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ABUNDANCE AND LIFE HISTORY FEATURES OF THE T LAKE NORTHERN PIKE POPULATION DURING 1986 AND 1987[1]

By

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ABSTRACT

The northern pike *Esox lucius* population in T Lake, near Dot Lake, Alaska, was sampled in 1986 and 1987 with variable mesh gill nets, trap nets, and a seine. Gill nets accounted for almost the entire catch of northern pike. Of various gill net configurations used, six-panel 46-meter long nets accounted for the majority of the catch. Annual estimates of abundance from mark-recapture experiments were 454 and 516 northern pike over 450 millimeters in fork length in 1986 and 1987, respectively. Estimated instantaneous total mortality between 1986 and 1987 was 0.1571, estimated instantaneous maximum natural mortality was 0.0406, estimated instantaneous minimum fishing mortality was 0.1165, and estimated recruitment in 1987 was 171 fish (33.1 percent). Gill net catch per unit of effort statistics did not adequately reflect changes in population abundance. Catchability coefficients ranged from 6.1 for small fish to 140.5 for large fish in 51 millimeter mesh. Females were more abundant than males in larger length classes. Length frequency modes decreased from 1986 to 1987, reflecting the relatively large recruitment that occurred. With a sample size of 274 fish, maximum age for males was 10, whereas, maximum age for females was 16. Length-at-age relationships were statistically different for males and females. Mean length-at-age in 1986 versus 1987 was significantly higher in 6 of 13 annual comparisons, indicating potential errors in age determination. Growth rate of T Lake northern pike was less than that reported in most other studies, ranging from 3 to 85 millimeters per year. Sport fishery harvests of T Lake northern pike between 1986 and 1987 were sustainable.

KEY WORDS: Northern pike, *Esox lucius*, T Lake, Alaska, gill nets, catchability coefficients, gear selectivity, abundance, mark-recapture, growth, length-weight, length-at-age, weight-at-age, sex ratios, mortality, recruitment.

INTRODUCTION

Northern pike *Esox lucius* have become increasingly popular with interior Alaska anglers in recent years. Next to Arctic grayling *Thymallus arcticus*, northern pike are the most sought after indigenous sport fish species in interior Alaska. Harvests of northern pike in interior Alaska averaged about 14,500 fish between 1977 and 1984 with more recent harvests being about 15,500 fish (Mills 1986). Interior Alaska accounts for 75% to 90% of the statewide Alaska northern pike harvest on an annual basis. Tanana River Drainage waters alone account for about 65% of the statewide northern pike harvest.

Periodic stock assessment and creel census studies of interior Alaska northern pike resources and fisheries were conducted from 1971-1984 (Peckham 1972-1985). Research conducted at Volkmar lake in 1985 (Peckham 1986) provided the first estimate of northern pike abundance in Alaskan waters along with life history information for the Volkmar Lake northern pike population. Research conducted in interior Alaskan lakes during 1986 provided additional estimates of northern pike population abundance along with catch per unit of effort statistics, catchability coefficients, and life history information for northern pike in Volkmar, George, and T Lakes (Peckham and Bernard 1987). The 1986 northern pike research program was continued in 1987 and a study of Minto Flats northern pike population dynamics was started. This report summarizes northern pike studies conducted in T Lake during both 1986 and 1987, even though many of the 1986 results were reported by Peckham and Bernard (1987). T Lake was referred to as Tee Lake by Peckham and Bernard (1987) and by Parker, Potterville and Bernard (1987).

Study Area

T Lake (158 ha) is a remote fly-in lake located approximately 17.7 km from the village of Dot Lake along the Alaska Highway (Figure 1). The lake lies at an elevation of 434 m and has a maximum depth of 17.4 m. The lake has one small inlet and an outlet that flows from the northeast corner of the lake into Billy Creek. The outlet is intermittent, flowing primarily during June following spring melt. Nearshore waters are shallow and these waters support beds of aquatic vegetation providing northern pike with spawning substrate. T Lake is typically ice-free from late May to early October.

Only one permanent recreational cabin is located along the lake shore, although a tent frame is also present. Recreational fishing pressure in T Lake is probably light (less than 50 angler days per year); however, the lake is relatively small and indigenous stocks likely cannot support a major intensive sport fishery. Fish species present include northern pike, burbot *Lota lota*, humpback whitefish *Coregonus pidschian*, and least cisco *Coregonus sardinella*. Research concerning burbot stock status in T Lake was summarized by Parker, Potterville, and Bernard (1987).

Study Objectives and Report Goal

The goal of this ongoing research program is the stock assessment of the northern pike population in T Lake and the investigation of the biology of this population relevant to management of interior Alaska northern pike sport

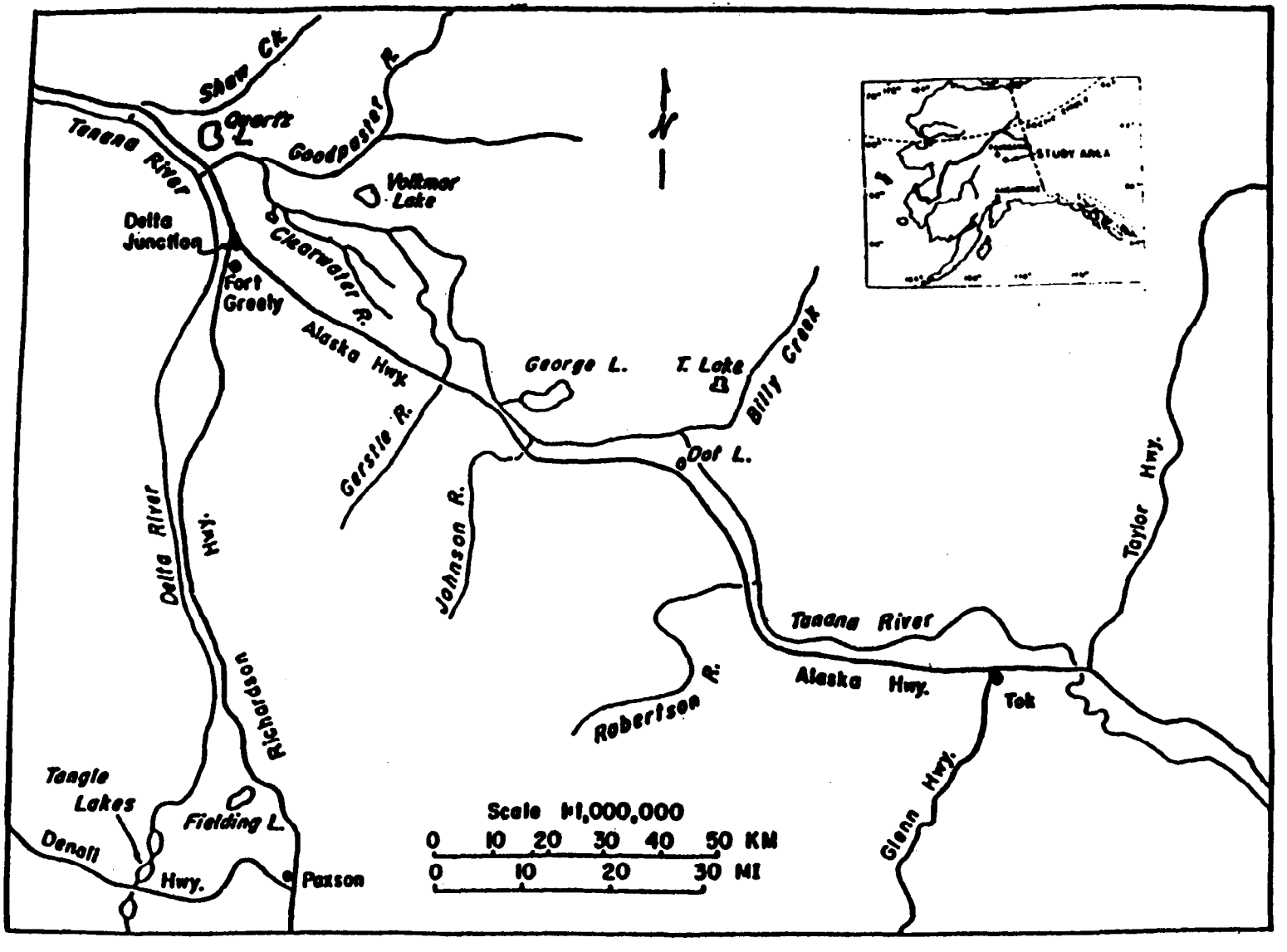

Figure 1. Location of T Lake, Alaska.

fisheries. The study was begun in 1986 and was continued in 1987. Objectives of the 1986 T Lake northern pike research program included estimation of population abundance, estimation of gill net catch per unit of effort statistics, and estimation of various life history features including sex, length, weight, and age composition. Specific objectives of the 1987 research program were:

(1) to estimate population abundance of northern pike in T Lake;

(2) to estimate the sex composition of the T Lake northern pike population; and,

(3) to estimate the parameters of the length-at-age relationship for the T Lake northern pike population.

Because many other important population statistics such as mortality and recruitment were obtained, those results are also presented in this report. The report is intended to summarize all significant information available at the time of writing concerning the T Lake northern pike population.

METHODS

Population abundance of T Lake northern pike was estimated with mark-recapture experiments. Two discrete sampling events took place during both the 1986 and 1987 mark-recapture experiments with a 3 to 10 day hiatus occurring between events. Variable mesh gill nets were used as the sampling gear in 1986; whereas in 1987, gill net sampling gear was augmented with trap net and seine gear. Seine gear consisted of a beach seine set from a boat and retrieved by hand to the shore. Six trap nets were set perpendicular to the shore and they were checked and emptied daily. Three different variable mesh gill net configurations (floating five-panel, floating six-panel, and sinking six-panel) were used in 1986. In 1987, only sinking six-panel gill nets were used. Detailed specifications of gill net, trap net, and seine gear are provided by Peckham and Bernard (1987).

Gill nets were fished in shallow water and they were set perpendicular to the shoreline. A minimum of six and a maximum of 12 gill nets fished from 12 to 24 hours each sampling day. Each gill net was checked about once per hour and fish were carefully removed to minimize sampling mortality. Size of gill net mesh for each captured northern pike was recorded. After northern pike were removed from gill nets, they were measured to the nearest millimeter of fork length (FL). Each captured northern pike was examined for presence of sexual products (sampling took place during spawning) or the external characteristics described by Casselman (1974) were used to identify sex. During the 1986 study, northern pike were weighed to the nearest 10 g on a Chatillon IN-6 or IN-25 spring scale. Weights were not measured during the 1987 study. Northern pike were tagged with Floy FD-68 anchor tags and a fin was clipped (left ventral in 1986 and right pectoral in 1987).

