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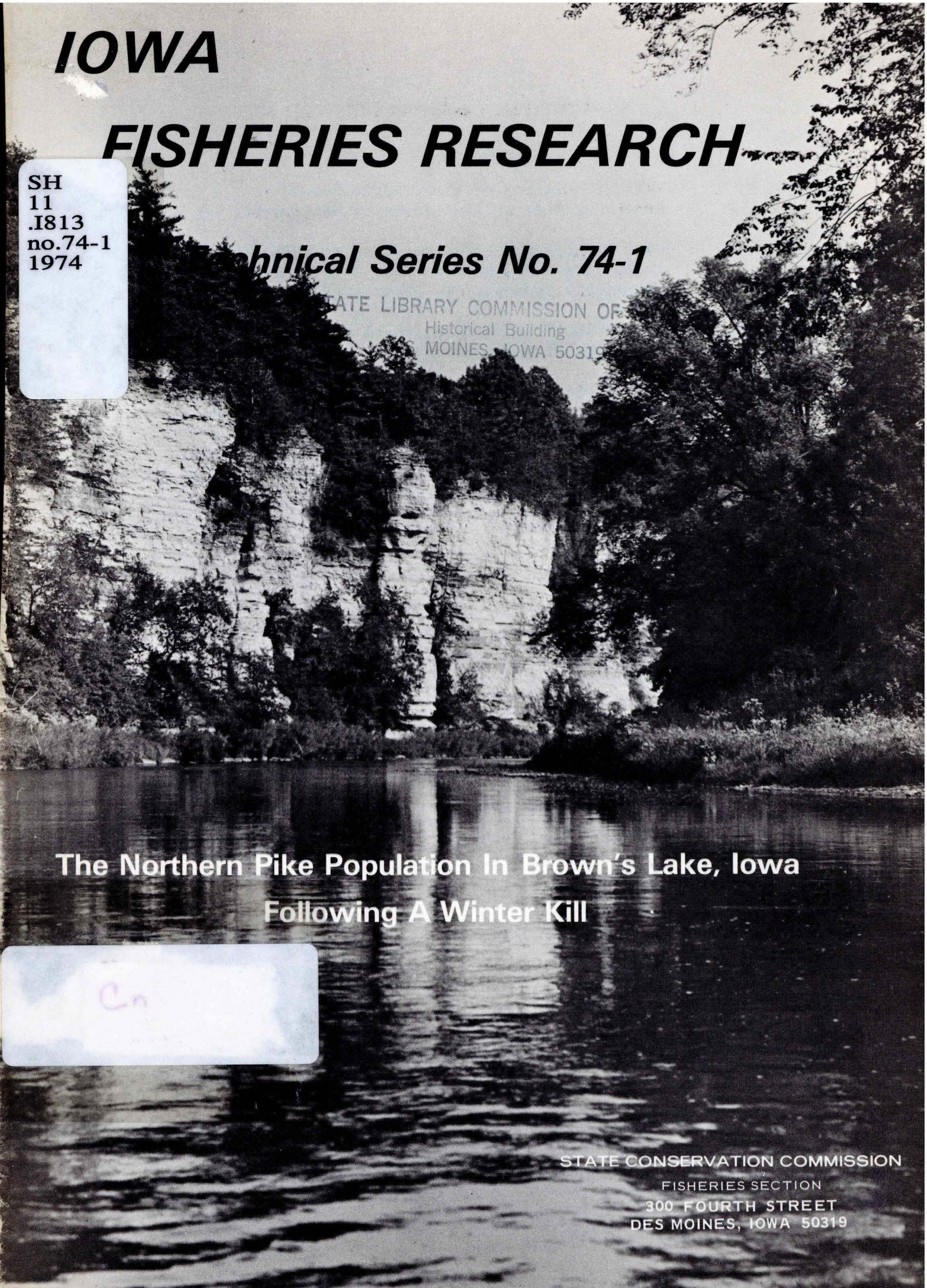

The Northern Pike Population In Brown's Lake, Iowa Following A Winter Kill

STATE CONSERVATION COMMISSION
FISHERIES SECTION
300 FOURTH STREET
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THE NORTHERN PIKE POPULATION IN BROWN'S LAKE, IOWA
FOLLOWING A WINTERKILL

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Technical Series 74-1
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ABSTRACT

Investigations to determine the magnitude of a northern pike population, life history, seasonal food habits and fecundity of northern pike were conducted at Brown's Lake from 1970-72, following a winterkill. Population estimates indicated a density of approximately 29 northern pike per hectare in March, 1970, that declined to about 4 fish per hectare in May, 1970. Standing crop was estimated at 11.4 kg/ha in early 1970, 2.4 kg/ha in May, 1970, and 3.5 kg/ha in 1972. Approximately 85% of the northern pike in Brown's Lake were harvested by intensive angling during a 4-week period. Length-weight relationships, body condition factors, and body-scale relationships were computed for 1970 and 1971. Growth accelerated for two years following the winterkill. Food habits showed northern pike ate predominately young carp during the first study year, and changed to bluegill when small carp were unavailable in the second year. About 75% of the northern pike collected for stomach analysis contained empty stomachs. Fecundity was determined and body weight explained more ova counts than total length and as many ova counts as length and weight combined. Recommendations for size limit and vegetation control for Brown's Lake are discussed.

INTRODUCTION

Through natural evulsion the Missouri River created several natural, clear, shallow oxbow lakes along the western border of Iowa. These oxbows represent the greatest amount of lake type habitat along the Missouri River in Iowa (Fish and Wildlife Task Force 1967). Most have populations of northern pike, *Esox lucius*, as the major predatory fish species along with various small sunfishes, catfishes, and minnows as forage. Winterkill from shallow depths and total loss of dissolved oxygen occurs commonly.

Brown's Lake, one of these oxbows, experienced a winterkill during the winter of 1968-1969. Fisheries surveys following the winterkill indicated moderate survival of adult northern pike and centrarchids. Survival of adult largemouth bass, *Micropterus salmoides*, and walleye, *Stizostedion vitreum*, was poor. Northern pike remained as the major predator to control rapidly expanding centrarchid populations. The effectiveness of a single predatory fish species for controlling a fast expanding panfish population remained doubtful since high densities of northern pike, 68-78 pike/hectare, did not previously control the abundance of bluegill (Beyerle 1971).

In order to improve management of fish populations in Missouri River oxbows, a more comprehensive study of northern pike in Brown's Lake was undertaken from 1970 through 1972. The primary objectives of this study were fourfold: (1) study the life history and population size of northern pike in an exbow lake, (2) determine seasonal food habits of northern pike, (3) determine northern pike dependence and interaction with forage and other predator species, and (4) determine fecundity of northern pike with respect to age, length and weight.

DESCRIPTION OF BROWN'S LAKE

Physical Characteristics

Brown's Lake, a natural oxbow of the Missouri River, is located two miles (3.2 km) west of Salix, Iowa (Plate 1). It was formed in the mid-1800's and has continually decreased in size from its original 324 hectares because of floods and siltation prior to river channelization. At elevation 335 m MSL the lake covers 89 surface ha, has a maximum depth of 3.1 m and a mean depth of .9 m. Submergent aquatic plants flourish during the summer, and the water area free from aquatic plants is normally reduced to about 38 ha.

Fisheries management in Brown's Lake consisted mostly of fisheries surveys and stockings (Table 1). One million walleye fry, 10,000 largemouth bass fingerlings, 40,000 channel catfish, *Ictalurus punctatus*, fingerlings and 500,000 northern pike fingerlings were stocked in 1967. No fish were stocked in 1968, but immediately following the winterkill, 1,000,000 walleye fry and 200,000 northern pike fry were stocked. Later in 1969, 10,000 largemouth bass fingerlings and about 1,600 yearling channel catfish were planted. In 1970, the lake received 250,000 walleye fry, 12,400 largemouth bass fingerlings and 20,000 channel catfish fingerlings. Northern pike were not added during 1970 or 1971. Two species were stocked in 1971; 10,000 largemouth bass fingerlings and 12,400 channel catfish fingerlings.

