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ABUNDANCE ESTIMATES OF THE VOLKMAR LAKE NORTHERN PIKE POPULATION WITH ESTIMATES OF AGE, SEX, AND LENGTH COMPOSITION, 1985 THROUGH 1987[1]

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ABSTRACT

The northern pike *Esox lucius* population in Volkmar Lake, northeast of Delta Junction, Alaska, was sampled twice in 1987 with seines, trap nets, and gill nets. Estimated abundance of northern pike over 299 millimeters in the lake during May 1987 was 6,998 fish, with 5,130 fish in the 300-549 millimeters class, 1,386 fish in the 550-649 millimeters class, and 482 fish in the 650 millimeters and larger class. The density of northern pike 300 millimeters and longer was estimated to be 25.6 fish per hectare. Between 1985 and 1987, the length frequency distributions of both sexes shifted towards smaller lengths. Between 1985 and 1987, medium-sized males decreased in abundance while there was no change in abundance of small and large male northern pike. Abundance of small females remained relatively constant between 1985 and 1987, while abundance of large females decreased and abundance of medium females increased. Abundance of young northern pike increased, from 1,234 to 1,914 age 5 fish and from 840 to 1,150 age 6 fish, between 1985 and 1987. Abundance of fish older than age 6 decreased over the same 2 year period. Relative stock density of stock size northern pike increased between 1986 and 1987, while the quality and preferred categories decreased and the memorable and trophy categories remained constant at 0.6 percent and 0 percent respectively. Growth generally decreased with increasing age. Although not significantly different, females generally had greater growth increments than males for a given age. Males experienced a sharp decrease in growth at age 6, while females experienced a similar decrease a year later at age 7.

KEY WORDS: Northern pike, *Esox lucius*, Volkmar Lake, Alaska, abundance, mark-recapture, growth, length-weight, length-at-age, age composition, sex ratios.

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 (Holmes 1987). 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 harvest of Alaskan northern pike on an annual basis and Tanana River drainage waters alone account for about 65% of the harvest. Minto Flats, George Lake, and Volkmar Lake are the three most popular northern pike fishing areas in the Tanana River drainage.

Periodic stock assessment and creel census studies of northern pike resources and fisheries of the Tanana River drainage 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 Alaska along with information on the life history of this population. Research conducted in interior Alaskan lakes during 1986 provided additional estimates of abundance along with catch per unit of effort (CPUE) statistics, catchability coefficients, and life history characteristics for northern pike in Volkmar, T, and George Lakes (Peckham and Bernard 1987). This research program was continued in 1987 and a study of northern pike in Minto Flats was initiated.

This report documents research conducted in 1987 concerning abundance and age, sex, and length composition of the northern pike population in Volkmar Lake. This report also summarizes abundance and age, sex, and length composition information collected from Volkmar Lake in 1985 and 1986 along with providing length information for northern pike sampled in 1983 and 1984.

Study Area

Volkmar Lake (64°07'30"N, 145°11'W) is a remote lake located approximately 25 km northeast of the town of Delta Junction (Figure 1). The lake, 273 ha in size, 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 into the flats towards the Goodpaster River. Volkmar Lake is usually ice free from late May through early October. Nearshore waters are shallow. These shallow areas support extensive beds of aquatic vegetation, providing northern pike with spawning substrate as well as rearing habitat for juvenile and adult fish. The lake is accessible during the open water season by float-equipped aircraft. Snow machines and ski-equipped aircraft provide a means of access during the winter.

The popularity of Volkmar Lake is growing because of recent land disposals around the lake by the State, because of improved winter access from new snow machine trails and roads in the Delta Agricultural Project, and because of increased summer and winter use by cabin owners around the lake and by cabin owners on the nearby Goodpaster River. About a dozen recreational cabins are presently located along the lake shore, and others are being constructed. In 1987 a sport fishing lodge was established on the eastern shore of the lake. The lodge operator provides transportation, living facilities, and boats for recreational anglers during the open water season. These various facilities

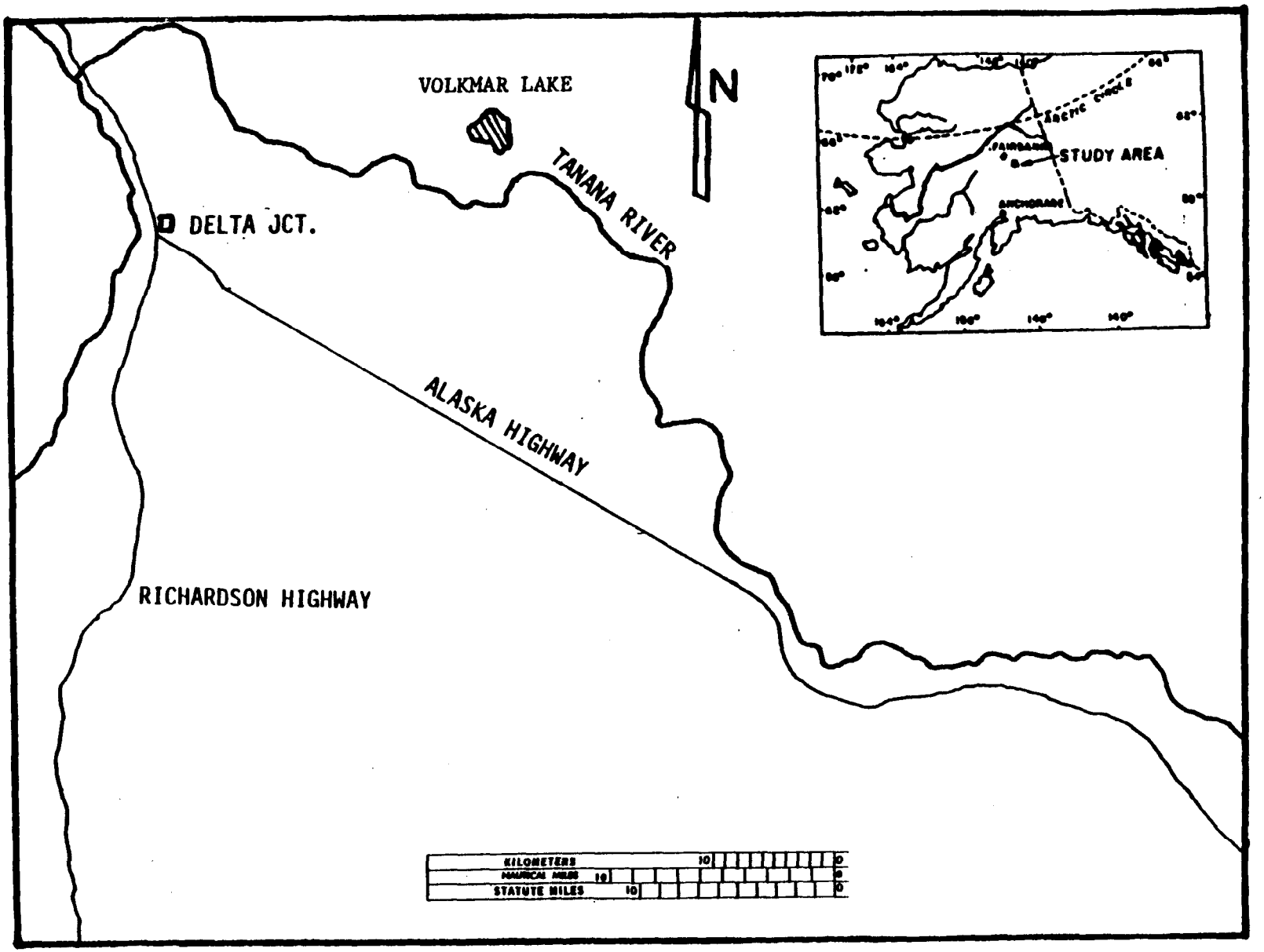

Figure 1. Location of Volkmar Lake, Alaska.

are used by recreational fishermen attracted to Volkmar Lake for open water angling. Other anglers fly to Volkmar Lake for day trips or to camp along the shoreline. In addition to summer angling, there are growing winter spear and hook-and-line sport fisheries at Volkmar Lake. Other fish species present include humpback whitefish *Coregonus pidschian*, least cisco *Coregonus sardinella*, and slimy sculpin *Cottus cognatus*.

Fishing pressure in Volkmar Lake is moderate, ranging from 273 to 546 angler-days per year. Since 1977, harvest of northern pike in Volkmar Lake has been reported in the statewide angler survey in only 3 of 10 years. In 1981, 648 northern pike were harvested during 458 days of fishing; 777 northern pike were harvested during 546 days of fishing in 1982; and, 430 northern pike were harvested during 430 days of fishing in 1983 (Mills 1982, 1983, 1984). An estimated 657 northern pike were harvested in Volkmar Lake during 1986 (Mills, personal communication).

Study Objectives and Report Goal

The goal of this research program is the stock assessment of northern pike in Volkmar Lake and the investigation of the biology of this population relevant to management of sport fisheries in interior Alaska. Although limited sampling was conducted in Volkmar Lake in 1983 and 1984, intensive sampling began in 1985 when abundance of northern pike was first estimated. In 1986, research efforts again centered on obtaining an abundance estimate. Different gear types were also evaluated to identify non-lethal, efficient means for the capture of northern pike. Seines proved to be the most effective of the gear types (gill nets, various trap and fyke nets, and seines) evaluated (Peckham and Bernard 1987). During the research in both 1985 and 1986, age, sex, length, and weight information were also collected from captured northern pike.

Specific objectives of the 1987 research program were to:

1) estimate abundance of northern pike in Volkmar Lake;

2) estimate the sex composition of this population; and,

3) estimate the parameters of the length-at-age relationship for this population.

Because other statistics, such as length frequency and age composition were obtained in the 1987 study, these results are included in this report. Because similar data (abundance, age, sex, length) were collected in both 1985 and 1986 and because the northern pike population was sampled in 1983 and 1984, this report is intended to provide a summary of all significant information available at the time of writing concerning the northern pike population in Volkmar Lake.

METHODS

Abundance of northern pike in Volkmar Lake in 1987 was estimated with a mark-recapture experiment. Two discrete sampling events took place with a 2 day hiatus between events. Most sampling was conducted with a beach seine set

from a boat and retrieved by hand to the shore. The seine was 66 m long and 3 m deep with 25 mm square mesh. The seine had a bag in the center. Trap nets were also set with various configurations (see Peckham and Bernard 1987 for gear specifications and gear fishing patterns). Gill nets, as described by Peckham and Bernard (1987), were also used to a limited degree to capture northern pike during 1987.

After northern pike were removed from the sampling gear, they were measured to the nearest millimeter of fork length. 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. Northern pike were tagged with Floy FD-68 anchor tags and the left pelvic fin was clipped. After obtaining data from each fish, live northern pike were returned to the water. To test for mixing of tagged fish throughout Volkmar Lake, the lake was divided into sampling sections (Figure 2), and section (also specific location within the section) of release was recorded for each fish.

Scales, sagittal otoliths, and cleithra were taken from all northern pike killed during sampling. Because preliminary analysis conducted prior to 1987 indicated that estimated ages from all three calcified structures were similar (Peckham and Bernard 1987), scales were taken from a subsample of live northern pike handled during the first sampling event in 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 Micron 770 Microfiche reader.

Abundance Estimation

Abundance of northern pike in Volkmar Lake was estimated with the Chapman modification of the single-mark Petersen estimator (Chapman 1951; Seber 1982). Prior to selecting this abundance estimator, a series of chi-square tests were conducted to test if inherent assumptions in the estimator had been met.