Scales, otolith bones, and cleithra bones were taken from sampling mortalities during both study years. Because preliminary analysis conducted during fall 1986 indicated that all three aging structures provided similar ages (on the

average), scale samples were taken from all northern pike handled during 1987. Scales were stored in coin envelopes and scales were later removed, cleaned, and mounted on gum cards. Gum cards were used to make scale impressions on 20 mil acetate using a Carver press at 60,000 kg/cm^2 (20,000 psi) heated to 93°C for 30 seconds. Scale impressions were read along their dorsal radius on a 3M Consultant Microfiche reader.

After obtaining various data from each fish as described above, each northern pike was returned to the water. Location of release was away from the fishing gear but within 200 m of the original capture location. T Lake was divided into two sections, and section of release and recapture was recorded for each fish.

Estimation Formulae and Calculation Procedures

The following are estimation and calculation procedures used for information presented in this report.

Population Estimate Calculations:

Population abundance of T Lake northern pike was estimated using the Chapman modification of the Petersen estimator described by Seber (1982):

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

where: M = Number of marked fish,
C = Number of fish examined for marks, and
R = Number of recaptured fish.

Variances of the population estimates were estimated as follows (Seber 1982):

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

In 1987, population abundance by length class was estimated based upon the proportion of fish caught within a length class to the total number of northern pike examined. Calculation procedures were as follows:

$$(3)\quad \hat{N}_i = \hat{P}_i(\hat{N});$$

where: $\hat{N}_i$ = Estimated number of length class i fish, and
$\hat{P}_i$ = Fraction of sampled northern pike in the ith length class.

Variances for the 1987 population estimates by length class were based upon Goodman's (1960) approach:

$$(4)\quad V[\hat{N}_i] = (\hat{P}_i^2 V[\hat{N}]) + (\hat{N}^2 V[\hat{P}_i]) - (V[\hat{P}_i]V[\hat{N}]);$$

where:

$$\hat{V}[\hat{P}_i] = \frac{\hat{P}_i(1-\hat{P}_i)}{n-1}.$$

CPUE and Catchability Coefficient Calculations:

Catch per unit of effort statistics for variable mesh gill nets were calculated as simple arithmetic averages of the catch of northern pike per hour of gill net fishing. Catch per unit of effort statistics (CPUE) for individual gill net mesh panels were calculated as follows:

$$(5)\quad \overline{CPUE}_{ijky} = \frac{\sum^{k} Catch_{ijky}}{\sum^{k} Hours_{ijky}};$$ where: i = Mesh size, j = Length class, k = Set number, and y = Year.

Variances for average CPUE by mesh size were calculated according to jackknife procedures in Efron (1982). Catchability coefficients (q) were calculated as follows:

$$(6)\quad \hat{q}_{ijy} = \frac{\overline{CPUE}_{ijy}}{\hat{N}_{jy}}.$$

Variances of catchability coefficients were calculated as follows:

$$(7)\quad V[q_{ijy}] \approx \frac{\overline{CPUE}_{ijy}^{2}}{\hat{N}_{jy}^{2}} \left\{ \frac{V[\overline{CPUE}_{ijy}]}{\overline{CPUE}_{ijy}^{2}} + \frac{\hat{V}[N_{jy}]}{\hat{N}_{jy}^{2}} \right\}.$$

Average catchability coefficients (combined across years) were calculated as follows:

$$(8)\ \text{Mean } \hat{q} = \frac{\hat{q}_{(86)} + \hat{q}_{(87)}}{2}.$$

Variances of the combined catchability coefficients were calculated according to jackknife procedures.

Sex Composition Calculations:

Sex composition was estimated as the proportion of each sex by length category and these data were converted to percents. Variances of the sex composition estimates by length class were calculated as follows:

$$(9) \quad V[\hat{p}_i] = \frac{\hat{p}_i(1-\hat{p}_i)}{n-1}; \quad \text{where: } \hat{p}_i = \text{Fraction of sampled fish of sex i within a length class.}$$

Abundance estimates for males and females by length class were calculated by multiplying the estimated proportion of sex i within a length class by the estimated abundance of northern pike in that same length class. Variances for these estimates were calculated with the Goodman (1960) formula provided earlier.

Length Frequency Calculations:

Minimum length categories for relative stock density were defined after review of Gablehouse (1984). Relative stock density estimates were calculated as the percent of all northern pike 300 mm FL and longer within a defined category. Variances for these estimates were calculated as follows:

$$(10) \quad V[\hat{p}_i] = \frac{\hat{p}_i(1-\hat{p}_i)}{n-1}; \quad \text{where: } \hat{p}_i = \text{Fraction of sampled fish i within a defined length class.}$$

Length-Weight Relationship:

Parameters of the length-weight relationship of T Lake northern pike were estimated through iterative least squares fitting with a computer program of the Marquardt algorithm. Only 1986 data were used to calculate parameters. The algorithm was estimated using a search over a set of starting values (a: 2 to 10 by 2 and b: 2.0 to 4.0 by 0.2). The set of estimates with the lowest least squares was selected as the best fit.

Length-at-Age and Weight-at-Age Relationships:

Mean length-at-age was calculated as the arithmetic mean length at each age for males and females treated separately. Variances were calculated in standard fashion using normal distribution theory.

Parameters of the von Bertalanffy equations for male and female T Lake northern pike were estimated for the length-at-age relationship through iterative least squares fitting with a computer program. Data from both 1986 and 1987 were used to estimate the male and female length-at-age relationships. Parameters were estimated 170 times, and each time the Marquardt algorithm began with a new set of initial parameter estimates. Initial values were as

follows: a: 0.2 to 1.2 by 2; b: 0.0 to 0.4 by 0.1; and c: -2.0 to 2.0 by 0.5. The set of estimates with the lowest least squares was selected as the best fit for that sex.

Parameters of the von Bertalanffy equation were estimated for the weight-at-age relationship through iterative least squares fitting with a computer program. Only 1986 data was used (both sexes) for the weight-at-age relationship. Parameters of the weight-at-age relationship were estimated based upon the Marquardt algorithm over a set of initial values (a: 0.0 to 2.0 by 0.2, b: 0.0 to 2.0 by 0.2, and c: -2.0 to 2.0 by 0.4) and again, the set of estimates with the lowest least squares was selected as the best fit.

Growth Rate Calculations:

Growth rates of male and female T Lake northern pike were calculated based upon length data treated in three ways. First, difference in mean length of northern pike by sex at age i and at age i+1 within yearly samples was calculated. Second, difference in mean length of male and female northern pike within an age cohort in 1986 versus mean length of the same cohort in 1987 was calculated. Third, differences in mean length of individually tagged northern pike caught during both 1986 and 1987 were calculated and these data were averaged by sex by length class.

Mortality and Recruitment Calculations:

Mortality of northern pike over 449 mm FL between 1986 and 1987 was estimated by subtracting the estimated number of fish still alive in 1987 from the estimated number alive in 1986. Recruitment of northern pike between 1986 and 1987 was estimated by subtracting the number of 1986 survivors in 1987 from the abundance estimate for 1987. Calculation procedures used for these mortality and recruitment estimates follow:

(11) $\hat{R}^*_{86} = \dfrac{(\hat{N}_{86})(R_{86})}{T_{86}}$; Estimated number of 1986 fish present in the 1987 sample;

(12) $\hat{S} = \dfrac{(\hat{N}_{87})(\hat{R}^*_{86})}{C_{87}}$; Estimated number of 1986 fish still alive in 1987;

(13) $\hat{M} = \hat{N}_{86} - \hat{S}$; Number of 1986 fish that died between 1986 and 1987; and,

(14) $\hat{J} = \hat{N}_{87} - \hat{S}$; Estimated number of fish that recruited in 1986;

where: $\hat{N}_{86}$ = Estimated number of northern pike (over 449 mm) at the completion of the 1986 sampling program (population estimate minus sampling mortalities);

$\hat{N}_{87}$ = Estimated number of northern pike (over 449 mm) in 1987;

T_{86} = Number of northern pike released alive in 1986 with tags;

C_{87} = Number of northern pike examined in 1987; and,

R_{86} = Number of 1986 tagged fish recaptured in 1987 sample.

Variances for $\hat{R}^*_{86}$ and $\hat{S}$ were calculated according to procedures in Goodman (1960). Variances for the estimated number of northern pike that died and that recruited between 1986 and 1987 were calculated as follows:

(15) $V[\hat{M}] = V[\hat{N}_{86}] + V[\hat{S}]$; Variance of the estimated number of 1986 fish that died between 1986 and 1987;

(16) $V[\hat{J}] = V[\hat{N}_{87}] + V[\hat{S}]$; Variance of the estimated number of fish that recruited in 1987;

where: $V[\hat{S}]$ = Variance of $\hat{S}$;

$V[\hat{N}_{86}]$ = Variance of the 1986 population estimate;

$V[\hat{N}_{87}]$ = Variance of the 1987 population estimate.

Annual instantaneous rates of total mortality (z), minimum fishing mortality (f), and maximum natural mortality (m) were adjusted for the number of elapsed days between the two population estimates after being calculated as follows:

(17) $\hat{z} = -\ln \frac{\hat{S}}{\hat{N}_{86}}$; where: $\hat{S}$ Defined by equation 12;

$\hat{N}_{86}$ Defined by equation 14;

$$(18)\quad f = \frac{\dfrac{(\hat{c})(\hat{z})}{\hat{N}_{86}}}{1 - e^{-\hat{z}}}$$; where: $\hat{c}$ Known minimum catch of northern pike over 449 mm FL during the interval between population estimates; and,

$$(19)\quad \hat{m} = \hat{z} - \hat{f}.$$

Because of potential problems with covariance terms in equations 15 and 16, the mortality and recruitment statistics and their variances were also estimated with bootstrap techniques of Efron (1982). Each of the n fish captured during 1986 and 1987 had a tagging history over the four sampling events. An n x 4 matrix was filled with these histories and n histories were randomly drawn with replacement to compose one bootstrap sample. One hundred such bootstrap samples were drawn. A complete set of statistics were calculated for each bootstrap sample according to Equations 1, 11-14, and 17-19. The numbers of northern pike inadvertently killed during sampling were removed prior to calculation with Equation 11. Bootstrap samples with negative instantaneous natural mortality rates were separated from those with positive instantaneous rates. Averages and standard errors were calculated for all bootstrap samples as well as for those samples with only positive instantaneous rates.