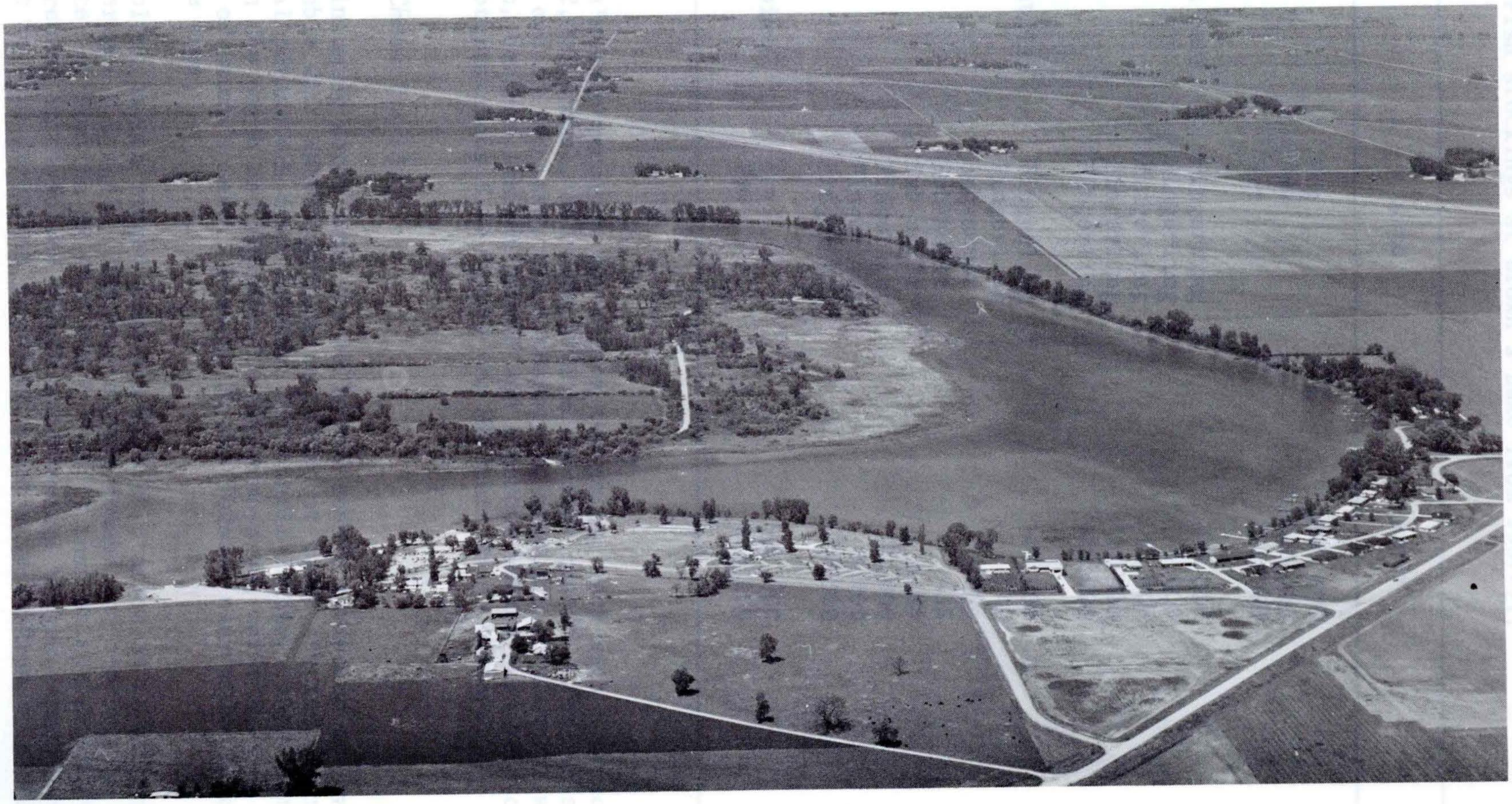

Plate 1. Aerial view of the Brown's Lake study area.

Table 1. Fish stockings at Brown's Lake from 1967-71.

Species	Size	Number	Stocking date
Walleye	Fry	1,000,000	4-29-67
	Fry	1,000,000	5- 3-69
	Fry	250,000	5- 6-70
Largemouth bass	Fingerling	6,000	9-20-67
	Fingerling	4,000	9-21-67
	Fingerling	10,000	9-17-69
	Fingerling	12,400	9-11-70
	Fingerling	10,000	9- 2-70
Channel catfish	Fingerling	40,000	9-18-67
	Fingerling	242	5-25-69
	Sub-adult	684	10- 2-69
	Sub-adult	455	10- 6-69
	Sub-adult	436	10- 8-69
	Fingerling	20,000	10- 5-70
	Fingerling	2,400	4-30-71
	Fingerling	10,000	9-28-71
Northern pike	Fry	500,000	4-18-67
	Fry	200,000	4-25-69

Brown's Lake receives water from two wells, each with a capacity of 1,500 gal/min (2,400 ℓ/min), and from limited surface runoff. The wells, located at the north end of the lake, are necessary to maintain an adequate water level for recreation, because limited runoff and a porous bottom substrate of Brown's Lake allows subterraineous flow toward the Missouri River channel.

Chemical Characteristics

The incoming water from the wells and runoff is medium to low in organic matter (Table 2). Water samples, collected at three stations, were analyzed for 15 chemical parameters from January, 1971 until January, 1972. Station 1B was located in the north end adjacent to the pump area, while Station 3B was in the south arm of Brown's Lake. Station 2B was located near midpoint of the north-south lake area.

Dissolved oxygen ranged from 8.3 mg/ℓ at Station 3B to 8.9 mg/ℓ at Station 2B and averaged 8.5 mg/ℓ. Chemical oxygen demand and biochemical oxgen demand were greater at Station 2B (2.8 and 4.4 mg/ℓ) than at either Station 1B or 3B. The differences in dissolved oxygen and chemical oxygen demand levels at Station 2B are due to more luxurient growth of aquatic vegetation at Station 2B than at

Table 2. Mean water chemical parameters of three sampling stations at Brown's Lake from January, 1971 to January, 1972.

Parameters[a]	Station 1B Mean	Station 1B Standard deviation	Station 2B Mean	Station 2B Standard deviation	Station 3B Mean	Station 3B Standard deviation
Dissolved oxygen (mg/ℓ)	8.4	3.46	8.9	2.84	8.3	2.05
Fecal coliform/100 ml	< 10	[a]	< 10	[a]	< 10	[a]
pH	7.7	.6	8.0	.55	8.3	.47
Phenolphthalein alkalinity (mg/ℓ)	7.7	20.4	13.4	17.8	12.3	10.6
Total alkalinity (mg/ℓ)	367	136	241	95	225	89
Organic nitrogen (mg/ℓ)	.51	.35	2.9	6.22	.63	.28
Ammonia nitrogen (mg/ℓ)	.29	.30	.28	.72	.09	.18
Nitrite nitrogen (mg/ℓ)	.012	.005	.012	.006	.013	.006
Nitrate nitrogen (mg/ℓ)	< .1	[a]	< .1	[a]	< .1	[a]
Total residue (mg/ℓ)	450	166	297	147	292	109
Total phosphate (mg/ℓ)	.06	.06	.17	.37	.03	.01
Biochemical oxygen demand (mg/ℓ)	2.4	1.0	4.4	6.9	2.4	1.5
Chemical oxygen demand (mg/ℓ)	21	9.7	28	12.0	24	5.9
Turbidity (JTU)	22	17	7	6	8	5
Total hardness (as $CaCO_3$ in mg/ℓ)	331	133	209	120	202	81

[a]All units expressed as mg/ℓ except fecal coliform, pH, and turbidity.

the other stations. Continuous pump operation in winter keeps about 2.5 ha of water ice free at Station 1B and also influenced most chemical parameters. Mean pH ranged from 7.7 at Station 1B to 8.3 at Station 3B. Phenolphthalien alkalinity also was lowest at Station 1B, 7.7 mg/ℓ and increased to 12.3 mg/ℓ at Station 3B. The reason for large standard deviations is the high readings recorded on 10 October, 1973. Phenolphthalien alkalinity at Station 1B on this date was 54 mg/ℓ, but was 0 for all other dates. Organic nitrogen was .51 mg/ℓ at the first station and 2.9 mg/ℓ at the second station. Ammonia levels rarely exceeded .3 mg/ℓ and averaged .22 mg/ℓ. Total phosphate was also lower at Station 1B than at Station 2B.

Water received from pumps was more turbid and contained more carbonates than lake water. Total alkalinity decreased from 367 mg/ℓ at the first station to 241 mg/ℓ and 225 mg/ℓ at Stations 2B and 3B respectively. Mean total hardness ($CaCO_3$) increased from 202 mg/ℓ at Station 3B to 331 mg/ℓ at Station 1B. Total residue and JTU turbidity values at Station 1B were about double the values obtained at Station 3B.

Fish Population Characteristics

Eleven fish species were recorded in net samples of Brown's Lake (Table 3). Black bullheads, *Ictalurus melas*, were the most abundant followed by carp, *Cyprinus carpio*, bigmouth buffalo, *Ictiobus cyprinellus*, and northern pike. Catch rates, fish/net day (F/ND), were highest for carp, (12.8 F/ND) in 1970 and declined to .7 F/ND in 1972. During the first year most of the carp caught were young-of-the-year. Catch rates of bullheads increased from 8.5 F/ND in 1970 to 11 F/ND in 1971. Bluegill, *Lepomis cyanellus*, were the most abundant centrarchid, followed by black crappie, *Pomoxis nigromaculatus*, and green sunfish, *Lepomis cyanellus*. Northern pike catch rates declined from 6.6 F/ND in 1970 to 1.45 F/ND and .52 F/ND in 1971 and 1972, respectively. The catch rate decrease of northern pike is explained by lowered population density from angler exploitation during the first year of study. Grand average catch rate was 3.3 F/ND in 1970, 1.8 F/ND in the second year and dropped to .8 F/ND for the last year.

METHODS AND PROCEDURES

Fish sampling was conducted for one complete week each month from March through October except during the month following ice melt when sampling was conducted daily. Subsequent periods were denoted by month and week. Scale samples, body length and weight were collected from northern pike 275 mm and longer during each sampling week. Sampling gear consisted of frame-trap nets and electrofishing, but the latter was discontinued early in 1970 because of poor catch success. The frame nets had 50 ft (15.24 m) leads with two 2 x 4 ft (.61 x 1.22 m) frames ahead of a hooped net 2 ft (.61 m) in diameter and 8 ft (2.44 m) long. A winged throat was formed by the frames and two additional throats were located in the hoop net section. Webbing, 3/4 inch (19 cm) bar measure, covered the entire net. Frame nets were set with leads perpendicular to shore in water depth sufficient to cover the entire net.

Table 3. Mean and standard deviation of catch effort expressed as fish per net day at Brown's Lake, 1970-72.

Fish species	1970 Mean	1970 Standard deviation	1971 Mean	1971 Standard deviation	1972 Mean	1972 Standard deviation
B bullhead	8.57	6.89	11.03	11.25	4.21	4.14
Y bullhead	.14	.13	.26	< .10	.20	< .10
Carp	12.88	10.45	2.54	.65	.76	.57
Bluegill	< .10	.19	1.12	.55	1.08	.53
B buffalo	7.94	5.40	2.17	.87	2.21	1.36
B crappie	.15	.36	.53	.32	.11	.10
G sunfish	< .10	< .10	---	---	---	---
Walleye	< .10	< .10	---	---	< .10	< .10
C catfish	.58	.73	.90	.56	< .10	< .10
Lm bass	---	---	---	---	< .10	< .10
N pike	6.63	4.38	1.45	.85	.52	.20
Grand average	3.36	2.60	1.82	1.38	.83	.64

Numerical estimates of northern pike populations were conducted in all three years. Each fish not utilized for ovary and stomach samples was tagged through the dorsal fin process with a serially numbered Floy dart tag and released. Five hundred seventy-nine northern pike were tagged the first year, while 190 were tagged in 1971 and 127 fish in 1972. The population size was estimated by the Peterson equation: $\hat{N} = \frac{MC}{R}$

where,

$\hat{N}$ = estimated number in the population
M = total number of fish marked in the sampling period
C = total number of fish captured in each sampling period
R = total number of fish recaptured in each sampling period.