First, the hypothesis H_o: $\rho_i = \rho$ (where ρ is the probability of capture and i corresponds to a length category) was tested and rejected ($\chi^2 = 37.5$, df = 3, $P < 0.005$; see Appendix Table 1). Therefore, sampling gears were selective for larger northern pike. A series of chi-square tests were used to select optimal length classes for stratification wherein variability in probabilities of capture within the length classes was minimized and the variability among length classes was maximized. Three length classes (300 to 549 mm; 550 to 649 mm; and 650 mm and larger) were ultimately selected that met these criteria (see Appendix Table 2).

Next, chi-square tests were conducted for each of these three length categories to determine if there were unequal probabilities of capture in different areas of the lake. The hypothesis H_o: $\theta_{Ai} = \theta_{Bi}$ (where θ is the probability of recapturing a fish in length class i and A and B are the sections of the lake) was not rejected in two of the three tests ($\chi^2 = 1.99$, df = 2, $0.500 > P > 0.250$; $\chi^2 = 0.61$, df = 2, $0.900 > P > 0.750$; and, $\chi^2 = 8.40$, df = 2, $0.025 > P > 0.010$ for small, medium-size, and large fish, respectively; see Appendix Table 3). There was adequate movement of marked

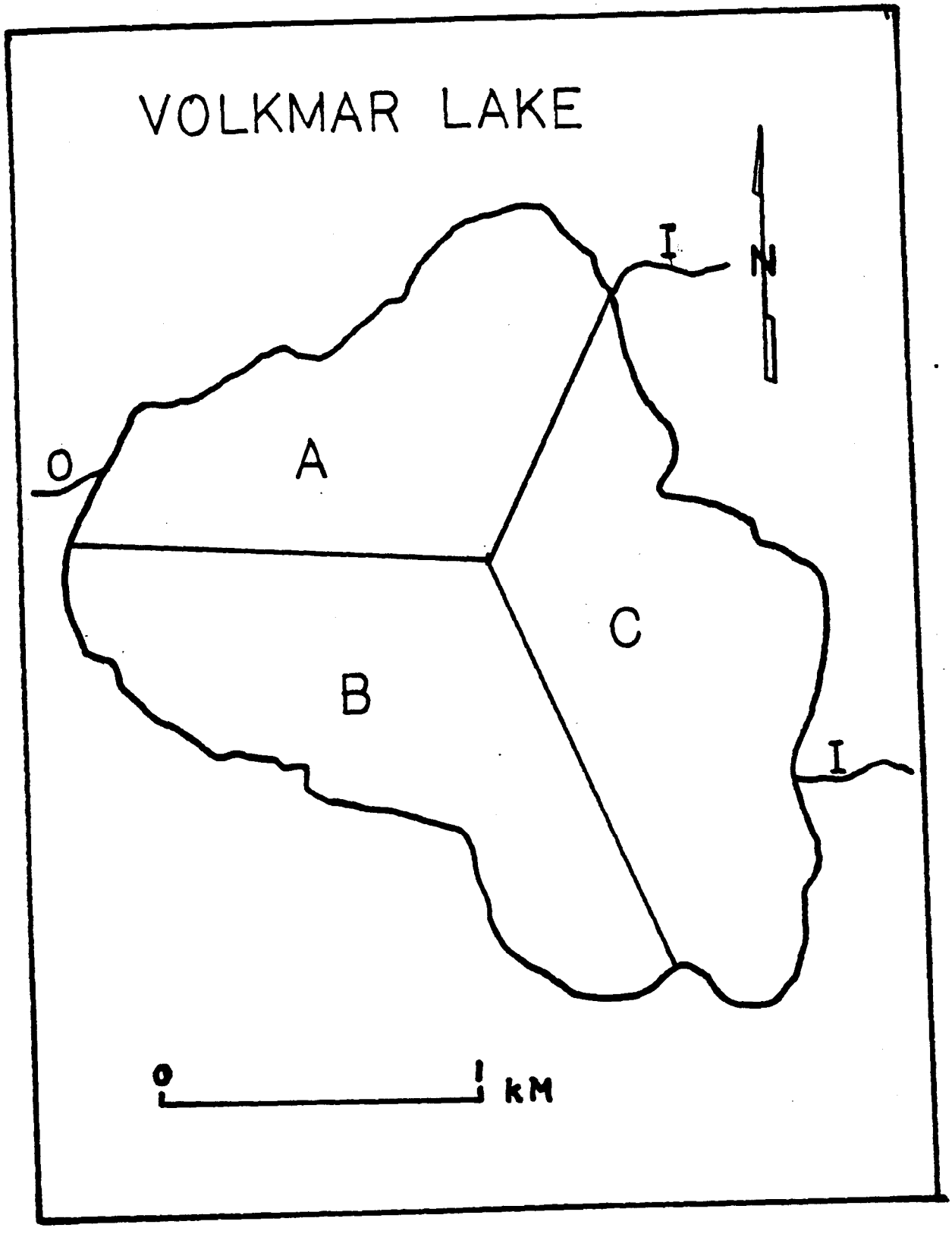

Figure 2. Volkmar Lake study sections.

fish across the lake in two out of three cases; but, mixing of large marked fish among the unmarked population was not completed by the second sampling event. The hypothesis H_o: $\rho_{Ai} = \rho_{Bi}$ (where ρ is the probability of capturing a fish in length class i and A and B are the two sections of the lake) was not rejected in two of the three tests ($\chi^2 = 0.34$, df = 1, $0.750 > P > 0.500$; $\chi^2 = 0.09$, df = 1, $0.900 > P > 0.750$; and $\chi^2 = 3.24$, df = 1, $0.100 > P > 0.050$ for small, medium, and large fish, respectively; see Appendix Table 4). The probability of capture for northern pike 650 mm and larger was higher in Section A during the second sampling event indicating that a Petersen estimate of abundance for this length class would be biased.

In situations of partial mixing and unequal probabilities of capture, the stratified method of Darroch (1961) produces an unbiased estimate of abundance so long as negative capture probabilities are not present in the estimator. Using the Darroch estimator and bootstrap methods of Efron (1982), 1,000 bootstrap abundance estimates for the 650 mm and larger category were calculated (see Clark et al. 1988 for details of methodology). Negative capture probabilities occurred in 70% of the estimates. Consequently, use of the Darroch estimator was dropped from consideration. Instead, Petersen abundance estimates for small and medium-size fish along with catch statistics were used through the following approach to estimate the magnitude of bias in the Petersen abundance estimator for large northern pike:

$$(1)\quad \hat{N}_{l.m} = \frac{\hat{N}_m C_l R_m M_l}{C_m M_m R_l};$$

where:

$\hat{N}_{l.m}$ = estimated abundance of large fish using data from large and medium-size fish;

$\hat{N}_m$ = Petersen estimate of abundance of medium-size fish;

M_l = number of large fish released during the first event;

M_m = number of medium-size fish released during the first event;

C_l = number of large fish caught during the second event;

C_m = number of medium-size fish caught during the second event;

R_l = number of large fish recaptured in the second event; and,

R_m = number of medium-size fish recaptured in the second event;

$$(2)\quad \hat{N}_{l.s} = \frac{\hat{N}_s C_l R_s M_l}{C_s M_s R_l};$$

where:

$\hat{N}_{l.s}$ = estimated abundance of large fish using data from large and small fish; and,

data for small fish are substituted in place of data for medium-size fish in the explanation above.

The averages of the estimates obtained by equation (1) and (2) provided a measure of the bias of the Petersen abundance estimate as follows:

(3) $\hat{N}_p - (\hat{N}_{l.m} + \hat{N}_{l.s})/2.$

Because estimated bias in the abundance estimator was insignificant (13 fish; 2.7% of the estimate), the Petersen method was used to estimate abundance of northern pike in the 650 mm and larger class.

Length Frequency Distribution

Length frequency distributions were calculated for males and females separately (1985 through 1987) and for sexes combined (1983 through 1987) using 25 mm length categories. These calculations were made using raw data and were not adjusted for sampling bias because estimates of sampling bias were not available for fish sampled in 1983 and 1984 and for fish smaller than 450 mm sampled in 1985.

Length-at-Age Estimation

Mean length-at-age was calculated as the arithmetic mean length at each age for males and females for 1985 through 1987. Variances and standard errors for these mean length-at-age estimates were calculated in standard fashion using normal distribution theory. Mean lengths-at-age for age 2 through 13 northern pike were plotted to show trends for this population from 1985 through 1987.

Length-Weight Relationship

The two parameters of the length-weight relationship for northern pike in Volkmar Lake were estimated through iterative least squares fitting with a computer program of the Marquardt algorithm. Parameters were estimated for data collected in 1986. 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 for the data set. These data and methods are summarized by Peckham and Bernard (1987) and are reported in this paper to provide a more complete description of the life history of northern pike in Volkmar Lake.

Composition Estimation

Abundance estimates and length, sex, and age composition data were used to provide estimates of the numbers of northern pike in the following categories: (1) small, medium, and large length classes; (2) males and females; (3) age cohorts; and (4) stock, quality, preferred, memorable, and trophy length classes (Gablehouse 1984).

Sex composition for three size categories, small (300-449 mm), medium (450-749 mm) and large (>749 mm) was defined as the proportion of the sample for a size category that was male or female. However, because abundance estimates for 1985 and 1987 were determined using differently defined size categories, the 1985 and 1987 abundance estimates were adjusted into the 1986 size categories before final abundance estimates by sex and size were calculated. This adjustment was accomplished by apportioning the fish within a 1985 or 1987 category into two or more groups: those with lengths falling within the 1986 definition for that category, and those falling into the next larger or smaller categories according to the 1986 definitions. The corresponding proportions, multiplied by the abundance estimate, resulted in an abundance estimate for each group. The groups were then reorganized to reflect the 1986 size definitions and the abundance estimates for groups within a category were summed to provide an abundance estimate for each standardized size category. These adjusted abundance estimates, multiplied by the proportions by sex, provided an abundance estimate by sex and size. It was not possible to estimate abundance by sex for the small fish in 1985, since abundance in 1985 was estimated only for fish larger than 449 mm.

To estimate abundance of northern pike by age, the sample was divided into size groups (small, medium, and large), and the age composition was calculated for each group. The age composition for each size group was then multiplied by the abundance estimate for that group to estimate numbers of fish by age in the size group. Finally, the numbers of fish of the same age were summed across size groups to estimate the age composition of the population.

After review of Gablehouse (1984), categories for estimates of relative stock density were defined as follows: stock, 300-524 mm; quality, 525-654 mm; preferred, 655-859 mm; memorable, 860-1,079 mm; and trophy, >1,079 mm. Relative stock density was defined as the proportion of all northern pike 300 mm and longer within a category. The estimates were made for each size category using the abundance estimates by size category as weighting factors as described for the age composition estimates.

Abundance of northern pike by sex and age was estimated as follows:

$$(4) \quad \hat{N}_i = \hat{p}_i(\hat{N});$$

where:

$\hat{N}_i$ = estimated number of northern pike 300 mm and longer in category i;

$\hat{p}_i$ = estimated proportion of northern pike 300 mm and longer in category i; and,

$\hat{N}$ = estimated abundance of all northern pike 300 mm and longer.