RESULTS

In 1986, variable mesh gill nets were used to capture 348 northern pike from T Lake during two sampling trips (many of these fish were captured more than once). During the first sampling event (30 May-1 June), 277 northern pike were tagged and released. A total of 106 northern pike were caught during the second sampling event (11-13 June). Sampling mortality during 1986 was 58 northern pike (16.7% of the fish caught at least once). Of the 348 northern pike caught at least once during 1986, 290 were released and assumed alive at the completion of the 1986 study (256 tagged and 34 untagged).

In 1987, three beach seine hauls made on 26 May caught no northern pike. Six trap nets fishing continuously from 26 May through 29 May (the first sampling event in 1987) caught 17 northern pike. Six sinking variable mesh gill nets caught the remaining 278 of the 295 northern pike captured during both sampling events in 1987. During the first sampling event, 191 northern pike were tagged and released. A total of 143 northern pike were caught during the second sampling event (1-3 June). Sampling mortality during 1987 was 28 northern pike (9.5% of the fish caught at least once). Of the northern pike caught at least once during 1987, 267 were released and assumed alive at the completion of the 1987 study (61 fish tagged in 1986 and recaptured and released again in 1987, 203 caught, tagged, and released for the first time in 1987, and 3 untagged and released).

Abundance

Both in 1986 and in 1987, abundance of northern pike in T Lake was estimated through the use of mark-recapture experiments and through calculation of catch per unit of effort statistics.

1986 Population Estimate:

Two hundred seventy-seven northern pike over 300 mm FL were caught, marked and released during the first sampling event in 1986. The second sampling event provided 106 northern pike over 300 mm FL including 55 recaptured fish. A chi-square test was used to determine if tagged fish had completely mixed with untagged fish between the two sampling events. The hypothesis tested was that a fish tagged and released during the first sampling event had the same probability of being recaptured in either half of the lake during the second sampling event regardless of where it was originally caught, tagged, and released. The test resulted in no significant differences ($\chi^2 = 3.58$, DF = 2, $0.10 < P < 0.25$) and the conclusion reached was that marked fish had completely mixed with untagged fish.

Because no northern pike between 300 and 449 mm FL were recaptured, only the population abundance of those northern pike 450 mm FL and larger could be estimated. Because gill nets were the sampling gear for both sampling events, and because gill nets are typically size selective, a chi-square test was used to test for equal probability of capture among length classes of marked fish over 450 mm FL. The four length classes tested resulted in significant differences ($\chi^2 = 12.06$, DF = 3, $0.005 < P < 0.01$) indicating that gill nets used to capture northern pike during the second sampling event in 1986 were selective for larger size fish. The length class at which differences occurred was 750 mm FL. Consequently, modified Petersen abundance estimates were calculated independently for northern pike between 450 and 749 mm FL (point estimate = 412 fish) and for those northern pike in excess of 749 mm FL (point estimate = 42 fish). The population estimates of the two length classes were summed, providing an overall estimate of abundance for those northern pike 450 mm FL and larger during 1986 of 454 fish (Table 1). Density of northern pike 450 mm FL and larger was estimated to be 2.80 fish per hectare (1.135 fish per acre).

1987 Population Estimate:

In 1987, 191 northern pike were caught, marked, and released during the first sampling event. The second sampling event provided 144 northern pike including 41 recaptured fish. As in 1986, a chi-square test was used to determine if marked fish had completely mixed with unmarked fish. The test resulted in no significant differences ($\chi^2 = 1.38$, DF = 2, $0.50 < P < 0.75$) indicating that, as in 1986, the marked fish had completely mixed with unmarked fish.

Unlike results for 1986, there was no detectable size selectivity for northern pike in the gill nets used during the second sampling event in 1987. Only 10 fish under 300 mm FL were caught and released during the first sampling event, and only one was caught during the second event (a new fish). Consequently,

Table 1. Estimated abundance of northern pike in T Lake during 1986.

Length Class (mm FL)	Number of northern pike					Sampling rate per event	
	Marked	Recaptured	Examined	Estimate[1]	S.E.	First	Second
300-449	18	0	10				
450-749	232	43	77	412	37	56.3%	18.5%
Over 749	27	12	19	42	5	64.2%	44.4%
Total (over 450 mm)				454	37		

[1] Estimate stratified by length due to significant chi-square test of equal probability of capture among length classes of marked fish over 449 mm FL (χ^2 = 12.06, DF = 3, 0.005 < P < 0.01).

only northern pike 300 mm FL or larger were used to estimate abundance. A chi-square test was used to test for equal probability of capture among length classes of marked fish 300 mm and larger. No significant differences were detected (χ^2 = 4.45, DF = 2, 0.1 $\leq$ P $\leq$ 0.25). Additionally, a Kolmogorov-Smirnov two-sample test on the length distributions of marked and recaptured fish indicated no significant differences (DN = 0.1457, P = 0.47). Consequently, all northern pike 300 mm FL and larger were used in the modified Petersen estimate of 623 fish (Table 2). Length distribution of all individual fish caught during both sampling events was used to apportion the overall population estimate into three length classes to facilitate comparisons between years (300-449 mm FL - 17.1%, 450-749 mm FL - 72.6%, 750 mm FL and larger - 10.3% of all fish caught at least once). Thus, 107 small fish, 452 medium-size fish, and 64 large fish were estimated to have comprised the 1987 northern pike population (Table 2). Combined abundance of fish 450 mm FL and larger was 516 northern pike. Density of northern pike 300 mm FL and longer was 3.85 fish per hectare (1.56 fish per acre); density of medium-size and large fish (450 mm FL and longer) was estimated at 3.19 fish per hectare (1.29 fish per acre).

Comparison of the 1986 and 1987 Population Estimates:

Estimates of T Lake northern pike population abundance were not significantly different between 1986 and 1987. Confidence intervals (95%) for both estimates overlap both the 1986 and the 1987 point estimates. Estimated abundance of medium-size northern pike (450-749 mm FL class) increased by 40 fish or about 9.7% (from 412 to 452 fish), but the increase was not statistically significant. The estimated abundance of large northern pike (over 749 mm FL) increased by 22 fish or about 52.4% (from 42 to 64 fish), but again, the increase was not statistically significant. The estimated abundance of both length classes (all fish over 449 mm FL) increased by 62 fish or about 13.7% (from 454 to 516 fish), again a statistically insignificant increase.

Catch Per Unit of Effort:

In 1986, sinking six-panel, floating six-panel, and floating five-panel variable mesh gill nets were used to capture northern pike. The highest catch rates occurred in the sinking six-panel gill nets. Because of observed length selectivity of gill nets used in 1986, catch per unit of effort statistics for small (less than 450 mm FL), medium-size (450-749 mm FL) and large (over 749 mm FL) northern pike were calculated separately for each year. Because northern pike abundance (as estimated by modified Petersen population estimates) in 1986 and 1987 was similar for both medium-size and large northern pike (although increasing trends were observed in 1987), it was expected that catch per unit of effort statistics calculated for each of these length classes of northern pike from the 1986 and 1987 sampling events would likewise be similar or would show slightly increasing trends. This expectation did not hold true. Overall catch per unit of effort (total catch in an entire variable mesh gill net fished for 1 hour) was 38% lower in 1987 (0.73 northern pike caught per hour) than in 1986 (1.18 northern pike per hour). The catch rate for small fish increased 57% from 0.07 to 0.11 northern pike per gill net hour (Table 3). The catch per gill net hour for medium-size northern pike

Table 2. Estimated abundance of northern pike in T Lake during 1987.

Length Class (mm FL)	Number of northern pike					Sampling rate per event	
	Marked	Recaptured	Examined	Estimate	S.E.	First	Second
Under 300	10	0	1				
300-449	35	5	18	107[1]	18	32.7%	16.8%
450-749	124	30	112	452[1]	53	27.4%	24.8%
Over 749	22	6	13	64[1]	13	34.4%	20.3%
Total over 300 mm	181	41	143	623[2]	70	29.0%	22.9%

1 Estimates by length class were calculated by multiplying the proportion of all individual fish caught during both sampling events within a length class by the overall population estimate of 623 fish.

2 Estimate not stratified by length due to insignificant results of: (1) chi-square test of equal probability of capture among length classes of marked fish over 299 mm FL ($\chi^2 = 4.45$, DF = 2, $0.25 < P < 0.1$); and, (2) Kolmogorov-Smirnov two-sample test of length distributions of marked and recaptured fish (DN = 0.1457, P = 0.47).

Table 3. Catch per unit of effort (catch per hour) of northern pike in 46 m long variable mesh gill nets fished in T Lake.

Hours Fished	Northern pike length class (FL)							
	Less than 450 mm		450-749 mm		More than 749 mm		All Lengths	
	No.	CPUE[1]	No.	CPUE[1]	No.	CPUE[1]	No.	CPUE[1]
1986 Data:								
295.1[2]	21	0.07	287	0.99	34	0.12	341	1.18
1987 Data:								
469.8[3]	51	0.11	254	0.54	39	0.08	344	0.73

1 CPUE is the catch of northern pike per hour of fishing a variable mesh gill net.

2 Data from the first sampling event only.

3 Data from both the first and second sampling events.

decreased by 45% and the catch per gill net hour for large northern pike decreased by 38% between 1986 and 1987 (Table 3).

Catch per unit of effort statistics were also calculated for each gill net mesh size used (25 mm, 38 mm, and 51 mm) during the 2 study years (effort is a 15 m long panel of a certain mesh size of a gill net fished for 1 hour). Catch per unit of effort in 25 mm mesh for all three length classes of northern pike increased between 1986 and 1987 (Table 4). Catch per unit of effort in 38 mm mesh increased for small fish, decreased for medium-size fish, and stayed about the same for large fish (Table 4). Catch per unit of effort in 51 mm mesh increased for small fish and decreased for medium-size and large fish (Table 4).

For all mesh and fish length classes, the catchability of northern pike in 1987 was dissimilar to the catchability in 1986. However, in only one case was the difference significant (Table 4). Catchability coefficients for medium-size and large fish caught in 25 mm mesh were 17.9% and 134.6% higher, respectively, in 1987. Catchability coefficients for fish caught in the 31 mm mesh were lower in 1987 for both medium-size and large fish (22.0% and 30.8%, respectively). Catchability coefficients for medium-size and large fish caught in 51 mm mesh were 61.9% and 50.6% lower in 1987, respectively. The one significant change in catchability was medium-size fish in 51 mm mesh ($P < 0.001$).

Life History

As T Lake northern pike were caught and sampled to document population abundance during 1986 and 1987, length, weight, sex and age data were collected from several hundred fish. This section of the report summarizes length, weight, sex, and age results.

