A TEN-YEAR STUDY OF NATIVE NORTHERN PIKE IN BUCKS LAKE, WISCONSIN

Including Evaluation of an 18.0-inch Size Limit

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ABSTRACT

From 1961 to 1970, a population study of the northern pike, *Esox lucius* Linnaeus, was conducted on Bucks Lake where northern pike were the only predator species present. Growth of these fish was the slowest reported locally and among the very slowest, regionally. The average standing crop of northern pike 10 inches and larger was 24.4 lbs/acre. The maximum standing crop was 42.5 pounds per acre which is equivalent to the maximum standing crop found for other waters.

The estimated annual fishing pressure for a three-year period was 19.7 hours per acre and the catch rate for all species was 1.0 fish per hour. Fifty-seven percent of all anglers were successful. Before the imposition of an 18.0-inch size limit, the catch of northern pike was 9.6 pike per acre, while after the size limit went into effect, only 1.1 pike per acre were caught. Before the 18.0-inch limit was set, 62 percent of the total catch of northern pike were under 18.0 inches.

Average annual total mortality of pike was 64 percent, natural mortality was 37 percent and exploitation rate was 9 percent. These data suggest that mortality due to angling has little, if any, effect on total mortality.

No northern pike tagged in Bucks Lake were captured in downstream areas despite intensive efforts to do so.

It was concluded that use of an 18.0-inch size limit on northern pike was not biologically justified in Bucks Lake.

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INTRODUCTION

The northern pike, ***Esox lucius*** Linnaeus, is the most abundant species in the catch of warm water game fish in northwestern Wisconsin (Churchill, 1968)--the region in which Bucks Lake is located. Preliminary surveys in Bucks Lake from 1958 through 1960 revealed the presence of a sparse, fluctuating and fast growing panfish population and a single-species predator population of abundant, slow-growing northern pike.

In order to improve management of the northern pike, a more comprehensive study of Bucks Lake was undertaken from 1961 through May, 1970. The study was abruptly terminated May 31, 1970 when a flash flood washed out a section of the Bucks Lake Dam. A segment of the growth studies of all species in Bucks Lake has been completed and previously reported (Snow, 1969).

The primary objectives of the present study were to document those phases of population dynamics concerning age and growth, standing crop, exploitation and total and natural mortality of the northern pike in Bucks Lake. Other objectives were to evaluate the effects of an 18.0-inch size limit which became effective during the fifth year of the study and to determine the extent of emigration of northern pike from Bucks Lake to Murphy Flowage, an intensively studied research area 1.5 miles downstream. This paper reports the results of these efforts.

STUDY AREA

Description

Bucks Lake is an 83-acre impoundment on Hemlock Creek, Rusk County. Prior to 1967, the water level was maintained by an old log dam dating back to logging days in the late 1800's. A new water control structure, built in 1967, maintained former water levels until high waters washed it out and terminated this study on May 31, 1970. Bucks Lake is a wilderness lake surrounded by upland hardwoods and a number of tamarack bogs. The entire shoreline is very shallow and a very high percentage of the bottom of the lake is covered by aquatic vegetation, stumps and logs (Fig. 1).

Fish Species Composition

Bucks Lake has a relatively limited fish population. There is only one predatory species, the northern pike. Other species present in small numbers are the bluegill, *Lepomis macrochirus* Rafinesque; pumpkinseed, *Lepomis gibbosus* (Linnaeus); black crappie, *Pomoxis nigromaculatus* (LeSueur); rock bass, *Ambloplites rupestris* (Rafinesque); yellow perch, *Perca flavescens* (Mitchill); white sucker, *Catostomus commersoni* (Lacepede); and several species of minnows.

Standing crops of panfish species have varied considerably from year to year. The estimated number of panfish has ranged from 5 to 134 fish per acre from 1961 through 1970. The number per acre of the three most abundant species--bluegills, pumpkinseeds and yellow perch--ranged from less than 1 to 96, less than 1 to 37 and 4 to 15, respectively, and collectively peaked in 1965 or 1966.

In addition, the relative abundance of each species with respect to the total number of panfish also varied from year to year. In 1961 and 1962, pumpkinseeds were most abundant, comprising 48 and 58 percent of the total, respectively. From 1963 through 1967, bluegills predominated, comprising from 40 to 72 percent of the total. From 1968 through 1970, yellow perch were most abundant, comprising from 63 to 83 percent of the total.

The fluctuations in panfish densities from year to year and the extremely low numbers of all panfish species in any year were probably due to low

Close-up of the old Bucks Lake dam before 1967.

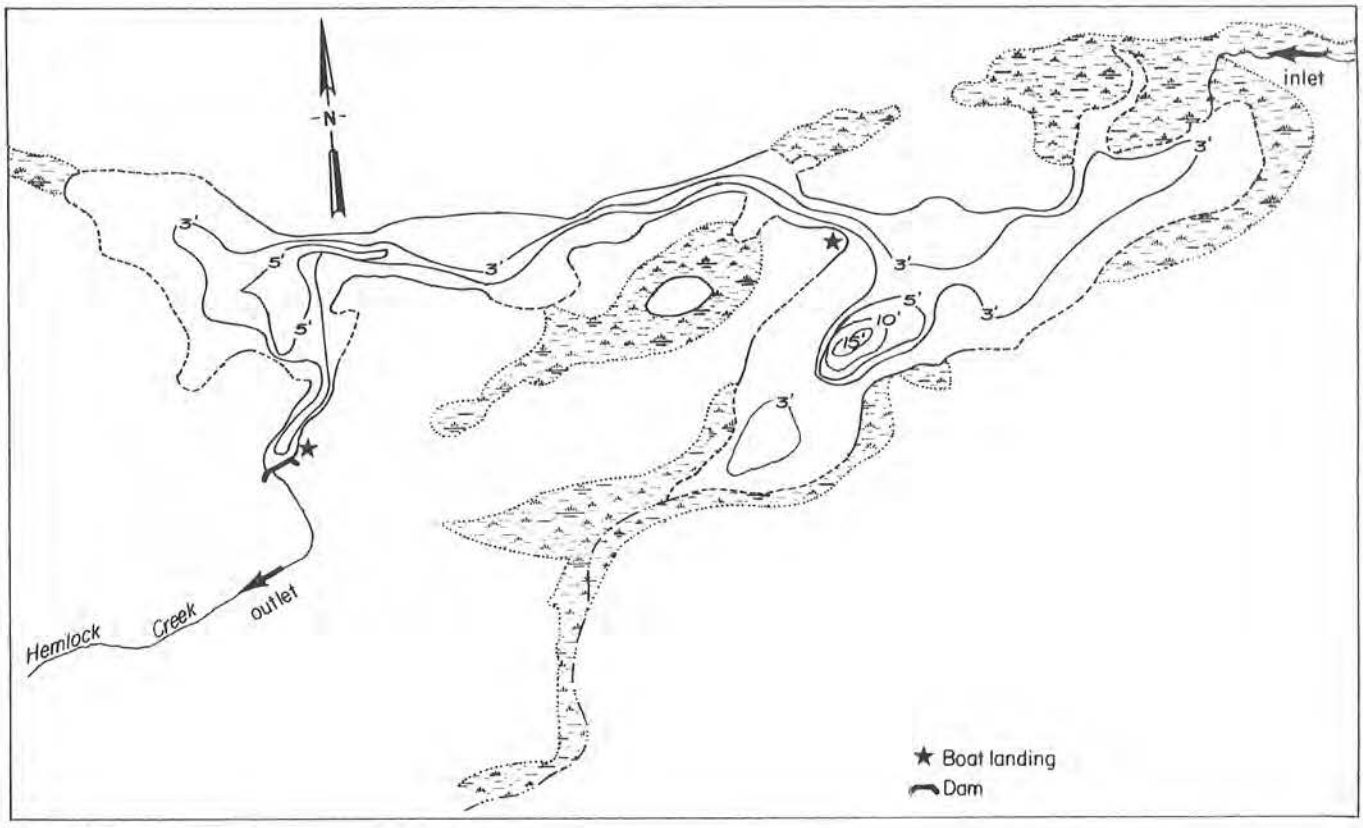

FIGURE 1
Contour map of Bucks Lake.

winter oxygen levels. Because the panfish species present never became really abundant, intraspecific competition for food and space was minimal and, therefore, they were able to grow exceptionally fast. Panfish from Bucks Lake grew faster than those in thirteen other lakes in northern Wisconsin (Snow, 1969).

Regulations

Prior to the initiation of this study, hook-and-line fishing regulations for northern pike in Bucks Lake were quite liberal during most years. However, from 1957 through 1970, regulations have become more restrictive. The bag limit from 1957 through 1962 was 25 fish, and from 1963 through 1970, it was 5 fish. There was no minimum size limit until January 1, 1966 when an 18.0-inch limit became effective. Year-round fishing was allowed until 1969. Thereafter, the season was closed from February 15 to the second Saturday of May.

Because of low winter oxygen conditions, Bucks Lake was open to dip netting from 1959 through 1963. Dip netting with nets up to three feet square was permitted in any manner through the ice from 7 a.m.-3:30 p.m. The limit was 25 pounds plus one fish of any species. In spite of close surveillance by Department personnel stationed at nearby Murphy Flowage, no dip netting on Bucks Lake was ever observed. Therefore, the effects of this harvest method, probably of little consequence, are not considered in this report.

The lower end of Bucks Lake and the new dam which was finished in 1967.

METHODS

Water Quality Analyses

Water samples for laboratory analyses were collected at the outlet to Bucks Lake in February, 1961 and on five occasions during 1969. The five samples in 1969 were taken: (1) just before the spring thaw, (2) at the peak of spring runoff, (3) at the beginning of summer, (4) during the warmest period in summer and (5) just before freeze-up.

