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CHARACTERISTICS OF A NORTHERN PIKE SPAWNING POPULATION

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ABSTRACT

The northern pike spawning population in Gilbert Lake was studied in 1968 and 1969 to determine characteristics of northern pike spawning habitat, gain additional knowledge on early life history, describe characteristics of the spawning population, and determine the extent of angler harvest of the spawning population.

The combined northern pike spawning population in Gilbert and Big Cedar lakes consisted of 2,500-3,000 fish with about one-half spawning in Gilbert Lake. Immigration into the spawning areas began in mid-March and varied directly with water temperature and ice breakup on Gilbert Lake. The average sex ratio ranged from 1 female to 2.0-2.3 males.

Female northern pike grew at a faster rate than males. The growth rate of northern pike in these waters is exceptionally good compared to the growth of northern pike in other waters. Male and female northern pike were mature at age II. A wide range of size was observed among male and female northern pike of the same age.

Egg densities and hence, spawning activity, were related to vegetation type. Egg densities were greatest where dense sedge mats and wild celery remains were present.

Harvest data showed that from 11 May 1968 through 31 August 1970, 131 tagged fish were taken by anglers in Big Cedar Lake for a 17.6-percent return of the 744 fish originally tagged. The greatest number of tagged fish were caught in May and June. Females were considerably more susceptible to angling than males.

CHARACTERISTICS OF A NORTHERN PIKE SPAWNING POPULATION

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INTRODUCTION

The loss of marshy, low-lying areas adjacent to many Wisconsin lakes is proceeding at a rapid rate because of man's activities. These areas are quite often known or suspected to be suitable spawning habitat for northern pike, *Esox lucius* Linnaeus. The effect of the loss of these spawning areas has not been thoroughly evaluated to date, but it seems likely that the loss can only be detrimental to northern pike populations.

The objectives of this study were to determine the essential characteristics of northern pike spawning habitat, to increase our knowledge of the early life history, to determine the characteristics of the spawning population, and to determine the extent of angler harvest of the spawning population. This type of data was needed to determine if the marshy, low-lying areas adjacent to lakes are essential to maintain adequate northern pike populations; such information will provide leads that can be applied in the development of managed northern pike spawning and rearing areas.

Northern pike rate high to Wisconsin and out-of-state anglers, especially in southern Wisconsin. Its value is enhanced by the fact that it bites more readily than many other game fish. According to a 1969 mail survey, the northern pike was the second most abundant game fish harvested, exceeded only by the harvest of walleye (Churchill 1970). Even though the northern pike is an important game fish in Wisconsin, knowledge essential to its management is inadequate.

STUDY AREA

Big Cedar and Gilbert lakes are located in Washington County in east central Wisconsin. Big Cedar Lake is an elongate lake of glacial origin and is situated between two high ridges left by the Green Bay lobe of the retreating Wisconsinan glacier. It has an area of 1,004 surface acres (406.4 ha) and a maximum depth of 105 ft (32 m). The lake consists of a deep south basin connected by a broad shallow terrace to a shallower north basin. Springs and seepage are major water sources. The lake is a moderately fertile, hard water lake having a methyl orange alkalinity of 98-155 ppm and a pH of 8.9.

Gilbert Lake adjoins Big Cedar Lake at its northern end by a narrow, but navigable channel. Gilbert Lake was originally part of Big Cedar Lake separated from the main body by two small islands. Currents in the big lake formed bars between the islands, creating a distinctly separate lake. Gilbert Lake is long and narrow, covering an area of 40 surface acres (16.2 ha). Maximum depth of about 8 ft (2.4 m) occurs in the extreme northern end of the lake; most of the rest of the lake is less than 2 ft (0.6 m) in depth. Several springs present along the edge of the channel joining the two lakes provide the major source of water for the lake. Gilbert Lake is a hard water and moderately fertile lake.

Gilbert Lake is approaching extinction due to the aquatic and marsh vegetation which encroach on its shores and add debris to its bottom. The lake is encircled by a sedge and tamarack marsh, and vegetation encroaching on the shoreline has produced a spongy, unstable shore. By early summer, the shallow portion of the lake is choked with vegetation and the only large areas of open water are at the north end. Water lilies, *Nymphaea tuberosa,* and scattered beds of *Nuphar* sp. are found throughout the lake and appear to almost completely cover the entire surface except for the extreme northern end. Cattails, *Typha* sp., are present along the shoreline. Bulrush, *Scirpus validus,* is found in rather heavy concentrations immediately south of the extreme northern end of the lake and is found in scattered concentrations elsewhere. Pondweed is found in many areas; two species, *Potamogeton amplifolius* and *P. pectinatus,* are dominant in the northern part of the lake. Bladderwort, *Utricularia vulgaris,* is scattered throughout the lake. In the southern half of the lake, wild celery, *Vallisneria americanus,* and an unidentified sedge are common.

Gilbert Lake was maintained as a fish refuge from 1925 to 1972. During those years, no fishing was allowed at any time.

SAMPLING

Adult Fish

All adult northern pike captured in this study were taken in fyke nets of various sizes. One 3-ft (0.9 m) fyke net made of 1.5-inch (38 mm) stretch mesh was set in the channel from Big Cedar Lake into Gilbert Lake during the spawning runs to trap adults moving into Gilbert Lake from 20 March to 9 April 1968 and from 27 March to 9 April 1969. The net completely blocked off the entire channel. In 1968, from 27 March to 9 May, another 3-ft (0.9 m) fyke net was set in the channel to trap adult northern pike emigrating from Gilbert Lake. Thus in 1968 between 27 March and 9 April, two nets were set simultaneously in the channel between Gilbert and Big Cedar lakes, but in reverse directions.

From 28 March to 3 April 1968, two 4-ft (1.3 m) fyke nets made of 1.5-inch (38 mm) stretch mesh and four 2-ft (0.6 m) fyke nets made of 1-inch (25 mm) stretch mesh were set in Gilbert Lake to obtain a sample for estimating the site of the spawning population (discussed further in a later section).

On 12 April 1969, four 4-ft (1.3 m) fyke nets made of 1.5-inch (38 mm) stretch mesh were set on the north end of Big Cedar Lake to obtain a sample for estimating the size of the spawning population. The entire south half of the lake was still frozen over at this time. These four nets were lifted and pulled out on 14 April.

Eggs, Fry, and Fingerlings

Eggs, fry, and fingerlings were collected in Gilbert Lake from 2 April to 4 June 1968 by means of fine mesh dip nets that were swept through the vegetation. Fine mesh seines, 1/8- and 1/4-inch mesh (3-6 mm), were used to collect some of the fingerlings.

Plankton

Zooplankton samples were collected periodically during and after the spawning period of 1968. Horizontal tows near the surface were made with a Clarke-Bumpus plankton sampler. Plankton hauls were of 3-minute duration and a No. 2 plankton net and bucket were used. Samples in most portions of the southern and northern areas of the lake were taken with the Clarke-Bumpus sampler. When vegetation became too abundant in the southern area, samples were taken by dipping with a graduated bucket. Each dip had a volume of 9.4 l; 20 dips constituted a sample at each station. The sample was strained through a No. 2 plankton net and bucket.

TAGGING

In 1968, each of the fish captured during the spawning migration into Gilbert Lake, during emigration from Gilbert Lake, and during netting in Gilbert Lake from 20 March to 9 May 1968 were tagged either with a No. 3 aluminum strap tag or with No. 3 and No. 4 Monel metal jaw tags. Generally, fish over 31 inches in total length were marked with Monel tags passing around the maxillary and premaxillary bones (Shetter 1936). Smaller fish were tagged in the lower jaw with aluminum strap tags, except for a few of the first ones netted during the spawning run that were tagged in the upper jaw with Monel tags. In addition to being tagged, all fish were also fin clipped. In 1969, all fish were fin clipped only.