Variances for Equation 4 are from Goodman (1960):

$$(5) \quad V[\hat{N}_i] = (\hat{p}_i^2 V[\hat{N}]) + (\hat{N}^2 V[\hat{p}_i]) - (V[\hat{p}_i] V[\hat{N}]);$$

where:

$$\hat{V}[p_i] = \frac{\hat{p}_i(1-\hat{p}_i)}{n-1}; \text{ and,}$$

n = number of northern pike sampled.

Growth Rate Estimation

Growth rates were calculated by age for three categories of northern pike: male, female, and sexes combined. Growth was defined as the mean of the differences in lengths of individually tagged fish measured in 1985 and 1986, 1986 and 1987, or 1985 and 1987. An instantaneous coefficient of growth (G) was calculated for each fish with age and length measurements for years 1985 and 1986, 1986 and 1987, or 1985 and 1987, according to the equation (modified from Ricker 1971):

$$(6) \quad G = \frac{ln l_2 - ln l_1}{\Delta t};$$

where: l_1 and l_2 = length of the fish at times t_1 and t_2, respectively.

The growth statistics were used to determine if growth data could be combined across years and sex. Using the growth statistics, a Kruskal-Wallis test revealed that there were no significant differences in growth by year for fish of the same age and sex ($P \leq 0.05$), so the 1985-1986 and 1986-1987 data were combined. Although further Kruskal-Wallis tests determined that there were no significant differences in growth by age between sexes ($P \leq 0.05$), mean growth by age was reported separately by sex due to differences in the age-length relationship for males versus females. Two-year growth (1985-1987) was also reported separately for males, females, and sexes combined.

RESULTS

In 1987, 1,294 northern pike were captured in Volkmar Lake during two sampling trips. Most fish were captured with seines (74.3% in seines, 22.4% in trap nets, and 3.3% in gill nets). Of these northern pike, 1,218 were released and assumed alive at the completion of the study (91 fish under 300 mm were released untagged and 1,127 fish 300 mm or longer were released with tags). Of the 1,294 fish captured, 165 northern pike had been tagged in 1984, 1985, or 1986 (Table 1). Sampling mortality during the 1987 study was 76 northern pike (5.9% of the fish caught at least once). Most of the sampling mortalities were small northern pike gilled in the mesh of trap nets (51 of the 76 dead northern pike were less than 300 mm, and all were killed in trap nets).

During the first sampling event (19-25 May 1987) in Volkmar Lake, 994 northern pike were caught. Most of the fish were captured with seines (695 fish caught in seines, 271 fish caught in trap nets, and 28 fish caught in gill nets). Most of the fish were 300 mm and longer and were released with tags (836 fish

Table 1. Number of northern pike captured in Volkmar Lake in 1987 with tags from sampling conducted during 1984, 1985, and 1986.

Category	Recaptured During 1987 Event No. 1 (19 - 25 May)	Recaptured During 1987 Event No. 2 (27 - 29 May)	Recaptured During Both 1987 Events	Recaptured at Least Once in 1987 (19 - 29 May)
From 1984 Sampling	1	1	0	2
From 1985 Sampling:				
1985 -> 1987	45	20	4	61
1985 -> 1986 -> 1987	20	10	2	28
All 1985 Sampling	65	30	6	89
From 1986 Sampling:				
1985 -> 1986 -> 1987	20	10	2	28
1986 -> 1987	52	26	4	74
All 1986 Sampling	72	36	6	102
Totals	118	57	10	165

over 299 mm were released alive providing the "mark", 24 fish over 299 mm died, 85 fish under 300 mm were released untagged, and 49 fish under 300 mm died). Sampling mortality during the first event totaled 73 fish (7.3%).

During the second sampling event (27-29 May 1987) in Volkmar Lake, 352 northern pike were caught. Most of the fish were captured with seines (305 fish caught in seines, 30 fish caught in trap nets, and 17 fish caught in gill nets). Fifty-two of the fish caught during the second sampling event had been marked during the first sampling event. Three of the 352 northern pike caught during the second sampling event died (0.9%) during capture or sampling (2 under and 1 over 300 mm). The remaining 349 northern pike were released alive (6 under 300 mm and 343 over 299 mm). Those over 299 mm were tagged prior to release.

Abundance Estimation

Estimated abundance of northern pike over 299 mm in Volkmar Lake during May 1987, was 6,998 fish (standard error = 1,278 fish). The stratified Petersen abundance estimate was composed of 5,130 fish in the 300-549 mm class, 1,386 fish in the 550-649 mm class, and 482 fish in the 650 mm and larger class (Table 2). The density of northern pike 300 mm and longer was estimated to be 25.6 fish per hectare.

Based on results of chi-square tests (see Appendix Tables 3 and 4), the Petersen abundance estimate of 482 fish (Table 2) for northern pike in the 650 mm and larger class was assumed to be biased. Abundance of northern pike in the 650 mm and larger class calculated with equations 1 and 2 as described in the Methods Section (an unbiased estimator in this situation) resulted in estimates of 464 and 474 fish using data and estimates for small and medium-size fish, respectively. Because these two unbiased estimates of abundance of large northern pike were not significantly different from the Petersen abundance estimate for large northern pike, it was concluded that the level of bias in the Petersen estimate was insignificant in relation to precision of the estimate (average difference = 13 fish or 2.7% of the Petersen estimate; coefficient of variation of the Petersen estimate = 15.8%). Hence, the Petersen abundance estimate was used as the estimator for northern pike in the 650 mm and larger category.

Length Frequency Distribution

Between 1985 and 1987, the length frequency distributions of both males sampled and females sampled shifted towards smaller lengths (Figure 3; Table 3). In 1985, males between 475 mm and 599 mm made up about 62% of the males sampled. These length groups decreased to 48% of the sample in 1986, and to only 28% in 1987. In 1985, males were unimodally distributed between 475 mm and 599 mm. The 1986 male length frequency distribution was bimodal, with modes at 375-474 mm and 525-649 mm. In 1987, these modes shifted to even smaller lengths, with modes at 275-374 mm and 550-599 mm.

Similarly, length frequencies of female northern pike in Volkmar Lake shifted downward between 1985 and 1987 (Figure 3; Table 3). In 1985, the 500-674 mm range made up 55% of the females sampled from Volkmar Lake. This percentage rose slightly to 64% in 1986, but fell to 45% in 1987. The larger females, 775-899 mm, fell even more drastically, from 20% in 1985 to only 1% by 1987.

Table 2. Estimated abundance of northern pike in Volkmar Lake during June 1985, June 1986, and May 1987.

Length Class (mm)	Number of northern pike caught during event(s)			Number of Recaptures	Estimated Abundance	Standard Error
	First	Second	Both			
ABUNDANCE IN JUNE 1985[1]:						
300-449	89	31	120	0	unknown	
450-699	722	204	926	40	3,615	248
Over 700	179	62	241	27	405	28
Total over 450 mm	901	266	1,167	67	4,020	250
ABUNDANCE IN JUNE 1986[2]:						
300-449	151	52	203	1	4,027	2,266
450-749	782	163	945	32	3,890	584
Over 749	38	6	44	1	136	65
Total over 300 mm	971	221	1,192	34	8,053	2,341
ABUNDANCE IN MAY 1987:						
300-549	491	145	636	13	5,130	1,242
550-649	207	119	326	17	1,386	294
Over 650	138	79	217	22	482	76
Total over 300 mm	836	343	1,179	52	6,998	1,278

[1] Data for 1985 taken from Peckham (1986).

[2] Data for 1986 taken from Peckham and Bernard (1987).

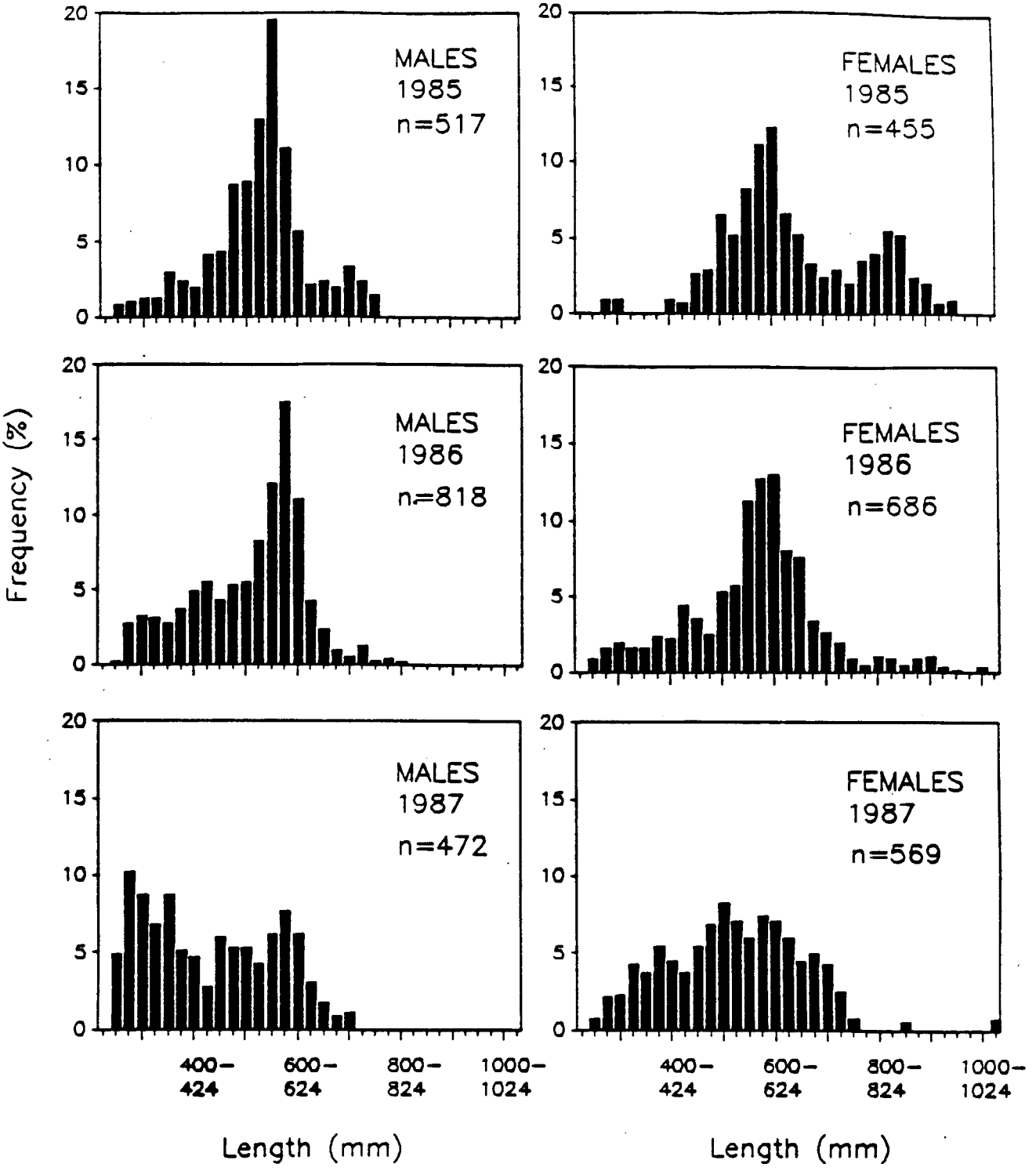

Figure 3. Length frequency distributions by sex of northern pike sampled in Volkmar Lake, 1985-1987.

Table 3. Length frequency distribution of northern pike sampled from Volkmar Lake by sex, 1985-1987.