In addition, a total of 18 alkalinity measurements were made at the outlet to Bucks Lake between July, 1965 and May, 1966. Oxygen content was also measured during late winter (January-March) for ten seasons between 1956 and 1970.

Population Estimates

Estimates of the northern pike population in Bucks Lake were made each spring from 1961 through 1970 and each fall from 1965 through 1967. The number of nets used and the netting effort varied each year. Six to ten nets were fished from 30- to 132-net days during the marking period, and 7-20 nets were fished from 55- to 152-net days during the recapture period which began from 1 to 14 days after the end of the marking period. All fyke nets had 5- by 6-foot frames and 1-inch bar mesh netting except in 1968 when 2 smaller nets were used and in 1964 when 4 smaller nets were used. The smaller nets had 4- by 6-foot frames and 1/2-inch bar mesh netting. Lead lengths used varied from 25 to 80 feet in length. An A.C. boom shocker was utilized for the fall marking period and fish captured the following spring were used for the recapture period. All fish were marked for future identification either by tagging with an aluminum strap tag on the preopercle bone, by fin clipping or by both methods, and all were measured to the nearest 0.1 inch in total length.

Population estimates of Ages I and II panfish which were not fully vulnerable to the sampling gear, were made by straight line extensions of Ages III through V on semilogarithmic graph paper. This method of estimating numbers of young panfish was similar to the method used by Mann (1965).

All standing crop estimates were calculated using Bailey's modification of the Petersen estimate as described by Ricker (1958). Initially, estimates were made in 4.0-inch groups. Using this method of grouping, complete estimates for all sizes of pike caught could not be made in all years because fish in some sizes were not recaptured. Therefore, estimates were made in only two size groups, 10.0 through 17.9 inches and 18.0 inches and larger. Because estimates made by the two methods were very similar, the larger size groups are used throughout the report.

Biomass was estimated using weighted mean weights based on the size distribution of the fish handled within each size range for each estimate. Pike were weighed only during 1964 and 1965 but these weights were used for all years. Weights were recorded to the nearest 0.01 pound. Confidence limits were determined for all population estimates by standard statistical procedures.

Mortality Estimates

In addition to making regular population estimates each spring, another estimate of the numbers of marked fish surviving from the previous year was also made. This gave an estimate of total mortality, and in years when fishing mortality was estimated, also natural mortality. Mortality notations are the same as those used by Ricker (1958) who defined a as the expectation of death from all causes (or total mortality rate), v as the expectation of death from natural causes (or natural mortality rate) and u as the expectation of death from angling (or exploitation rate).

Age and Growth Determinations

Age and growth data were obtained from 2,669 northern pike from 1961 through 1969. Each spring, scales were taken from all fish handled during the marking period or from stratified samples which usually amounted to 10 to 20 fish per one-inch group. Age and growth by sex was determined from 1964 through 1969 and during these years, scale collection was stratified by sex as well as by length. Several scales were removed from the anterior region between the dorsal fin and the lateral line.

Actual age determinations were made from plastic impressions of 3 to 5 scales observed through a binocular microscope which magnified the scales 20 or 35 times their original size. Since all scales were collected in spring, the age recorded is the same as the number of growing seasons completed. All growth data presented in this report are based on total length at the time of capture; no back-calculations were made.

Estimates of Harvest, Fishing Pressure and Exploitation Rates

The intensity of the creel census varied considerably throughout the study period. From 1961 through the 1964 open-water season (April through mid-November), creel census data was obtained by two methods: unscheduled field checks and volunteer reporting.

Starting with the 1964-65 ice fishing season and continuing through the 1967-68 ice fishing season, a stratified creel census was maintained. Field checks were stratified by day of week and time of day. On each check, anglers were counted and then checked individually. Time of day, hours fished, total catch, length of fish, tag number and fin clips were recorded. After January 1, 1966 anglers were also asked how many undersized northern pike were returned to the water. Using these data, total fishing pressure was calculated by the following formula:

$$A = \frac{b}{c} \times d \times e$$

where A is the total fishing pressure for any one month, b is the total number of anglers interviewed for that month, c is the total number of counts made for the same month, d is the number of days in the month and e is the number of potential fishing hours per day. In winter, the number of potential fishing hours per day was considered to be 8 and in summer, 12. (These numbers were based on field observations.)

The average number of fish caught per hour for each month was calculated from the individual interviews and multiplied by total potential fishing hours for that month to give an estimate of harvest. The sum of these monthly harvest estimates was used to estimate seasonal and annual harvest and hours fished. The number of marked fish in the catch was projected to the total catch to estimate the total number of marked pike caught. Exploitation rates were calculated by dividing the total number of pike marked each spring by the number of marked pike caught annually.

RESULTS AND DISCUSSION

Water Quality

Water samples collected in 1961 and on five occasions in 1969, indicate that Bucks Lake is a soft water, relatively infertile impoundment (Table 1). Total alkalinity ranged from 7 to 61 mg/l and dissolved phosphorous, from 0.04 to 0.01 mg/l. Other parameters measured displayed considerable seasonal variation; however, they are all quite similar to the ranges reported for other soft water lakes in northern Wisconsin (Poff, 1961).

From a more detailed analysis, total alkalinity was found to vary from 17 to 56 mg/l in samples collected from July, 1965 through May, 1966. (Fig. 2). The annual average for 1965-1966 was 40 mg/l. The highest alkalinity was recorded in February and the lowest at the peak of the spring runoff in March and April. Extreme variations in alkalinity which occurred during winter months were the result of winter thaws which were preceded by air temperatures in the middle to high 40's.

Bucks Lake has a history of low dissolved oxygen levels during late winter. During eight of the ten years of sample collections in late winter (January through March), the oxygen content at the outlet was 1 mg/l or less. Dissolved oxygen levels elsewhere in the lake were also low except for levels in the former stream channel between the upper boat landing and the inlet (Fig. 1). In this region, dissolved oxygen concentrations were 3.9 mg/l or above during all critical periods checked. Despite the low oxygen levels throughout most of the lake, a fish kill has never been observed.

Population Size and Standing Crop

Population estimates of northern pike were made each spring from 1961 through 1970 and each fall from 1965 through 1967. Based on spring netting, the average population estimate for pike 10.0 inches and larger was 27.3 pike per acre (24.4 lbs/acre). This spring pike population varied from a low of 12.4 pike (13.3 lbs/acre) to a high of 49.3 pike (36.8 lbs/acre). Based on fall netting, the average number and pounds of pike per acre averaged 36.1 pike weighing 33.0 pounds. This fall pike population varied from a low of 26.9 pike per acre (29.0 lbs/acre) to a high of 50.6 pike (42.5 lbs/acre) (Table 2).

Based on spring population estimates, total standing crop increased from 1961 through the fall of 1965, then decreased until the study terminated in June, 1970. The greatest increase occurred from the spring of 1962 to the spring of 1963 when standing crop increased from 20.1 to 34.5 pounds per acre. The greatest decline occurred from the fall of 1965 to the fall of 1966 when standing crop dropped from 42.5 to 27.6 pounds per acre (Table 2).

Of the two size groups estimated in spring, there was considerable variation in abundance of the 10.0- to 17.9-inch group (ranging from 8.6 to 45.0 pike per acre), while the 18.0-inch and larger group varied from only 2.3 to 6.1 pike per acre (Fig. 3). When fall estimates are included, the maximum value for the larger group increases from 6.1 to 7.9 pike per acre

TABLE 1
Water Analyses at the Outlet to Bucks Lake, 1961 and 1969

Parameter*	1961	1969				
	Feb 7	Mar 3	Apr 14	June 2	Aug 4	Nov 17
Specific Conductance	136	113	32	–	–	–
pH	6.8	6.9	6.5	7.3	7.4	7.1
Total Alkalinity	61	44	7	37	45	45
NO_2 -N	–	0.004	0.005	0.003	<0.002	<0.002
NO_3 -N	0.18	0.08	0.02	<0.1	0.1	0.1
NH_3 -N	0.01	0.07	0.06	0.09	0.03	0.00
Org-N	0.14	0.25	0.47	0.54	1.06	0.32
P(dis)	0.02	0.01	0.03	0.04	<0.03	<0.03
P(tot)	0.125	0.11	0.02	0.09	0.1	0.1
Cl	1.2	0	<0.05	<1	1.0	1.3
SO_4	8	3	3	6	9	8
Ca	8	10	1	6.1	5.3	4.1
Mg	4	6	0.92	4.14	6.10	4.27
Na	2.5	2.3	0.90	2.0	2.15	2.5
K	0.3	0.3	0.85	0.24	1.10	0.70
Fe	0.05	0.48	–	0.21	0.34	0.10
Mn	–	0.05	–	0.07	2.96	0.09
Zn	–	0.02	–	–	0.02	0.07

*Units of measurement are mg/l with the exception of pH which is measured in units and specific conductance which is measured in micro–mhos/cm^2 at 25 C.

while the maximum value for the smaller group remains unchanged (Table 2).

Variation in abundance of northern pike from year to year may be a result of increases and decreases in the available food supply. Numbers of Age I panfish--bluegills, pumpkinseeds, black crappie and rock bass--and Age I and II yellow perch reached peak levels from 1963 through 1965, the same years as peak levels of northern pike (Fig. 4). Evidence from nearby Murphy Flowage supported the conclusion that during these years, northern pike may have been feeding on the young panfish. (In 1969, Johnson reported that northern pike in Murphy Flowage consumed 2.0- to 3.0-inch centrarchids--the equivalent of Age I panfish in Bucks Lake.) Thus, there seems to be a relationship between panfish abundance and northern pike abundance in Bucks Lake; however, statistically, this relationship was not significant (Fig. 5).