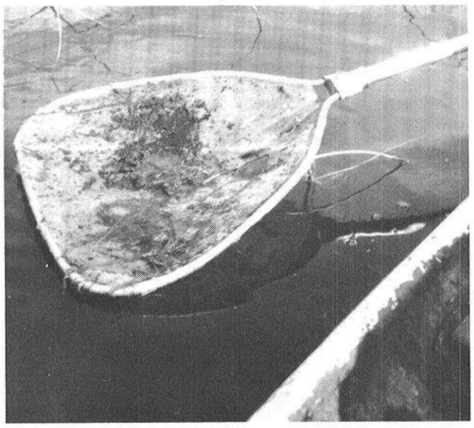
Recaptures of tagged northern pike from Big Cedar Lake were reported voluntarily by anglers; no rewards were offered. News releases were prepared to alert anglers to the presence of tagged fish and to provide information on how to report the capture of tagged fish. Reporting forms that could be used by anglers to report tagged fish were distributed to resorts on Big Cedar Lake. To stimulate cooperation, all reports of tagged fish were acknowledged with a form letter giving the sex and age of the fish at the time of tagging.

COLLECTION OF FISH DATA

Length Measurements and Sex Determinations

All yearling and older northern pike collected were measured to the nearest tenth of an inch in total length. Fry and fingerling fish were measured to the nearest millimeter in total length. All measurements have been converted to the metric system.

Sex was determined for all mature fish captured. Since all of the fish were taken during the spawning season, it was possible to determine sex of the fish by external examination. All males were classified as ripe since milt was readily shed from all of them. Females were classified as hard, when only a few eggs were shed as pressure was applied to the abdominal walls; as ripe, when eggs were readily shed when slight pressure was applied to the abdominal walls; and as spent, when only a few eggs could be extruded and the abdominal area was extremely flabby.



Fine mesh net used to sample northern pike eggs and fry.

No. 4 Monel-metal jaw tag passing around the maxillary and premaxillary bones.

Fecundity Determinations

Eleven hard females were collected during the spawning run on 26 March 1968. The fish were weighed to the nearest gram and measured to the nearest millimeter in total length; their ovaries were removed and preserved in 20 percent Formalin (Lagler 1956).

Fecundity of each of the 11 females was determined by the volumetric method. After the outer tissue of the ovaries was cut and excess liquid was removed, the volume of each ovary was determined. Along the length of each ovary, four evenly spaced samples were taken. The combined volume of these four samples was approximately 5 percent of the ovary's total volume.

A counting board was used to count the number of eggs in each sample. This counting board consisted of a 1½- (38 mm) by 5-inch (127 mm) piece of 3/8-inch (9.5 mm) plastic containing 105 holes which were 1/8 inch (3 mm) in diameter and depth (Carbine 1944).

Stomach Analyses

The entire stomach and intestine was examined from 46 fry and fingerlings collected in Gilbert Lake, 15 April to 4 June 1968. Quantitative determination consisted of counting each individual food item (whole organisms and fragments). Miscellaneous plant remains and items that were assumed taken incidental to feeding (vegetation and woody materials) were not recorded. Percentages are based on the number of stomachs containing food.

The food items in the stomachs are expressed as percentage frequency of occurrence and mean number of organisms per stomach.

Population Estimates

The population of northern pike in Gilbert and Big Cedar lakes was estimated from the Petersen equation:

$$P = M(U+R)/R$$

where M is the number of fish marked during the first period, U is the number of unmarked fish captured during the second period, and R is the number of marked fish recaptured during the second period. Fyke nets, as described earlier, were used for the mark and recapture periods. The fish were either tagged, fin clipped or both during the mark and recapture periods in 1968 and only fin clipped during the mark and recapture periods in 1969.

In 1968, the estimate of the spawning population in Gilbert Lake was based on fish tagged and fin clipped on the spawning run into Gilbert Lake from 20 March through 28 March 1968 and on fish netted in Gilbert Lake on 29 March to 3 April 1968.

Three methods were used in 1969 to estimate the spawning population in both lakes combined and were: (1) based on fish tagged and fin clipped in 1968 and recaptured on the spawning run into Gilbert Lake from 27 March through 9 April 1968; (2) based on fish tagged and fin clipped in 1968 and recaptured in Big Cedar Lake on 14 April 1968; and (3) based on fish fin clipped on the spawning run into Gilbert Lake from 27 March through 9 April 1969 and recpatured in Big Cedar Lake on 14 April 1969.

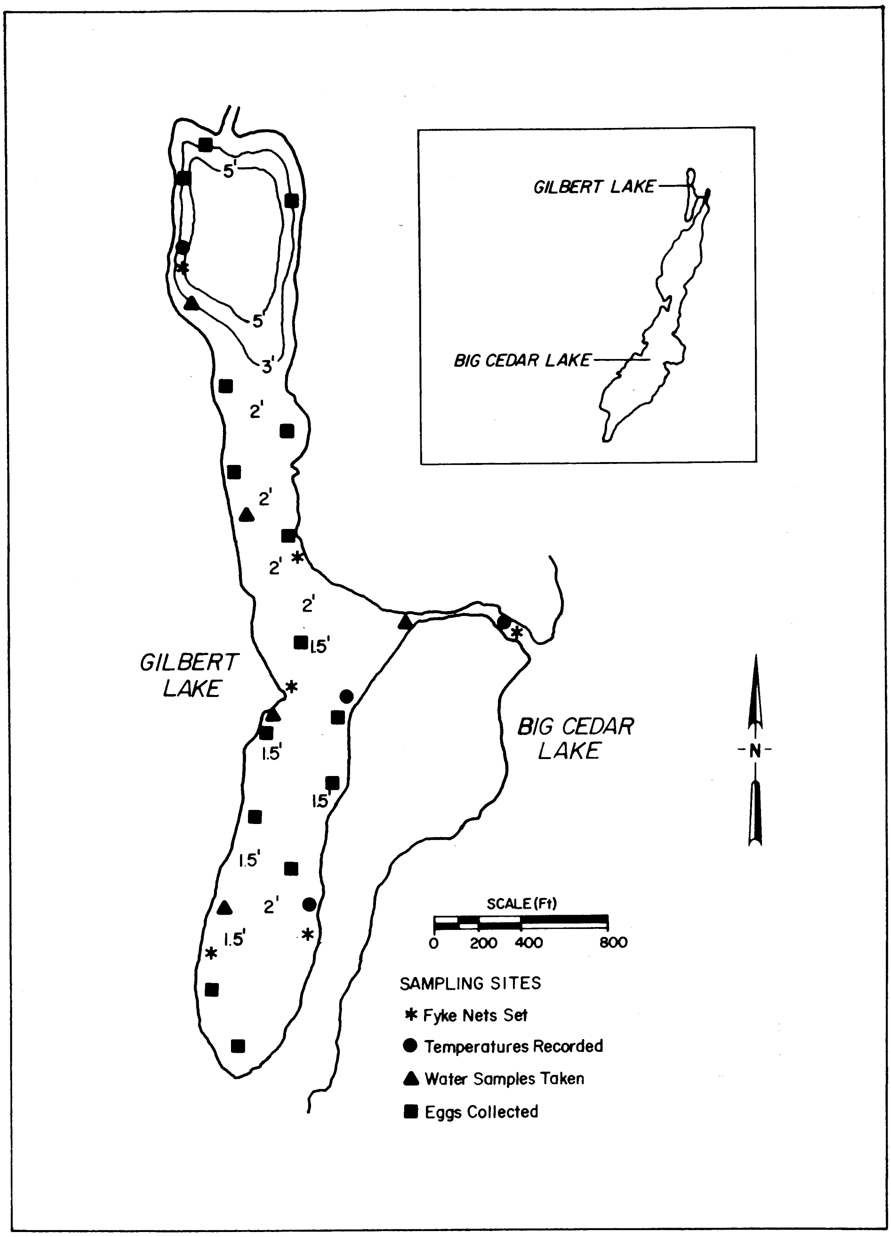


FIGURE 1. *Study area and sampling sites.*

Aging

Scales were taken from an area above the lateral line and about midway along the body length. Scales from this area are more typical in form and are larger in size than from other parts of the body (Frost and Kipling

1959). Three to six scales were impressed on cellulose acetate slides by a roller press similar to that described by Smith (1954). Examination and measurements of scales were made with a microprojector at the magnification 44x. The distance from the focus to the margin of the scale and to each annulus was measured to the nearest millimeter along the anterior radius most nearly colinear with the focus, as described by Hile (1954). The validity of the annulus as a year mark for this species was established by Williams (1955) from observations of known-aged fish over three years.

A body-scale relationship was determined from the measurement of 629 northern pike grouped into one-half inch total length intervals from 13 to 40 inches (33-102 cm).