Sex Ratios and Population Composition by Sex:

Most of the northern pike caught during both sampling years were females (Table 5). Because of the potential size selectivity of the gill nets used to obtain samples, the proportions of female and male northern pike in each of three length classes (same length classes used earlier) were calculated for both study years. These proportions were used in conjunction with estimates of abundance of northern pike in each length class to estimate the number of females and males in each length category. The female to male ratio increased in the larger size classes (Table 5). Males were predominant in the 300-449 mm FL class during both study years (Table 5). In the medium-size fish category (450-749 mm FL), males and females were about equally abundant in 1986, whereas in 1987, females outnumbered males by a factor of about 2 to 1 (Table 5). During both study years, only females were found in the large fish category (over 749 mm FL). Overall, the proportion of females was larger in 1987 than in 1986 (Table 5).

Table 4. Northern pike catch per unit of effort (catch per hour) and catchability coefficients (q) by mesh size in 15 m long gill net panels fished in T Lake.

	Data statistics by gill net mesh and by fish size class[1]								
	25 mm mesh			38 mm mesh			51 mm mesh		
Statistic	Small fish	Medium fish	Large fish	Small fish	Medium fish	Large fish	Small fish	Medium fish	Large fish
1986 Data (hours fished = 295.1)[2]									
$\overline{CPUE}$[3]	0.027	0.083	0.003	0.028	0.323	0.026	0.002	0.336	0.059
S.E.	0.010	0.021	0.003	0.011	0.041	0.010	0.002	0.041	0.017
qx10[5]		20.120	6.974		78.403	61.910		81.553	140.476
S.E.		5.409	0.830		12.190	24.923		12.357	43.794
1987 Data (hours fished = 469.8)[4]									
$\overline{CPUE}$[3]	0.058	0.124	0.011	0.045	0.277	0.028	0.007	0.141	0.045
S.E.	0.011	0.018	0.005	0.055	0.026	0.008	0.004	0.019	0.010
qx10[5]	53.974	27.305	16.363	41.771	61.132	42.856	6.101	31.064	69.348
S.E.	13.907	5.128	7.797	51.663	9.177	15.334	3.450	5.584	20.686
Catchability Coefficients Combined for Both Years									
qx10[5]	53.974	23.713	11.669	41.771	69.768	52.383	6.101	56.309	41.912
S.E.	13.907	5.409	0.830	51.663	12.190	24.923	3.450	12.357	43.794
Statistical Comparison of "q's" for the Two Years									
Z Stat.[5]		0.964	1.197		-1.132	-0.651		-3.723	-1.468
Significance[5]		NS	NS		NS	NS		0.001	NS

1 Small fish: less than 450 mm FL; medium fish: 450 to 749 mm FL; large fish: more than 749 mm FL.

2 Data from the first sampling event only.

3 CPUE is the catch per hour of fishing a 15 m long gill net panel.

4 Data from both the first and second sampling events.

5 Tests for significant differences among years; two tailed test; normality and large sample sizes assumed. NS means not significant at $\alpha = 0.005$.

Table 5. Sex composition of the T Lake northern pike population.

Category	Northern Pike by FL Class (mm) Small 300-449	Medium 450-749	Large Over 749	All Fish Over 299	All Fish Over 449
1986 Population					
Sample Size	13	270	32	315	302
No. of Females	1	139	32	172	171
No. of Males	12	131	0	143	131
Fem. to Male Ratio	1:12.0	1:0.94	1:0.00	1:0.83	1:0.77
Total Abundance	---	412	42	---	454
Percent Females	7.7	51.5	100.0	---	55.9
S.E. of % Females	7.7	3.0	0.0	---	---
Abundance of Females	---	212	42	---	254
S.E.(Abund. of Fem.)	---	23	5		23
Percent Males	92.3	48.5	0.0	---	44.1
S.E. of % Males	7.4	3.0	0.0	---	---
Abundance of Males	---	200	0	---	200
S.E.(Abund. of Males)	---	22	0	---	22
1987 Population					
Sample Size	46	206	32	284	238
No. of Females	16	139	32	187	171
No. of Males	30	67	0	107	67
Fem. to Male Ratio	1:1.88	1:0.48	1:0.0	1:0.57	1:0.39
Total Abundance	107	452	64	623	516
Percent Females	34.8	67.5	100.0	65.2	71.8
S.E. of % Females	7.1	3.3	0.0	---	---
Abundance of Females	37	305	64	406	369
S.E.(Abund. of Fem.)	10	39	13	42	41
Percent Males	65.2	32.5	0.0	34.8	28.2
S.E. of % Males	7.0	3.3	0.0	---	---
Abundance of Males	70	147	0	217	147
S.E.(Abun. of Males)	14	23	0	27	23

Length Frequency:

Length frequency plots were developed by tabulating all northern pike caught at least once into 50 mm FL classes by sex. Length frequency plots demonstrated that female northern pike were larger on average than male northern pike during both study years (Figure 2). In 1986, length frequency modes of males and females were separated by 50 to 100 mm and in 1987 length frequency modes were separated by 200 mm (Figure 2). In 1986, males were most abundant in the 600 to 649 mm FL class; whereas, in 1987, they were most abundant in the 450 to 499 mm FL class (Figure 2). Female northern pike were most abundant in the 650 to 699 mm FL class in 1987; whereas, in 1986, both the 650 to 699 mm and the 700 to 749 mm FL classes represented peak abundance. During both years, northern pike that could not be sexed were sampled for length (n = 33 in 1986; n = 11 in 1987). These fish were included in the "all northern pike" category shown in Figure 2 (along with males and females). Peak abundance for the combined category in 1986 was in the 600 to 649 mm FL class; whereas in 1987, peak abundance was in the 450 to 499 mm FL class.

Length frequency data were also analyzed to develop relative stock density estimates. After review of Gablehouse (1984), minimum fork length for various categories of northern pike were defined as follows: stock: 300 mm; quality: 525 mm; preferred: 655 mm; memorable: 860 mm; and trophy: 1,080 mm. No "trophy" size northern pike were caught in either year. The proportion of "memorable" size northern pike remained at about the same level during both years with the 1986 index being 1.4% and the 1987 index being 1.8% (Table 6). Both the "preferred" and "quality" estimates decreased from 1986 to 1987 (preferred declined from 40.9% to 31.7% and quality declined from 44.3% to 26.7%). The estimate for "stock" size northern pike increased in 1987 (39.8%) over the 13.5% estimate obtained in 1986 (Table 6).

Length-Weight Relationship:

The length weight relationship for T Lake northern pike was developed using 1986 data only because weights were not recorded for fish caught in 1987. Parameters of the length weight relationship were: a = 8.3318; S.E.(a) = 0.13554; b = 3.2889; S.E.(b) = 0.04686; correlation (a,b) = 0.9122; and n = 317 (Figure 3). Inspection of plots showed no significant differences in the length-weight relationship for males versus females.

Age Composition:

In 1986, 62 northern pike (30 males and 32 females) were aged. In 1987, 212 northern pike (78 males and 134 females) were aged. The oldest male was 11 years old and the oldest female was 16 years old. The proportion of females increased at the older ages during both study years with only females being represented in the samples at age 11 and older (Table 7). For males in 1986, age 8 fish were most prevalent followed by age 5, 6, and 7 fish. These four age classes represented 70% of the male sample. In 1987, age 5 and 6 fish were most prevalent in the male sample, comprising 50% of that sample (Table 7). Age 8 and 9 fish were most prevalent in the 1986 female sample, followed by age 6, 7, and 10 fish, respectively (Table 7). In 1987, age 6, 7, 8, 9, and 10 fish were all about equally represented in the female sample and

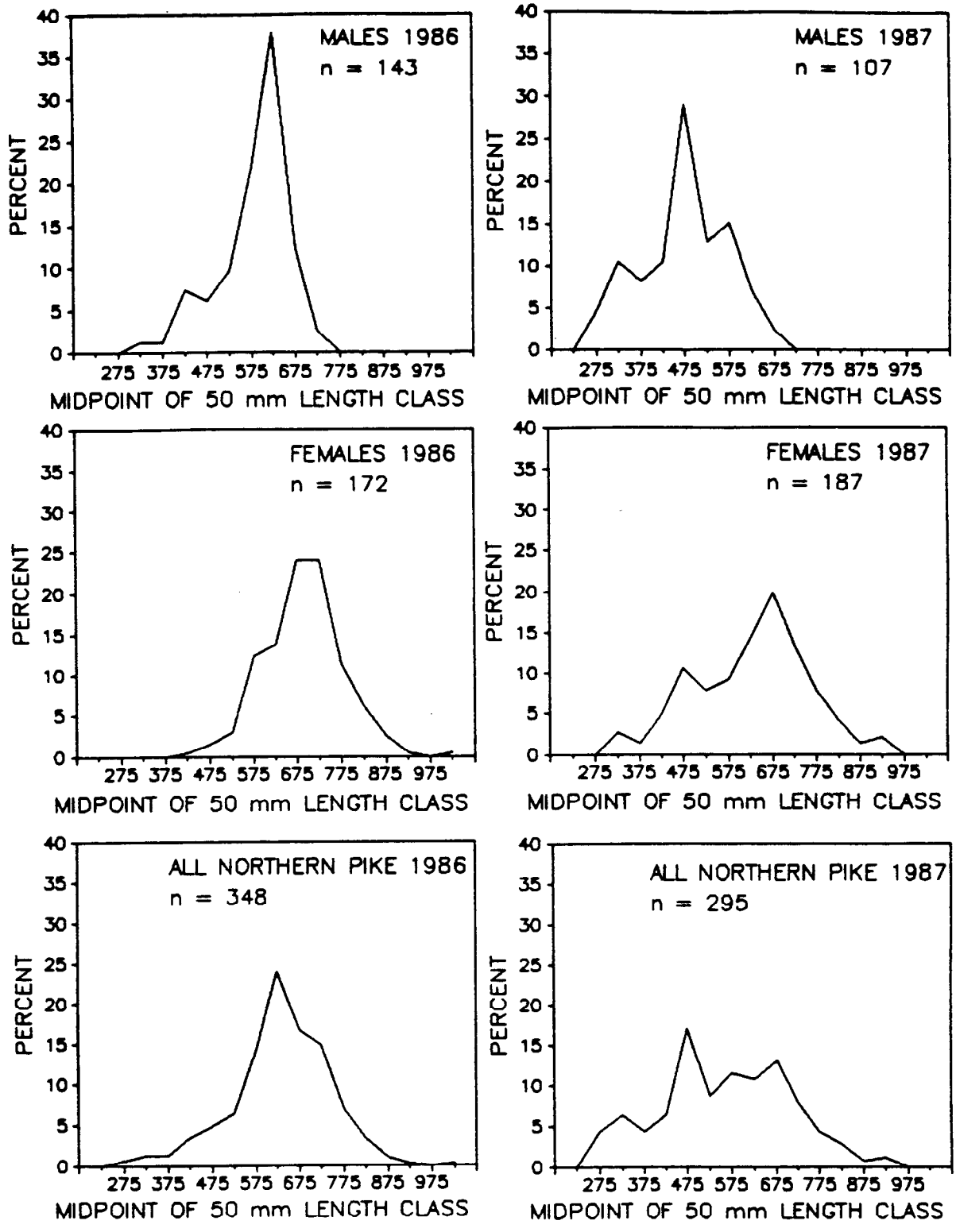

Figure 2. Length frequency plots for northern pike sampled from T Lake in 1986 and 1987.