Confidence intervals for the 95% level were determined from the sample standard error:

$$\left(N \sqrt{\frac{(\hat{N}-M)(\hat{N}-C)}{MC(\hat{N}-1)}} \right)$$

where the equation components were the same as before.

Age and growth of northern pike was determined from scale samples and body length and weight measurements collected during each sampling week. Length-weight regression, body condition factors, body-scale regression and back calculation of body length at each year of life were calculated using conventional procedures in a complete age and growth computer program (Mayhew 1973).

Northern pike were collected for stomach analysis from random samples of weekly catches. Stomachs were removed in the laboratory through an abdominal incision. The stomach was placed in a cheesecloth bag and preserved with 10% formalin. Volumetric measurements of stomach contents were made immediately upon removal and the individual diet items identified later.

Fecundity of northern pike was determined from ovaries collected shortly prior to spawning. Ovaries were removed in laboratory and placed in cheesecloth bags and preserved in 10% formalin. Ovaries were measured volumetrically and eggs were counted in three, 3 ml aliquots. The average number of eggs in each sample was multiplied by the total ovary volume to determine number of eggs per fish.

ESTIMATED POPULATION SIZE

Population estimates were conducted simultaneously with food habit and age growth studies. Estimates were started on 16 January, 1970 and continued through 30 October, 1972. Estimates ceased for the first year on 8 May because no marked fish were recaptured after this date.

Validity of fish population estimates rely upon certain assumptions that must be made. Ricker (1958) listed six important assumptions. All were met in this study except the assumption of random mixing of marked and unmarked fish or that distribution of fishing effort (in subsequent sampling) is proportional to the number of fish present in different parts of the body of water. The estimates for the first three periods were made while ice covered the lake, except the area adjacent to the water pumps. Most fish collection and release occurred in the ice-free portion. This factor would bias estimates for Periods 1 through 3. Marked fish did not appear to suffer greater natural mortality than unmarked, because very few dead marked were observed on the lake. Recruitment was minimized by tagging only fish larger than 300 mm in total length (TL). There was no indication marked fish were more susceptible to netting than unmarked fish.

Eight hundred seventy northern pike were captured during 1970, of which 579 were tagged and 42 recaptured (Table 4). A majority of the fish were tagged from 8 February to 4 April. Individual period estimates ranged from 2,546 ± 849 northern pike at Period 3 to 319 ± 296 on 29 April. Estimated population density of northern pike in Brown's Lake in 1970 was 27 per ha at maximum water level elevation and would vary no more than ± 10 per ha at the .05 level of sampling probability. On 8 May the density was estimated at 4 per ha with 95% confidence intervals of ± 1.

Fewer fish were captured and tagged during the second year of the study. Three hundred sixty-two fish were captured, of which 196 were tagged and 26 recaptured. More pike were tagged in spring and early summer than in autumn. Individual period estimates ranged from 634 fish ± 214 during Period 1 to 318 fish ± 191 on 30 October. Density of northern pike was estimated at 5 per ha during the third period which varied no more than ± 2 per ha at the .05 sampling probability level.

Table 4. Numerical population estimate of northern pike from 1970-72.

Sampling period	Number caught	Number marked	Number recaptured	Population estimate $\hat{N}$	95% confidence interval
1970					
Jan 1-16	73	42	2	1,533	
Feb 3-7	86	78	3	2,236	
Feb 8-13	115	102	5	2,546	
March 23-27	144	118	7	2,427	849
March 30-31	169	75	7	1,810	652
April 1-4	110	71	5	1,562	658
April 6-9	51	28	4	357	158
April 10-16	34	10	1	340	318
April 20-29	29	11	1	319	296
May 4-8	59	44	7	370	120
1971					
April 1-15	74	60	7	634	214
April 16-30	63	40	4	630	289
May 1-June 15	104	23	5	478	184
Oct 1-15	46	24	3	552	365
Oct 16-30	32	23	2	318	191
Nov 1-15	43	26	5	372	194
1972					
March 16-30	48	37	3	592	317
April 1-15	63	15	2	472	307
April 16-30	32	15	1	480	456
May 1-June 30	28	11	1	308	268
July 16-30	42	18	2	378	246
Aug 16-30	25	13	1	325	306
Sept 1-Oct 30	43	18	2	387	247

Only 281 northern pike were captured during the third year, while 12 of the 127 tagged fish were recaptured. Individual period estimates ranged from 592 ± 317 on 30 March to 325 ± 306 on 30 August. The estimated on 30 July of 378 fish ± 246 was considered the most reliable estimate because it was based on the greatest number of recaptured fish. Northern pike density ranged from 7 per ha at Period 1 to 36 per ha at the sixth sampling period.

Population estimates were higher during spring of each year than estimates made during the summer and autumn (Figure 1). The decrease could be explained by the spawning behavior of northern pike and increased vulnerability to nets during the spawning season. During summer and fall northern pike were more randomly distributed throughout Brown's Lake and catch success declined.

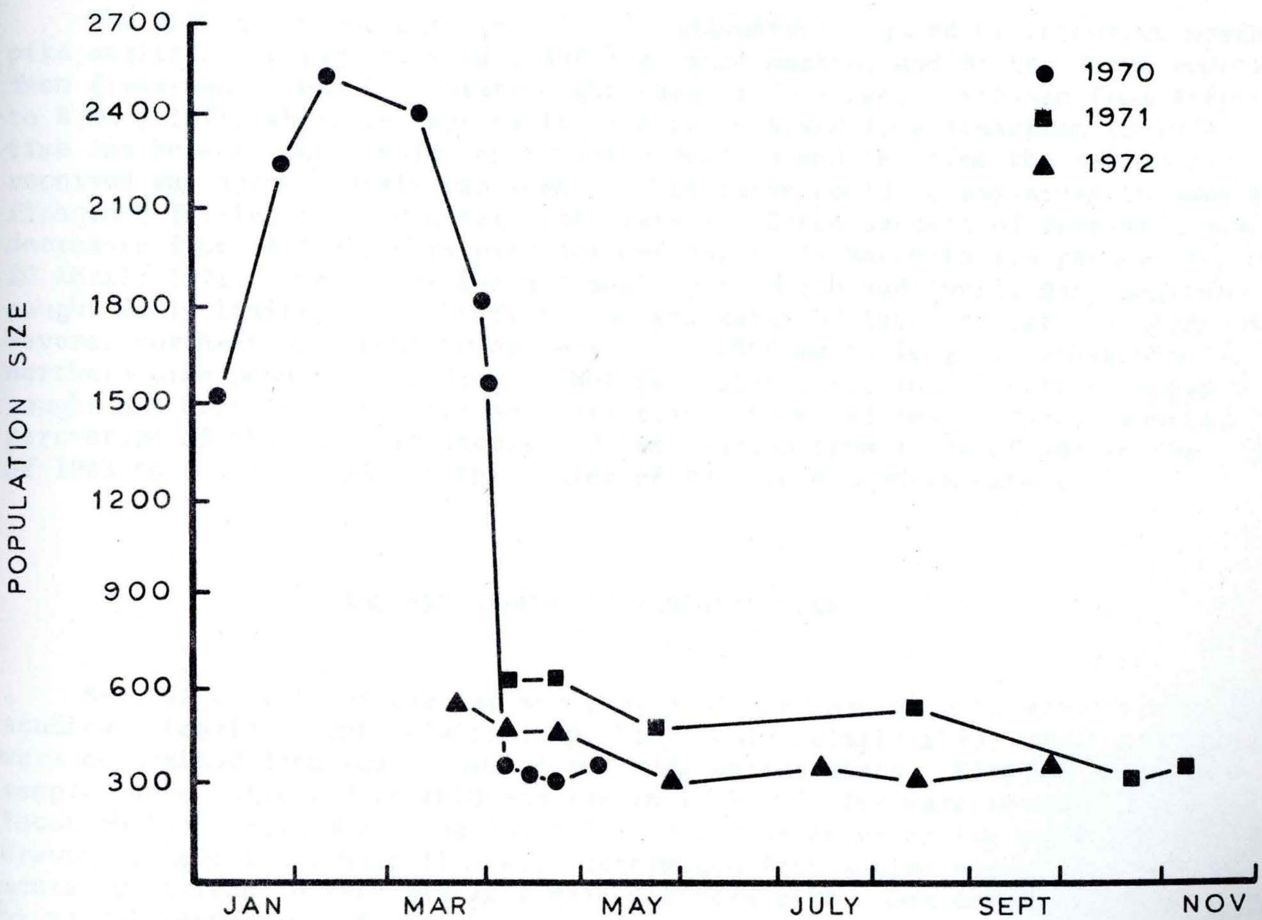

Figure 1. Numerical estimate of the northern pike population from 1970-72.

Mean weight of northern pike tagged during the first year was 566 g and increased to 632 g the second year, and was 1,009 g in 1972. Prior to 6 April, 1970 northern pike tagged had a mean weight of 565 g and those tagged after 6 April averaged 577 g. Using these means and population estimates for Period 5, 1970 standing crop of northern pike in Brown's Lake was 11.5 ± 4.7 kg/ha prior to 6 April, 1970 and decreased to 2.4 ± .7 kg/ha during Period 10. Standing crop estimates for 1 May-15 June, 1971 and 1 May-30 June, 1972 were 3.3 ± 1.3 kg/ha and 3.5 ± 3.0 kg/ha, respectively. After the northern pike decrease in 1970, standing crop of northerns increased from 2.4 kg/ha in 1970 to 3.3 kg/ha in the second year and reached 3.5 kg/ha the third year.

The population decrease in 1970 was undoubtedly caused by intensive northern pike angling. During the study, 898 fish were marked, and 85 tags were received from fishermen (Table 5). Sixty-eight tags or 79.7% were received from 4 April to 8 May, 1971, while 16 tags or 18.6% were received from fishermen in 1972. The time lag between the population estimate decline and the time the tags were received was approximately two weeks. This lapse could be explained in part by fishermen failing to return tags immediately. Catch success of fyke nets also decreased from 14.1 northern pike per net day on 31 March to 1.8 per net day on 29 April, 1971. During the intense angling in March and April, many anglers caught daily limits, took the fish home and returned later to catch another limit. Several northern pike kept by anglers were < 300 mm in length. Other studies of northern pike population indicated before a size limit was effective, anglers caught and kept large numbers of small fish. Snow and Beard (1972) reported the percentage of the catch 18 inches and less varied from a low of 34% in the winter of 1963 to a high of 88% in the summer of 1962 in Wisconsin waters.