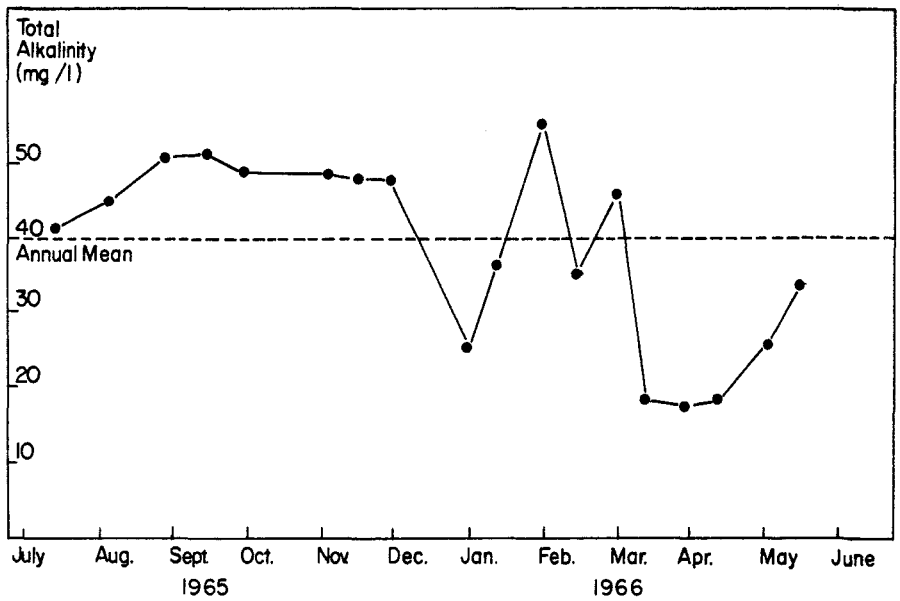

FIGURE 2
Total alkalinity at the outlet to Bucks Lake, July, 1965 through May, 1966.

A possible reason for this lack of significance is the abundant minnow population which was probably also utilized as forage. From 1966 through 1968, panfish numbers declined drastically, yet numbers of pike remained at 25 to 28 pike per acre. In 1969 and 1970, numbers declined to 13 pike per acre. Therefore, we believe that the minnow population alone could support a population of 10 to 15 pike per acre in the absence of panfish forage and that the increases in pike numbers that occurred were largely in response to increased forage provided by increases in panfish abundance.

In spite of this year-to-year variation in pike numbers, the average standing crop of northern pike in Bucks Lake was exceptionally high compared to the standing crops of northern pike reported for other waters. In a study of 59 game fish lakes, Moyle et al. (1950) reported an average biomass of 8.0 pounds per acre and a maximum biomass of 42.5 pounds per acre. In a summary of standing crop estimates for lakes and reservoirs, Carlander (1955) reported a mean biomass of approximately 8.5 pounds of northern pike per acre and a maximum, of approximately 21 pounds per acre. Possible explanations for the high standing crop of northern pike in Bucks Lake compared to the

TABLE 2
Standing Crop and Biomass of Northern Pike in Bucks Lake

Time of Estimate	10.0– to 17.9–inch Fish		18.0–inch and Larger Fish		All Fish	
	No. Fish per Acre	No. Lbs. per Acre	No. Fish per Acre	No. Lbs. per Acre	No. Fish per Acre	No. Lbs. per Acre
Spring						
1961	8.6	6.7	3.8	6.6	12.4	13.3
1962	20.3	15.2	2.7	4.9	23.0	20.1
1963	38.7	28.8	3.3	5.7	42.0	34.5
1964	27.9	21.5	4.8	8.1	32.7	29.6
1965	45.0	29.5	4.3	7.3	49.3	36.8
1966	25.7	18.4	2.3	4.0	28.0	22.4
1967	23.1	18.3	3.6	6.1	26.7	24.4
1968	19.2	16.5	5.6	9.3	24.8	25.8
1969	15.0	12.4	6.1	10.6	21.1	23.0
1970	9.4	8.1	3.9	6.8	13.3	14.9
Avg.	23.3	17.5	4.0	6.9	27.3	24.4
Fall						
1965	44.6	31.9	6.0	10.6	50.6	42.5
1966	27.4	21.7	3.5	5.9	30.9	27.6
1967	19.0	15.7	7.9	13.3	26.9	29.0
Avg.	30.3	23.1	5.8	9.9	36.1	33.0

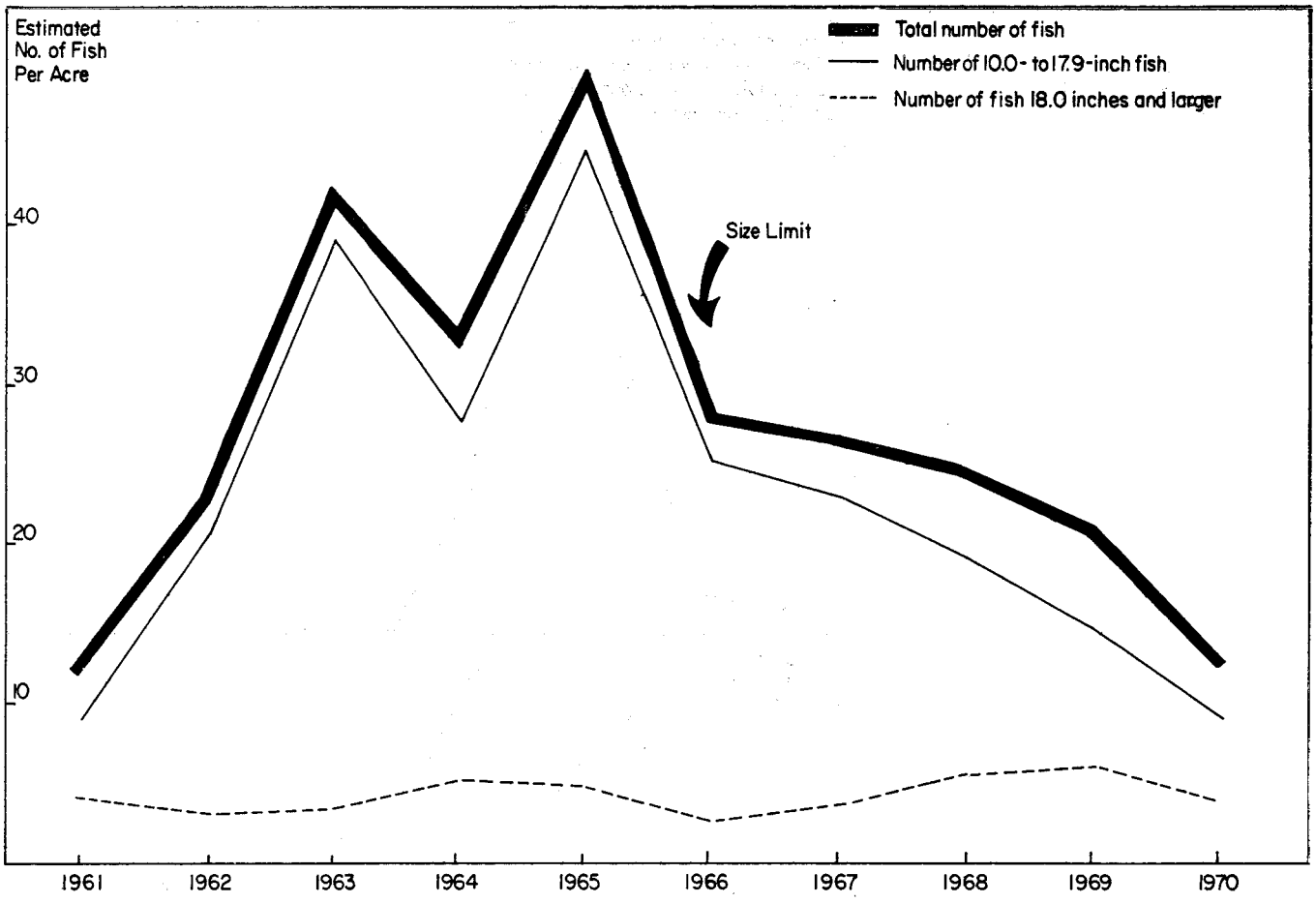

FIGURE 3
Standing crop of northern pike based on spring population estimates, 1961-1970.

standing crops of pike in other waters may be (a) that the studies by Moyle et al. and Carlander undoubtedly, in some cases, included different sizes of fish than those reported for Bucks Lake and (b) that, as the only predator species in Bucks Lake, northern pike may be able to attain higher standing crops than the fish documented in the other two studies.

Nevertheless, in a comparison of standing crop of northern pike only over 14.0 inches long, the minimum size estimated in two other studies, it was found that Bucks Lake estimates were still considerably higher than estimates for two other lakes for which comparable data are available (Table 8, Appendix). Spring population estimates for northern pike in Bucks Lake over 14.0 inches averaged 18.5 pike per acre (19.5 lbs/acre). An estimate of northern pike over 14.0 inches long for a one-year study in Maple Lake, Minnesota was 11.9 pike per acre (Seaburg and Moyle, 1964) and in Whitmore Lake, Michigan, 0.8 pike or 2.25 pounds per acre (Cooper and Schafer, 1954).

Age and Growth

The growth rates of the northern pike in Bucks Lake for both male and females have remained quite constant throughout the 9-year study period. The 18.0-inch size limit, which began January 1, 1966, had no effect on growth of pike in later years. After their sixth year of life, northern pike declined drastically in numbers (Table 9, Appendix). Of 2,669 pike aged, only 61 were older than six years. The oldest and largest pike captured during the entire study was a 12-year-old measuring 34.3 inches in length.