Table 6. Relative stock density estimates of T Lake northern pike.

Category	Gablehouse[1] Minimum Length	1986 Data		1987 Data	
		Relative Stock Density[1]	S.E.	Relative Stock Density[1]	S.E.
Stock	300 mm FL	13.4	1.6	39.8	2.9
Quality	525 mm FL	44.3	2.4	26.7	2.6
Preferred	655 mm FL	40.9	2.3	31.7	2.8
Memorable	860 mm FL	1.4	0.5	1.8	0.8
Trophy	1,080 mm FL	0	0	0	0
Totals		100.0		100.0	

[1] Relative stock density expressed as a percentage; categories taken from Gablehouse (1984).

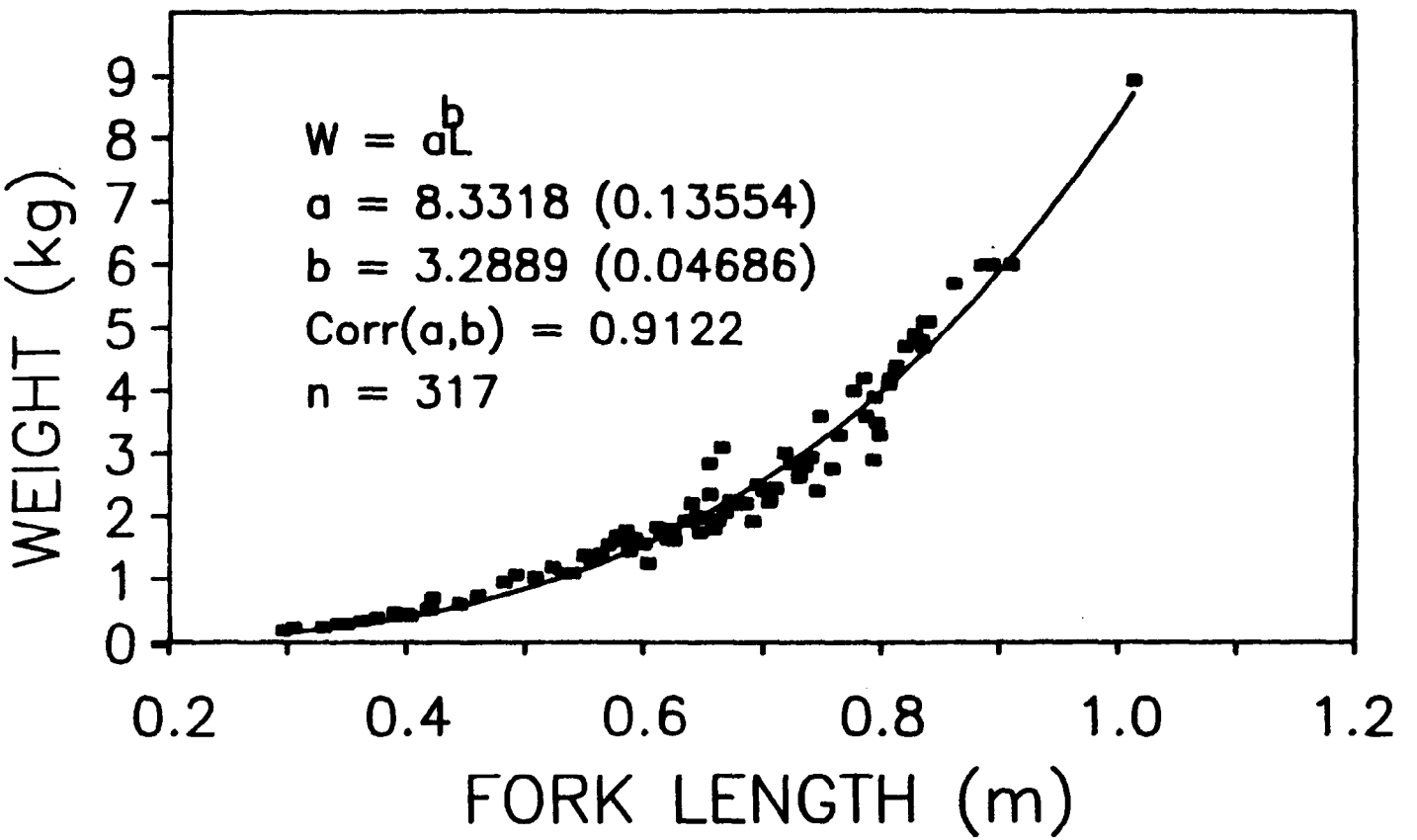

Figure 3. Length-weight relationship for T Lake northern pike in 1986.

Table 7. Age composition of T Lake northern pike.

	1986 Data					1987 Data				
Age	No. Males	No. Females	% Female	No. Fish	% Fish	No. Males	No. Females	% Female	No. Fish	% Fish
2						1		0	1	-
3	3		0	3	5	7	2	22	9	4
4	4		0	4	7	10	4	29	14	7
5	5	2	29	7	11	20	12	37	32	15
6	5	5	50	10	16	19	23	55	42	20
7	5	5	50	10	16	8	20	71	28	14
8	6	7	54	13	21	7	20	74	27	13
9	1	7	88	8	13	2	23	92	25	12
10	1	4	80	5	8	4	22	85	26	12
11		2	100	2	3		4	100	4	2
12										
13							2	100	2	1
14										
15							1	100	1	-
16							1	100	1	-
All	30	32	-	62	100	78	134	-	212	100

those ages comprised over 80% of that sample (Table 7). Age 8 fish followed by age 6 and 7 fish were most prevalent in the combined sample in 1986; whereas, in 1987, age 6 fish followed by age 5, 7, 8, 9, and 10 fish were most prevalent in the combined sample (Table 7).

Length-at-Age Relationship:

Length-at-age samples collected during both study years were combined and these data were used to estimate parameters of the von Bertalanffy equation for male and female segments of the T Lake northern pike population. Parameters of the male and female equations were compared through the use of Hotelling's T^2 test. Hypothesis tested was that the male and female length-at-age equations were equal. Significant differences were found ($p < 0.01$) and the hypothesis was rejected. Consequently, separate length-at-age relationships for male and female T Lake northern pike with estimation parameters were developed (Figure 4). Length-at-age of male northern pike was significantly less than length-at-age of female northern pike in T Lake.

Although few age samples were collected in 1986, comparisons were made between mean length-at-age samples collected in 1986 versus mean length-at-age samples collected in 1987 for both males and females. Comparisons were made through the use of the "Student's" t* test (hypothesis tested was that mean length at age was equal in 1986 and 1987). Of 13 possible comparisons, significant differences ($p < 0.05$) were found in 5 of the comparisons and in all 5 cases, mean length-at-age in 1987 was significantly less than that in 1986 (Tables 8 and 9).

Weight-at-Age Relationship:

Parameters of the von Bertalanffy weight-at-age relationship were based upon 1986 data only ($n = 71$) because weight data were not collected in 1987. Parameters of the T Lake northern pike weight-at-age relationship follow: $a = 0.963$ (S.E. = 0.086); $b = 0.18512$ (S.E. = 0.0472); $c = 0.929$ (S.E. = 0.466); correlation (a,b) = -0.9702; correlation (b,c) = 0.8619; and correlation (a,c) = -0.7298. The asymptotic weight for T Lake northern pike was 7.36 kg.

Growth Rate:

Growth rate of T Lake northern pike was evaluated through three approaches: (1) differences in mean length of northern pike at age within yearly samples (Table 10); (2) differences in mean length by age cohort in 1986 versus 1987 samples (Table 11); and, (3) differences in length for tagged fish caught in 1986 and recaptured in 1987 (Figure 5 and Table 12). Growth for males and females was calculated separately in all three cases due to documented differences in length-at-age for males and females.

For the most part, the first two approaches failed to provide useful information concerning T Lake northern pike growth rate. It was expected that growth rate of females would be faster than that of males and it was expected that growth rate for both males and females would decrease among older cohorts and larger length classes. Neither of the first two approaches demonstrated differences in growth rate by sex. The first approach (Table 10) demonstrated