AGE AND GROWTH OF NORTHERN PIKE

Several aspects of the age and growth of northern pike in Brown's Lake were studied. Length-weight relationship, body-scale relationship, condition factor were determined from scale samples and body measurements. Sixty-four scale samples were collected in 1970 and 146 in 1971. Scales were removed from a location three rows above the lateral line at the anterior tip of the dorsal fin. Growth of male and female fish were determined from scales and paired body measurements taken from 30 male and 26 female northern pike. Sex determination was made by visual inspection of gonad.

Length-Weight Relationship

Length-weight relationship was computed independently for both years using the transformed linear regression model

$$\mathrm{Log}_{10}W = \log_{10}a + b\ \log_{10}TL$$

where W is weight in grams and TL is total length in millimeters. Data were grouped in 25 mm intervals ranging from 315 mm to 593 mm in 1970 and from 293 mm to 760 mm in 1971.

Table 5. Number and percent of tags returned and catch rate of northern pike from 1970-72.

Period	Number of tags returned	Percent tags returned	Catch per net day
1970			
Jan 1-16	0	0.0	
Feb 3-7	0	0.0	5.37
Feb 8-13	0	0.0	5.75
March 23-27	0	0.0	6.54
March 30-31	0	0.0	14.08
April 1-4	3	3.5	13.75
April 6-9	14	16.4	5.19
April 10-16	36	42.3	4.20
April 20-29	14	16.4	1.81
May 4-8	1	1.1	2.95
Total	68	79.7	
1971			
April 1-15	0	0.0	2.46
April 16-30	6	7.0	2.62
May 1-June 15	9	10.5	0.90
Oct 1-15	0	0.0	0.95
Oct 16-30	0	0.0	0.92
Nov 1-15	1	1.1	0.86
Total	16	18.6	
1972			
March 16-30	0	0.0	0.46
April 1-15	0	0.0	0.60
April 16-30	0	0.0	0.40
May 1-June 30	0	0.0	0.32
July 16-30	1	1.1	0.84
Aug 16-30	0	0.0	0.78
Sept 1-Oct 30	0	0.0	0.45
Total	1	1.1	

The following constants were computed from paired length and weight observations:

1970 $\text{Log}_{10}W = -6.674 + 3.555\ \text{Log}_{10}TL$

1971 $\text{Log}_{10}W = -5.701 + 3.154\ \text{Log}_{10}TL$

with correlation coefficients (r) of .973 for 1970 and .975 for 1971.

Ridenhour (1957) calculated a length-weight regression for northern pike at Clear Lake, Iowa:

$$\text{Log } W = -5.552 + 3.122 \text{ Log } TL$$

where W = weight in grams and TL = total length in millimeters.

Using the 1971 length-weight regression from this study, a 476 mm fish weighed 555 g, and the same length fish in Ridenhour's study weighed about 640 g. The northern pike in Clear Lake were significantly heavier at all lengths than Brown's Lake fish.

Calculated weights were computed for each sample year at 25 mm intervals in body length (Table 6). Predicted weight differed only slightly from emperical values with most fluctuation occurring in the smallest and largest fish. A fish 335 mm long in 1970 weighed 200 g, but in the following year this weight was not attained until total length was 350 mm. In the upper portion of the curve a 508 mm northern pike weighed 850 g in 1970, while a 540 mm fish weighed the same in 1971.

Data were grouped at 25 mm intervals for males and females in 1970. Total body length ranged from 297 mm to 464 for the males and 350 mm to 507 mm for females. The following length-weight regressions were determined (Figure 2):

Males $$\text{Log}_{10}W = -5.532 + 3.114 \text{ Log}_{10}TL$$

Females $$\text{Log}_{10}W = -7.541 + 3.907 \text{ Log}_{10}TL$$

Analysis of covariance revealed a significant difference in regression coefficients at the .05 level between sexes. The difference in weight between males and females resulted from collecting these fish during spawning season. Gravid females would have a significantly greater b value. A 400 mm male fish weighed about 370 g, while a female the same length was nearly 40 g heavier. A larger weight difference occurred as the fish increased in length. At 450 mm in length, a female northern pike was about 125 g heavier than a male the same length.

Brown and Clark (1965) calculated the following length-weight regressions of northern pike by sex in Ohio:

Female $$\text{Log } W = -2.2008 + 2.9020 \text{ Log } L$$

Males $$\text{Log } W = -2.1265 + 2.7788 \text{ Log } L$$

where W is weight in ounces and L is total length in inches. From this regression a female fish 25 inches (635 mm) long would weigh about 72 ounces (2,037 g), and a male fish the same length would weigh about 60 ounces (1,698 g).

Table 6. Predicted weight of northern pike at 25 mm total length intervals using regression coefficient for individual year.

Class mean (mm)	1970 Weight (g)	Number	Class mean (mm)	1971 Weight (g)	Number
311	154	2	303	134	5
335	201	8	324	165	4
362	264	4	350	210	14
385	329	13	373	257	19
408	405	11	396	311	12
437	516	12	425	389	22
464	639	7	449	461	13
484	742	3	473	544	12
508	882	2	503	660	6
593	1,529	1	522	742	4
			546	855	5
			571	985	6
			604	1,185	4
			623	1,297	2
			643	1,432	4
			671	1,638	4
			707	1,932	2
			717	2,019	2
			748	2,308	5

Condition Factor

Mean condition factor (K) was compared for fish captured in 1970 and 1971 (Table 7). In 1970, mean (K) was .62, while mean (K) was .54 for fish collected during the second year. Values of (K) for fish collected in 1970 ranged from .54 for northern pike 297-321 mm in length to .87 for fish of 572-597 mm. Range in (K) was lower for fish captured in the second year, from .44 for fish 311-335 mm long to .62 for fish 736-761 mm in length. Larger fish collected in both years had higher condition factors than smaller fish.

Mean (K) of males and females were compared for 1970 (Table 8). Mean (K) for males was .57 and .63 for females. Condition values ranged from .47 to .66 for males, and from .51 to .71 for females. The reason for a poorer condition in 1971 may in part be explained by the availability of less forage in 1971 compared with 1970. A partial explanation for greater (K) values in females than for males was gonadal development increasing the weight of female fish.

Ridenhour (1957) computed condition factors for northern pike in Clear Lake and Ventura Marsh, Iowa. Mean K value was .84 for both lakes compared to an overall mean of .58 at Brown's Lake.

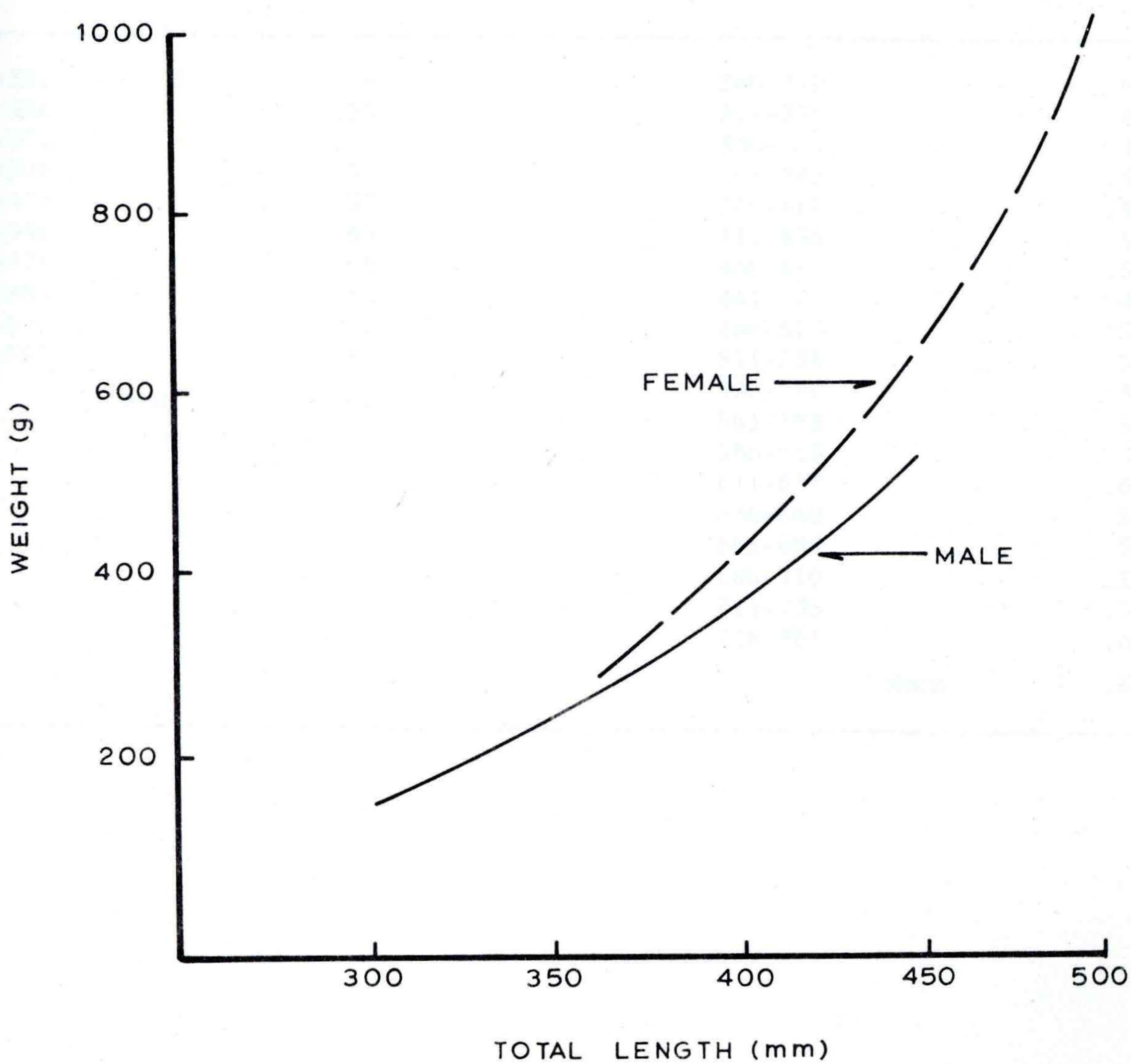

Figure 2. Length weight regression for male and female northern pike.