	1985				1986				1987			
	MALES		FEMALES		MALES		FEMALES		MALES		FEMALES	
Length (mm)	n	%	n	%	n	%	n	%	n	%	n	%
<225					1							
225-249	1								1			
250-274	4	1			1		6	1	23	5	4	1
275-299	5	1	4	1	22	3	11	2	48	10	12	2
300-324	6	1	4	1	26	3	13	2	41	9	13	2
325-349	6	1	1		25	3	11	2	32	7	24	4
350-374	15	3	1		22	3	11	2	41	9	21	4
375-399	12	2	1		30	4	16	2	24	5	31	5
400-424	10	2	4	1	40	5	15	2	22	5	25	4
425-449	21	4	3	1	45	6	30	4	13	3	21	4
450-474	22	4	12	3	35	4	24	3	28	6	31	5
475-499	45	9	13	3	43	5	17	2	25	5	39	7
500-524	46	9	30	7	45	6	36	5	25	5	47	8
525-549	67	13	24	5	68	8	39	6	20	4	40	7
550-574	101	20	38	8	99	12	77	11	29	6	34	6
575-599	57	11	51	11	143	17	87	13	36	8	42	7
600-624	29	6	56	12	91	11	89	13	29	6	40	7
625-649	11	2	30	7	35	4	55	8	14	3	34	6
650-674	12	2	24	5	19	2	52	8	8	2	25	4
675-699	10	2	15	3	8	1	23	3	4	1	28	5
700-724	17	3	11	2	4		18	3	5	1	24	4
725-749	12	2	13	3	10	1	13	2	1		14	2
750-774	7	1	9	2	2		6	1	1		4	1
775-799	1		16	4	3		3		1		2	
800-824			18	4	1		7	1			2	
825-849			25	5			6	1	1		2	
850-874			24	5			3				3	1
875-899			11	2			6	1				
900-924			9	2			7	1			1	
925-949			3	1			2				1	
950-974			4	1			1				1	
975-999			1									
1,000-1,024							2					
1,025-1,049											4	1
TOTAL	517	100	455	100	818	100	686	100	472	100	569	100

In 1985, the female sample had two modes, one mode at 500-674 mm and another larger mode at 775-899 mm. In 1986 the female sample was unimodal, with a peak between 525 and 674 mm. In 1987, the distribution was flattened out with most female northern pike falling between 450 and 724 mm. The percent frequencies for these length categories ranged from 4% to 8%.

Since sample sizes for 1983 and 1984 were small and few fish were sexed, length frequency distributions by sex for these years were unavailable. However, it was possible to calculate length frequency distributions for sexes combined for 1983 through 1987, and peaks occurred between 500 and 599 mm in most years (Figure 4; Table 4).

Length-at-Age Estimation

The 1985, 1986 and 1987 mean lengths-at-age for males were in close agreement (Figure 5; Table 5). Lengths of young females were also in close agreement across the 3 years, but were inconsistent over age 9, perhaps due to small sample sizes (Figure 5; Table 6). For most ages, females were larger than males (Figure 6).

Length-Weight Relationship

The estimated parameters of the length-weight relationship for the 324 fish sampled in 1986 were: a = 8.3161; S.E.(a) = 0.07183; b = 3.1102; S.E.(b) = 0.02520; correlation (a,b) = 0.8211 (Figure 7).

Composition Estimation

Between 1985 and 1987 medium-sized males decreased in abundance while there was no significant change in abundance of small and large northern pike (Figure 8; Tables 7, 8, and 9). Abundance of small females remained relatively constant between 1985 and 1987, while abundance of large females decreased and abundance of medium females increased (Figure 8; Tables 7, 8, and 9).

Abundance of young northern pike increased, from 1,238 to 1,914 age 5 fish and from 840 to 1,150 age 6 fish, between 1985 and 1987. Abundance of fish older than age 6 decreased over the same 2 year period (Figure 9; Tables 10, 11, and 12). Of the fish greater than 299 mm in 1987, 91% were age 6 or younger. In 1986, 78% of the fish greater than 299 mm were age 6 or younger. In 1987, the age 5 cohort was the most abundant (1,914 fish) and was probably the youngest cohort fully recruited into the population estimate. Estimated abundance of northern pike by year class decreased as age increased from age 5 to age 12. In 1987, there was a dramatic decrease in abundance of the 1975 through 1980 year classes (Figure 10).

Relative stock density of stock size northern pike increased between 1986 and 1987, while the quality and preferred categories decreased and the memorable and trophy categories remained constant with 0.6 and 0.0%, respectively (Table 13). Relative stock densities adjusted for sampling bias were not available for 1985, but unadjusted densities showed the same general trend between 1985 and 1986 (Table 14).

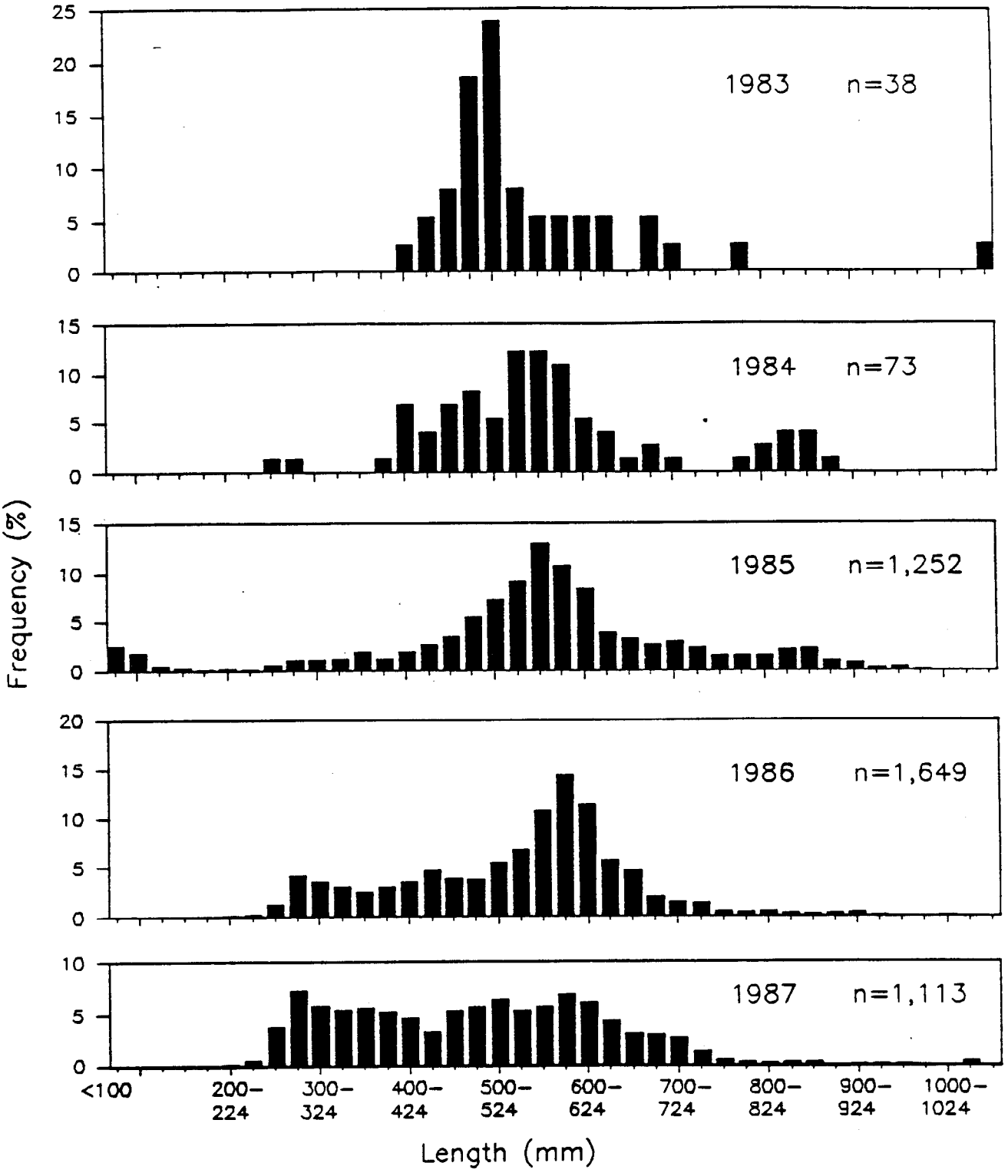

Figure 4. **Length frequency distributions of northern pike sampled in Volkmar Lake, 1983-1987.**

Table 4. Length frequency distribution of northern pike sampled from Volkmar Lake, 1983-1987.

	YEAR									
	1983		1984		1985		1986		1987	
Length (mm)	n	%	n	%	n	%	n	%	n	%
<100					31	2	1			
100-124					22	2	1			
125-149					6					
150-174					3					
175-199					1					
200-224					2				1	
225-249					1		3		5	
250-274			1	1	7	1	20	1	42	4
275-299			1	1	13	1	67	4	82	7
300-324					13	1	57	3	65	6
325-349					15	1	49	3	61	5
350-374					24	2	40	2	63	6
375-399			1	1	14	1	49	3	58	5
400-424	1	3	5	7	24	2	58	4	52	5
425-449	2	5	3	4	32	3	76	5	36	3
450-474	3	8	5	7	43	3	63	4	60	5
475-499	7	18	6	8	69	6	61	4	64	6
500-524	9	24	4	5	91	7	89	5	72	6
525-549	3	8	9	12	114	9	112	7	60	5
550-574	2	5	9	12	163	13	178	11	64	6
575-599	2	5	8	11	134	11	237	14	78	7
600-624	2	5	4	5	105	8	187	11	69	6
625-649	2	5	3	4	48	4	94	6	48	4
650-674			1	1	40	3	76	5	34	3
675-699	2	5	2	3	32	3	33	2	32	3
700-724	1	3	1	1	37	3	24	1	29	3
725-749					29	2	23	1	15	1
750-774					19	2	8		5	
775-799	1	3	1	1	18	1	7		3	
800-824			2	3	19	2	8		2	
825-849			3	4	26	2	6		3	
850-874			3	4	27	2	4		3	
875-899			1	1	12	1	6			
900-924					10	1	7		1	
925-949					3		2		1	
950-974					4		1		1	
975-999					1					
1,000-1,024							2			
1,025-1,049									4	
1,050-1,074	1	3								
Total	38	100	73	100	1,252	100	1,649	100	1,113	100