Calculations of length at each annulus were made from measurements of the anterior radius applied in the formula:

$$L, = C+S,/S\ (L-C)$$

where *L,* is the length of the fish at the time of each annulus formation, *C* is the length of the fish at the time of scale formation, *S,* is the length of the anterior radius of the scale at each annulus, *S* is the length of the anterior radius at the time of capture, and *L* is the total length of the fish at time of capture.

ENVIRONMENTAL MEASUREMENTS

Water temperatures before and during the spawning period were recorded on either an 8-day Ryan or a 7-day Taylor thermograph. Taylor minimum-maximum thermometers were also used to record temperatures on the spawning sites. Water temperatures were recorded in the channel leading into Gilbert Lake and in Gilbert Lake (Fig. 1).

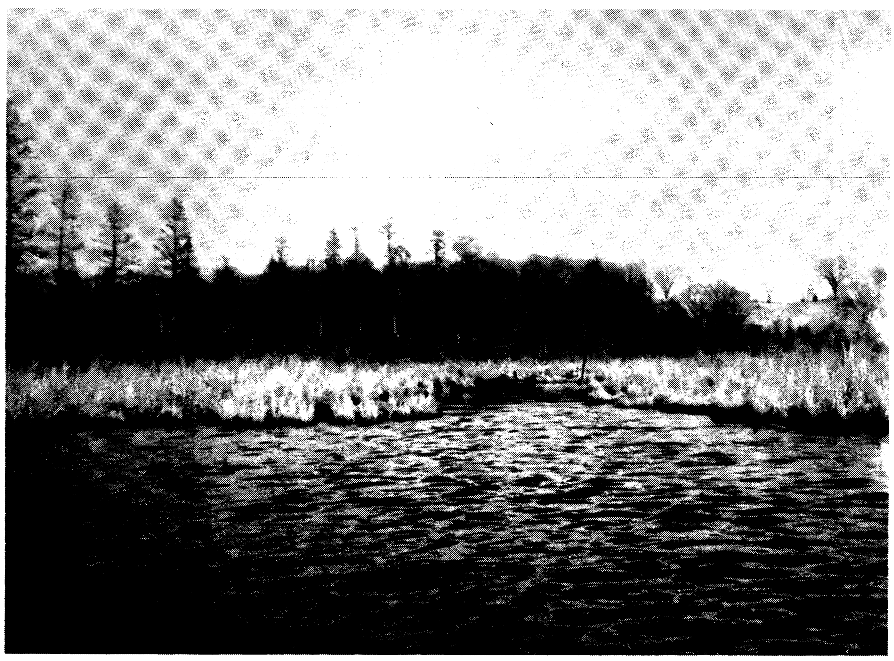
From 20 March to 4 June 1968, weekly measurements of water chemistry were obtained on Gilbert Lake. These data consisted of measurements of dissolved oxygen, pH, and alkalinity.

REPRODUCTION

MOVEMENTS OF ADULT FISH

Immigration

Gilbert Lake warms before Big Cedar Lake in early spring and northern pike congregate in or near the channel between the two lakes even before the ice begins to recede on the lakes. Springs along the channel free it of ice 1 to 2 weeks before the ice goes out in the lakes. In some years, the channel may not even freeze over throughout the winter. Franklin and Smith (1963) reported that the first appearance of the adults in George Lake off the entrance of a nursery slough coincided with the development of sufficient clearance between inshore ice and the lake bottom to provide access to the nursery slough. This same condition has been noted by other biologists (Embody 1918; Carbine 1942).



Channel between Gilbert and Big Cedar lakes. Fyke net set across entire channel (center of picture) to trap fish during immigration and emigration periods.

The channel between Gilbert and Big Cedar lakes was completely blocked off with a fyke net from 20 March to 9 April 1968 (Table 1) and from 27 March to 9 April 1969 (Table 2) to capture northern pike entering into Gilbert Lake to spawn. In 1968, the spawning immigration must have begun before 19 March, because fish were netted the first day after the net was set and an appreciable number of untagged fish (not netted in the channel) were subsequently captured in Gilbert Lake. Likewise in 1969, it is not known if the net was set before immigration began, since heavy snow fall and extremely cold weather prevented us from lifting the net until four days after it was set.

Water temperatures during the entire immigration period ranged from 33 to 57° F (0.6-13.9° C), but 38-51° F (3.4-10.6° C) was the temperature

TABLE 1. *Daily movement of male and female northern pike during the 1968 spawning run into Gilbert Lake.*

Dates Netted*	Male No. of Fish	Male Average Length Inches	Male Average Length (cm.)	Male Percent in Run Daily	Male Percent in Run Accumulative	Female No. of Fish	Female Average Length Inches	Female Average Length (cm.)	Female Percent in Run Daily	Female Percent in Run Accumulative	Ratio of Females to Males	Total No. of Fish
March												
20	0	– –	– –	– –	– –	3	32.8	(83.3)	2.4	2.4	3:0	3
21	32	22.7	(57.7)	11.1	11.1	7	25.2	(64.0)	5.6	8.0	1:4.6	39
22	26	22.9	(58.2)	9.0	20.1	3	21.3	(54.1)	2.4	10.4	1:8.7	29
23	29	22.8	(57.9)	10.1	30.1	9	29.0	(73.7)	7.2	17.6	1:3.2	38
24	52	23.2	(58.9)	17.9	48.0	15	25.7	(65.3)	12.0	29.6	1:3.5	67
25	27	23.5	(59.7)	9.3	57.3	19	26.7	(67.8)	15.2	44.8	1:1.4	46
26	93	22.6	(57.4)	32.2	89.5	32	26.1	(66.3)	25.6	70.4	1:2.9	125
27	22	21.8	(55.4)	7.6	97.1	16	25.3	(64.3)	12.8	83.2	1:1.4	38
28	4	21.2	(53.8)	1.4	98.5	1	33.2	(84.3)	0.8	84.0	1:4.0	5
30	1	32.5	(82.5)	0.4	98.9	5	31.4	(79.7)	4.0	88.0	1:0.2	6
April												
2	0	–	–	–	–	3	33.3	(84.5)	2.4	90.4	3:0	3
3	1	21.8	(55.4)	0.4	99.3	8	23.3	(59.2)	6.4	96.8	1:0.1	9
4	2	22.5	(57.2)	0.7	100.0	4	24.7	(62.7)	3.2	100.0	1:0.5	6
Total	289					125						414
Average		22.8	(57.9)				26.5	(67.3)			1:2.3	

*The fyke nets were lifted on 1, 5, 6, and 9 April, but no fish were found in the nets on these dates. On 29 and 31 March and on 7 and 8 April, the nets were not lifted.

TABLE 2. *Daily movement of male and female northern pike during the 1969 spawning run into Gilbert Lake.*

Dates Netted*	Male No. of Fish	Male Average Length Inches	Male Average Length (cm.)	Male Percent in Run Daily	Male Percent in Run Accumulative	Female No. of Fish	Female Average Length Inches	Female Average Length (cm.)	Female Percent in Run Daily	Female Percent in Run Accumulative	Ratio of Females to Males	Total No. of Fish
March												
31	43	24.8	(63.0)	23.4	23.4	12	26.3	(66.8)	13.3	13.3	1:3.6	55
April												
2	10	25.5	(64.8)	5.4	28.8	4	27.2	(69.1)	4.5	17.8	1:2.5	14
4	14	25.3	(64.3)	7.6	36.4	12	29.9	(75.9)	13.3	31.1	1:1.2	26
5	5	23.3	(59.2)	2.7	39.1	9	23.8	(60.5)	10.0	41.1	1:0.6	14
7	57	22.2	(56.4)	31.0	70.1	27	24.3	(61.7)	30.0	71.1	1:2.1	84
9	55	21.9	(55.6)	29.9	100.0	26	24.2	(61.5)	28.9	100.0	1:2.1	81
Total	184					90						274
Average		23.1	(58.7)				25.4	(64.5)			1:2.0	

*From 27 through 30 March, the fyke nets were set but were not lifted. Likewise, on 1, 3, 6, and 8 April, the nets were not lifted.

range during the period when most immigration took place. The intensity of the immigration varied directly with water temperatures and the peak coincided with ice breakup on Gilbert Lake which occurred on 25 March 1968 and 9 April 1969. In George Lake, Minnesota, the first immigration occurred when water temperatures were between 34 and 40°F (1.1-4.5°C), but immigration increased in intensity when water temperatures reached the 36-37°F (2.2-2.8°C) range (Franklin and Smith 1963). Clark (1950) recorded spawning runs at 32°F (0°C) in Ohio waters. Water temperatures during the peak immigration period in Gilbert Lake were thus higher than those reported for George Lake and for Ohio waters.