Table 7. Condition factors by 25 mm total length intervals of northern pike for combined sexes.

1970 Class range (mm)	1970 K	1971 Class range (mm)	1971 K
297-321	.54	286-310	.63
322-346	.55	311-335	.44
347-371	.56	336-360	.48
372-396	.56	361-385	.52
397-421	.57	386-410	.48
422-446	.63	411-435	.50
447-471	.66	436-460	.52
472-496	.68	461-485	.49
497-521	.58	486-510	.53
572-597	.87	511-535	.52
		536-560	.46
Mean	.62	561-585	.52
		586-610	.59
		611-635	.61
		636-660	.58
		661-685	.58
		686-710	.55
		711-735	.55
		736-761	.62
		Mean	.54

Table 8. Condition factors by total length intervals for northern pike - 1970.

Males		Females	
Class range (mm)	K	Class range (mm)	K
300-311	.58	363-375	.57
312-325	.47	376-387	.51
326-337	.61	388-399	.58
338-350	.61	400-411	-
351-363	.58	412-423	.62
364-375	.54	424-435	.62
376-383	.66	436-447	.65
384-400	.56	448-459	-
401-413	.56	460-471	.66
414-425	.54	472-483	.68
426-437		484-495	.71
438-450	.61	496-507	.71
451-464	.57	Mean	.63
Mean	.57		

Body-Scale Relationship

Growth history was determined from the body-scale regression computed from measurements taken in 1971. The scale image was magnified (54X) and measured from the focus to margin along the medium anterior field. Mean scale radii lengths were paired with corresponding body measurements, and intervals established at 25 mm. Ranges in body size were identical to those in length-weight calculations. Body-scale regressions were determined using a linear model with the origin centered so when S = 0, L = 0. The linear model was:

$$L = b\ S$$

where L is total length in mm and S is the corresponding scale radius in mm. Equation for 1970 and 1971 were as follows (Figure 3):

1970 $L = 2.23\ S$

$L = 2.40\ S$

The slope of the regressions were slightly different. A fish collected the first year with a magnified scale radius of 300 mm was about 680 mm in length, while a fish collected in 1971 with the same scale size was about 715 mm long. Little difference in fish length appeared for a magnified scale radius over 100 mm.

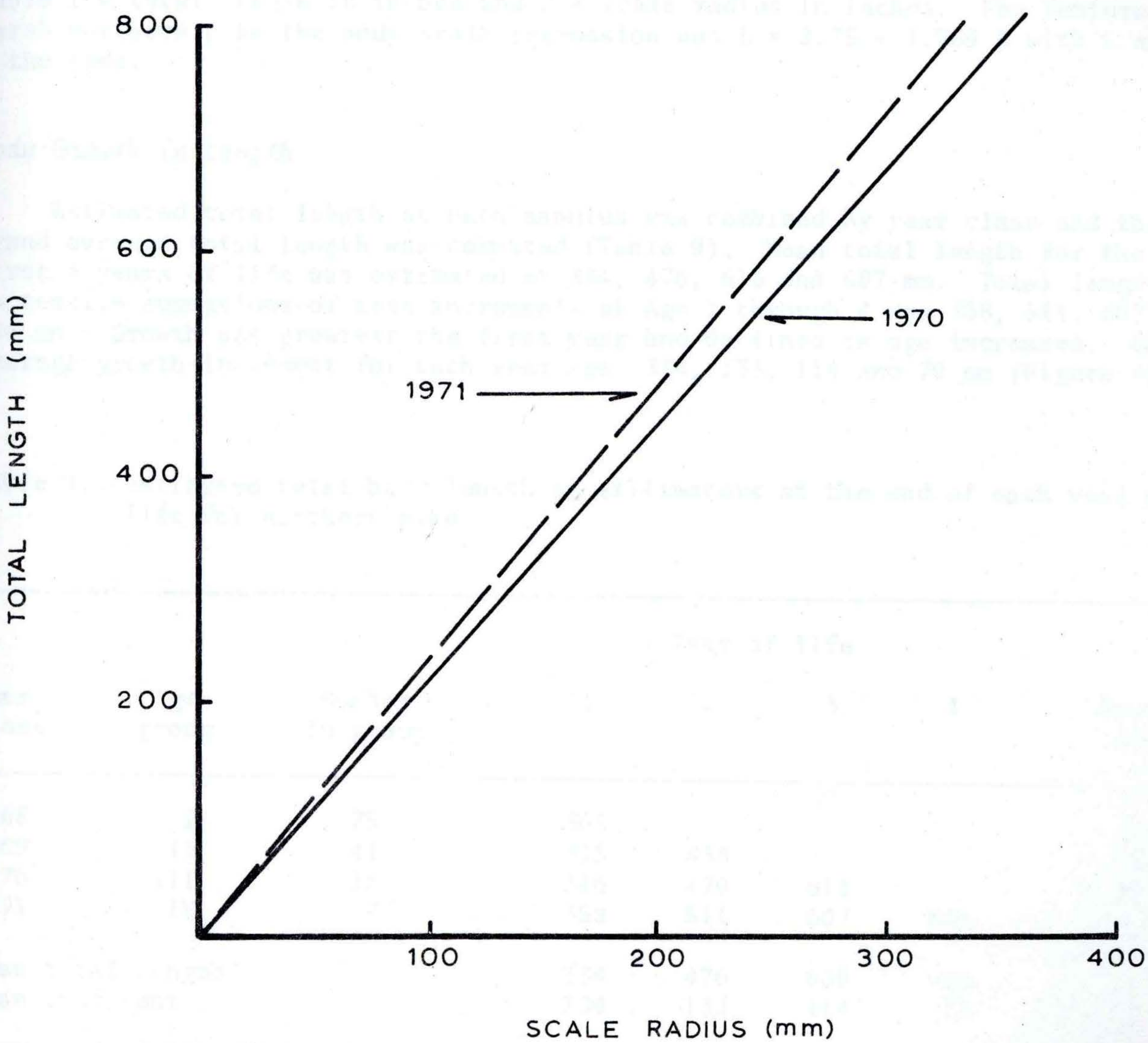

Figure 3. Total length-scale radius regression for northern pike.

Analysis of covariance revealed no significant difference between the regressions of 1970 and 1971 at the 95% level.

Ridenhour (1957) calculated the following linear body-scale regression for northern pike at Clear Lake:

$$L = 1.383 + 2.278 R$$

where L = total length in inches and R = scale radius in inches. For Ventura Marsh northern pike the body scale regression was $L = 2.75 + 1.969 R$ with L and R the same.

Body Growth in Length

Estimated total length at each annulus was combined by year class and the grand average total length was computed (Table 9). Mean total length for the first 4 years of life was estimated at 334, 476, 610 and 687 mm. Total length by successive summations of mean increments at Age 1 through 4 was 358, 511, 607 and 686 mm. Growth was greatest the first year and declined as age increased. Grand average growth increment for each year was 334, 133, 114 and 79 mm (Figure 4).

Table 9. Estimated total body length in millimeters at the end of each year of life for northern pike.

Year class	Age group	Number in group	Year of life 1	2	3	4	Growth index
1968	I	75	305				0
1969	II	41	325	438			+ 3.24
1970	III	18	346	479	611		+ 20.9
1971	IV	7	358	511	607	686	- .2
Mean total length			334	476	609	686	
Mean increment			334	133	114	79	

In comparison with growth of northern pike from other locations, the present study differed somewhat geographically, but generally northern pike grew at similar rates. Ridenhour (1957) found northerns attained 12.1 (309), 16.6 (425), 20.4 (522), 24.3 (622) inches (mm) for Ages 1 through 4 in Clear Lake. In Ventura Marsh northerns were 18.4 inches (471 mm) long at the end of the second year. The fish in Clear Lake grew slower than those of the present study, while Ventura Marsh fish grew at about the same rate. Shields (1957) found northern pike in Fort Randall attained a body length of 701 mm by the end of the fourth year.