The average annual growth increments decreased from 8.3 inches during the first year to 2.4 inches by the third growing season (Fig. 6). From the fourth through seventh year of life, annual growth increments decreased only from 1.9 to 1.5 inches.

The growth rate of northern pike in Bucks Lake is exceptionally slow compared to the growth of northern pike in other waters. With one exception, growth of northern pike from Bucks Lake was slower than the growth of northern pike from six other lakes in the same drainage system (Snow, 1969). In another comparison, growth of Bucks Lake northern pike ranked among the very slowest for age groups I through VII in 16 of 36 bodies of water (Carlander, 1969). Lakes in which northern pike growth was slower were in Canada, England and Scotland. Possible explanations for this slow growth rate of northern pike in Bucks Lake are the shortage of forage fish and the high population density of 10.0- to 17.9-inch northern pike.

Female northern pike grew at a slightly faster rate than males. After the second growing season, females were 0.4 inches longer than males (Fig. 7). The greatest difference is length occurred during the fifth growing season when females averaged 1.0 inches longer than males. The majority of both sexes reached the legal size limit (18.0 inches) during their fifth

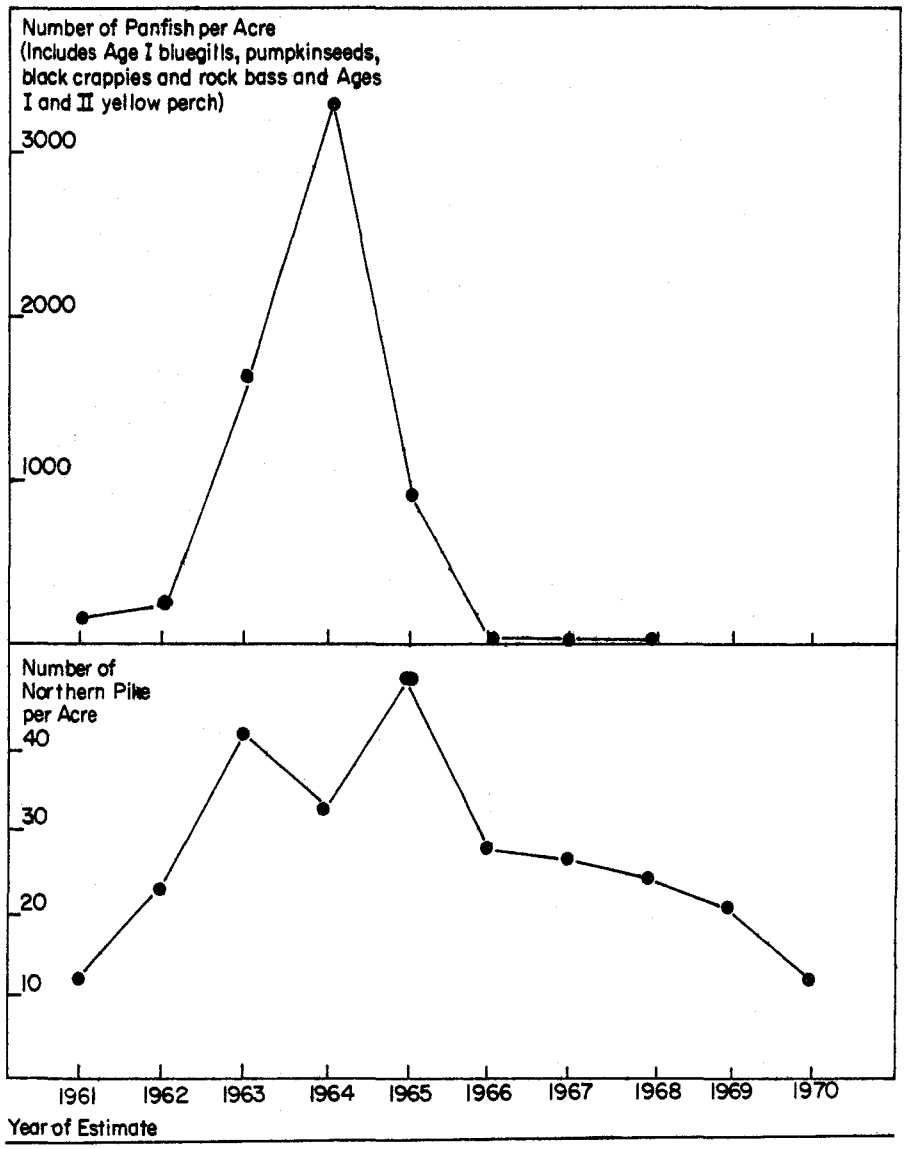

FIGURE 4
Abundance of panfish and northern pike, 1961-1970.

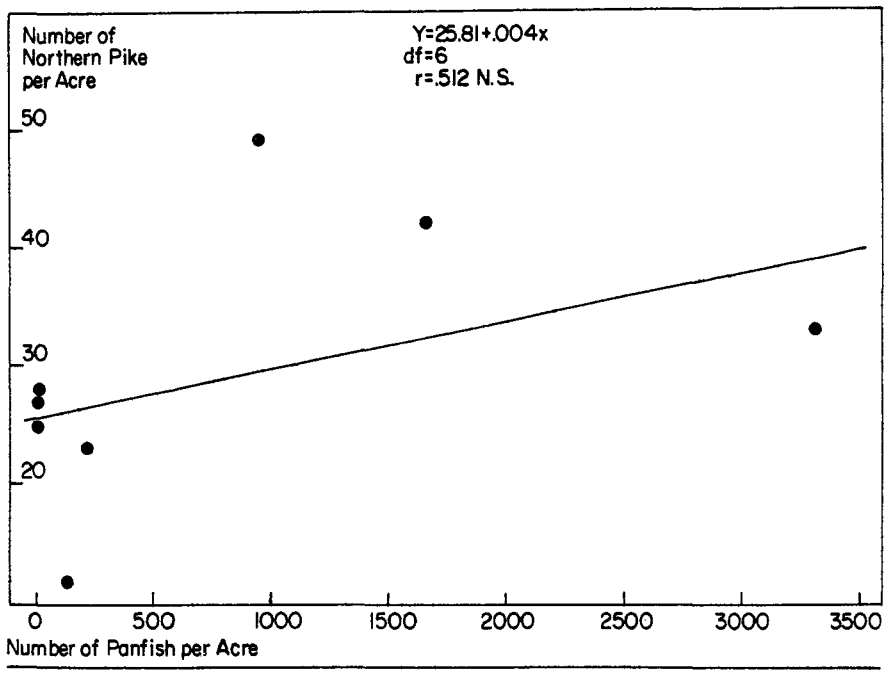

FIGURE 5
Relationship between abundance of northern pike and abundance of panfish, 1961-68.

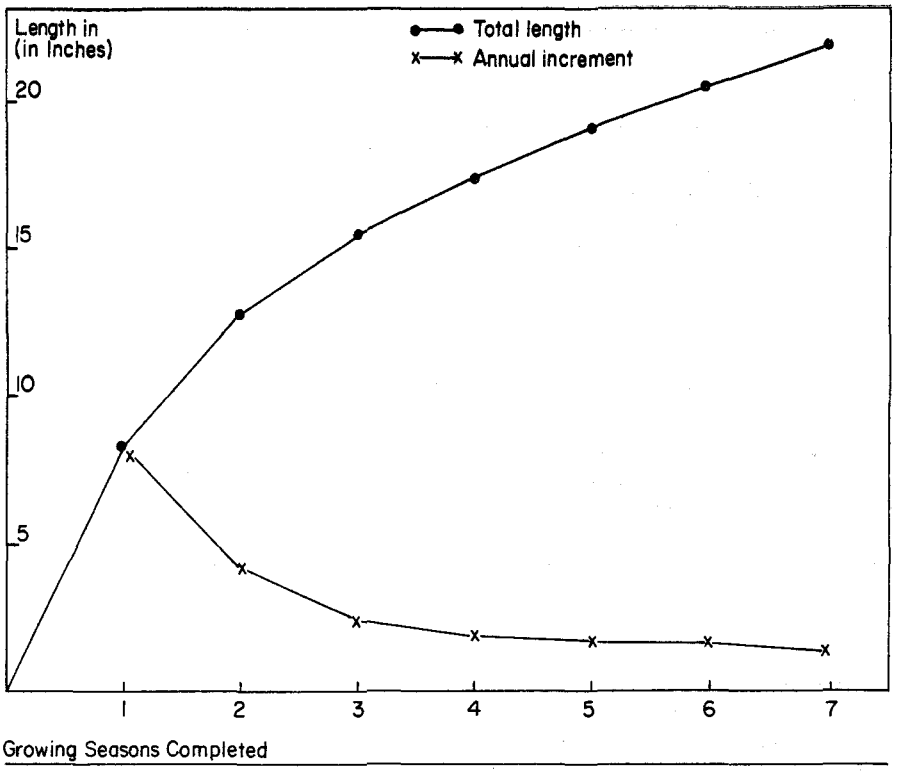

FIGURE 6
Average growth and annual increments for northern pike (sexes combined), 1961-69.