The pattern of spawning run over a 24-hour period was not studied in detail. However, based on net checks made twice daily on 25 and 26 March 1968, northern pike appeared to be as active in the afternoon and early evening as during the late evening and early morning. Similar numbers of fish were taken during both periods. No inference could be made about movement during late morning because the run started to decrease rapidly on 26 March. Franklin and Smith (1963) reported that in Lake George, the peak fish passage occurred between 9:00 p.m. and 4:00 a.m. in 1956 and between 8:00 p.m. and 9:00 p.m. in 1957. Carbine (1942) reported that 95 percent of the fish at Peterson's Ditches, Houghton Lake, Michigan, ran between 9:00 p.m. and 6:00 a.m., with most of them moving between 9:00 p.m. and 3:00 a.m. and with the peak occurring between 9:00 p.m. and midnight.

At Gilbert Lake, the immigration period lasted 15 consecutive days in 1968; however, the beginning of the run had occurred before the fyke net was set. In 1969, fish were taken for 10 consecutive days. Beginning and ending dates were not known, however, since the beginning of the run had most likely occurred before the fyke net was set and the net was pulled before the run was completed. In 1968, most of the run passed in 4 consecutive nights while in 1969, most of the run passed in 2 consecutive nights. In George Lake, most of the run passed in 5 or 6 consecutive nights if the temperature did not drop (Franklin and Smith 1963).

TABLE 3. *Population estimates of spawning populations in Big Cedar and Gilbert Lakes, 1968 and 1969.*

Lake and Year Of Estimate	No. Males	No. Females	No. in Combined Population: Total	No. in Combined Population: Confidence Limits
Gilbert Lake				
1968*	757	456	1,170	1,000-1,400
Big Cedar and Gilbert Lakes				
1969**	1,740	928	2,660	2,300-3,300
1969***	1,830	1,355	2,980	2,500-3,700
1969****	1,800	1,156	2,880	2,100-4,500

* Based on fish tagged and fin clipped on the spawning run into Gilbert Lake from 20 through 28 March, 1968 and on fish netted in Gilbert Lake on 29 March 1968.

** Based on fish tagged and fin clipped in 1968 and recaptured on the spawning run into Gilbert Lake from 27 March through 9 April 1969.

*** Based on fish tagged and fin clipped in 1968 and recaptured in Big Cedar Lake on 14 April 1969.

****Based on fish fin clipped on the spawning run into Gilbert Lake from 27 March through 9 April 1969 and recaptured in Big Cedar Lake on 14 April 1969.

Emigration

In 1968, a 3-ft (0.9 m) fyke net was set in the channel on 27 March, about 1 to 2 days after the peak of the spawning run occurred. Fish caught in the net would reflect emigration of the adults out of Gilbert Lake. Fish were captured the first day after the net was set; the greatest net catches were made during the first few days. A total of 183 northern pike (tagged and untagged) were captured over the netting period which extended to 9 May. It appeared that some random movement was occurring between Gilbert and Big Cedar lakes because some of the females that were netted during the first several days were ripe.

Of the 183 fish netted, 120 were males, 62 were females, and 1 could not be sexed. The sex ratio was 1 female to 1.9 males. The males and females averaged 23.1 and 26.5 inches (58.4-67.3 cm) in total length, respectively. Out of the 183 fish, 87 males and 44 females (or 71.6 percent) had been tagged earlier during the immigration period.

Only a small fraction of the spawning population was netted during the emigration period. When most of the emigration was occurring, fish could have escaped from the net, since holes were found frequently in the net during that period. Net catches decreased to very low levels in May and the net was removed on 9 May. Subsequent angler catches of fish tagged in Gilbert Lake indicated, however, that emigration continued through the end of May. In Lake George, adult fish began to leave the spawning marsh shortly after spawning was completed, but some individuals remained for considerable periods (Franklin and Smith 1963). These authors found that the fish at Lake George remained in the spawning marsh for 107 days in 1956, 80 days in 1957, and 71 days in 1958.

NATURE OF SPAWNING POPULATIONS

Population Size

In 1968, the spawning population in Gilbert Lake was estimated to be comprised of 757 males and 456 females or a combined estimated population of 1,170 fish (Table 3). There was sufficient evidence from test netting in 1968 to indicate that a majority, but not all, of the northern pike spawning population in Big Cedar Lake spawned in Gilbert Lake.

Three methods were used in 1969 to obtain an estimate of the spawning population in both lakes. Population size was estimated at 1,740, 1,830, and 1,800 males and 928, 1,355, and 1,156 females. All of the 1969 estimates were quite consistent, indicating a standing population of 2,500-3,000 spawning adults (2.5-3.0 fish per acre), with about one-half of the population spawning in Gilbert Lake.

Condition of Spawners

Inasmuch as little is mentioned in the literature on the condition of fish after spawning, it is interesting to note that the condition of spawning northern pike in Gilbert Lake was adversely affected by spawning activities. Many of the fish netted after spawning had gashes on their bodies and fins which were badly frayed. Some dead fish were observed in the lake after spawning had occurred.

Sex Ratios

Males and females differed in their pattern of movement into Gilbert Lake. Relative to the total number of males in the run, males tended to move into and out of the spawning area faster than females moved. By 24 March 1968, 48.0 percent of the males had already moved into the spawning area as compared to 29.6 percent of the females (Table 1). From 30 March through 4 April 1968, the last day that fish were netted, the run consisted primarily of females. Of the total number of fish captured during the entire netting period, 1.5 percent of the males and 16.0 percent of the females were netted from 30 March through 4 April 1968. These results agree with the findings of other biologists who have reported that males enter the spawning area first (Clark 1950; Fabricius and Gustafson 1958). Carbine (1942) observed this tendency in 1940, but not in 1939. Franklin and Smith (1963) noted higher ratios of males to females early and late in the run, but the numbers of fish involved were small and the data were inconclusive.

The majority of the northern pike netted were males (Tables 1 and 2). Out of 424 fish netted in 1968, 289 were males, 125 were females, and 10 could not be sexed. The sex ratio was 1 female to 2.3 males. In 1969, 184 males were netted from a total of 274 fish for a sex ratio of 1 female to 2.0 males. These sex ratios agree with the findings of other biologists who have reported the ratio of adult fish on the spawning grounds to range from 1 female for 1-3 males (Carbine 1942; Clark 1950; Franklin and Smith 1963).

Length Frequency

A trend in the average size of fish netted during the spawning run was found for males but not for females. The average size of the males increased as the run progressed and then declined after the peak (Tables 1 and 2). Evidence of this trend was found by some biologists but not by others: Smitt (1895) and McNamara (1937) reported an increase in the average size of male and female fish as the run progressed; however, Franklin and Smith (1963) and Carbine (1942) found little change in the average size of male and female fish during the run.

The length frequency of male and female northern pike taken in Gilbert Lake, 1968 and 1969 and in Big Cedar Lake, 1969 is shown in Table 4. Males in the spawning run ranged between 13.3 and 33.4 inches (33.8-84.8 cm), with the majority of males and females ranging between 19 and 25 inches (48.3-63.5 cm).

The average length of males in Gilbert Lake was 22.8 inches (57.9 cm) in 1968 and 23.1 inches (58.7 cm) in 1969, while for the females, it was 26.5 inches (67.3 cm) in 1968 and 25.4 inches (64.5 cm) in 1969 (Table 5). In Big Cedar Lake in 1969, males averaged 22.7 inches (57.7 cm) in length and females, 26.3 inches (66.8 cm). The average lengths of the male and female northern pike in Gilbert and Big Cedar lakes were greater than those reported by Franklin and Smith (1963) for northern pike in Lake George and by Carbine (1942) for fish in Houghton Lake.