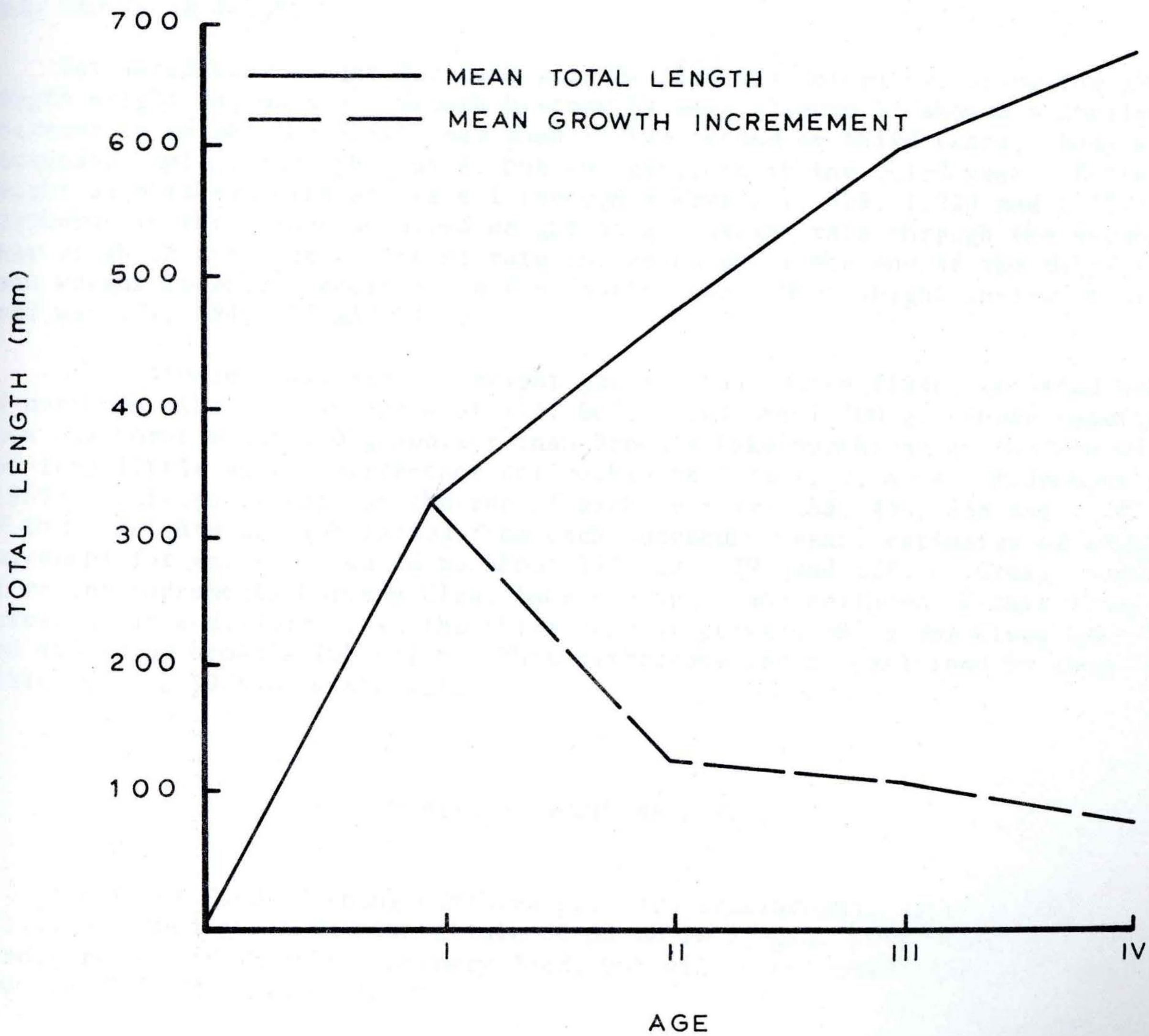

Figure 4. Growth in body length for northern pike by year class from the 1971 data.

A growth index for years 1968 to 1971 was calculated by measuring yearly percentile deviation of growth from the grand average increment. The resulting values were subtracted from 100 and adjusted so their sum was 0. The 0 value indicated average growth while positive or negative values indicated above or below average growth. Growth indices were average in 1968 and in 1971, and were slightly above average with +3.24 in 1969 and reached the maximum of +20.9 in 1970 (Table 9). This could be partially explained by better forage availability, particularly 0-age carp and buffalo.

Body Growth in Weight

Estimated body weight for each year of life was determined using the 1971 length-weight regression. Growth history by year (Figure 5) showed a smaller increase in weight the first year than in the second or third years. Body weight increased rapidly through year 4, but was greatest in the third year. Estimated weight of northern pike at years 1 through 4 were 171, 555, 1,210 and 1,757 g. Northerns in this study acquired weight at a constant rate through the second year at which time the increment rate increased until the end of the third year. Mean weight increment declined in the fourth year. Mean weight increment at each year was 171, 384, 655 and 547 g.

Other studies show similar weight gains. Van Oosten (1946) reported weight of northern pike through Age 4 at 113, 567, 1,304 and 1,700 g. These results show northerns about 100 g heavier than Brown's Lake northerns at the end of year 3, but very little weight difference noticeable at Ages 1, 2, or 4. Ridenhour's (1957) predicted weights at the end of each year are 159, 440, 838 and 1,445 g. If these weights are subtracted from each succeeding year, estimates of weight increment for each year would be about 159, 281, 397 and 508 g. Gross comparison of weight increments between Clear Lake northerns and northern of this study reveal a large difference in the third year of growth, 397 g for Clear Lake fish and 655 g for Brown's Lake fish. This difference can be explained by rapid growth following the 1968-69 winterkill.

FOOD HABITS OF NORTHERN PIKE

The first food of young northern pike are crustaceans; later, insects are utilized. When northern pike attain 60-65 mm in length, they are almost exclusively predatory with fish as the primary food, but will occasionally feed on salamanders and crayfish (McCarraher 1962).

Stomach examinations of 188 northern pike in 1970 showed 50 contained measureable contents. Early season examinations in March through May indicated 40-50% of the fish collected had full or partially full stomachs (Table 10). About 18% of the fish collected from June thorugh September contained stomachs with measureable contents. Mean stomach volume was 49.1 ml, with volumes increasing from 35.2 ml in January to 60 ml in September. Carp were the most abundant fish species and comprised the largest volume found in stomachs during the first year (Table 11). Carp were found in 68% of the stomachs while bigmouth buffalo were present in 9.3% of northern pike stomachs. Crayfish and leeches

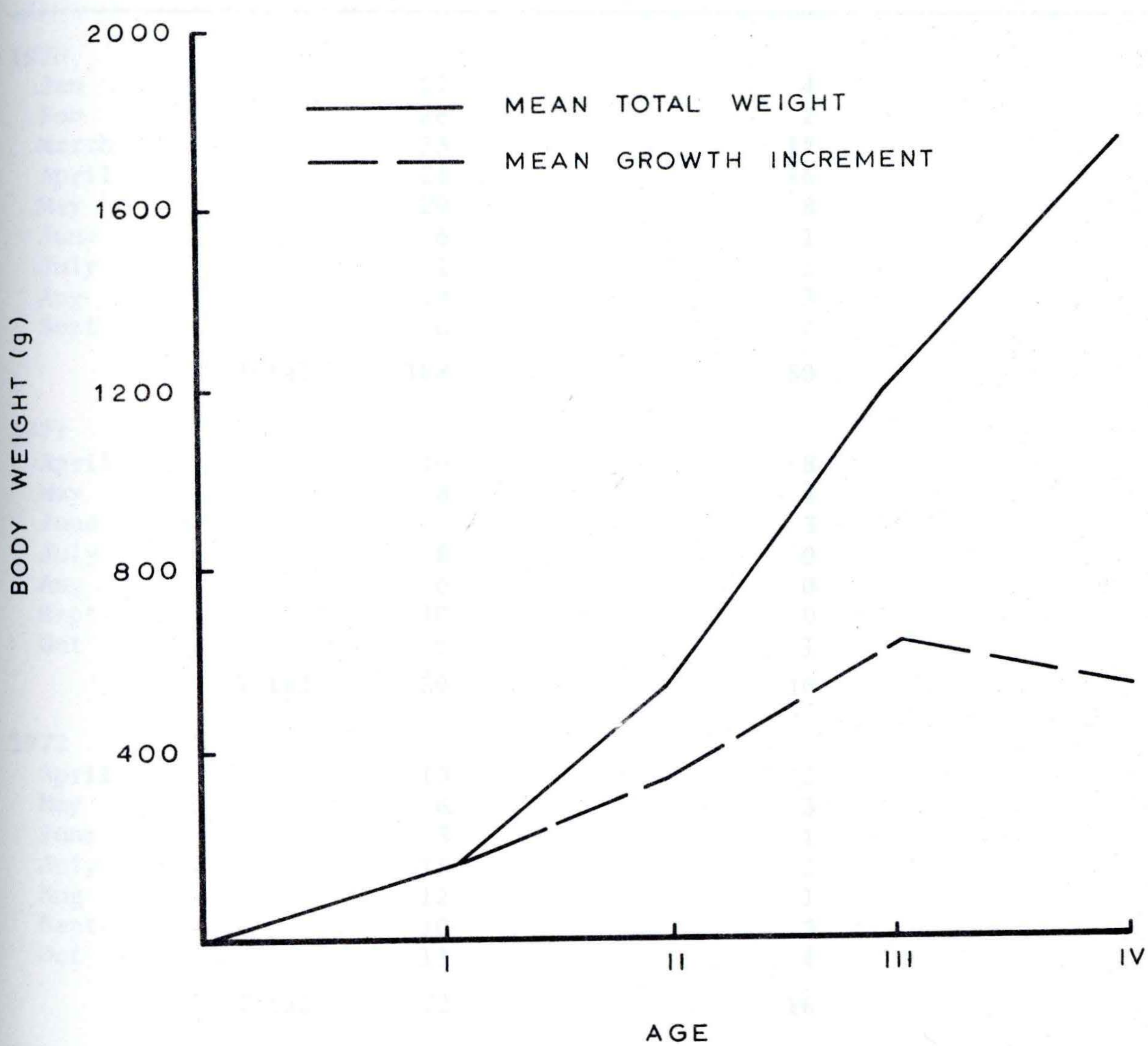

Figure 5. Growth history of northern pike by age group.

Table 10. Number and mean volume of stomachs collected from northern pike in Brown's Lake from 1970-72.

Date	Number of fish collected	Number of stomachs collected	Mean volume (ml)
1970			
Jan	27	4	35.2
Feb	28	2	73.5
March	53	17	37.7
April	28	14	42.1
May	20	8	40.0
June	6	1	50.0
July	2	1	55.0
Aug	18	3	60.0
Sept	6	0	
Total	188	50	
1971			
April	16	8	42.2
May	8	4	37.5
June	5	3	22.0
July	8	0	
Aug	6	0	
Sept	10	0	
Oct	6	1	40.0
Total	59	16	
1972			
April	13	2	19.0
May	8	3	26.6
June	3	1	19.0
July	13	2	24.0
Aug	12	1	18.0
Sept	10	3	35.6
Oct	13	4	25.2
Total	72	16	

Table 11. Food items found in the stomach contents of northern pike in Brown's Lake from 1970-72.

Year	Food item	Number	Percent occurrence	Percent volume
1970	Carp	51	68.0	67.3
	B buffalo	7	9.3	22.3
	W crappe	1	1.3	2.5
	Crayfish	2	2.6	3.0
	Leech	2	2.6	.2
	Unknown	12	16.0	4.6
1971	Bluegill	14	60.8	62.4
	W crappie	1	4.3	6.3
	B crappie	2	8.6	10.8
	C catfish	1	4.3	5.4
	Crayfish	2	8.6	3.2
	Frog	1	4.3	5.2
	Unknown	2	8.6	6.4
1972	Bluegill	11	55.0	62.7
	W crappie	3	15.0	26.9
	Lm bass	1	5.0	4.5
	Crayfish	2	10.0	3.7
	Unknown	3	15.0	2.0

were utilized by northern pike, but to a lesser extent. Sixteen percent of the stomachs collected in 1970 contained unidentifiable items. The predominance of carp in northern pike stomachs was attributed to the high population density of young-of-the-year fish following the winterkill. The digestive action in northern pike stomachs rendered some items unidentifiable.