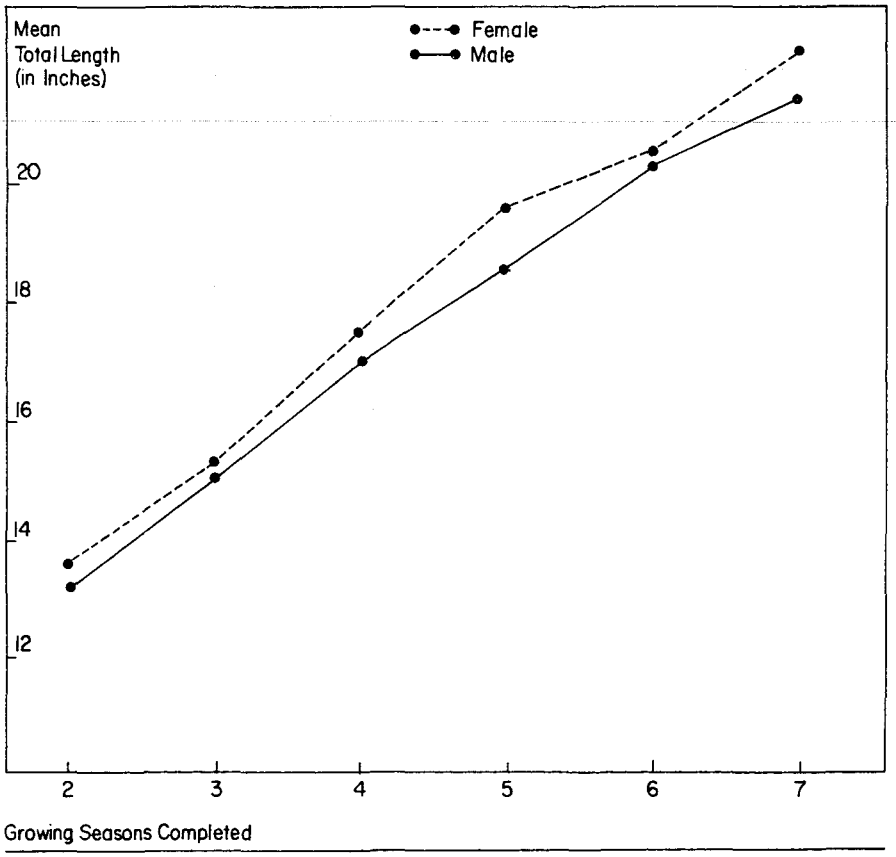

FIGURE 7
Comparison of growth of male and female northern pike, 1964-69.

year of life.

A length-weight relationship was calculated from 197 pike grouped in half-inch intervals from 10.5 to 23.5 inches. The length-weight relationship for Bucks Lake northern pike is expressed by the regression:

$$Log\ W = -3.836 + 3.139\ Log\ L$$

where W is the weight in pounds and L is the total length in inches. In the graphic presentation of this regression there is close agreement between the calculated and empirical data for sizes of pike through 21.0 inches in length (Fig. 8). Discrepancies are noticeable among larger pike mainly because of smaller sample size.

The regression equation for the Bucks Lake northern pike is almost identical to the regression equation of an abundant population of northern pike from Lake George, Minnesota (Groebner, 1964). Thus, the length-weight relationship of pike in these waters is similar.

Movement

One of the objectives of the Bucks Lake study was to determine the extent of movement of northern pike to Murphy Flowage, an intensively studied research area 1.5 miles downstream. From 1961 to 1967, 491 pike were tagged. During these 7 years, despite over 5,000 net days of fishing, a compulsory creel census (annual fishing pressure of 59 hours per acre) and intensive electrofishing, no northern pike tagged in Bucks Lake were caught in Murphy Flowage or in areas downstream from Murphy Flowage.

Of the 491 pike tagged in Bucks Lake, there were 198 multiple recoveries--all within Bucks Lake. The 198 recoveries represent returns from 156 pike, or 32 percent of the individuals marked (Table 3). It can therefore be concluded that downstream movement of northern pike from Bucks Lake is virtually nonexistent or at the most, extremely limited.

Harvest

The estimated average annual fishing pressure for all species on Bucks Lake was 19.7 hours per acre (Table 4). Seasonally, the pressure varied from 4.1 to 12.6 hours per acre in winter and from 8.5 to 17.7, in summer. The average catch rate for the entire creel census period was 1.0 fish

TABLE 3
Tagging and Recovering Records for Northern Pike from Bucks Lake

Year Tagged	Number Tagged	Recoveries * From Angling	From Netting & Electrofishing	From All Sources	Individual Fish Recovered No.	Percent
1961	99	20	17	37	30	30
1962	100	13	12	25	24	24
1963	192	22	54	76	51	27
1967	100**	–	60	60	51	51
Total	491	55	143	198	156	—
Avg.	—	—	—	—	—	32

*All fish were tagged by May 15 or earlier each year. Recoveries during the initial tagging period or during netting and electrofishing for population estimates immediately following tagging are not included in this table.

**In 1967, northern pike from 14.0–through 16.0–inches were the only sizes tagged. Because of the 18.0–inch size limit, there were no recoveries of these fish from angling.

per hour while seasonally, it was 0.3, in summer and 1.6 fish per hour during winter. Individual seasonal catch rates varied from 0.2 to 3.0 fish per hour during winter and from 0.1 to 0.6 fish per hour in summer. The percentage of successful anglers for all species averaged 57 percent annually, varying seasonally from 46 to 98 percent in winter and 14 to 60 percent in summer and averaging 82 percent in winter and 32 percent in summer.

TABLE 4
Estimated Fishing Pressure and Quality in Bucks Lake

Year and Season	Percent Successful Angler Trips	No. Hours Fished Per Acre	No. Fish Caught Per Hour
1964–65			
Ice	98	12.6	3.0
1965–66			
Open Water	60	17.7	0.6
Ice	93	4.8	1.8
Both Seasons	—		—
Total		22.5	
Avg.	77	—	0.8
1966–67			
Open Water	14	8.5	0.1
Ice	91	4.1	1.4
Both Seasons	—		—
Total		12.6	
Avg.	53	—	0.5
1967–68			
Open Water	22	13.8	0.1
Ice	46	4.2	0.2
Both Seasons	—		—
Total		18.0	
Avg.	34	—	0.2
1964–68			
Open Water	32	13.3	0.3
Ice	82	6.4	1.6
Both Seasons	—		—
Total		19.7	
Avg.	57	—	1.0

All fishing statistics for Bucks Lake were considerably less than those reported over a five-year period (1957-1961) for Murphy Flowage where fishing pressure was 97 hours per acre, where catch rate was 2.2 fish per hour and where 67 percent of all anglers were successful (Churchill and Snow, 1964).

The total catch of fish during the four winter and three summer seasons of stratified creel census varied considerably. The total estimated catch of fish varied from a high in the winter of 1964-65 of 3,121 fish or 22.7 pounds per acre to a low of 45 fish or 0.5 pounds per acre in the open-water season of 1966 (Table 10, Appendix). The highest estimated catch of bluegills was 1,702 fish in the winter of 1964-65 and the lowest catch was 0 fish in the winter of 1967-68. The catch of yellow perch fluctuated from a high of 532 fish in the winter of 1964-65 to 0 during the open-water season of 1967. Numbers of black crappies, rock bass and pumpkinseeds caught also showed some variation but, with the exception of an estimated catch of 405 pumpkinseeds in the 1964-65 winter season, these three species of panfish were never caught in any abundance during the study.

The average size of all northern pike caught in the two seasons prior to the 18.0-inch size limit was 17.6 inches, while for pike caught over 18.0 inches, the average size was 19.7 inches. During 1966 and 1967 (after the size limit was imposed), the average size of northern pike caught was 19.6 inches;

a size which was practically identical to the average length of pike caught during 1964 and 1965.

The catch of northern pike declined after an 18-inch size limit went into effect on January 1, 1966. In the winter of 1964-65, the estimated number of northern pike caught per acre was 5.4 pike weighing 7.6 pounds (Table 10, Appendix). During the 1965 open-water season and the 1965-66 ice fishing season, the catch of northern pike per acre was 9.6 pike weighing 9.8 pounds. The total number of pike caught in the 1965-66 ice fishing period was not affected by the size limit regulation because no northern pike were caught between January 1, 1966 and the open-water season in April. After the size limit was imposed, the total annual harvest of pike per acre dropped to 1.1 pike weighing 1.9 pounds in 1966 and 1.1 pike weighing 1.6 pounds in 1967.

Before the 18.0-inch size limit became effective, anglers caught and kept large numbers of small northern pike. In a voluntary creel census from 1962 through 1964, 65 percent of 221 pike recorded were under 18.0 inches in length. Seasonally, the percentage of the catch under 18.0 inches varied from a low of 34 percent in the winter of 1963 to a high of 88 percent in the summer of 1962. During the stratified creel census conducted from the winter of 1964 through the summer and winter of 1965, 62 percent or 767 of 1,245 pike caught were less than 18.0 inches. This 62 percent varied seasonally from 41 percent in the winter of 1964 to 78 percent in the summer of 1965. The overall percentage of pike under 18.0 inches kept before the 18.0-inch limit became effective, was 62 percent.

After the 18.0-inch size limit went into effect, the number of undersized pike caught and released was recorded. During the 1966 open-water and ice fishing seasons, an estimated 282 pike of the total catch of 377 northern pike caught were undersized, and during the entire 1967 season, 658 of the total catch of 748 northern pike caught were undersized and had to be released. Undersized northern pike comprised 75 percent of the total catch in 1966, 88 percent in 1967 and 84 percent for the two years combined. Although these percentages seem high, they are not entirely unrealistic because they are similar to the percentages caught for at least three seasons before the establishment of the 18.0-inch size limit.

After the 18.0-inch size limit was imposed in Bucks Lake, the exploitation rate of northern pike declined drastically. In 1965, the exploitation rate was 21 percent while in 1966 and 1967, the first two years after the 18.0-inch limit, the exploitation rates dropped to 3 and 2 percent, respectively (Table 5). The decline in exploitation is largely the result of the 18.0-inch size limit, but is also related to a concurrent drop in fishing pressure (Table 6) and standing crop of larger northern pike (Table 2).