Age and Growth

The body-scale relationship was determined to be:

$$L = 1.106 + 2.541\,(R)$$

where L is the total length in inches and R is the length of the anterior scale radius in mm x 44. The overall body-scale relation is linear. Franklin and Smith (1960) determined the development of the scale patterns in northern pike. According to their calculations, the length of the fish at the time scales developed in the area in which scales were taken for this study was 36 mm (1.4 inches) which is slightly more than the value (1.106 inches) from the body-scale relation. For purposes of back calculations, 1.4 inches was used, since it was considered more reliable.
males (452 fish) and females (173 fish) in different age groups indicated differences in growth rate, so the data for males and females were kept separate (Tables 6 and 7).

Obtaining length-frequency information from spawning northern pike.

Two estimates of general growth are given in the bottom section of Tables 6 and 7. One is based on the grand average calculated total lengths and the second on the summation of the grand average annual increments of length. The present discussion is based on the sums of increments, since this curve should represent the average growth that northern pike might have if the population were not subjected to selective destruction of individuals with the more rapid growth (Fig. 2).

Female northern pike grew at a faster rate than males (Fig. 2). After the first growing season, females were 0.5 inches (13 mm) longer than males and at the end of the second year, the difference had increased to 1.8 inches (46 mm). At the end of the ninth year, female northern pike were 7.1 inches (180 mm) longer than males. Differential growth between sexes has also been noted by other investigators.

Male northern pike usually grow more slowly than the females (McCarraher 1957; Moen and Lindquist 1954) particularly after the second year (Frost and Kipling 1959; Frost and Kipling 1965; Clark and Steinbach 1959).

The average annual growth increments for male northern pike decreased from 9.8 inches (249 mm) during the first year to 3.4 inches (86 mm) by the third year. From the fourth through tenth year of life, annual growth increments decreased only from 1.8 to 0.9 inches (46-23 mm). For females, the average annual growth increments decreased from 10.3 inches (262 mm) during the first year to 3.0 inches (76 mm) by the fourth year. From the fifth through ninth year of life, annual growth increments increased from 1.4 to 2.0 inches (36-56 mm).

The growth rate of northern pike in Gilbert and Big Cedar lakes is exceptionally good compared to the growth of northern pike in other waters. At the end of their third year of life, male northern pike averaged 20.4 inches (51.8 cm) in total length, while females averaged 23.1 inches (58.7 cm). The average total length of northern pike from 8 drainage lakes in northwestern Wisconsin was 17.4 inches (44.2 cm) for sexes combined (Snow 1969). Average growth for northern pike (sexes combined) in Bucks Lake, an 83-acre (23.6 ha) impoundment in Rusk County was 15.4 inches (39.1 cm) at the end of the third year (Snow and Beard 1972). Druckenmiller (1972) reported an average

TABLE 4. *Length frequency distribution (in percent) of males and females in Gilbert and Big Cedar Lakes, March through April 1968-69.*

Length Groups (Total Length in Inches)*		Males Gilbert 1968	Males Gilbert 1969	Males Big Cedar 1969	Females Gilbert 1968	Females Gilbert 1969	Females Big Cedar 1969
13.0–15.9	(33.0–40.4)	1.3	0	0	1.6	1.1	1.3
16.0–18.9	(40.6–48.0)	11.4	6.6	4.9	0.8	5.5	2.6
19.0–21.9	(48.3–55.6)	31.5	30.0	40.1	22.4	25.5	18.1
22.0–24.9	(55.9–63.2)	30.8	34.8	35.7	20.8	23.4	23.4
25.0–27.9	(63.5–70.9)	15.9	19.6	15.0	14.4	15.6	15.6
28.0–30.9	(71.1–78.4)	6.9	7.6	3.3	12.8	8.9	18.2
31.0–33.9	(78.7–86.1)	2.2	0.5	1.0	16.0	13.4	16.9
34.0–36.9	(86.3–93.7)	0	0	0	9.6	5.5	1.3
37.0–40.9	(93.9–103.8)	0	0	0	1.6	1.1	2.6
Total Fish		289	184	207	125	90	77

*Centimeters in parenthesis.

TABLE 5. *Average lengths of males and females in spawning runs from various localities.*

Location and Source of Data	Year	Total Length in Inches* Male		Female	
Gilbert Lake (present study)	1968	22.8	(57.9)	26.5	(67.3)
	1969	23.1	(58.7)	25.4	(64.5)
Big Cedar Lake (present study)	1969	22.7	(57.7)	26.3	(66.8)
Lake George, Minnesota (Franklin and Smith 1963)	1957	17.8	(45.2)	18.8	(47.8)
	1958	15.8	(40.1)	16.8	(42.7)
Houghton Lake, Michigan (Carbine 1942)	1939	21.2	(53.8)	23.5	(59.7)
	1940	19.8	(50.3)	23.2	(58.9)

*Centimeters in parenthesis.

TABLE 6. *Calculated length (inches) of male northern pike at the end of each year of life, Gilbert and Big Cedar Lakes, 1968-69.*

Age	Number of Fish	Total Length (Inches) at End of Year 1	2	3	4	5	6	7	8	9	10
I	0										
II	44	9.7	18.5								
III	61	10.7	17.9	21.2							
IV	81	10.3	17.4	20.2	21.8						
V	68	9.5	16.4	20.1	21.9	22.9					
VI	78	9.5	16.5	20.1	22.1	23.2	24.0				
VII	57	9.5	16.7	20.4	22.4	23.7	24.7	25.4			
VIII	30	9.1	15.3	20.0	22.3	23.7	24.7	25.6	26.2		
IX	24	9.3	16.6	20.8	23.2	24.6	25.7	26.6	27.2	27.8	
X	9	8.4	15.6	21.0	23.2	24.9	26.0	27.0	27.9	28.6	29.2
Grand Average Calculated Total Length*		9.8 (24.9)	17.0 (43.2)	20.4 (51.8)	22.2 (56.4)	23.5 (59.7)	24.6 (62.5)	25.8 (65.5)	26.8 (68.1)	27.9 (70.9)	28.7 (72.9)
Increment of Average		9.8 (24.9)	7.2 (18.3)	3.4 (8.6)	1.8 (4.6)	1.3 (3.3)	1.1 (2.8)	1.2 (3.0)	1.0 (2.5)	1.1 (2.8)	0.9 (2.3)
Growth Based on Summation of Length Increments		9.8 (24.9)	17.0 (43.2)	20.4 (51.8)	22.2 (56.4)	23.5 (59.7)	24.6 (65.5)	25.8 (65.5)	26.8 (68.1)	27.9 (70.9)	28.8 (73.2)

*Centimeters in parenthesis.

TABLE 7. *Calculated length (inches) of female northern pike at the end of each year of life, Gilbert and Big Cedar Lakes, 1968-69.*

Age	Number of Fish	Total Length (Inches) at End of Year 1	2	3	4	5	6	7	8	9
I	0									
II	20	10.4	20.6							
III	37	10.2	18.2	22.1						
IV	29	11.3	19.6	24.1	26.6					
V	34	10.2	19.0	23.8	26.4	27.4				
VI	28	9.5	17.5	22.4	25.3	27.0	28.2			
VII	13	10.1	17.5	22.2	24.9	27.1	28.6	29.6		
VIII	9	9.8	18.3	23.2	26.4	28.9	31.0	32.1	33.0	
IX	3	10.0	20.9	24.6	27.2	29.2	31.6	33.3	35.1	36.3
Grand Average Calculated Total Length*		10.3 (26.2)	18.8 (47.8)	23.0 (58.4)	26.0 (66.0)	27.5 (69.8)	28.9 (73.4)	31.2 (79.2)	33.5 (85.0)	35.5 (90.1)
Increment of Average		10.3 (26.2)	8.5 (21.6)	4.3 (10.9)	3.0 (7.6)	1.4 (3.6)	1.5 (3.8)	1.8 (4.6)	2.2 (5.6)	2.0 (5.1)
Growth Based on Summation of Length Increments		10.3 (26.2)	18.8 (47.8)	23.1 (58.7)	26.1 (66.3)	27.5 (69.8)	29.0 (73.7)	30.8 (78.2)	33.0 (83.8)	35.0 (88.9)

*Centimenters in parenthesis.