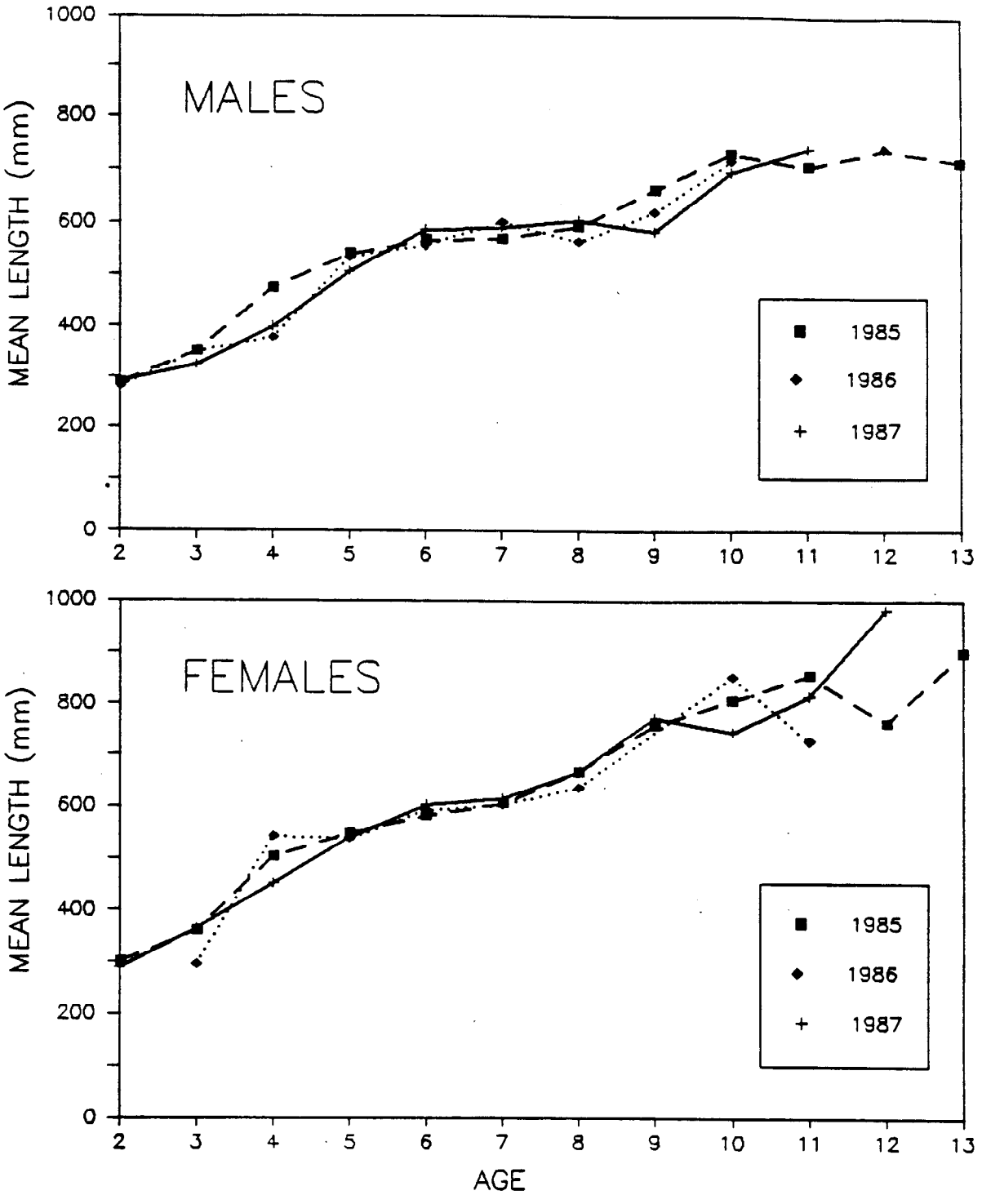

Figure 5. Mean length-at-age of male and female northern pike in Volkmar Lake, 1985-1987.

Table 5. Mean length at age of male northern pike from Volkmar Lake, 1985-1987.

	1985			1986			1987		
Age	Sample Size	Mean (mm)	SE	Sample Size	Mean (mm)	SE	Sample Size	Mean (mm)	SE
2	10	288	9	1	280		9	290	8
3	23	350	10	4	351	29	123	324	4
4	56	472	8	7	377	24	77	397	9
5	48	538	5	3	531	36	107	505	8
6	21	565	10	9	555	11	58	583	8
7	21	565	9	4	597	20	22	587	11
8	20	591	10	3	562	10	14	604	21
9	21	665	14	4	621	47	8	583	21
10	6	731	12	1	718		4	696	73
11	6	706	15				1	741	
12	1	740		1	743				
13	1	716							
Total	234			37			423		

Table 6. Mean length at age of female northern pike from Volkmar Lake, 1985-1987.

Age	1985			1986			1987		
	Sample Size	Mean (mm)	SE	Sample Size	Mean (mm)	SE	Sample Size	Mean (mm)	SE
2	6	301	10				8	288	10
3	5	361	47	7	295	9	60	365	7
4	22	503	13	1	543		118	452	7
5	39	549	10	12	540	13	125	541	7
6	36	582	10	9	593	20	110	603	7
7	26	607	12	6	603	16	47	617	12
8	22	669	15	4	638	25	23	667	9
9	26	759	16				14	773	36
10	30	806	13	4	852	45	9	744	24
11	19	856	12	1	727		6	816	73
12	6	763	55				2	983	81
13	5	900	16						
19	1	912							
Total	243			44			522		

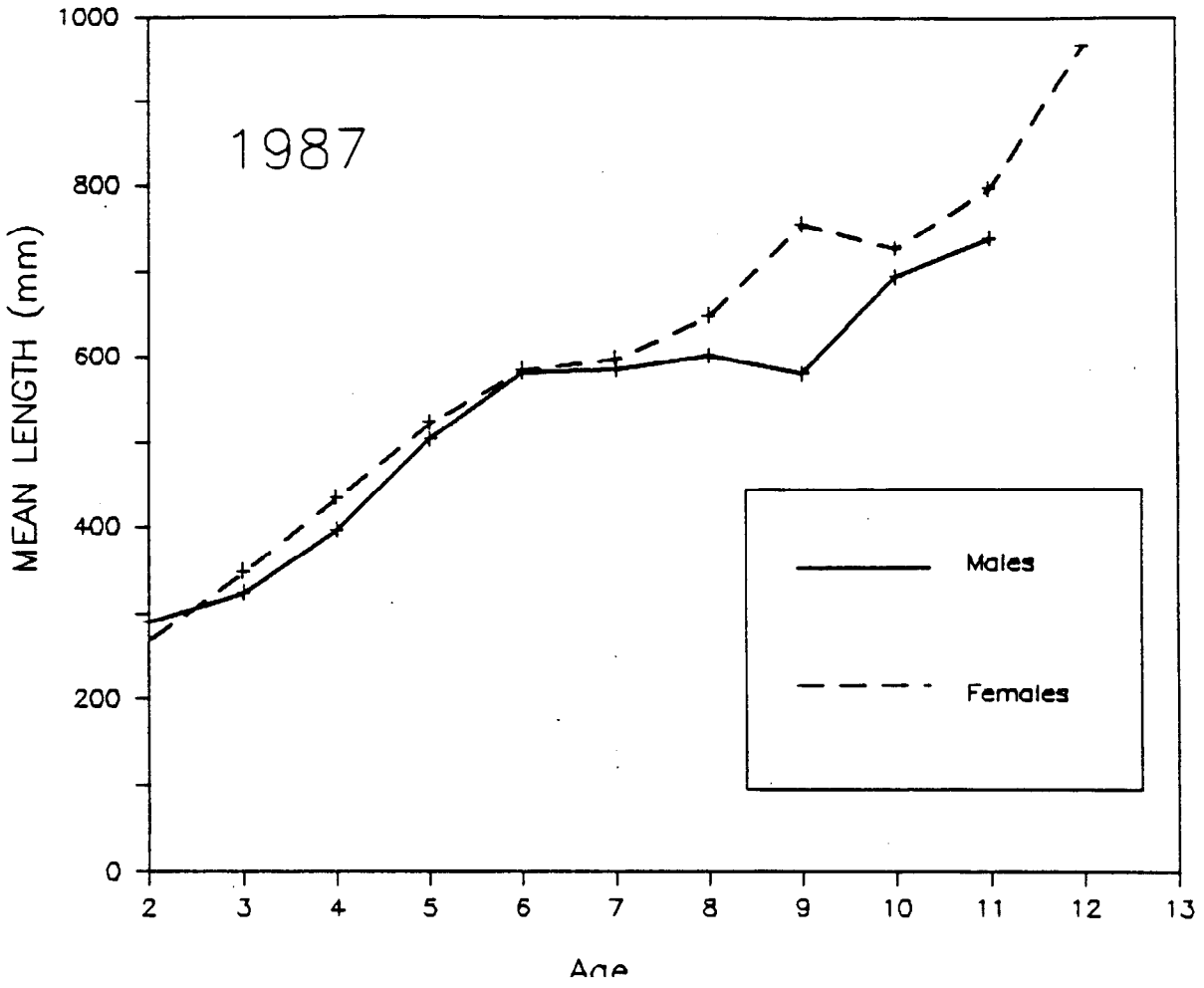

Figure 6. Mean length-at-age of male and female northern pike in Volkmar Lake, 1987.

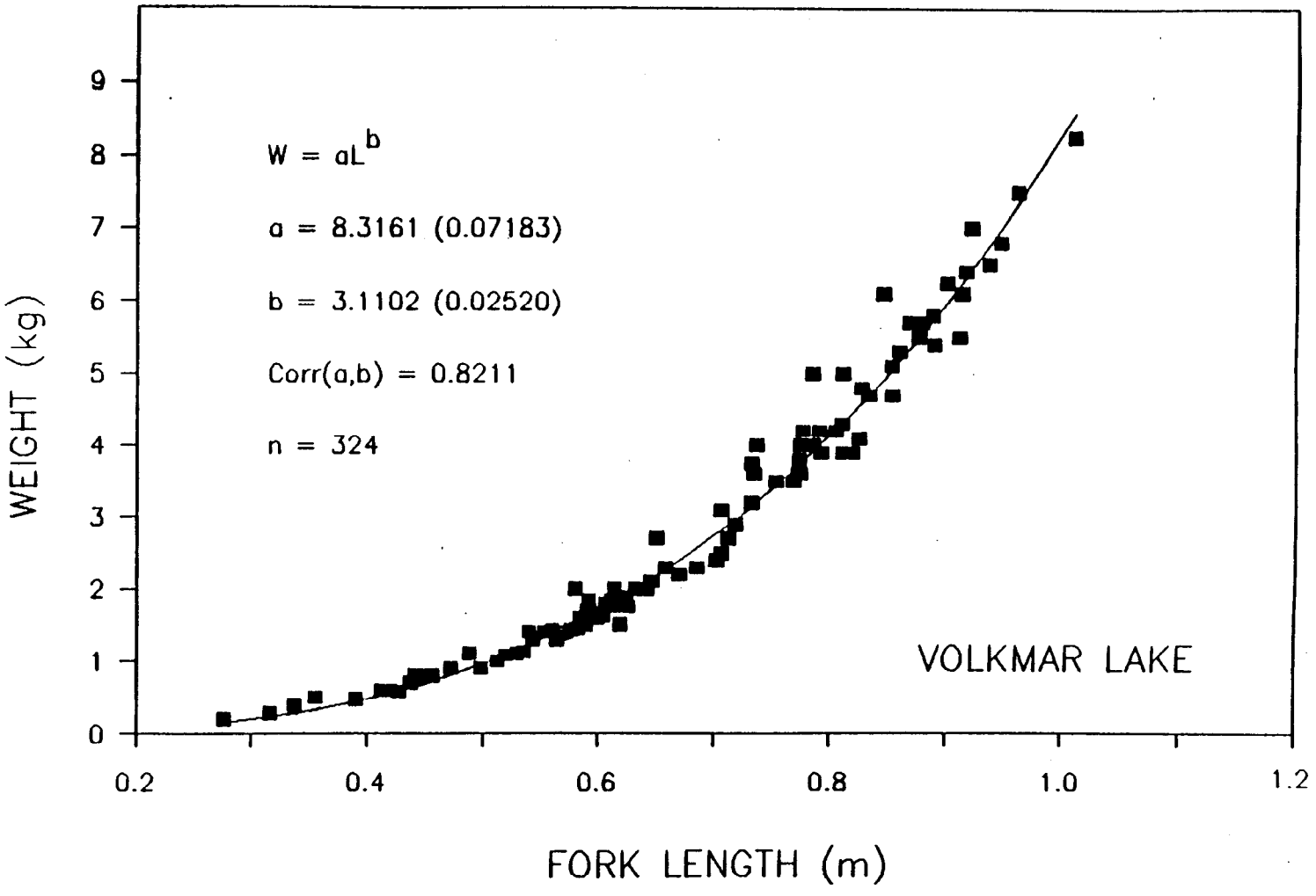

Figure 7. Length-weight relationship of northern pike in Volkmar Lake.