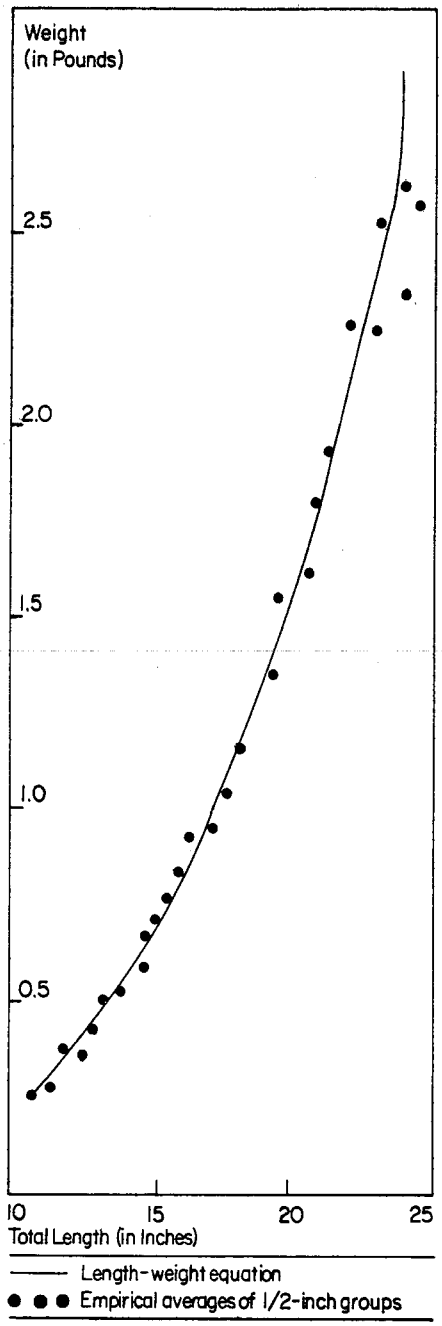

FIGURE 8
Calculated and empirical length-weight relationships for northern pike (sexes combined).

Mortality

Total annual mortality *(a)* of northern pike averaged 64 percent and varied from a low of 35 percent in 1967 to a high of 84 percent in 1962 (Table 7). High mortality is a normal characteristic of northern pike populations. In a comparison of mortality in four Minnesota lakes, Groebner (1964) reported annual averages in total mortality of 65 percent to 88 percent and annual variation in one lake of 39 percent to 89 percent. With the exception of 1964, there was a steady decline in total mortality in Bucks Lake, from approximately 80 percent in 1961 and 1962 to a low of 35 percent in 1967. In 1968 and 1969, mortality increased to 71 and 82 percent, respectively. Total mortality in 1968 and 1969 was therefore almost the same as in 1961 and 1962. The extreme variations in mortality which occurred in northern pike from Bucks Lake are probably related to the variations in the available food supply.

Because of the high density of the pike population, one might also expect variations in mortality to be related to population density, however, this relationship was not significant (Fig. 9). Despite this lack of significance, figure 9 suggests that total mortality decreases as population density increases--just the opposite of what might be expected. Increases in available food supply from 1963 through 1965 (Fig. 4), may account for this unexpected trend.

The estimated average annual exploitation *(u)* by anglers was 9 percent and for 1965, 1966 and 1967 was 21, 3 and 2 percent, respectively. Natural mortality *(v)* averaged 37 percent and for the same years was 36, 41 and 33 percent, respectively (Table 7). In comparison, average exploitation in Lake George, Minnesota, (14 percent) was slightly higher than in Bucks Lake while average natural mortality in Lake George (51 percent) was considerably higher than in Bucks Lake (Groebner, 1964).

Exploitation rate and natural mortality together equal total mortality. All three parameters were determined only during a three-year period in Bucks Lake (1965-67) and, unfortunately, these years happened to be the three years of lowest total

TABLE 5

*Exploitation Rate of Northern Pike from Bucks Lake**

Year	Number Fish Marked	Estimated Number Marked Fish Caught	Annual Exploitation Rate
1964	308	46	15**
1965	922	189	21
1966	738	22	3***
1967	526	12	2

* Exploitation rates are estimated from the partial creel censuses.

** The 1964 exploitation rate is for winter only since no creel census was conducted in the summer of 1964.

*** After January 1, 1966, an 18.0–inch size limit was in effect on Bucks Lake.

TABLE 6

Comparison of Fishing Data Before and After an 18.0–inch Size Limit on Northern Pike in Bucks Lake

Fishing Statistics	Before (1965)	After (1966 & 1967)
Fishing Pressure		
Hours per acre	22.5	15.3
Pounds per acre	9.8	1.8
Catch		
Total no.	797	93
No. per 100 acres	43.0	7.3
Length of fish caught (in inches)	17.6	19.6
Annual exploitation rate (percent)	21	3

TABLE 7

Annual Mortality of Northern Pike from Bucks Lake

Year	Percent Angling Mortality	Percent Natural Mortality	Percent Total Mortality
1961	–	–	79
1962	–	–	84
1963	–	–	57
1964	15*	–	69
1965	21	36	57
1966	3	41	44
1967	2	33	35
1968	–	–	71
1969	–	–	82
Avg.	9	37	64

* Angling mortality is based on the ice fishing season only.

mortality. Despite limited data, some interesting observations on the relationship between angling, natural and total mortality can be made. Fishing pressure was believed to be even lower in 1968 and 1969 than in 1966 and 1967. (Estimates of fishing pressure in 1968 and 1969 are substantiated by close surveillance by Department personnel stationed nearby and by a stratified creel census based on 65 field observations made from December, 1969 to April, 1970. During this time period, only 17 anglers were checked and no pike were caught.) If the decline in exploitation during 1965-67 were to have been the cause of the decline in total mortality during those same years, then one would expect as fishing pressure dropped even lower in 1968 and 1969, that total mortality would likewise decline. Total mortality in 1968 and 1969 did not, however, decline (Table 7). Thus, it is believed that the decline in exploitation from 1965-1967 had little, if any, relationship to the decline in total mortality during those years.

A few other generalizations can be made based on the data presented in table 7. The high total mortality found for northern pike in Bucks Lake was not affected by the presence of the 18.0-inch size limit, since over 80 percent mortality was observed in two different years--one before and one after the size limit went into effect. Nor was the high total mortality caused by variations in exploitation rates, since total mortality was high in two years (1968 and 1969) when few anglers were fishing the lake and catching northerns. High natural mortality thus appears to be the major cause of the high total mortality observed.

In summary, it is known that mortality is higher for smaller pike than for larger pike (Snow, unpublished). Coupled with the fact that fish in the 10.0- to 17.9-inch size range grew slowly and comprised approximately 85 percent of the population (Table 2), this means that: (a) most northern pike in Bucks Lake die from natural causes before they reach legal size of 18.0 inches and (b) most pike that are caught by anglers probably would have died anyway during the year.

Evaluation of Size Limit

Historically, there have been two main purposes in establishing a size limit. One objective is the maintenance of an adequate number of adult females by preventing the capture of too many young fish before they have spawned; the other, is the promotion of the maximum yield of the kind of catch which is regarded as most desirable (Allen, 1954).

In Bucks Lake, male northern pike mature at Age I or II, which on the average, is two to three years before they reach the minimum size of 18.0 inches. Most females are capable of spawning at least once before they reach a length of 18.0 inches. The fact that males and females usually spawn at least twice has been reported for northern pike in northern Wisconsin (Snow, 1969), southern Wisconsin (Mackenthun, 1948) and North America and Europe (Carlander, 1969). Therefore, use of a size limit to protect a segment of the spawning population from capture is inadequate justification for a size limit on northern pike because in the vast majority of lakes, northern pike can spawn at least once and usually two or more times before they reach a length of 18 inches.

Evaluation of the second purpose for the size limit--that of promoting maximum yield of desirable fish--was approached by comparing growth rate, population density and several fishing statistics before and after the 18.0-inch limit became effective.

There has been very little variation in growth of northern pike in Bucks Lake throughout the study (Table 9, Appendix). Therefore, it can be concluded that the 18.0-inch limit in Bucks Lake did not affect growth rates and thus growth had no effect on any increase or decrease in yield which may have occurred.

The 18.0-inch size limit appears to have had little, if any, effect on the population density of northern pike. After the 18.0-inch size limit went into effect, numbers of pike between 10.0 and 17.9 inches declined steadily and, with the exception of 1970, numbers of pike over 18 inches increased slightly (Fig. 3). The most logical explanation for this small increase in numbers of larger pike from 1967 through 1969 is recruitment from the extremely abundant population of smaller northern pike in 1965. That this increase in numbers of larger pike could occur even with no size limit is demonstrated by the increase that occurred in 1964 and 1965 after a peak in abundance of smaller pike in 1963 (Fig. 3). A possible explanation for the decline in the standing crop of smaller pike after the size limit is the drastic decline in panfish numbers from 1966 through 1968. Thus it appears that all sizes of northern pike were controlled by the available food supply, not by the size limit.

While the 18.0-inch size limit did not appear to affect growth or population density, it did affect angling statistics. Factors compared are total pressure, total catch rate, average length and exploitation rate. The average size of northern pike over 18.0 inches caught was practically the same before (19.6 inches) and after (19.7 inches) the 18.0-inch limit was set. All other comparisons declined drastically (Table 6). The most dramatic decline--the catch rate--encompasses both pressure and harvest and dropped from 43.0 northern pike per 100 hours to 7.3 for all sizes combined and from 11.6 to 7.2, for northern pike over 18.0 inches. Fishing pressure dropped from 22.5 to 15.3 hours per acre, indicating along with the decline in catch rate, that fewer anglers were coming to Bucks Lake to fish after the size limit went into effect.

