two groups were finclips and length distributions. The hook and line treatment group received a partial lower caudal clip so they could be distinguished from the seine treatment group in case of tag loss. Lengths of fish caught with hook and line gear were not evenly distributed between the three length categories. The first 60 fish that were caught were used regardless of length. This was a result of low catch per unit effort.

Mortality rate was defined as the number of northern pike that died within 15 days of capture (by gear type) divided by the total number captured with each gear:

$$\hat{m}_k = \frac{X_k}{n_k} \qquad \text{(L.1)}$$

where:

m_k = the mortality rate of fish that were caught with gear k

n_k = the number of fish that were caught with gear k; and,

X_k = the number of fish caught with gear k that died.

The standard error of this rate is estimated by (Zar 1984):

$$SE[\hat{m}_k] = \left\{ \frac{\hat{m}_k \, (1 - \hat{m}_k)}{n_k - 1} \right\}^{\frac{1}{2}} \qquad \text{(L.2)}$$

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A one-tailed binomial test was performed to determine if the mortality rate for seined fish held for 15 days was significantly greater than 10%. Binomial confidence intervals were calculated for each estimate of mortality due to each of the gear (seine and hook and line). Binomial confidence intervals were calculated as (Zar 1984):

$$LCI_k = \frac{X_k}{X_k+(n_k-X_k+1)F_{\gamma 1,\gamma 2}} \qquad (L.3)$$

$$UCI_k = \frac{(X_k+1)\ F_{\gamma 1',\gamma 2'}}{n_k-X_k+(X_k+1)\ F_{\gamma 1',\gamma 2'}} \qquad (L.4)$$

where:

LCI_k = lower 90% confidence interval for the mortality rate of gear k;

UCI_k = upper 90% confidence interval for the mortality rate of gear k;

n_k = the number of fish that were caught with gear k;

X_k = the number of fish that were caught with gear k that died;

$F_{\gamma 1,\gamma 2}$ = probability from the F distribution with $\gamma 1, \gamma 2$ degrees of freedom where:

$\gamma 1 = 2(n_k-X_k+1)$; and,
$\gamma 2 = 2X_k$;

$F_{\gamma 1,\gamma 2}$ = probability from the F distribution with $\gamma 1, \gamma 2$ degrees of freedom where:

$\gamma 1' = 2(X_k+1)$;
$\gamma 2' = 2(n_k-X_i)$.

Condition (K)

Condition factors (K) from three groups of northern pike captured in 1992 (seined fish at George and Volkmar lakes, and hook and line-captured fish at George Lake) and estimates of K from fish sampled at George Lake in 1991 and 1986 were compared.

To estimate K of northern pike from George Lake in 1992, lengths and weights recorded for the northern pike used in the holding experiment previously described were used. To estimate K of northern pike from Volkmar Lake in 1992, equal numbers of fish from 300-449, 450-599, and 600-749 mm length (FL) intervals were sampled for length and weight in conjunction with the stock

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assessment program for northern pike in Volkmar Lake program. Weight measurements were taken with the same Chatillion 806-H scale used at George Lake in 1992. To increase sample sizes for seine treatments from George and Volkmar Lakes in 1992, data from northern pike used for estimating percent fat content were also used.

Length and weight data from historic data bases were used to calculate K for northern pike from George Lake in 1991 and 1986. Only data from fish 300-749mm (FL) were used for K comparisons. Data used from 1991 and 1986 were collected under similar conditions, shortly after ice out in the spring. Length was measured to the nearest mm (FL). Northern pike were weighed to the nearest 10 g with a Chatillion IN-6 or IN-25 scale at George Lake in 1986 (Peckham and Bernard 1987). Weights used from George Lake in 1991 were measured with the same Chatillion spring scale used at George and Volkmar Lakes in 1992.

Condition factor (K) was calculated according to the isometric formula (Anderson and Gutreuter 1983):

$$K = (W/L^3)(10^5); \qquad (L.5)$$

where:

W = weight of fish (g)
L = fork length of fish (mm).

An analysis of variance (Zar 1984) was used to test for significant differences in mean the condition factors among the following groups:

a) caught once with a seine in George Lake in 1986;
b) caught once with a seine in George Lake in 1991;
c) caught once with a seine in George Lake in 1992;
d) caught once with hook and line gear in George Lake in 1992; and,
e) caught once with a seine in Volkmar Lake in 1992.