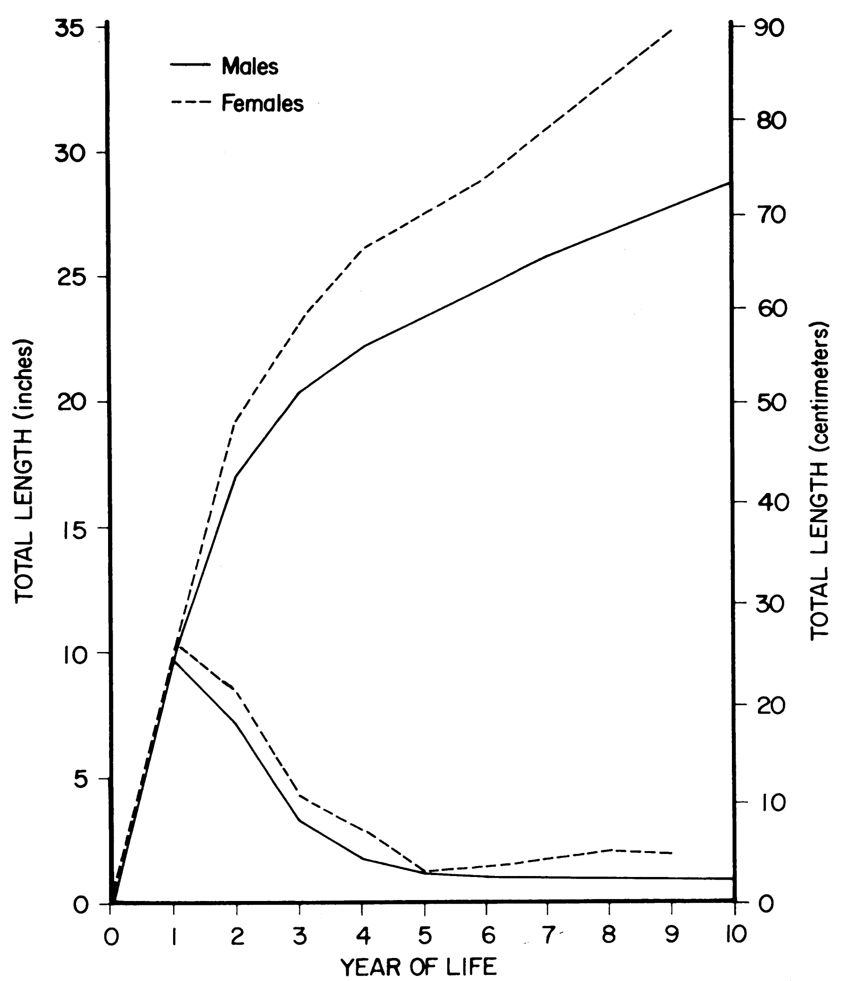


FIGURE 2. *Growth in length and annual length increments of northern pike from Gilbert and Big Cedar lakes.*

length of 22.8 inches (57.9 cm) for age III northern pike (sexes combined) taken from numerous lakes in southeastern Wisconsin. Annual growth rate of northern pike is generally slower in the northern part of their range than in the south, but their life span is longer in the north (Miller and Kennedy 1948; Van Engel 1940).

Age at Maturity

All age II northern pike taken in 1968 and 1969 were mature. This included 44 males ranging in total length from 13.4 to 20.8 inches (34-42.8 cm) and 20 females ranging in length from 15.9 to 22.6 inches (40.4-57.4 cm). The age at which all fish from a given year class reach sexual maturity was not determined. Sexual maturity at age II for male and female northern pike from Gilbert and Big Cedar lakes is in agreement with most of the available literature. In Europe, males usually mature at age II or III and females at age III (Alm 1959). In South Dakota, males mature at age I and females at age II (McCarraher 1959; Fogle 1963); in Ohio, age II females produced eggs (Clark 1958); in Nebraska, females mature at age IV (McCarraher 1959); and in Great Bear Lake, Canada, males mature at age VI and females at age VI (Miller and Kennedy 1948).

TABLE 8. *Age-length relationship (total length in inches) of northern pike from Gilbert and Big Cedar Lakes, 1968-69.*

Age	Males				Females			
	Average Length*		Length Range*		Average Length*		Length Range*	
II	18.5	(47.0)	13.4–20.8	(34.0–52.8)	20.6	(52.3)	15.9–22.6	(40.4–57.4)
III	21.2	(53.8)	17.9–26.5	(45.5–67.3)	22.1	(56.1)	17.4–27.8	(44.2–70.6)
IV	21.8	(55.4)	18.3–29.1	(46.5–73.9)	26.6	(67.6)	18.0–32.5	(45.7–82.5)
V	22.9	(58.2)	19.1–28.4	(48.6–72.1)	27.4	(69.6)	19.3–34.2	(49.0–86.8)
VI	24.0	(61.0)	20.1–33.4	(51.1–84.8)	28.2	(71.6)	23.2–35.8	(58.9–90.9)
VII	25.4	(64.5)	21.9–35.1	(55.6–89.1)	29.6	(75.2)	23.9–37.0	(60.7–93.9)
VIII	26.2	(66.5)	22.3–30.9	(56.6–78.4)	33.0	(83.8)	25.0–37.5	(63.5–95.2)
IX	27.8	(70.6)	23.4–33.5	(59.4–85.0)	36.3	(92.2)	34.0–40.0	(86.3–101.6)
X	29.2	(74.2)	27.3–32.1	(69.3–81.5)	–		–	

*Centimeters in parenthesis.

Frost and Kipling (1967) reported that in Lake Windermere, England, length rather than age determines when a northern pike, male or female, will first spawn. The majority of northern pike in Lake Windermere spawn for the first time at age II (males and females); at the time of spawning, the mean length of the males is 15.0 inches (38.1 cm) and the mean length of the females is 16.6 inches (42.1 cm).

TABLE 9. *Estimated egg production of eleven female northern pike from Gilbert Lake, 1968.*

Total Length (in Inches)*		Weight (in Pounds)**		No. of Eggs
13.4	(34.0)	0.6	(271)	5,970
17.3	(43.9)	1.4	(634)	13,380
19.2	(48.8)	1.7	(770)	18,610
22.5	(57.2)	2.9	(1314)	30,720
23.9	(60.7)	3.4	(1541)	37,190
24.6	(62.5)	4.0	(1808)	40,720
25.0	(63.5)	3.7	(1672)	42,860
27.5	(69.8)	5.4	(2441)	57,930
28.6	(72.6)	6.5	(2938)	65,570
30.0	(76.2)	8.3	(3752)	76,290
33.7	(85.6)	10.7	(4836)	110,160
AVG. 24.2	(61 3)	4.4	(1998)	45,400

*Numbers in parenthesis are total lengths in centimeters.

**Numbers in parenthesis are weights in grams.

Age-Length

A wide range of size was observed among male and female northern pike of the same age (Table 8). Age II males ranged from 13.4 to 20.8 inches (34.0-52.8 cm). These large size ranges were noted in all age groups. Similar ranges were found by Frost and Kipling (1967) who reported great variation in ages of northern pike from 1 to 4 years for the 1945-57 year classes in Lake Windermere, England. Causes of this wide range of size can only be suggested. Spawning time occurs over several weeks so that some fish could hatch earlier then others and hence have a longer growing season. Other possible causes may be environmental ones. For example, one fish may spend its life in a place which is conducive to better growth than that occupied by its neighbor in the same lake.

Fecundity

The gonad of a female northern pike consists of two pear-shaped, orange-colored ovaries which fill the body cavity when the fish is ready to spawn. Carbine (1944) has demonstrated that before spawning, the ovaries contain immature eggs which constitute 4.1 percent of the total volume and mature eggs which constitute 95.9 percent. He found that the immature eggs are very small and much more numerous than the mature eggs, but only the mature eggs will be shed in the current year. The mature eggs are the obvious ones in the ovaries and those of concern here.

Eleven females ranging in total length from 13.4 to 33.7 inches (34.0-85.6 cm) were used to determine fecundity. The relationship between total length of the fish and egg numbers was determined by the following regression:

$$Log\ F = -7.227 + 3.161\ Log\ L$$

where $Log\ F$ is the number of eggs and $Log\ L$ is the total length of the fish in centimenters.