Fifty-nine northern pike were collected for food habit studies in 1971, and 16 contained food items. More than one-half of the fish sampled in April, May and June had eaten immediately prior to collection. Very few of the later season northern pike contained measurable food items in the stomachs. Mean stomach content volume was 35.3 ml ranging from 22 ml in June to 42.2 ml in April. Stomach content volume remained nearly uniform through 1971 and showed little increase from April through October. Northern pike appeared to utilize only smaller fish for food. Bluegill predominated the food eaten by northern pike and were found in 67% of the stomachs. Black crappie and crayfish were the second most important food items and were found in 8.6% of the stomachs. Carp and bigmouth buffalo were absent from stomachs during the second year because rapid body growth made them unsuitable for forage. The low reproduction of carp and bigmouth buffalo in 1971 also contributed to their absence in northern pike stomachs.

Sixteen stomachs were collected during the third year from a total sample of 72 northern pike. During April, May and June, 15-37% of the fish stomachs collected contained food items, with a mean volume of 23.8 ml, which ranged from 18 to 25.2 ml. Little change occurred in the frequency of occurrence of food items in stomachs from spring to autumn. Mean volume increased from early samples to later samples. During 1972, bluegill were the most frequently consumed fish species, and were found in 55% of the stomachs examined. White crappie was the next most predominant species utilized by northern pike, occurring in 15% of the stomachs. Largemouth bass and crayfish were found in 5% and 10% of the stomachs, respectively. Unknown items were found in 15% of the stomachs.

Stomach content analysis showed carp were present in 43.9% by number and 34.9% by volume (Table 12). This was followed by bluegill, 22.4% by number and 29.3% by weight. All other species were present in 25% by number and 33.5% by volume of the northern pike stomachs. Seaburg and Moyle (1964) found few centrarchids in northern pike stomachs and questioned the value of northern pike for controlling panfish populations in Minnesota waters. During 1970, when 0-age carp were available, northern pike consumed them in large quantity, but by 1971, northern pike were feeding mostly on bluegill or crappie. Size of prey seemed to be a function of abundance, with pike often taking smaller prey when it was abundant in Wisconsin (Johnson 1959).

Table 12. Food items found in the stomach contents of northern pike in Brown's Lake from January, 1970-October, 1972.

Stomach contents	Number	Percent number	Percent volume
Car	51	43.9	34.9
B buffalo	7	6.0	11.5
Bluegill	26	22.4	29.3
B crappie	2	1.7	3.1
W crappie	5	4.3	8.4
C catfish	1	.8	1.6
Lm bass	1	.8	.9
Frogs	1	.8	1.5
Crayfish	4	3.4	2.2
Leeches	2	1.7	.1
Unknown	17	14.6	4.1

Fish collected in April, May, June and late fall contained fewer empty stomachs. Seaburg and Moyle (1964) found feeding to be heaviest in spring and fall. The results of this study show feeding was heaviest in spring, but less in fall. Centrarchids and small fish may not be available to northern pike during summer months, because of the protection offered by the lush growth of rooted aquatic vegetation. No black or yellow bullhead were found in stomachs even though small black bullheads were the most abundant fish in daily net catches. In Brown's Lake, during 1970, 72% of the northern pike sampled contained empty stomachs; while 68% and 76% of the fish sampled in 1971 and 1972, respectively, contained empty stomachs. Johnson (1959) found 55% of fish stomachs examined in Wisconsin were completely empty.

FECUNDITY

One aspect important in monitoring a fish population is fecundity, which was determined from 36 and 30 ovary samples in 1970 and 1971, respectively. Mean ovary volume in 1970 ranged from 36 ml for 325-350 mm fish to 258 ml for 526-550 mm fish (Table 13). Estimated mean egg numbers ranged from 5,800 to 48,400 for the same length intervals. During the second year, mean ovary volume ranged from 36 ml for 351-375 mm fish to 300 ml for 651-675 mm fish. Mean egg number ranged from 6,600 to 64,300 for the same length intervals.

Table 13. Mean volume and number of eggs from northern pike during 1970-71.

Year	Length interval (mm)	Mean length (mm)	Mean weight (g)	Mean volume of eggs (ml)	Mean number of eggs	Standard deviation
1970	326-350	327	322	36	5,800	---
	351-375	368	288	29	6,100	---
	376-400	388	330	37	8,900	400
	401-425	414	462	51	11,800	4,500
	426-450	437	537	73	13,500	6,100
	451-475	466	686	92	16,800	3,600
	476-500	484	750	69	17,900	1,000
	501-525	506	913	133	32,100	4,400
	526-550	535	1,100	258	48,400	---
1971	351-375	359	312	36	6,600	1,000
	376-400	400	352	51	7,900	---
	401-425	415	417	58	10,400	2,400
	426-450	446	550	100	18,400	---
	451-475	457	577	77	14,100	4,600
	476-500	492	642	89	18,700	13,600
	501-525	515	739	132	27,300	10,500
	526-550	540	667	90	22,800	13,500
	551-575	562	955	136	29,000	5,200
	576-600	590	1,100	230	44,700	---
	601-625	620	1,050	246	43,100	----
	626-650	---	---	---	---	---
	651-675	664	1,670	300	64,300	---

Carbine (1944) estimated an average Houghton Lake, Michigan northern pike 23.6 inches (604 mm) long contained 32,200 eggs. A fish from Brown's Lake of comparable length contained 44,000 eggs. Vessell and Eddy (1941) found northern pike 431 to 480 mm long in Minnesota contained an average of 22,000 eggs with a range of 9,000 to 35,000. Northerns in Brown's Lake of comparable length contained 17,900 ± 1,000 eggs in 1970 and 18,700 ± 13,600 in 1971.

Ova-length, and ova-weight regressions were computed for both years using the linear model:

$$Y = a + b\ TL$$

and

$$Y = a + b\ W$$

where, Y was the estimated number of eggs and TL was total length in mm and W was weight in g. The ova on length regressions for both years were (Figure 6):

1970 $Y = 169.4\ TL - 58{,}910$

1971 $Y = 155.2\ TL - 54{,}351$

with correlation coefficients (r) of .74 and .79 for 1970 and 1971, respectively. Coefficient of determination (R^2) values showed about 55% of the 1970 ova counts, and 62% of the 1971 ova counts were explained by TL measurements. A 400 mm fish in 1970 contained 10,000 eggs, while a 1971 fish the same length contained about 10,000 eggs. The slope of regression lines differs slightly for the two years with fish in 1971 containing slightly more eggs than 1970. A 1970 fish, 700 mm in length contained about 57,000 ova while a fish the same length collected the second year contained nearly 60,000 ova. Differences between the ova-length regression for both years were tested in a t-distribution and no significant difference occurred between regressions ($P > .05$).

Ova on body weight regression were computed for 1970 and 1971 and the coefficients to satisfy the normal equation were as follows:

1970 $Y = 40.1\ W - 7{,}747$

1971 $Y = 44.0\ W - 7{,}690$

with correlation coefficients (r) of .82 for the first year and .89 for 1971. Coefficient of determination (R^2) were .67 and .80 for 1970 and 1971 regressions, respectively. Fish collected the first year weighing 600 g contained about 15,000 ova, while 1971 fish was expected to contain 18,000 ova, 80% of the time (Figure 7). As fish weight increased the regression line differences became more pronounced. At 1,500 g, 1970 fish contained 53,000 ova, and a year later the fish would produce 58,000 ova. Ova-weight regression differences for both years were tested in a t-distribution, but no significant difference at the 95% level was revealed.

Multiple regressions for ova on TL and weight was computed using the model:

$$Y = a + b_1\ TL + b_2\ W$$

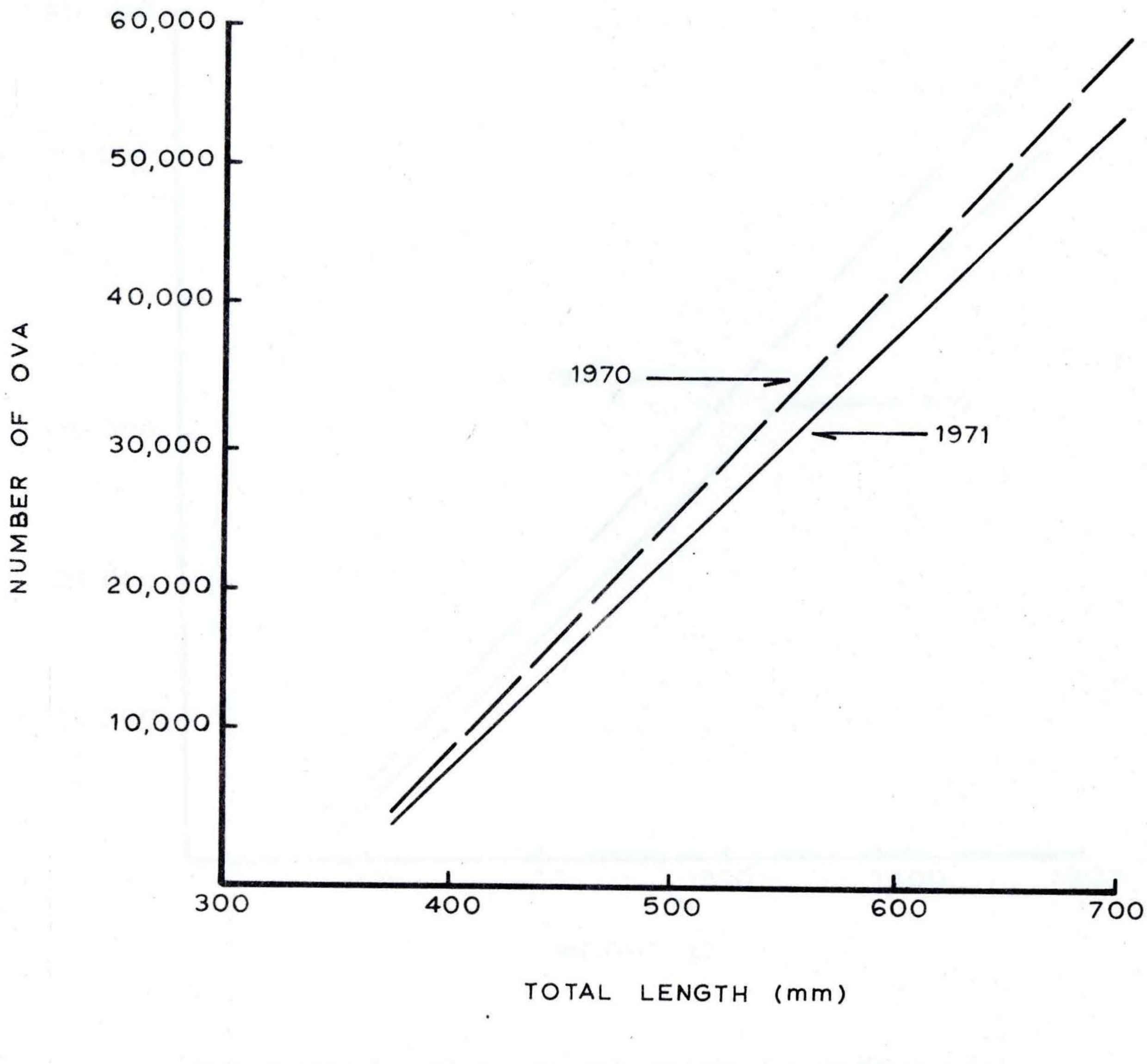

Figure 6. Linear regression of ova on total length for northern pike.