Duncan's multiple range test (Zar 1984) was used to test for individual differences between the treatment groups.

Percent Fat Content

Percent fat content of northern pike was measured for fish captured with seines at George and Volkmar lakes in 1992. Northern pike sampled for fat content were sacrificed and the body cavity opened. The contents of the digestive tract and the gonads were removed, the air bladder deflated, and the body cavity wiped clean. Fish were air-weighed to the nearest 0.1 g with an Ohaus triple beam balance. A second weight (to the nearest 0.1 g) was obtained by suspending the fish from the same Ohaus triple beam balance while the fish was totally immersed in a 189 l (50 gal) tub of water. Care was taken to ensure no portion of the fish touched the sides of the tub; all fish were suspended about 8 cm above the bottom of the tub. Water temperatures

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were taken in the tub with a BCR thermometer to the nearest 1 degree C for determining water density. Length and sex of fish were also recorded. The same scales were used at Volkmar Lake and George Lake. Up to two hours of time elapsed between the time of death and the time of weighing, however care was taken to protect the fish from drying.

Percent body fat was calculated with the following formula (Morales et al. 1945):

$$\% \text{ Body Fat} = 100 \left\{ \frac{Df}{dff - df} \right\} \left\{ \frac{Dff}{Sp.\ Gr.} \right\} - 1 \qquad (L.6)$$

$$= 100 \left\{ \frac{0.9348}{1.1000 - 0.9348} \right\} \left\{ \frac{1.1000}{Sp.\ Gr.} - 1 \right\} \qquad (L.7)$$

$$= 100 \left\{ \frac{6.2245}{Sp.\ Gr.} - 5.6586 \right\} \qquad (L.8)$$

where:

Df = density of body fat = 0.9348 (Horak 1966)
Dff = density of fat free body = 1.1000 (Behnke 1961; Mendez and Kallias 1977)
Sp. Gr. = specific gravity of fish

The specific gravity of a fish was calculated according to the formula (Horak 1966):

$$Sp.\ Gr. = \frac{Wa\ (D)}{Wa - Ww} \qquad (L.9)$$

where:
Wa = the weight of the fish in air;
D = the density of water (temperature related);
Ww = the weight of the fish in water.

A two-sample t-test (Zar 1984) was used to make comparisons between percent body fat.

In addition Pearson correlation analysis (Zar 1984) was used to test the relationship between condition factor and percent fat content.

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RESULTS

Handling Mortality

One dead fish from the 1992 seine group (1.6%) was observed during the experiment on handling mortality (Appendix L1). This fish died seven days after it was released into the enclosure (Appendix L2). In 1991 nine fish (12.3%) had died after being held for 10 days (Appendix L1). Two dead fish from the hook and line group (3.3%) were observed (Appendix L1). These mortalities occurred one and six days after release into the enclosure (Appendix L2). Mortality rates for northern pike in the seine and hook and line groups were not significantly greater than 10% (single-tailed binomial test, $P > 0.10$).

Condition (K)

Analysis of variance showed that the mean condition factor was not significantly different between length groups ($P = 0.65$). Analysis of variance also showed that the mean condition factors of northern pike from the following treatment groups were not the same ($P < 0.01$):

a) caught once with a seine in George Lake in 1986;
b) caught once with a seine in George Lake in 1991;
c) caught once with a seine in George Lake in 1992;
d) caught once with hook and line gear in George Lake in 1992; and,
e) caught once with a seine in Volkmar Lake in 1992.

Duncan's multiple range test (comparison error rate = 0.10) for variable K did not detect a significant difference between the following treatment groups from George Lake: seine 1992, seine 1991, and hook and line 1992 (Appendix L3). A difference was also not detected between Volkmar 1992 and George 1986. Condition factor was significantly higher for Volkmar 1992 and George 1986 than for George Lake: seine 1992, seine 1991, and hook and line 1992.

Percent Fat Content

The means of percent fat content for the George and Volkmar Lakes treatment groups were 14.89% (SE = 1.00) and 17.79% (SE = 1.41), respectively. These means are significantly different (Student's $t = -1.68$, $DF = 52.4$, $P = 0.09$). No statistical difference (Kolmogorov-Smirnov 2 sample test $D = 0.17$ and $P = 0.80$) was detected between Volkmar and George Lakes length distributions. Percent fat content and condition factor for northern pike were significantly correlated for George Lake ($r = 0.59$, $P < 0.01$) and not significantly correlated for Volkmar ($r = -0.17$, $P = 0.37$).