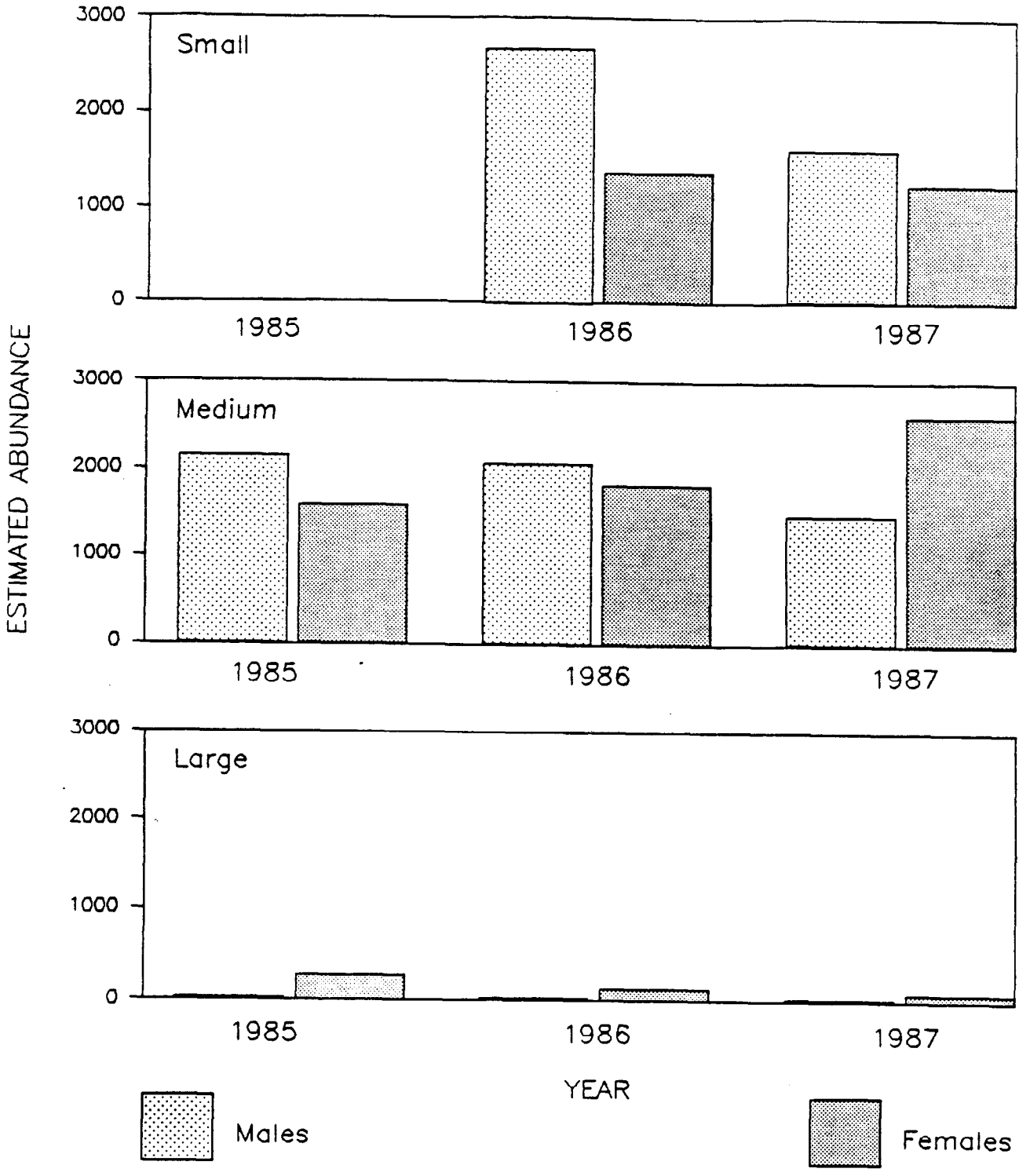

Figure 8. Sex composition of three size categories of northern pike in Volkmar Lake, 1985-1987.

Table 7. Sex composition of the northern pike population in Volkmar Lake, 1985.

Category	Northern Pike by Length Class (mm)				
	Small 300-449	Medium 450-749	Large >749	All Fish >299	All Fish >449
Sample Size	84	746	128	958	874
No. of Females	14	317	120	451	437
No. of Males	70	429	8	507	437
F:M ratio	1:5.00	1:1.35	1:0.07	1:1.12	1:1.00
Total Abundance	---	3,732	288	---	4,020
Percent Females	16.7	42.5	93.8	47.1	50.0
SE of % Females	4.1	1.8	2.1	1.6	1.7
Abundance of Females	---	1,586	270	---	2,010
SE (Abun. of Fem)	---	125	23	---	142
Percent Males	83.3	57.5	6.2	52.9	50.0
SE of % Males	4.1	1.8	2.1	1.6	1.7
Abundance of Males	---	2,146	18	---	2,010
SE (Abun. of Males)	---	158	6	---	142

Table 8. Sex composition of the northern pike population in Volkmar Lake, 1986.

Category	Northern Pike by Length Class (mm)				
	Small 300-449	Medium 450-749	Large >749	All Fish >299	All Fish >449
Sample Size	284	1,130	49	1,463	1,179
No. of Females	96	530	43	669	573
No. of Males	188	600	6	794	606
F:M ratio	1:1.96	1:1.13	1:0.14	1:1.19	1:1.06
Total Abundance	4,027	3,890	136	8,053	4,026
Percent Females	33.8	46.9	87.8	45.7	48.6
SE of % Females	2.8	1.5	4.7	1.3	1.4
Abundance of Females	1,361	1,824	119	3,680	1,957
SE (Abun. of Fem)	772	280	57	1075	291
Percent Males	66.2	53.1	12.2	54.3	51.4
SE of % Males	2.8	1.5	4.7	1.3	1.4
Abundance of Males	2,666	2,066	17	4,373	2,069
SE (Abun. of Males)	1,503	3,902	10	1,276	307

Table 9. Sex composition of the northern pike population in Volkmar Lake, 1987.

Category	Northern Pike by Length Class (mm)				
	Small 300-449	Medium 450-749	Large >749	All Fish >299	All Fish >449
Sample Size	308	622	23	953	645
No. of Females	135	398	20	553	418
No. of Males	173	224	3	400	227
F:M ratio	1:1.28	1:0.56	1:0.15	1:0.72	1:0.54
Total Abundance	2,822	4,094	82	6,998	4,176
Percent Females	43.8	64.0	87.0	58.0	64.8
SE of % Females	2.8	1.9	7.2	1.6	1.9
Abundance of Females	1,236	2,620	71	4,059	2,706
SE (Abun. of Fem.)	312	419	12	750	424
Percent Males	56.2	36.0	13.0	42.0	35.2
SE of % Males	2.8	1.9	7.2	1.6	1.9
Abundance of Males	1,586	1,474	11	2,939	1,470
SE (Abun. of Males)	77	244	6	548	239

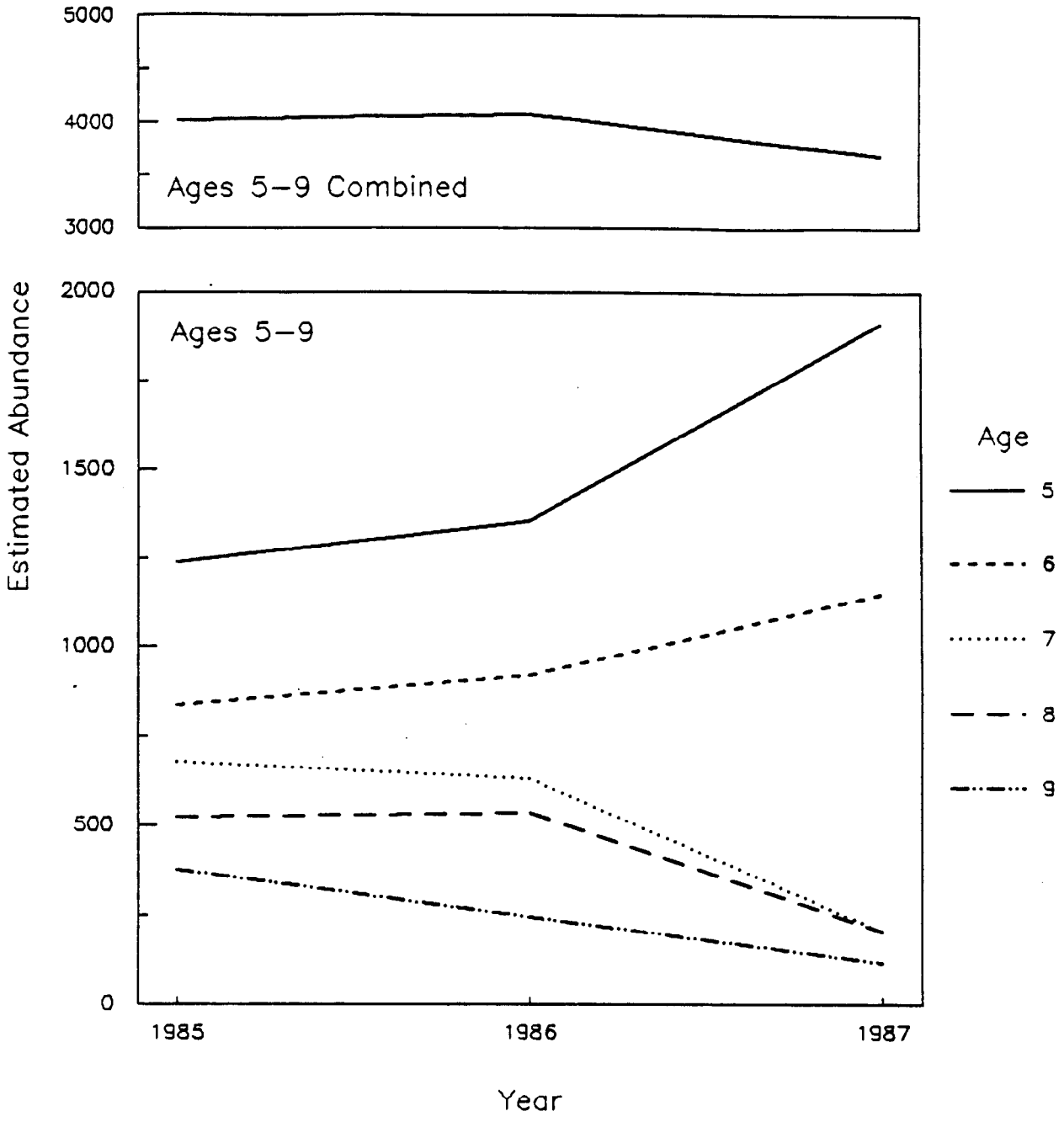

Figure 9. Abundance of northern pike ages 5-9 in Volkmar Lake in 1987.

Table 10. Age composition of the northern pike population in Volkmar Lake (>449 mm), 1985.