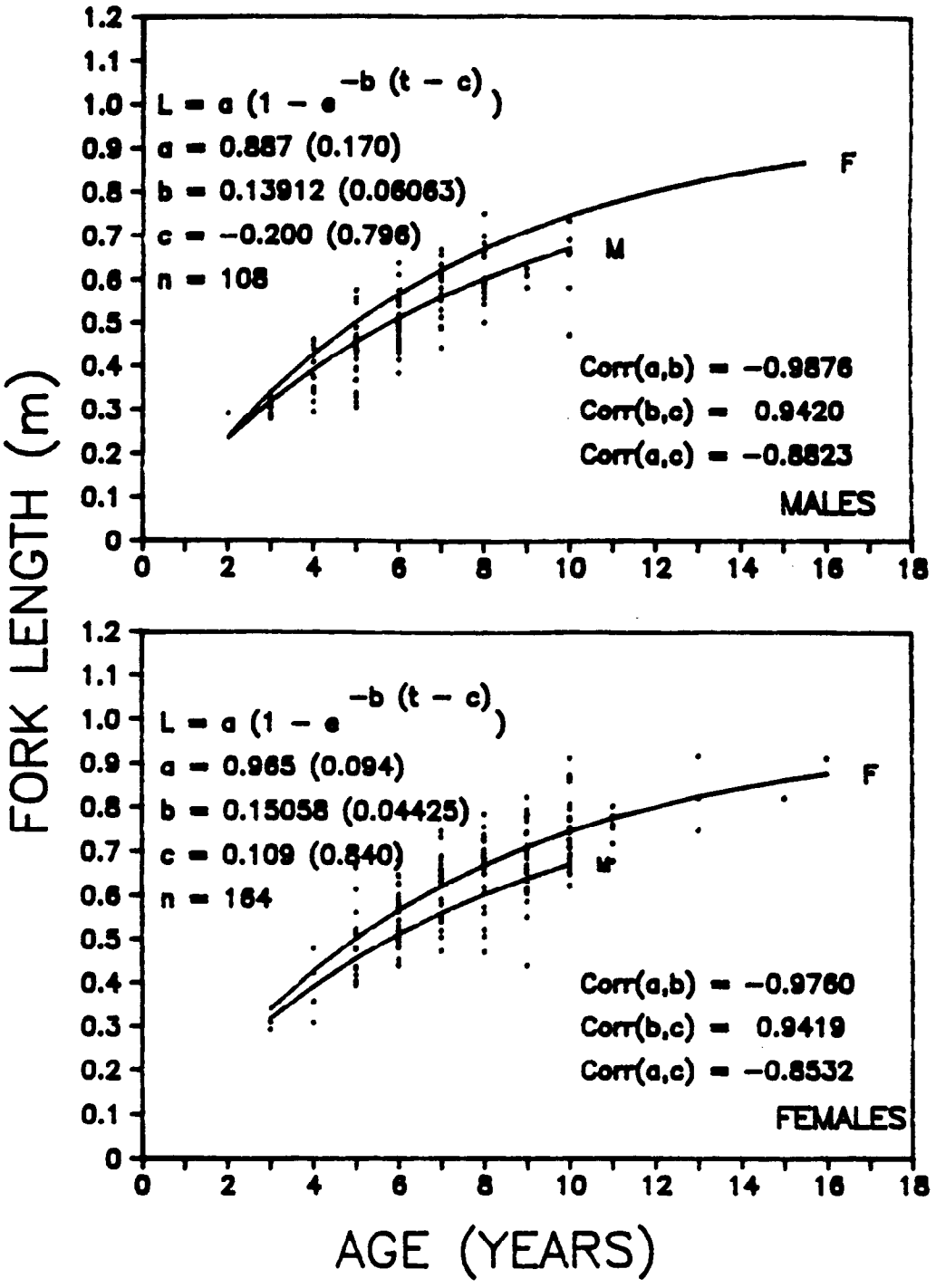

Figure 4. Length-at-age relationship for T Lake northern pike.

Table 8. Mean length-at-age for male T Lake northern pike.

	1986 Data			1987 Data			Combined Data			Annual Comparison			
Age	Sample Size	Mean	S.E.	Sample Size	Mean	S.E.	Sample Size	Mean	S.E.	t*[1] Scr.	DF	Tab t*[1]	Sig. Level
2				1	303		1	303					
3	3	340	6	7	307	6	10	317	7	3.25	8	2.31	5%
4	4	387	37	10	395	18	14	392	16	0.22	12	2.18	NS
5	5	495	51	20	436	14	25	448	15	1.12	5	2.57	NS
6	5	577	31	19	488	10	24	507	13	3.59	22	2.07	5%
7	5	604	30	8	551	20	13	571	18	1.53	11	2.20	NS
8	6	675	25	7	582	19	13	625	20	3.01	11	2.20	5%
9	1	621		2	616	22	3	618	13				
10	1	747		4	613	49	5	639	47				
All	30			78			108						

[1] t* Scr. is the "Student's" t statistic as described by Snedecor and Cochran (1980); Tab. t* is the tabled value for the t statistic with the appropriate degrees of freedom (DF) at the 5% level; variances were tested for equality with an F test; normality assumed in the distribution of lengths; NS means not significant.

Table 9. Mean length-at-age for female T Lake northern pike.

	1986 Data			1987 Data			Combined Data			Annual Comparison			
Age	Sample Size	Mean	S.E.	Sample Size	Mean	S.E.	Sample Size	Mean	S.E.	t*[1] Scr.	DF	Tab t*[1]	Sig. Level
3				2	314	9	2	314	9				
4				4	405	38	4	405	65				
5	2	511	63	12	530	34	14	527	30	0.22	12	2.18	NS
6	5	613	28	23	548	14	28	559	13	1.98	26	2.06	NS
7	5	683	22	20	617	15	25	630	14	2.05	23	2.07	NS
8	7	730	14	20	654	18	26	672	15	3.33	23	2.07	5%
9	7	773	22	23	672	17	29	693	16	3.03	28	2.05	5%
10	4	821	36	22	748	16	26	759	15	1.80	24	2.06	NS
11	2	752	22	4	767	27	6	762	19	0.35	4	2.78	NS
12													
13				2	845	86	2	845	86				
14													
15				1	832		1	832					
16				1	925		1	925					
All	32			134			164						

[1] t* Scr. is the "Student's" t statistic as described by Snedecor and Cochran (1980); Tab. t* is the tabled value for the t statistic with the appropriate degrees of freedom (DF) at the 5% level; variances were tested for equality with an F test; normality assumed in the distribution of lengths; NS means not significant.

Table 10. Growth rates of T Lake northern pike determined from length-at-age analysis.

	1986 Males		1987 Males		1986 Females		1987 Females	
Age	Mean Length (mm FL)	Length Change (mm)	Mean Length (mm FL)	Length Change (mm)	Mean Length (mm FL)	Length Change (mm)	Mean Length (mm FL)	Length Change (mm)
2			303	4				
3	340	47	307	88				
4	387	108	395	41			405	125
5	495	82	436	52	511	102	530	18
6	577	27	488	63	613	70	548	69
7	604	71	551	31	683	47	617	37
8	675	-54	582	34	730	43	654	18
9	621	126	616	-3	733	48	672	76
10	747	--	613	--	821	-69	748	19
11					752	--	767	--
12								
13							845	--
14								
15							832	93
16							925	--

Table 11. Annual increment of growth by cohort from 1986 to 1987 for T Lake northern pike from mean length-at-age analysis.

	Cohort Age in		Males			Females		
Cohort	1986	1987	Length in 1986	Length in 1987	Annual Growth in mm	Length in 1986	Length in 1987	Annual Growth in mm
1985	1	2		303				
1984	2	3		307			314	
1983	3	4	340	395	55		405	
1982	4	5	387	436	49		530	
1981	5	6	495	488	-7	511	548	37
1980	6	7	577	551	-26	613	617	4
1979	7	8	604	582	-22	683	654	-29
1978	8	9	675	616	-59	730	672	-58
1977	9	10	621	613	-8	773	748	-25
1976	10	11	747			821	767	-54
1975	11	12				752		
1974	12	13					845	
1973	13	14						
1972	14	15					832	
1971	15	16					925	

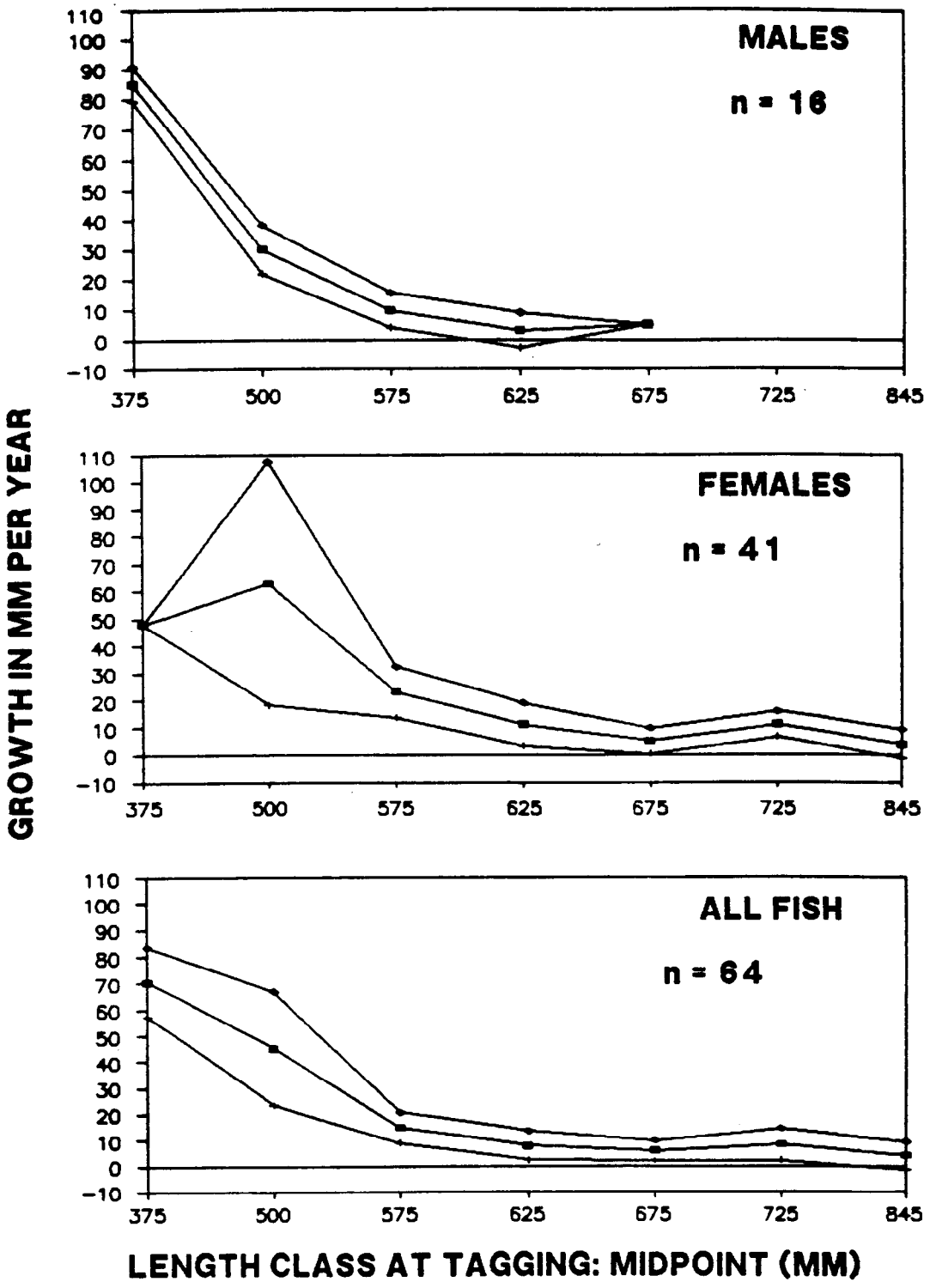

Figure 5. Growth increments of tagged T Lake northern pike between 1986 and 1987 (with 90% confidence intervals).

Table 12. Growth increments of tagged northern pike between 1986 and 1987.