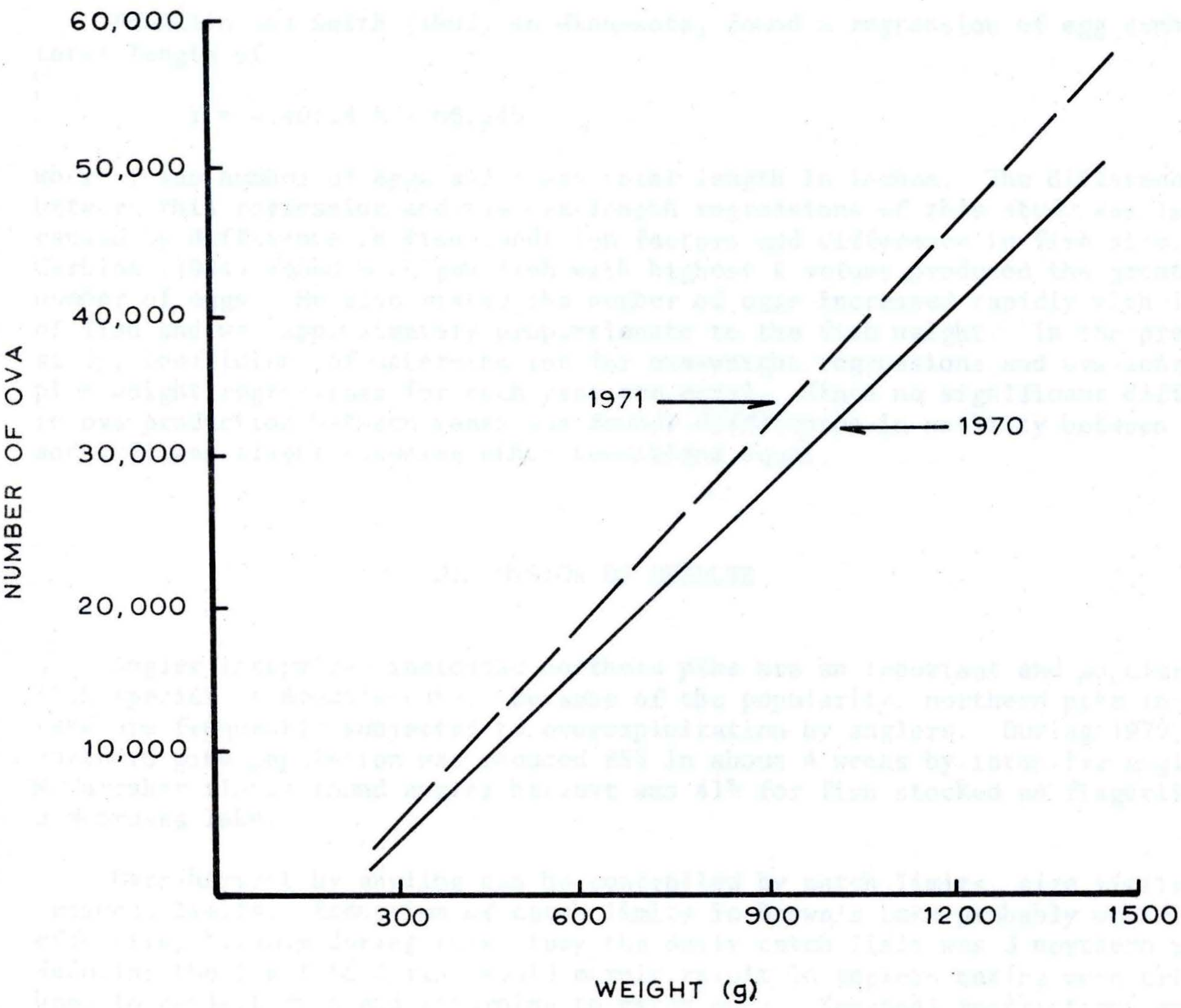

Figure 7. Linear regression of ova on body weight for northern pike.

The multiple regression coefficients were:

$$1970 \quad Y = 16.1\ TL + 43.3\ W - 2{,}525$$

$$1971 \quad Y = 3.5\ TL + 43.2\ W - 8{,}895$$

with correlation coefficients (r) of .82 for the first year and .90 for the second year. These multiple regressions of ova on TL and weight were made to improve estimation of ova counts, but no improvement was obtained. Coefficient of determination (R^2) values were identical to values obtained from ova on weight regressions for each year.

Franklin and Smith (1963) in Minnesota, found a regression of egg number on total length of

$$Y = 4{,}401.4\ X - 66{,}245$$

where Y was number of eggs and X was total length in inches. The differences between this regression and the ova-length regressions of this study was largely caused by difference in fish condition factors and difference in fish size. Carbine (1944) found Michigan fish with highest K values produced the greatest number of eggs. He also stated the number of eggs increased rapidly with length of fish and was approximately proportionate to the fish weight. In the present study, coefficient of determination for ova-weight regressions and ova-length plus weight regressions for each year are equal. Since no significant differences in ova production between years was found, differences in natility between 1970 and 1971 was slight assuming other conditions equal.

DISCUSSION OF RESULTS

Angler interviews indicated northern pike are an important and popular game fish species in Brown's Lake. Because of the popularity, northern pike in Brown's Lake are frequently subjected to overexploitation by anglers. During 1970, the northern pike population was reduced 85% in about 4 weeks by intensive angling. McCarraher (1962) found angler harvest was 41% for fish stocked as fingerling in a Nebraska lake.

Over-harvest by angling can be controlled by catch limits, size limits, and seasonal limits. Reduction of catch limits in Brown's Lake probably would not be effective, because during this study the daily catch limit was 3 northern pike. Reducing the limit to 2 fish would merely result in anglers making more trips home to deposit fish and returning to catch more. Seasonal restrictions would decrease angler harvest by allowing fishermen to fish when northern pike are less vulnerable to angling. A major disadvantage of seasonal restrictions at Brown's Lake is the selection of angler types. If the angling season was restricted to summer months, shore fishermen would be at a greater disadvantage than boat fishermen because boat fishermen could fish in the open water-aquatic vegetation transition zone. Size limits would control the angling harvest by allowing anglers to keep only large fish. In affect, a smaller percentage of the pike population would be vulnerable to harvest, and the smaller fish would remain to sustain the fishery.

Population density and structure can be manipulated by controlling two biological factors, growth and survival. Growth of northern pike in Brown's Lake compares favorably with growth in other areas. Growth could be improved by making more forage available. A stunted bluegill population was present, and at the current population density, northern pike were unable to control the forage base. If a vegetation control was implemented, more forage would be available, particularly during the summer and autumn. This study revealed growth was greater, immediately following winterkill when young carp were available for forage. Food habits showed feeding activity peaked in the spring, but was slight in summer and fall. Other studies revealed feeding was heaviest in spring and fall. Overall, northern pike in Brown's Lake appear to feed less often than pike in other studies. Sixty-seven to 76% of the northerns collected for stomach analysis contained empty stomachs while Johnson (1959) in Wisconsin, found 55% to contain empty stomachs. Growth history of northern pike shows annual increment of growth was accelerated during the first two years following the winterkill when forage was abundant.

RECOMMENDATIONS FOR MANAGEMENT

Northern pike are a popular, angler sought fish species in Brown's Lake and their life history indicated they are compatible with the environment in Missouri River oxbows. Population estimates indicated harvest restrictions must be implemented to restrict overharvest, as occurred in 1970 when nearly 85% of the population was caught in slightly more than 30 days. Stomach analysis and netting catch rates show they are not efficient predators or an effective control of the bluegill forage base at the present density. Conditions could be improved to provide better angling by initiating the following recommendations, which by and large would also benefit other sight feeding predators, such as walleye and largemouth bass.

1. Improve forage utilization by employing aquatic vegetation control. Chemical control is not economically practical because of the area involved. Biological control would be a better choice if the control organism could be managed. The reduction of aquatic vegetation would expose more forage to predators and provide better growing conditions for both predators and prey.

2. Size limits for northern pike must be initiated to attain a desirable northern pike-forage ratio. The daily possession limit of three did not effectively limit angler harvest in 1970, and the effectiveness of a daily possession limit of two fish is questionable. Anglers would react similar to those in 1970 by catching their daily possession limit, removing those fish and returning to catch more.

3. Increased forage utilization could be achieved by supplemental stockings of northern pike and largemouth bass fingerlings, if reproduction of either species appears to be inadequate. Addition of the fingerlings would improve the predator-forage ratio if a size limit was also implemented. The increased largemouth bass population would improve utilization of the forage base under present conditions.

4. Lake management could be changed if short term quantity northern pike angling was desired. Biologists could induce lake winterkill and stock northern pike fry following the winterkill to provide angling the year after stocking. The first three recommendations are far more practical and utilize the resources more efficiently.

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