Age Class	Sample Size	Estimated Abundance	SE of Est. Abundance	Percent of Total Est. Abundance	SE of Percent
5	90	1,238	137	30.8	46
6	59	840	112	20.9	41
7	49	677	99	16.8	37
8	42	525	86	13.1	34
9	47	377	65	9.4	29
10	36	179	35	4.5	21
11	26	120	27	3.0	17
12	7	37	17	0.9	10
13	6	23	9	0.6	8
19	1	4	4	0.1	3
Total	363	4,020	250	100	

Table 11. Age composition of the northern pike population in Volkmar Lake (>299 mm), 1986.

Age Class	Sample Size	Estimated Abundance	SE of Est. Abundance	Percent of Total Est. Abundance	SE of Percent
2	1	288[1]	278	3.6	19
3	6	1,726[1]	1,064	21.4	41
4	11	1,969[2]	1,069	24.5	43
5	23	1,357	375	16.9	37
6	19	924	231	11.5	32
7	13	632	186	7.8	27
8	11	535	169	6.6	25
9	5	243	111	3.0	17
10	7	282	107	3.5	18
11	1	49	49	0.6	8
12	1	49	49	0.6	8
Total	98	8,053	2,341	100	

[1] Estimated abundance is only for age 2 and 3 northern pike larger than 299 mm.

[2] All age 4 and older northern pike were larger than 299 mm.

Table 12. Age composition of the northern pike population in Volkmar Lake (>299 mm), 1987.

Age Class	Sample Size	Estimated Abundance	SE of Est. Abundance	Percent of Total Est. Abundance	SE of Percent
2	9	85[1]	21	1.2	11
3	146	1,379[1]	331	19.7	40
4	198	1,842[2]	430	26.3	44
5	233	1,914	340	27.4	45
6	169	1,150	169	16.4	37
7	31	205	39	2.9	17
8	37	205	37	2.9	17
9	22	118	26	1.7	13
10	13	60	16	0.9	9
11	7	30	12	0.4	7
12	2	8	6	0.1	3
Total	867	6,998	1,278	100	

[1] Estimated abundance is only for age 2 and 3 northern pike larger than 299 mm.

[2] All age 4 and older northern pike were larger than 299 mm.

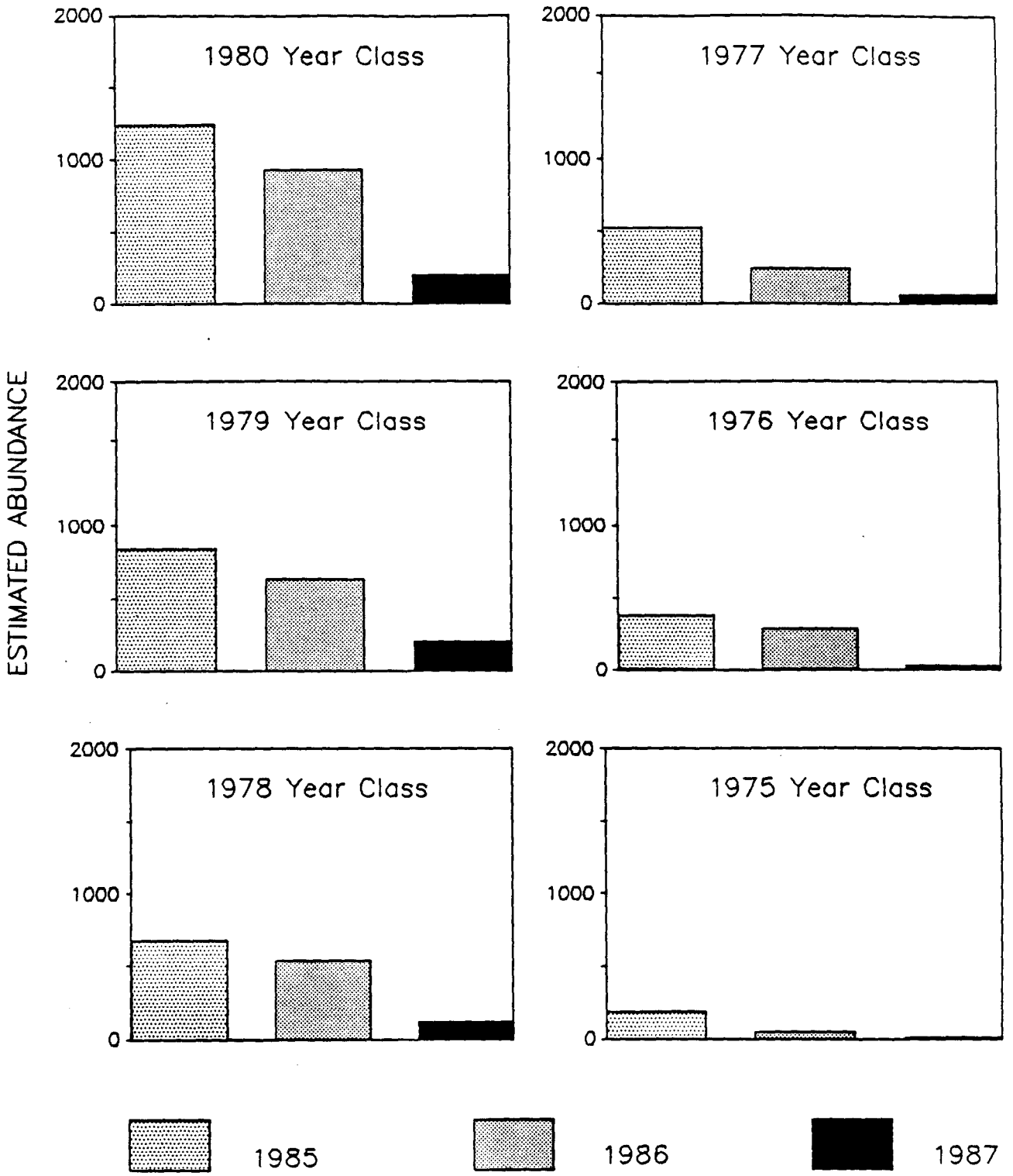

Figure 10. Estimated abundance (1985-1987) of six year classes of northern pike from Volkmar Lake.

Table 13. Adjusted relative stock density estimates of northern pike in Volkmar Lake, 1986-1987.

Category	Gablehouse[1] Minimum Length (mm)	1986 Estimated Abundance	1986 Relative Stock Density[1]	1986 SE	1987 Estimated Abundance	1987 Relative Stock Density[1]	1987 SE
Stock	300	4,727	58.7	0.5	4,617	66.0	0.6
Quality	525	2,723	33.8	0.5	1,913	27.3	0.3
Preferred	655	553	6.9	0.3	429	6.1	0.3
Memorable	860	50	0.6	0.1	39	0.6	0.9
Trophy	1,080	0			0		
Total		8,053	100		6,998	100	

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

Table 14. Unadjusted relative stock density estimates of northern pike in Volkmar Lake, 1985-1987.

Category	Gablehouse[1] Minimum Length (mm)	1985 n	1985 Relative Stock Density[1]	1985 SE	1986 n	1986 Relative Stock Density[1]	1986 SE	1987 n	1987 Relative Stock Density[1]	1987 SE
Stock	300	325	27.9	1.3	542	34.8	1.2	531	54.0	1.6
Quality	525	577	49.5	1.5	828	53.2	1.3	323	32.9	1.5
Preferred	655	218	18.7	1.1	168	10.8	0.8	119	12.1	1.0
Memorable	860	46	3.9	0.6	19	1.2	0.3	10	1.0	0.3
Trophy	1,080	0			0			0		
Totals		1,166	100		1,557	100		983	100	

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

Growth Rate Estimation

Growth generally decreased with increasing age. Although not significantly different according to Kruskal-Wallis tests ($P \leq 0.05$), females generally had greater growth increments than males for a given age (Figure 11; Table 15). Males experienced a sharp decrease in growth at age 6, while females experienced a similar decrease a year later at age 7 (Figure 11).

DISCUSSION

Sex ratios skewed towards females in the older and larger sized portions of the population as found in Volkmar Lake are typical of northern pike populations in general. For example, in T Lake, females represented 34.8%, 67.5%, and 100.0% of the fish in the small, medium, and large size categories in 1987 (Clark 1988), and the northern pike population in George Lake consisted of 39.5%, 65.9% and 100.0% females for the small, medium and large-sized, fish respectively (Clark et al. 1988). Carlander (1969) provides a review of studies conducted outside of Alaska, and in general the same phenomena occur. Although relatively consistent with reports of sex composition in the nearby George and T lakes, the Volkmar Lake sex composition changed across years. While the proportion of females in the small and medium categories increased from 16.7% to 43.8% and from 42.5% to 64.0%, respectively, between 1985 and 1987, the proportion of females in the large category decreased from 93.8% in 1985 to 87.0% in 1987.

Mean lengths-at-age of northern pike in Volkmar Lake were generally intermediate between northern pike in George and T Lakes (Figure 12). Relative stock densities of northern pike in Volkmar and George Lakes were very similar, while those of the population of T Lake differed. Most northern pike in Volkmar and George Lakes were concentrated in the smallest (stock) size category with about one-fourth of the fish falling within the quality size category. The T Lake population, in contrast, was distributed more evenly between three categories, stock, quality and preferred. While only a small percent of the populations of all three lakes were large (memorable or trophy) fish, T Lake, with 1.8% of its population falling into the memorable category, had more large fish than the other two lakes.

Differences in relative stock density between the three lakes may be due to differences in fishing pressure. T Lake, which had the lower relative density of small fish and the greater relative density of large fish also experienced the least fishing pressure during 1987. Volkmar Lake, which was intermediate between T and George Lakes was also intermediate in amount of fishing pressure, and George Lake, which had the lowest percent of large fish and the greatest percent of small fish experienced the highest exploitation rate of the three lakes during 1987 (see Clark 1988 for a discussion of exploitation rates).

Maximum ages of northern pike in George, Volkmar, and T Lakes were 12, 12, and 16, respectively (Clark 1988; Clark et al. 1988). An inverse relationship between maximum age and exploitation rate may explain the older fish found in T Lake.