Length Class	Males			Females			All Fish[1]		
	Mean Growth	S.E.	Sample Size	Mean Growth	S.E.	Sample Size	Mean Growth	S.E.	Sample Size
< 449 mm	85.0	3.5	2	48.0	0	1	70.5	8.0	4
450-549 mm	30.0	4.9	2	63.0	27.1	3	45.1	13.2	7
550-599 mm	9.7	3.4	6	23.0	5.6	5	14.8	3.5	12
600-649 mm	3.0	3.5	5	11.3	4.7	7	7.8	3.3	12
650-699 mm	5.0	0	1	5.3	2.8	12	5.9	2.3	15
700-749 mm				11.3	2.8	8	8.3	3.7	9
> 750 mm				4.0	3.3	5	4.0	3.3	5

[1] All fish category includes data for 7 fish for which sex was uncertain.

no trend in decreased growth in larger length classes and older age categories. The second approach (Table 11) demonstrated large decreases in growth rate among older age cohorts and length classes. Both methods indicated substantial negative growth for larger and older northern pike (up to -69 mm for age 10 females in 1986: Table 10; and up to -59 mm for the 1978 male cohort: Table 11). The first approach appeared to have failed (due to negative growth rates) at about age 8 (around 675 mm FL) and above for males and at about age 10 (around 800 mm FL) and above for females (Table 10). The second approach appeared to have failed at about 500 mm FL (1981 cohort) for males and at about 650 mm FL (1979 cohort) for females (Table 10).

The third approach provided useful information, however sample sizes were not large (males = 16 samples; females = 41 samples; sex uncertain = 7 samples). Significant decreases in growth rate were apparent for both males and females as length categories increased (Figure 5). Growth rate of males was significantly faster than growth rate of females in the 300 to 449 mm FL category (Table 12). For all other length categories, females demonstrated larger growth increments, although not all differences were statistically significant (Table 12).

Mortality and Recruitment

Because abundance of northern pike above 449 mm FL in T Lake was estimated in both 1986 and 1987, and because a large proportion of the population was marked, mortality of the 1986 population, survival of the 1986 population, and recruitment into the 1987 population could be estimated. Fifty-one of the estimated 454 northern pike in 1986 (Table 1) were killed through the sampling program, leaving an estimated 403 northern pike over 449 mm FL alive in the lake at the completion of sampling. During the 1986 sampling program, 238 northern pike over 449 mm FL were tagged, released, and assumed alive at the completion of the sampling program. During the 1987 sampling program, 235 northern pike over 449 mm FL were caught at least once (Table 2), and of this sample, 67 were tagged fish from 1986. An additional 26 fish had the 1986 fin clip present, but did not have a tag (tag loss estimated at 28%). Thus, 93 northern pike of the 235 sampled in 1987 were known (marked) 1986 fish. Using these data, 345 northern pike were estimated to have survived (85.6%) between 1986 and 1987 and 58 (14.4%) were estimated to have died (Table 13). Annual instantaneous mortality of northern pike above 449 mm FL between 1986 and 1987 was estimated to have been 0.1571. Recruitment of new fish into the 449 mm FL and above length class was estimated at 345 northern pike (33.1%) in 1987 (Table 13).

Bootstrap techniques used to estimate standard errors of mortality and recruitment statistics (due to concern for the lack of covariance terms in the variance estimators used in this study) resulted in more conservative estimates of the variances for mortality and recruitment than estimates reported in Table 13. The standard error of the total mortality estimate using all 100 bootstrap samples was 69 fish and the standard error estimate using only those bootstrap samples with a positive instantaneous natural mortality rate was 33 fish. The standard error of the recruitment estimate using all 100 bootstrap samples was 67 fish and the standard error using only those bootstrap samples with a postitive instantaneous natural mortality rate was 55 fish.

Table 13. Estimated mortality and recruitment of T Lake northern pike over 449 mm FL between 1986 and 1987.

Category	Estimated No. of Fish	Estimated Percent	Standard Error in No. of Fish	Notes
Survival	345	85.6%	60	See Appendix
Mortality	58	14.4%	71	See Appendix
Fishing (min.)	43	10.7%	--	See Text
Natural (max.)	15	3.7%	--	See Text
Recruitment	171	33.1%	81	See Appendix

During the time interval between population estimates, anglers returned tags from creeled T Lake northern pike, and these anglers provided information concerning total catches. Anglers returned 19 tags and they reported catching 43 northern pike over 449 mm FL. All anglers may not have provided voluntary creel information. Using these data, minimum fishing mortality of northern pike over 449 mm FL was estimated to have been 43 northern pike (10.7% of the 1986 population) and maximum natural mortality was estimated to have been 15 northern pike (3.7% of the 1986 population). Minimum annual instantaneous fishing mortality for northern pike over 449 mm FL was estimated to have been 0.1165 between 1986 and 1987. Maximum annual instantaneous natural mortality for northern pike over 449 mm FL was estimated to have been 0.0406 between 1986 and 1987. A graphic description of abundance, mortality (fishing and natural), and recruitment of the northern pike population over 449 mm FL in T Lake in 1986 and 1987 is provided in Figure 6.

DISCUSSION

A length stratified abundance estimator was used in 1986, whereas, in 1987, length stratification was not needed, even though variable mesh gill nets were the primary sampling tool in both years. This difference in detectable length-selectivity was probably more a factor of availability than catchability. The chi-square test used to detect length selectivity in the 1986 estimate was relevant to the second sampling event only. The requirement for an unbiased mark-recapture estimate is that there be no selectivity during one of the two sampling events. In 1986, the estimate of abundance of northern pike larger than 449 mm FL was 454 fish after length stratification. If stratification would have been ignored, the estimate of abundance would have been 449 fish; a difference of only 5 fish (a similar comparison with the 1987 data results in a difference of only 10 fish). This seemingly minor difference or bias observed in the 1986 data can only be explained if there was no size selectivity of fish marked during the first sampling event. Since the same gill nets were used during both sampling events in 1986, the catchability of northern pike must have been the same for both events. Therefore, the availability of northern pike to the gear must have changed between the two 1986 sampling events. Because population estimates were started within 2 days of the time that ice on T Lake thawed, were continued during a time frame when water temperatures were rapidly rising, and took place at the time when northern pike were spawning, it seems likely that behavior of northern pike was changing, at least among some length classes. Thus fish availability as influenced by behavior rather than catchability due to net selectivity is the suspect reason for the significant chi-square result. This conclusion has further significance with regard to the correlation between estimated abundance and catch per unit of effort analysis.

Abundance of T Lake northern pike was assessed through both mark-recapture experiments and catch per unit of effort analysis; however, observed trends from 1986 to 1987 were different for the mark-recapture experiments and the CPUE analysis. Based upon discussion provided in the previous paragraph, it seems likely that northern pike availability to gill net gear changed over a fairly short time interval (a few days). If northern pike availability to the

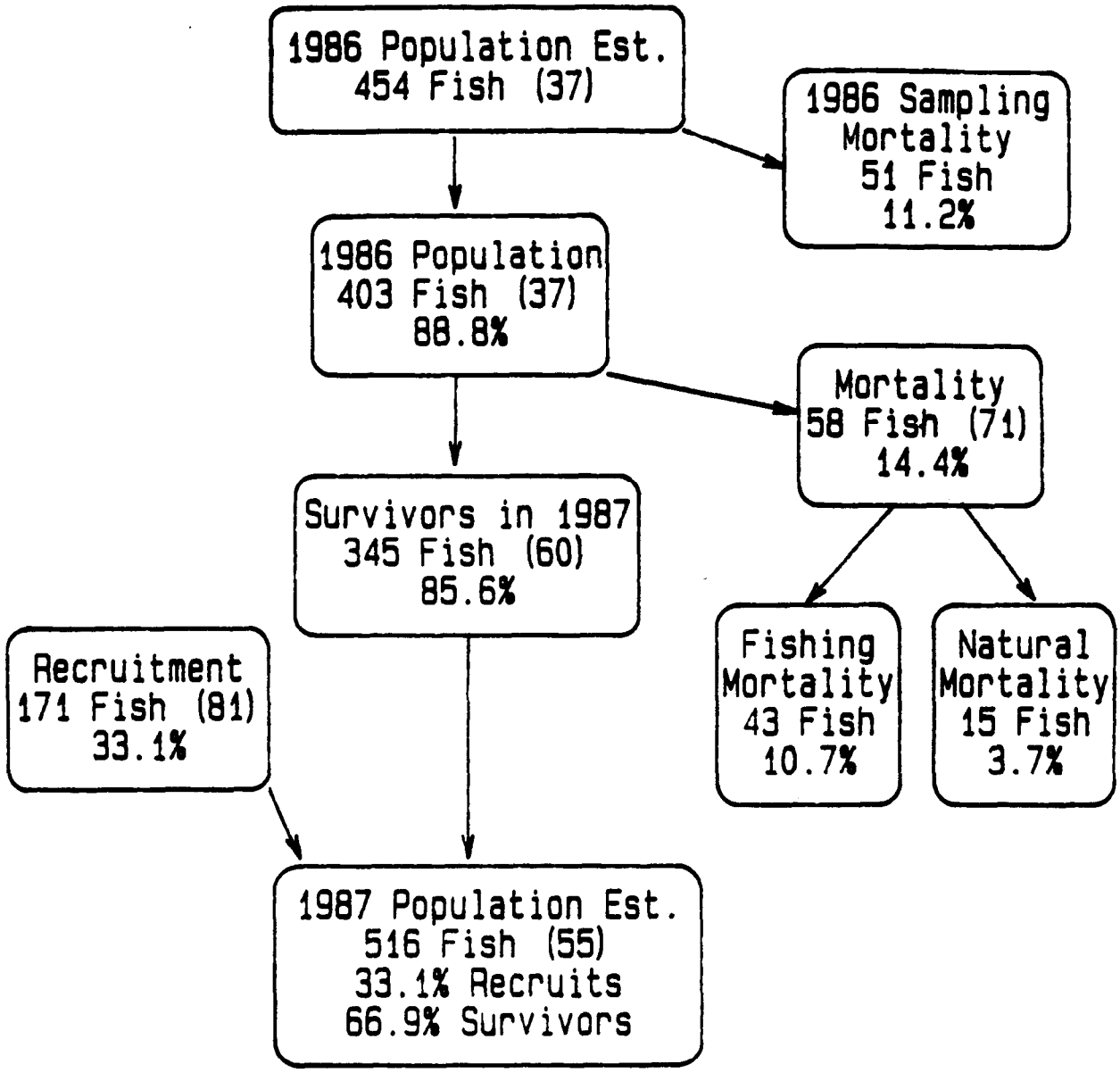

Figure 6. Diagrammatic presentation of estimates of abundance, mortality, and recruitment of T Lake northern pike between 1986 and 1987 (standard errors are in parentheses; fishing mortality is a minimum estimate; natural mortality is a maximum estimate).

fishing gear changes, then comparative catch per unit of effort statistics become less reliable as an indicator of population abundance. Thus, the differential trends observed in the two abundance assessment techniques become more understandable. Catch per unit of effort analysis based upon gill net data collected in late May or early June for assessment of abundance of the T Lake northern pike population will probably only be successful on a very gross level and in future research, these efforts should be dropped in favor of the mark-recapture approach.