Fecundity was roughly proportional to the weight of the northern pike sampled. A 23.9-inch (60.7 cm), 3.4-lb (1541 g) fish contained 37,190 eggs while a 28.6-inch (72.6 cm), 6.5-lb (2938 g) fish contained 65,570 eggs (Table 9). There was an average of 10,300 eggs per pound of fish.

These data are similar to other published estimates. Carbine (1944) estimated that an average Houghton Lake fish 23.6 inches (59.9 cm) in length would contain 32,200 eggs (Franklin and Smith 1963). This estimate compares to an estimate of 37,600 eggs for a fish of the same length from Lake George. Moen and Lindquist (1954) counted 22,745 eggs in a fish weighing 2.5 lb (1132 g). This estimate compares to an estimate of 25,750 for fish of the same weight in Gilbert Lake.

SPAWNING CONDITIONS

Time of Spawning

Spawning time in Gilbert Lake is based on general field observations in 1968. Spawning activity was first noted on 25 March and extended through the first week in April, with the greatest intensity of spawning occurring during the afternoons of 28 and 29 March at surface water temperatures which ranged from 50 to 64° F (10-17.8° C). During the emigration netting period, a ripe, 22.3-inch (56.6 cm) female was captured on 1 May, indicating that some spawning may occur as late as early May.

At Lake George, spawning occurred in April (Franklin and Smith 1963). Spawning periods observed by other workers were 1 to 15 May in Saskatchewan lakes (Rawson 1932), 28 March to 18 April in Ohio lakes (Clark 1950), mid-April for the run into Peterson's Ditch, off Houghton Lake (Carbine 1942) and early April to early May in Lake Windermere, British Isles (Frost and Kipling 1967). The spawning periods reported by these biologists and the spawning time found in the present study indicate that northern pike from widely distant waters tend to spawn at the same general time--midspring.

Environmental Influences

The relationship of environmental stimuli to the onset of spawning has been studied by several workers: McNamara (1937) reported that spawning took place on bright days, and Clark (1950) noted that cool nights tended to inhibit early morning spawning. Franklin and Smith (1963) only observed spawning between 2:00 p.m. and 6:00 p.m. at surface water temperatures which ranged from 52 to 63° F (11.1-17.2° C). Fabricius (1950) showed that suitable vegetation and high and rising water temperatures were the primary environmental factors influencing the onset of spawning. These observations and conclusions have been clarified by the extensive aquarium studies of Fabricius and Gustafson (1958) who have shown that water temperatures, daily light intensity, and the presence of suitable vegetation work together to stimulate spawning.

Egg densities, and hence spawning activity, were related to vegetation type. Egg densities were greatest in areas where dense mats of sedge and wild celery remains were present. These areas were located in the southern half of the lake. In other areas having similar water depth and temperature but where a similar mat of vegetation was not present, egg densities were lower. Bottom vegetation in these other areas consisted of bulrush stems, fragments of lily pads, broken rushes, and small pieces of debris.

The fact that highest egg densities were found among the most dense vegetation has been confirmed by a number of other biologists. Monten (1948) and Monten (1950) noted that prolarval density was related to vegetation, and that highest prolarval densities occurred in dense tufts of *Carex* spp. Since prolarvae do not move far immediately after hatching, this observation probably indicated that egg density was highest in the *Carex*. These observations were confirmed by Fabricius and Gustafson (1958) who showed that adults deposited eggs only over dense but relatively short vegetation such as *Carex* spp. The highest egg densities at Lake George usually occurred in dense mats of sterile clumps of *Eleocharis* spp., and the next highest densities occurred in the shore vegetation, which included extensive stands of *Carex* spp. (Franklin and Smith 1963).

SUMMARY

The immigration period lasted at least 16 days and the intensity of the immigration varied directly with water temperatures and the ice breakup on Gilbert Lake. Water temperatures during the immigration period were between 33 and 57° F (0.6-13.9° C); at the time of peak spawning, temperatures ranged from 38 to 51° F (3.4-10.6° C). Maximum emigration occurred 2 or 3 days after the spawning peak, but continued at a low level for a period of another 30 days.

The combined spawning population in Gilbert and Big Cedar lakes was 2,500-3,000 spawning adults with about one-half of the population spawning in Gilbert Lake.

Relative to the total number of males in the run, males tended to move into and out of the spawning area faster than females moved. The sex ratio was 1 female to 2.3 males in 1968 while in 1969, it was 1:2.0.

A trend in the average size of fish netted was found for males but not for females. The average size of the males increased as the run progressed and then declined after the peak. Males and females averaged 22.8 and 26.5 inches (57.9 and 67.3 cm) in total length, respectively, in 1968 and 23.1 and 25.4 inches (58.7 and 64.5 cm), respectively, in 1969.

Female northern pike grew at a faster rate than males. At the end of the third year, males averaged 20.4 inches (51.8 cm) and females, 23.1 inches (58.7 cm).

The growth rate of adult northern pike in Gilbert and Big Cedar lakes is expectionally good compared to the growth of northern pike in other waters.

Male and female northern pike were mature at age II at which time the mean length was 18.5 inches (47.0 cm) for the males and 20.6 inches (52.3 cm) for the females.

A wide range of size was observed among male and female northern pike of the same age.

The relationship between total length of the fish in centimeters and egg numbers was determined by the regression, $Log\ F = -7.227 + 3.161\ Log\ L$, where $Log\ F$ is the number of eggs and $Log\ L$ is the total length of the fish in centimeters. Fecundity was roughly proportional to the weight of the northern pike sampled. There were an average of 10,300 eggs per pound of fish.

Major spawning activity occurred from late March through early April; however, a ripe female was taken as late as 1 May 1968. Spawning was observed during the afternoons at water temperatures which ranged from 50 to 64° F (10-17.8° C) at the surface.

Egg densities and hence, spawning activity, were related to vegetation type. Egg densities were greatest in areas where dense mats of sedge and wild celery remains were present.

EARLY LIFE HISTORY

EGG DEVELOPMENT AND SURVIVAL

Eggs were first collected on 2 April 1968. During the sampling period, eggs were collected at nearly all stations around Gilbert Lake (Fig. 1). Eggs were relatively abundant through 5 April but by 9-10 April, very few or none were collected at the various stations. Observations of eggs which were artificially fertilized and placed on a fiberglass mat in the lake indicated that hatching had begun by 9 April and was probably completed by 12 April. The observed incubation period was 13-16 days; water temperatures during this period ranged from 36 to 60° F (2.2-16.6° C).

Although egg survival is usually high under natural conditions, eggs did not survive well in Gilbert Lake in 1968. The causes for this mortality could not be documented. The majority of eggs which died in Gilbert Lake apparently were lost in the early stages. Low oxygen levels, extreme water temperatures and rapid rates of water temperature change are factors which have been found to cause heavy mortality of eggs from other species of fish. At Gilbert Lake, there was no evidence that egg survival was affected by either oxygen concentrations or water temperatures during the egg stage.

FRY AND FINGERLINGS

Growth and Survival

Fry were first captured on 12 April 1968. Since no fry were collected in the immediate vicinity of the established embryo stations, they were captured wherever they could be found, which happened to be only in the southern half of the lake. Few fry were captured, indicating that in addition to poor egg survival, fry mortality may also have occurred. Again, no explanation for this mortality was found.

Of the fry that did survive in Gilbert Lake, fry between 10 and 12.5 mm did not contain food items, nor was yolk sac absorption complete in fry at these lengths. Other researchers have corroborated this finding. In Lake George, the smallest fry containing food was 10.3 mm long and only 32 of 254 fish (12.6 percent) between 10.0 and 12.3 mm long had started to feed (Franklin and Smith 1963). Hunt and Carbine (1951) also reported that fish 10 to 11 mm in length had not started

TABLE 10. *Growth of young northern pike in Gilbert Lake, 1968.*

Date	Number of Fish	Length Range (mm)	Average Length (mm)
April			
15	6	10.0–11.0	10.5
18	6	11.0–12.5	12.0
23	3	15.0–17.0	15.5
26	2	13.0–15.5	14.5
29	5	15.5–17.5	16.5
May			
1	9	14.0–18.0	16.0
6	3	16.5–21.0	19.0
15	6	23.0–30.0	27.5
23	1	–	35.5
June			
4	5	40.5–47.5	44.0

to feed.