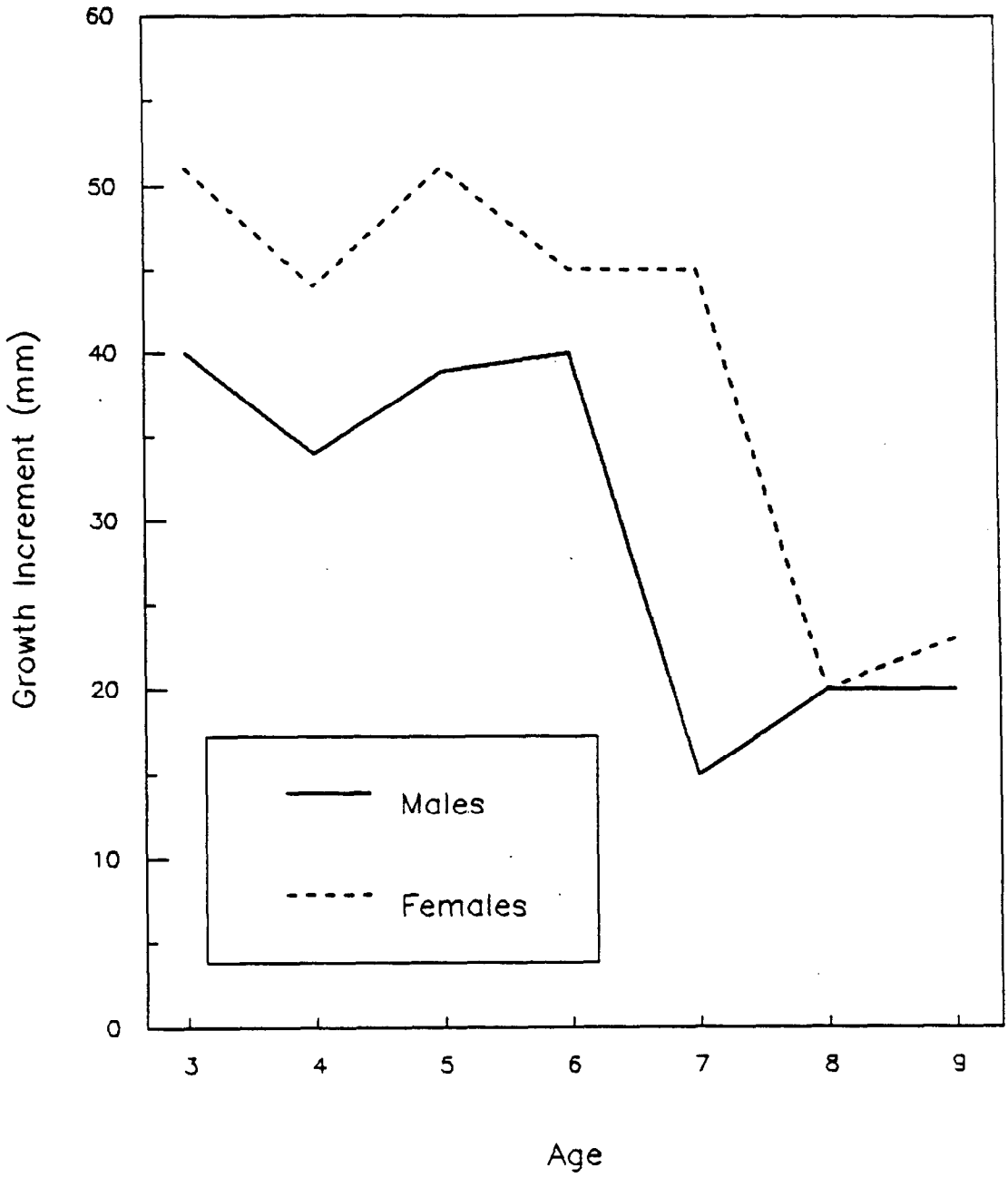

Figure 11. Growth increments of male and female northern pike in Volkmar Lake.

Table 15. Mean growth by age of northern pike from Volkmar Lake.[1]

	Males			Females			Sexes Combined		
Age	Sample Size	Mean (mm)	SE	Sample Size	Mean (mm)	SE	Sample Size	Mean (mm)	SE
ONE YEAR GROWTH									
2	2	75		5	52	11	8	55	10
3	4	40	12	15	51	8	23	48	6
4	20	34	3	16	44	3	41	39	2
5	11	39	6	19	51	4	36	47	3
6	5	40	8	12	45	5	18	43	4
7	4	15	4	5	45	11	10	34	8
8	3	20	4	3	20	6	6	20	3
9	3	20	4	3	23	8	4	28	7
10	0			4	31	13	4	31	13
11	0			2	30	10	2	30	10
12	0			1	15		1	15	
13	0			1	32		1	32	
Total	52			86			154		
TWO YEAR GROWTH									
2	1	52		5	84	18	7	78	13
3	2	89	51	4	98	13	8	98	11
4	9	76	7	8	109	10	20	94	6
5	1	15		4	74	18	5	62	19
6	3	54	12	5	87	19	11	78	10
7	1	29		5	37	10	8	44	11
8	0			4	72	17	5	78	15
9	1	37		1	54		3	45	6
10	0			1	20		2	40	28
11	0			1	38		1	38	
12	0			0			0		
13	0			0			0		
Total	18			38			70		

[1] There was no significant difference between growth of males and females; sample sizes for sexes combined include fish of unknown sex.

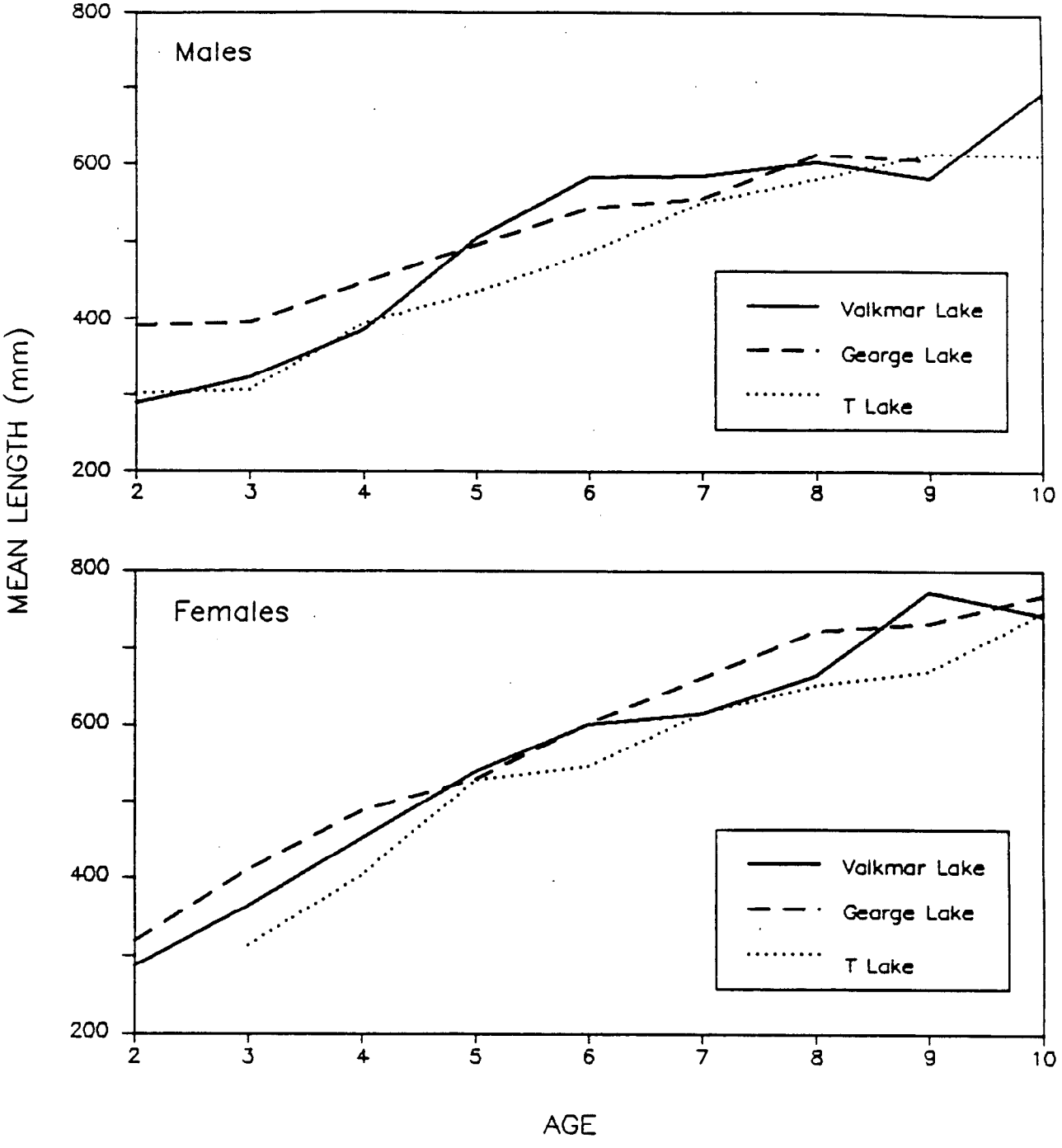

Figure 12. Mean length-at-age of male and female northern pike in Volkmar, George, and T Lakes in 1987.

Length-at-age relationships for male and female northern pike in Volkmar Lake were different, with females having the larger mean length-at-age, a trend typical for northern pike in the southern portion of their range (see Carlander 1969). This same trend occurred in T Lake (Clark 1988) and George Lake (Clark et al. 1988).

Although abundance of northern pike decreased only slightly between 1985 and 1987, a number of the findings from this study indicate that the composition of the population is changing. The Volkmar Lake population is shifting towards smaller, younger fish, and of special concern should be the loss of the larger and older females. This shift may be due in part to good recruitment over the past 3 years, but it is likely that this shift is also due to increased fishing pressure.

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APPENDICES

Appendix Table 1. Numbers of northern pike tagged by length class in Volkmar Lake 19-25 May then sampled 27-29 May 1987.

Length Class (mm)	Recaptured		Not Recaptured
300 - 449	3		282
450 - 549	10		196
550 - 649	17		190
Over 650	22		116
	$\chi^2 = 37.5$[1]	$P < 0.005$	DF = 3

[1] The χ^2 value is the test statistic for the hypothesis of equal probability of capturing fish across the four length classes.

Appendix Table 2. Numbers of northern pike tagged in Volkmar Lake 19-25 May then sampled 27-29 May 1987, by length classes used for abundance estimation.

Length Class (mm)	Recaptured		Not Recaptured
300 - 549	13		478
550 - 649	17		190
Over 650	22		116
	$\chi^2 = 34.91$[1]	$P < 0.005$	DF = 3

[1] The χ^2 value is the test statistic for the hypothesis of equal probability of capturing fish across the three length classes.

Appendix Table 3. Numbers of northern pike tagged in each of two areas in Volkmar Lake 19-25 May and their location 27-29 May, 1987.

Area of Release	Area of Recapture A	Area of Recapture B	Not Recaptured
SMALL FISH: 300 to 549 mm:			
Released in A	4	3	325
Released in B	3	4	153
	$\chi^2 = 1.99$[1]	$0.500 < P < 0.250$	DF = 2
MEDIUM-SIZE FISH: 550 to 649 mm:			
Released in A	6	7	141
Released in B	2	2	66
	$\chi^2 = 0.61$[1]	$0.900 < P < 0.750$	DF = 2
LARGE FISH: 650 mm and larger:			
Released in A	6	4	87
Released in B	9	3	29
	$\chi^2 = 8.40$[1]	$0.025 < P < 0.010$	DF = 2

[1] The χ^2 value is the test statistic for the hypothesis of equal probability of recapturing fish in either half of Volkmar Lake (see Seber 1982). Because of small sample sizes, areas "B" and "C" shown in Figure 2 were combined and are reported above as area "B".

Appendix Table 4. Numbers of tagged and untagged northern pike captured by area in Volkmar Lake 27-29 May 1987.

Category	Area A	Area B
SMALL FISH: 300 to 549 mm:		
Recaptured Fish	6	7
New Fish	72	60
$\chi^2 = 0.34$[1]	$0.750 < P < 0.500$	DF = 1
MEDIUM-SIZE FISH: 550 to 649 mm:		
Recaptured Fish	8	9
New Fish	52	50
$\chi^2 = 0.09$[1]	$0.900 < P < 0.750$	DF = 1
LARGE FISH: 650 mm and larger:		
Recaptured Fish	15	7
New Fish	26	31
$\chi^2 = 3.24$[1]	$0.100 < P < 0.050$	DF = 1

[1] The χ^2 value is the test statistic for the hypothesis of equal probability of capturing tagged fish in either half of Volkmar Lake (see Seber 1982). Because of small sample sizes, areas "B" and "C" shown in Figure 2 were combined and are reported above as area "B".