Estimated density of northern pike in T Lake in 1986 (2.80 fish over 449 mm FL per hectare) and in 1987 (3.85 fish over 299 mm FL and 3.19 fish over 449 mm FL per hectare) was in the low range of densities estimated to date for Alaskan waters as well as low in relation to densities reported for more southerly waters. Density for those northern pike over 449 mm FL in Volkmar Lake, Alaska, was estimated at 14.7 fish per hectare in 1985 (Peckham 1986). A second estimate obtained in 1986 was, again, 14.7 fish per hectare (Peckham and Bernard 1987). Preliminary estimates of density of northern pike over 449 mm FL in George Lake and in Minto Flats, Alaska, in 1987 were 4.0 and 2.3 fish per hectare, respectively (Holmes 1987). Seaburg and Moyle (1964) estimated density of northern pike over 250 mm TL in Grove Lake, Minnesota, at 7.6 fish per hectare, and estimated density of northern pike over 355 mm TL in Maple Lake, Minnesota, at 4.8 fish per hectare. Density of northern pike over 356 mm TL in Murphy Flowage, Wisconsin, was estimated by Snow (1978) over a series of years with a range from 5.8 to 40.6 fish per hectare (mean = 20.8 fish per hectare). Kempinger and Carline (1978) estimated density of northern pike in Escanaba Lake, Wisconsin, over a series of years and found a mean of 6.9 fish per hectare for age 1 and above fish and a mean of 0.9 fish per hectare for fish over 560 mm TL.

The predominance of females in the T Lake northern pike population in 1986 and 1987, particularly in the larger length classes, is typical of northern pike populations. In 1986, females represented 30.1% and 45.6% of the sampled northern pike under 450 mm FL in Volkmar and George Lakes, respectively (Peckham and Bernard 1987). For those northern pike between 450 and 749 mm FL, females represented 44.6% and 76.3% in Volkmar and George Lakes, respectively. For the large size class (over 750 mm), females represented 86.0% and 100.0% in Volkmar and George Lakes, respectively. Carlander (1969) provides a review of studies conducted outside of Alaska.

Modal lengths of T Lake northern pike in 1986 were larger than similar values obtained in Volkmar and George Lakes. Volkmar Lake northern pike length frequency modes occurred at about 575 mm FL for both sexes, whereas, modal values for George Lake occurred at about 425 mm FL for males and at about 475 mm FL for females (Peckham and Bernard). The trend of larger northern pike in T Lake as compared to Volkmar and George Lakes is likely due the lower exploitation rate by the respective sport fisheries (see last paragraph of discussion). Due to strong recruitment between 1986 and 1987, length frequency modes decreased in T Lake in 1987 over 1986 modes.

T Lake northern pike were heavier at length than northern pike from Volkmar Lake and from George Lake (Peckham and Bernard 1987). This may be due to the

lower northern pike density in T Lake as compared to density of northern pike in Volkmar and George Lakes.

Maximum ages identified for T Lake northern pike were similar to maximum ages found to date in Volkmar and George Lakes (Peckham and Bernard 1987). For males, maximum ages were 9, 11, and 13 for George, T, and Volkmar Lakes, respectively. For females, maximum ages were 13, 14, and 16 for George, Volkmar, and T Lakes, respectively. The reason that the oldest northern pike have been found in T Lake is probably due to the lower exploitation rate by the T Lake sport fishery (see last paragraph of discussion).

Length-at-age relationships for males and females in T Lake were significantly different, with females having the larger mean length-at-age. This same trend also occurred in Volkmar Lake (Peckham and Bernard 1987) and is typical of northern pike populations in the southern portion of their range (see Carlander 1969). Length-at-age relationships for males and females in George Lake were not significantly different (Peckham and Bernard 1987), a pattern typical of northern pike populations in northern Canada.

Of three approaches used to evaluate growth rate of T Lake northern pike, two failed to provide useful information. The failed approaches resulted in negative growth increments; biologically a nonsense result. This occurred largely as the result of mean length-at-age statistics for 1986 being larger than similar statistics for 1987; particularly with older fish. The simplest explanation of these results is error in aging scales with a bias between years. Other investigators have had difficulty in using scales to age northern pike (see Carlander 1969), but have not reported such a bias between years. In experiments involving repetitive northern pike scale aging, both between and within readers, errors appeared to be largely random (Dave Bernard, personnel communication). This result is at odds with the simple explanation offered above. Research is needed to validate scale ages, and long term research with tagged individuals in T, Volkmar, and George Lakes may provide scale age validation results.

Growth increments as determined from tagged (1986) and recaptured (1987) T Lake northern pike indicated a growth rate similar to other northern pike populations for fish from 450 to 549 mm FL. But, growth of larger T Lake fish was slower than other northern pike populations. Mean growth of Volkmar Lake northern pike less than 550 mm FL when tagged ranged from 31 to 107 mm annually (Peckham and Bernard 1987) as contrasted with a range of 30 to 85 mm for T Lake northern pike. Mean growth of northern pike in Volkmar Lake that were more than 549 mm FL when tagged ranged from 14 to 45 mm annually (Peckham and Bernard 1987) as contrasted with a range of 3 to 23 mm for T Lake northern pike. Volkmar Lake northern pike growth rates are more similar to growth rates documented for southern waters than are T Lake northern pike growth rates (see Carlander 1969).

Instantaneous total mortality rate (0.1571) and maximum instantaneous natural mortality rate (0.0406) of T Lake northern pike were relatively low compared to similar statistics for Volkmar Lake. In Volkmar Lake, the instantaneous total mortality rate was 0.35 and the instantaneous natural mortality rate was 0.16; 2.2 and 3.9 fold higher respectively, than that observed in T Lake (Dave

Bernard, personnel communication). Instantaneous total and natural mortality rates of the T Lake and Volkmar Lake northern pike populations were both low in comparison to similar statistics for more southerly waters. Johnson and Peterson (1955) reported an instantaneous total mortality rate of 0.6 for age 3 to 8 northern pike in Ball Club Lake, Minnesota. An instantaneous total mortality rate of 0.497 was reported for a lake in southern Minnesota by Scidmore (1955). Instantaneous natural mortality rate of northern pike in Murphy Flowage, Wisconsin, ranged from 0.09 to 0.86 with a mean of 0.40 (Snow 1978).

Because natural mortality rates of studied Alaskan northern pike populations are considerably less than those typical of more southerly waters, intrinsic rates of population increase must also be considerably less for Alaskan northern pike populations. Consequently, relative surplus yield available to a fishery must also be considerably less than is typical of a southerly northern pike population. This leads to the obvious conclusion that sustainable exploitation rates must be less for Alaskan stocks as compared to more southerly northern pike populations. Hence, reliance of Alaskan fishery management strategies on demonstrated sustainable yields and sustainable exploitation rates observed in studied waters located well south of Alaska, will likely lead to fishery over-exploitation and collapse of stock abundance and composition in Alaskan northern pike populations. Alaskan fishery managers will need to develop management strategies specifically for Alaskan northern pike populations.

Minimum sport fishing harvest in T Lake between 1986 and 1987 was documented to have been 43 northern pike over 449 mm FL, resulting in a minimum exploitation rate estimate of 11.7%. Estimated exploitation rate of northern pike in Volkmar Lake between 1985 and 1986 was 16.3% (Holmes 1987). This level of exploitation appears to be sustainable because estimated abundance between these years remained the same (Dave Bernard, personnel communication). Recent exploitation rates of northern pike in Minto Flats and in George Lake were approximately 29% and 42%, respectively, and these exploitation rates were judged as unsustainable by Holmes (1987). A substantial number of northern pike (171 fish; 33.1% increase) recruited to the T Lake northern pike population in 1987. Based upon this large recruitment and the relatively low exploitation rate (10.7%) estimated between 1986 and 1987, it seems likely that the minimum estimated harvest of 43 northern pike in T Lake represented a sustainable yield. Definitive determination of sustainable yield or better yet, maximum sustainable yield, of T lake northern pike will require additional information concerning population abundance, mortality rates, and recruitment rates obtained over a series of years. Determination of sustainable exploitation rates will also be useful for application to other interior Alaska waters. Thus it is recommended that this line of research be continued in T Lake and in other waters for the next few years.

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APPENDIX

APPENDIX

The following is provided for detailed information concerning calculation of mortality and recruitment estimates for the T Lake northern pike population between 1986 and 1987.

$\hat{N}_{86}$ = 403 = estimated number of northern pike (over 449 mm) at completion of 1986 sampling (454 fish - 51 sampling mortalities).

$\hat{V}[\hat{N}_{86}]$ = 1394 = variance of 1986 population estimate.

$\hat{N}_{87}$ = 516 = estimated number of northern pike (over 449 mm) in 1987.

$\hat{V}[\hat{N}_{87}]$ = 2978 = variance of 1987 population estimate.

T_{86} = 238 = number of northern pike released alive in 1986 with tags.

C_{87} = 235 = number of northern pike examined in 1987.

R_{86} = 93 = number of 1986 tagged fish recaptured in 1987 sample of 235.

$\hat{R}^*_{86}$ = 157 = estimated number of 1986 fish present in 1987 sample of 235.

$\hat{V}[\hat{R}^*_{86}]$ = 477 = variance of estimated 1986 fish in 1987 sample of 225 (calculated with Goodman (1960) formula; see Table 2).

$$\hat{S} = 345 = \frac{(\hat{N}_{87})(\hat{R}^*_{86})}{C87} = \text{estimated number of 1986 fish still alive in 1987.}$$

$\hat{V}[\hat{S}]$ = 3612 = variance of the estimated number of 1986 fish still alive in 1987 (calculated with Goodman (1960) formula; see Table 2).

$\hat{M}$ = 58 = $\hat{N}86 - \hat{S}$ = number of 1986 fish that died between 1986 and 1987.

$\hat{V}[\hat{M}]$ = 5006 = $\hat{V}[\hat{N}_{86}] + \hat{V}[\hat{S}]$ = variance of the estimated number of 1986 fish that died between 1986 and 1987.

$\hat{J}$ = 171 = $\hat{N}_{87} - \hat{S}$ = estimated number of fish that recruited in 1987.

$\hat{V}[\hat{J}]$ = 6590 = $\hat{V}[\hat{N}_{87}] + \hat{V}[\hat{S}]$ = variance of the estimated number of fish that recruited in 1987.