Another noticeable decline which is closely related to the drop in pressure is the exploitation rate which dropped from 21 to 3 percent (Table 6). With the exception of the average length of pike caught, the 18.0-inch size limit had an adverse effect on angling.

In recent years, public pressure and opinion has become an additional factor in forming our fishing regulations. This was an important factor in the establishment of the 18.0-inch limit in Bucks Lake and other lakes in several northwestern Wisconsin counties in 1966. One of the arguments presented in favor of a size limit was that smaller northern pike were not wort keeping. However, one of the more interesting results of this study was that given the opportunity, anglers *did* keep a relatively large number of small northern pike.

During a three-year period before the 18.0-inch limit became effective, 62 percent of all the northern pike caught and kept were less than 18 inches. For example, of 118 northern pike anglers checked during the open water fishing season of 1965, 104 anglers or 88 percent kept northern pike under 18.0 inches in length. All total, they had 109 northern pike under 18.0 inches or 79 percent of the

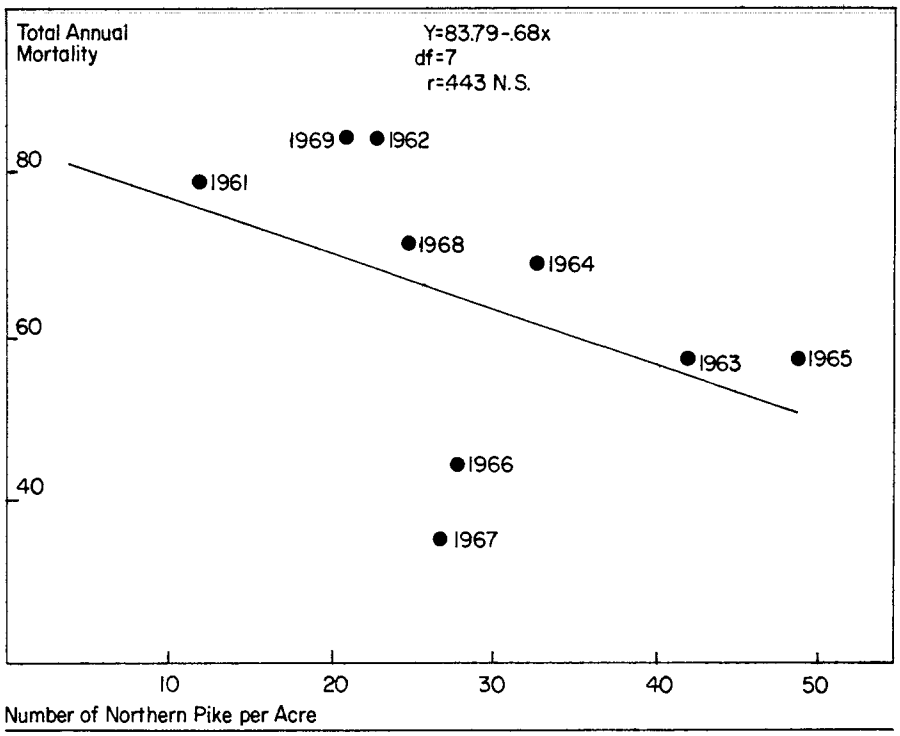

FIGURE 9
Relationship between total annual mortality and population density of northern pike at the beginning of each year, 1961-68.

139 pike recorded. Northern pike as small as 12.0 inches were kept and 51 pike or 37 percent of the total were under 15.0 inches in total length.

After the 18.0-inch size limit became effective, an estimated 84 percent of the total catch were less than 18.0 inches. One reason for the difference in percent of small northern pike caught before (62 percent) as compared to after the 18.0-inch limit is that before January 1, 1966 some anglers probably released the smaller pike (of which no record is available) whereas the 84 percent recorded after the 18.0-inch limit was set, includes all pike caught and released. If anglers had been allowed to keep the smaller pike after the 18.0-inch limit went into effect, the total catch for 1966 and 1967 would have been 377 and 748 northern pike, respectively, as compared to the actual harvest of only 95 and 90 legal pike, respectively.

Thus, if fishing regulations allow it, anglers will keep large numbers of small northern pike, especially when these small pike constitute a high percentage of the total catch. Data from Bucks Lake redefine the kind of catch that is regarded as desirable, or at least acceptable. Although some anglers believe that the only northern pike that are acceptable are the large ones, the majority of the anglers on Bucks Lake kept pike of any size.

Because northern pike smaller than 18.0 inches are acceptable to anglers and because the harvest of small pike does not affect future fishing, data presented here seem to indicate that an 18.0-inch size limit on northern pike has an adverse effect on angling quality.

The conclusions and statements made in this section are based on the assumption that spawning areas and production of young pike are adequate in Bucks Lake. It is believed that this assumption applies to most waters in Wisconsin where native populations of either fast- or slow-growing northern pike are present. Possible exceptions are those waters that have experienced loss of suitable spawning habitat due to land development or other reasons.

MANAGEMENT IMPLICATIONS

Northern pike population density, which fluctuates widely from year to year in Bucks Lake, is, from all observations, not related to harvest by angling. On the average, 64 percent of all northern pike die each year regardless of any size limits or variation in harvest by angling. Anglers in Bucks Lake thus harvest pike which probably would have died anyway during the year from natural causes.

Before the 18.0-inch limit went into effect, anglers kept large numbers of small northern pike--62 percent of an estimated 1,245 caught were less than 18.0 inches. After the size limit was established, the pressure dropped 32 percent, the total catch of northern pike declined 29 percent (including sublegals) and the catch of northern pike over 18.0 inches long dropped an estimated 57 percent. The average length of pike over 18.0 inches caught before and after the size limit was set remained practically the same.

Before the 18.0-inch size limit, anglers had a choice: they could keep the smaller northern pike (i.e., those less than 18.0 inches in total length) if they so desired, and a large percentage of the anglers did. After the 18.0-inch limit was in effect, anglers had to release 84 percent of their total catch of northern pike. By all standards of comparison, the quality of fishing declined after the 18.0-inch limit became effective.

In Bucks Lake, the 18.0-inch size limit did not accomplish its intended purposes: (a) It did not promote the maximum yield of the most desirable size of pike since northern pike less than 18.0 inches were found to be acceptable to anglers. The fact that most anglers kept small pike when given the opportunity suggests that most anglers do not want size limits on northern pike and that the establishment of size limits is advocated only by a small number of anglers. (b) Nor did the size limit prevent the capture of too many young pike before they were able to spawn. Data from other lakes show that northern pike mature at early ages and most males and females spawn one or more times before they reach a length of 18.0 inches.

Based on data presented here, the use of a size limit in the management of northern pike is a highly questionable conservation practice. No justifications for the use of an 18.0-inch size limit on Bucks Lake were found. It is believed that a similar size limit would be ineffective in most other Wisconsin lakes as well, even those in which the northern pike is not the dominant predator species.

SUMMARY AND CONCLUSIONS

A population study of the northern pike was conducted on Bucks Lake from 1961 through 1970. Data on age, growth, standing crop, harvest, exploitation, mortality and movement were collected before and after the imposition of an 18.0-inch size limit.

Growth of the northern pike was the slowest reported locally, and among the very slowest, regionally. Growth for the same age groups was quite constant over the years and pike averaged only 15.4 inches in total length after three growing seasons. Females grew only slightly faster than males, the maximum average difference being only one inch at Age V. Both sexes reached the legal size of 18.0 inches during the latter part of the fourth or during the fifth growing season. There was close agreement between the calculated and empirical data for the length-weight relationship of Bucks Lake northern pike and the regression equation was similar to that found for another dense population of northern pike.

Ten spring population estimates averaged 27.3 pike and 24.4 pounds per acre and varied from a low of 12.4 pike and 13.3 pounds per acre to a high of 49.3 pike and 36.8 pounds per acre. The maximum biomass found in Bucks Lake is equivalent to the maximum found in other waters. The synchronous variations in abundance of northern pike and panfish which occurred suggests that there is a close relationship between the abundance of the predator species and the availability of forage species. Almost all the variations in standing crop of northern pike occurred among pike smaller than 18 inches in length.

The estimated annual fishing pressure for all species was 19.7 hours per acre and varied from 12.6 to 22.5 hours per acre. The catch per hour averaged 1.0 fish (species combined) and 57 percent of all anglers were successful. The catch of northern pike the year before the 18.0-inch size limit went into effect, was estimated at 9.6 pike weighing 9.8 pounds per acre. The first year after the 18.0-inch size limit was set, the average harvest of northern pike was 1.1 fish weighing 1.9 pounds per acre and the second year, 1.1 pike weighing 1.6 pounds per acre. The percentage of undersized pike caught was 62 percent before and 84 percent after the size limit.

High mortality is a normal characteristic of northern pike populations. In Bucks Lake, total annual mortality averaged 64 percent and varied from 35 to 84 percent during a nine-year period. The average annual exploitation rate by angling was 9 percent for the three years of creel census (1965-67), while natural mortality averaged 37 percent for the same years. Because total mortality was high, in years when fishing pressure was not, most pike appear to be dying of natural causes. On the average, the majority of northern pike caught by anglers are pike which would have died anyway during the year from natural causes.

No northern pike tagged in Bucks Lake were captured in downstream areas despite intensive efforts to determine the extent, if any, of such downstream migration.