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DISCUSSION

Burkholder (1992) reported northern pike caught by seine and held in an enclosure at George Lake longer than five days (13 to 16 days) in 1991 experienced greater mortality (31.5%) than northern pike captured by hook and line (6.2%) and held (5 to 16 days) in the same enclosure during the same time period. Mortalities between these treatment groups for days 1-5 of the holding time were not appreciably different. Based on these observations, speculations arose that seining influenced long term (greater than five days) survival of fish or that northern pike seined in 1991 in George Lake were less fit than fish captured by hook and line. Results from the experiment conducted in 1992 do not confirm either speculation.

Unfortunately, the experiment conducted in 1992 ended after holding seined fish for 10 days. Approximately 60% of the mortalities observed on seined fish held in 1991 occurred after day 10, so it is unknown if greater mortality would have occurred had seine fish in 1992 been held for the same length of time as they were in 1991. Mortality of northern pike after 10 days for fish caught with seines and with hook and line in 1991 was 12.3% and 5.4%, respectively. Although these mortality rates are not directly comparable to the 1992 results (1.7% and 3.3%), it appears that mortality rates of hook and line fish were very similar in 1991 and 1992 and that the mortality rate of seined fish was greater in 1991 than 1992. Even if mortality of seined fish would have continued to occur after 10 days in 1992 at the same rate as in 1991, mortality of seined fish in 1992 (4.4%) would have been significantly less than the mortality of seined fish in 1991 (31.5%) and similar to mortality of hook and line fish in 1991 (6.2%). Mortality increased only slightly after 10 days for the hook and line fish in 1991.

Condition factors are traditionally used as measures of well being, and low values may indicate underlying problems in population density, growth, or physiological stress (Gutreuter and Childress 1990). However, Scheirer and Coble (1991) found that measures of condition remained unchanged even when growth was significantly reduced, and suggested that condition may be an unreliable indicator of stress or well being in northern pike. Comparisons of condition factor do not indicate that northern pike seined in George Lake in 1991 were less fit than fish seined or caught by hook and line in 1992. The comparisons do suggest that northern pike were less fit in 1991 and 1992 than in 1986. Cause(s) in the decline of condition is unknown.

Since condition factor may not be a reliable indicator of stress or well being in northern pike, percent fat content was also investigated as a index of well being. The negative correlation between condition factor and percent fat content for northern pike in Volkmar Lake in 1992 suggests that there is a problem with the data, likely resulting from measurement error. Due to this circumstance, the results concerning both condition factor and percent fat content for Volkmar Lake should be viewed with caution.

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Reasons for the higher mortality rate of seined fish held at George Lake in 1991 may never be known. It should be emphasized, however, that mortality of northern pike captured with either gear type in 1992 and held for up to 11 days did not exceed 10%, which was the level of sampling mortality judged to be unacceptable.

Appendix L1. The number of northern pike that died while confined in an enclosure at George Lake by capture gear and year.

Days Until Death	Seine 1992 (n=60)	Seine 1991 (n=73)	Hook and Line 1992 (n=60)	Hook and Line 1991 (n=242)
0				1
1		1	1	
2				2
3				2
4				
5				
6			1	
7	1			1
8		1		1
9		4		3
10		3		1
Totals	1	9	2	11
Percentage	2%	12%	3%	5%

Appendix L2. Number of northern pike captured with seines and hook and line in George Lake during 1992 that were held for a given number of days.

Holding Time (days)	Seine	Hook and Line
	n	n
8	29	19
9	10	24
10	21	
11		17
Totals	60	60

Appendix L3. Duncan grouping and mean condition factor for treatment groups of northern pike.

Treatment Group			Sample Size	Sample Mean	Duncan Grouping[a]
Lake	Year	Gear			
George Lake	1986	Seine	267	0.7694	A
Volkmar Lake	1992	Seine	120	0.7442	A
George Lake	1992	Seine	96	0.7097	B
George Lake	1991	Seine	125	0.7028	B
George Lake	1992	Hook & Line	60	0.6986	B

[a] Means with the same letter are not significantly different using Duncan's Multiple Range Test (comparison error rate = 0.10).