From a comparison of several population parameters and fishing statistics before and after the size limit was fixed, it was concluded that an 18.0-inch size limit on northern pike did not accomplish its intended purpose and is generally not an effective management technique.

APPENDIX

TABLE 8

Estimated Number, 95 Percent Confidence Limits and Sample Sizes of Northern Pike from Bucks Lake, 1961–1970

Year of Estimate	10.0–13.9 Inches	14.0–17.9 Inches	18.0–21.9 Inches	22.0+ Inches	Totals: 14.0 Inches & Larger	Totals: 10.0 Inches & Larger
1961						
Spring						
Population Estimate	–	453	262	17*	732	–
Confidence Limits	–	256–1533	156–700	–	412–2233	–
Sample Sizes (m, c, r)**	8,23,–	46,68,6	42,49,7	4,5,–	–	–

TABLE 8 (Cont.)

Estimated Number, 95 Percent Confidence Limits and Sample Sizes of Northern Pike from Bucks Lake, 1961–1970

Year of Estimate	10.0–13.9 Inches	14.0–17.9 Inches	18.0–21.9 Inches	22.0+ Inches	Totals: 14.0 Inches & Larger	Totals: 10.0 Inches & Larger
1962						
Spring						
Population Estimate	–	875	192	29	1096	–
Confidence Limits	–	384–2500	100–660	16–125	500–3285	–
Sample Sizes (m, c, r)**	19,27,–	50,69,3	33,34,5	9,12,3	–	–
1963						
Spring						
Population Estimate	–	1593	249	14	1856	–
Confidence Limits	–	256–3525	168–570	8–29	432–4124	–
Sample Sizes (m, c, r)**	49,55,–	141,112,9	57,47,10	8,6,3	–	–
1964						
Spring						
Population Estimate	885	1512	404	8	1924	2809
Confidence Limits	393–2950	1072–3217	246–1475	5–235	1323–4927	1716–7877
Sample Sizes (m, c, r)**	59,59,3	193,187,23	59,47,6	4,3,1	–	–
1965						
Spring						
Population Estimate	1578	1958	335	16	2309	3887
Confidence Limits	1049–2272	1339-3125	241–520	10–62	1590–3707	2639–5979
Sample Sizes (m, c, r)**	409,53,13	375,93,17	130,48,18	8,7,3	–	–
Fall						
Population Estimate	1573	2094	414	17*	2525	4098
Confidence Limits	933–2800	1507–3228	279–744	–	1786–3972	2719–6772
Sample Sizes (m, c, r)**	56,280,9	113,481,25	67,98,15	–,20,–	–	–
1966						
Spring						
Population Estimate	1162	1153	168	20	1341	2503
Confidence Limits	712–2689	907–1569	117–336	16–64	1040–1969	1752–4658
Sample Sizes (m, c, r)**	242,47,9	408,112,39	74,24,10	16,4,3	–	–
Fall						
Population Estimate	522	1727	283	10	2020	2542
Confidence Limits	171–1200	1075–2150	192–500	5–31	1272–2681	1443–3881
Sample Sizes (m, c, r)**	12,173,3	86,702,34	50,163,28	4,12,4	–	–
1967						
Spring						
Population Estimate	455	1461	294	13	1768	2223
Confidence Limits	291–838	1262–1830	224–405	9–30	1495–2265	1786–3103
Sample Sizes (m, c, r)**	67,128,18	366,474,118	85,120,34	8,10,6	–	–
Fall						
Population Estimate	246	1279	586	17*	1882	2128
Confidence Limits	120–360	550–1925	300-943	–	850–2868	970–3228
Sample Sizes (m, c, r)**	18,81,5	77,630,37	66,230,25	5,8,–	–	–
1968						
Spring						
Population Estimate	257	1343	442	15	1800	2057
Confidence Limits	184–405	1313–1500	390–535	10–39	1713–2074	1897–2479
Sample Sizes (m, c, r)**	81,72,22	630,530,248	230,199,103	8,14,7	–	–
1969						
Spring						
Population Estimate	–	931	478	32	1441	–
Confidence Limits	–	650–1500	364–656	22–73	1036–2229	–
Sample Sizes (m, c, r)**	7,30,–	195,104,21	164,101,34	15,14,6	–	–
1970						
Spring						
Population Estimate	–	710	311	16	1037	–
Confidence Limits	–	290–2470	180–610	11–90	481–3170	–
Sample Sizes (m, c, r)**	1,4,–	74,47,4	61,55,10	7,6,2	–	–

*In years when there were no recaptures, the average from other years (17) was used.

**m is the number of pike marked on the first run, c is the total number of marked pike recaptured and the number of unmarked pike captured on the second run and r is the number of marked pike recaptured on the second run.

TABLE 9
*Number and Average Total Length of 9 Age Groups of Northern Pike from Bucks Lake**

	Growing Seasons Completed								
	1	2	3	4	5	6	7	8	9
1961									
Avg. Length	7.9	12.2	15.4	16.9	18.9	19.3	21.0	–	31.7
No. Fish	38	23	17	27	19	19	8	0	1
1962									
Avg. Length	7.2	13.6	16.7	18.6	20.1	24.6	22.8	32.5	33.3
No. Fish	26	25	37	25	15	3	1	2	2
1963									
Avg. Length	8.0	12.2	15.8	17.9	18.9	23.3	23.0	28.6	27.8
No. Fish	41	70	120	45	17	3	3	2	1
1964									
Avg. Length	8.6	13.7	15.8	17.5	18.8	20.1	23.6	–	21.9
No. Fish	48	94	80	102	26	13	4	0	1
1965									
Avg. Length	8.0	12.9	14.5	17.4	19.0	20.3	22.0	21.7	–
No. Fish	12	88	32	28	62	26	11	3	0
1966									
Avg. Length	9.8	12.5	14.9	17.3	19.3	21.6	23.8	27.5	–
No. Fish	7	102	153	64	41	17	2	1	0
1967									
Avg. Length	8.1	13.1	15.4	17.7	19.8	21.0	–	–	–
No. Fish	51	67	99	105	60	18	0	0	0
1968									
Avg. Length	8.6	13.4	15.2	16.7	18.2	21.2	22.8	–	–
No. Fish	31	50	85	149	79	31	6	0	0
1969									
Avg. Length	8.8	12.2	14.9	16.6	19.2	20.3	21.0	–	–
No. Fish	35	18	39	36	44	45	12	0	0
All years									
Length									
Avg. Total Length	8.2	12.9	15.4	17.3	19.0	20.7	22.0	26.9	29.6
Avg. Annual Increments	8.3	4.7	2.4	1.9	1.6	2.3	1.5	–	–
Sum of Increments	8.3	13.0	15.4	17.3	18.9	21.2	22.7	–	–
Total No. Fish	289	538	662	581	363	175	47	8	5

*Based on fish taken during April and May, 1961–69.

TABLE 10

Total Harvest Estimated from a Stratified Creel Census, 1964–68

Year and Season	Bluegill	Perch	Crappie	Rock Bass	Pumpkin-seed	Northern Pike	Total
1964–65							
Ice							
Total no. fish	1,702	532	29	5	405	448	3,121
No. fish per acre	20.6	6.4	0.4	–	4.9	5.4	37.7
No. lbs. per acre	11.3	2.2	0.2	–	1.4	7.6	22.7
1965–66							
Open Water							
Total. no. fish	177	116	0	0	15	570	878
No. fish per acre	2.2	1.4	–	–	0.2	6.9	10.7
No. lbs. per acre	0.8	0.3	–	–	–	6.2	7.3
Ice							
Total no. fish	305	71	19	3	13	227	638
No. fish per acre	3.7	0.9	0.2	–	0.2	2.7	7.7
No. lbs. per acre	1.3	0.3	0.2	–	0.1	3.6	5.5
Annual total							
Total no. fish	482	187	19	3	28	797	1,516
No. fish per acre	5.9	2.3	0.2	–	0.4	9.6	18.4
No. lbs. per acre	2.1	0.6	0.2	–	0.1	9.8	12.8
1966–67							
Open Water							
Total no. fish	17	9	0	0	0	19	45
No. fish per acre	0.2	0.1	–	–	–	0.2	0.5
No. lbs. per acre	0.1	–	–	–	–	0.4	0.5
*Ice**							
Total no. fish	23	360	3	0	3	76	465
No. fish per acre	0.3	4.4	–	–	–	0.9	5.6
No. lbs. per acre	0.1	1.6	–	–	–	1.5	3.2
Annual total							
Total no. fish	40	369	3	0	3	95	510
No. fish per acre	0.5	4.5	–	–	–	1.1	6.1
No. lbs. per acre	0.2	1.6	–	–	–	1.9	3.6
1967–68							
Open Water							
Total no. fish	109	0	0	0	0	39	148
No. fish per acre	1.3	–	–	–	–	0.5	1.8
No. lbs. per acre	0.5	–	–	–	–	0.6	1.1
Ice							
Total no. fish	0	114	16	0	0	51	181
No. fish per acre	–	1.4	0.2	–	–	0.6	2.2
No. lbs. per acre	–	0.6	0.1	–	–	1.0	1.7
Annual total							
Total no. fish	109	114	16	0	0	90	329
No. fish per acre	1.3	1.4	0.2	–	–	1.1	4.0
No. lbs. per acre	0.5	0.6	0.1	–	–	1.6	2.8

* These figures have been adjusted because of biased sampling. Ninety–four percent of all December creel checks were made in the afternoon. Randomized checks in December of 1965 and 1967 showed that afternoon fishing accounted for 85 percent and 75 percent of the total, respectively. Therefore, the afternoon checks in December, 1966 were estimated as accounting for 80 percent of the total fish taken and the total hours and catch were adjusted accordingly.

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