In Gilbert Lake, young northern pike had attained an average total length of only 44.0 mm 54 days after hatching (Table 10). In Lake George, however, young northern pike were 93 and 89 mm long after 54 days in 1956 and 1957, respectively (Franklin and Smith 1963). Clearly, growth of fingerling northern pike in Gilbert Lake was poor but no explanation of this slow growth was found.

TABLE 11. *Food of young northern pike in Gilbert Lake, 1968 in percent frequency of occurrence and (in parentheses) average number of organisms per stomach.*

Food Items	Size Range of Fish (in mm) 13-25*	26-35*	36-48*
Cladocera**	100.0 (26.9)	100.0 (43.4)	100.0 (47.0)
<u>Ceriodaphnia</u>	100.0 (8.5)	100.0 (11.0)	16.6 (26.0)
<u>Bosmina</u>	60.9 (9.9)	20.0 (1.0)	16.6 (1.0)
<u>Chydorus</u>	47.8 (1.9)	80.0 (3.4)	33.3 (2.5)
<u>Pleuroxus</u>	4.3 (1.0)		
<u>Simocephalus</u>	8.7 (1.5)	40.0 (2.5)	100.0 (10.3)
<u>Eurycercus</u>	4.3 (4.0)	80.0 (7.0)	100.0 (5.3)
<u>Daphnia</u>			16.6 (1.0)
Eucopepoda	100.0 (32.1)	100.0 (34.2)	83.3 (5.8)
Cyclopidae	100.0 (31.2)	100.0 (34.0)	83.3 (5.8)
Harpacticoida	34.8 (1.6)	20.0 (1.0)	
Nauplii	13.0 (2.7)		
Ostracoda	21.7 (1.6)	100.0 (1.8)	33.3 (1.0)
Insecta**	30.5 (1.6)	100.0 (3.4)	66.6 (4.5)
Tendipedidae	30.5 (1.6)	100.0 (3.4)	66.6 (4.0)
Annelida			83.3 (4.0)
Fish Remains			16.6 (1.0)

*Stomach analyses are based on 23, 5 and 6 stomachs from fish in the 13- to 25-mm, 26- to 35-mm and 36- to 48-mm range, respectively. All stomachs sampled contained food.

**Includes unidentified organisms that belong in this category.

TABLE 12. *Number of zooplankton per liter of surface water in the southern (Section A) and northern (Section B) one-half of Gilbert Lake, 1968.*

Food Items	April 22 A	April 22 B	April 29 A	April 29 B	May 6 A	May 6 B	May 15 A	May 15 B	June 4 A	June 4 B
Cladocera	0.9	0.6	0.6	1.9	0.4	2.9	1.0	0.3	6.4	0.1
<u>Daphnia</u>	0.4	0.2	0.4	0.1	0.2	2.5	0.2	0.2	0.2	0.1
<u>Ceriodaphnia</u>	0.1	*	*	0	0	0	0.6	0.1	1.5	*
<u>Bosmina</u>	0.4	0.4	0.2	1.8	0.2	0.4	0	0	0.1	0
<u>Simocephalus</u>	0	0	0	0	0	0	0	0	0.5	0
<u>Eurycercus</u>	0	0	0	0	0	0	0.1	0	0	0
<u>Sida</u>	0	0	0	0	0	0	0	0	0.1	0
<u>Scapholeberis</u>	0	0	0	0	0	0	0.1	0	4.0	*
Eucopepoda	0.1	0.5	0.2	*	0.1	0.1	0.4	*	2.3	0.1
Cyclopidae	0.1	0.4	0.1	*	0.1	0.1	0.2	*	1.5	0.1
Harpacticoida	0	0	0	0	*	0	0.1	0	0.1	0
Nauplii	0	*	0.1	0	*	*	0.1	*	0.7	*
Ostracoda	0.1	*	*	*	*	0	0.2	0	0.3	0
Rotatoria	0.3	0.3	0.4	0.7	0.4	0.5	1.9	1.2	3.1	0.9
Acari	*	0	*	0	0	0	0	0	0	0

*Less than 0.1 per liter.

Food

The principal food items taken by northern pike up to 48 mm in length in Gilbert Lake were Cladocera (especially *Ceriodaphnia, Simocephalus,* and *Eurycercus),* Eucopepoda (mostly Cyclopidae), and insects, especially Tendipedidae larvae (Table 11). *Ceriodaphnia* were utilized by all fish ranging in size from 13 to 48 mm. *Simocephalus* were important in the diet of fish in the 36- to 48-mm size range. *Eurycercus* became an important part of the diet after the fish had obtained a length of 26 mm. Cyclopidae were found in most fish sampled, however, there was greater utilization of Cyclopidae by fish under 35 mm. Tendipedidae larvae became an important segment of the diet for fish 26 mm and larger. Fish remains were found in only one northern pike that was 47.5 mm long. Ostracods were eaten in small numbers, but were not an important element of the diet.

The food items consumed by young northern pike in Gilbert Lake are essentially the same as that reported by other biologists. Hunt and Carbine (1951) and McCarraher (1957) noted that as northern pike increase in size, food selected follows a sequence of microcrustacea, insects, and vertebrates (chiefly other northern pike and tadpoles). Frost (1954) found that in Lake Windermere, the small northern pike passed directly from a diet of microcrustacea to one of fish. The principal food items taken by young northern pike in the slough at Lake George were cladocerans (especially *Daphnia* and *Ceriodaphnia),* copepods (mostly Cyclops), *Hyalella* spp., and insects, especially Tendipedidae larvae and Ephemeroptera and Zyoptera nymphs (Franklin and Smith 1963). In a managed marsh at Lake Ripley, Wisconsin, young northern pike up to 23 mm fed on copepods and cladocerans while fish from 37 to 53 mm contained Diptera larvae in addition to copepods and cladocerans (Kleinert 1970).

There appeared to be no relationship between the density and composition of zooplankton in the surface waters to that in the stomachs of young northern pike in Gilbert Lake. Based on the surface samples, the density of zooplankton in Gilbert Lake was low (Table 12).

SUMMARY

Eggs were collected throughout the lake with the greatest densities being found in the southern half. The incubation period was 13-16 days. Survival was apparently quite low in the early stages of development inasmuch as fry were very scarce in 1968. Fry did not eat prior to yolk sac absorption which occurred when fry had reached a length of 12.5 mm. The major food items consumed by young northern pike in Gilbert Lake were Cladocera (especially *Ceriodaphnia, Simocephalus,* and *Eurycercus),* Eucopepoda (mostly Cyclopidae), and insects (especially Tendipedidae larvae). There appeared to be no relationship between the density and composition of zooplankton in the surface waters and that in the stomach contents of young fish.

TAG RETURNS AND RECOVERIES

RETURNS BY ANGLERS

From 11 May 1968 (opening date of the 1968 season) through 31 August 1970, anglers reported the capture of 131 tagged northern pike in Big Cedar Lake, for a minimum return of 17.6 percent of the 744 fish tagged (Table 13).*

For all years combined, the greatest number of tagged fish were caught in May and June. Only 10.7 percent of the tagged fish were caught during the ice fishing season, 1 December through 15 February, for all years.

Low returns of tagged fish have also been found by other workers. Over a 3-year period in Lake Poygan, Wisconsin, anglers reported 84 tagged northern pike for an 8.7 percent harvest rate, with May being the month during which most tags were returned (Priegel 1968). Anglers reported 72 tagged northern pike over a 2-year period from Big Lake Butte des Morts, Wisconsin, for a 4.3-percent harvest rate; of these 72 tags, 24 tags were returned in May and 23 in June (Priegel 1968). Anglers reported 85 tagged northern pike (22.1-percent return) after a 2-year period in the Black River just below the Onalaska Spillway, Wisconsin (Finke 1966). Fifty percent of these returns occurred in May 1964, the first month after tagging and the month when the fishing season opened.

*The number of northern pike originally tagged in Gilbert Lake was 752, however, 8 of these were found dead after the 1968 spawning season.

Of the tagged fish reported taken by anglers, 69 were males and 62 were females. Based on the total length of the fish at the time they were tagged, the recaptured males averaged 24.3 inches (61.7 cm) in total length and the females, 26.9 inches (68.3 cm). Both of these measurements were somewhat greater than the average total lengths of males and females measured at the time of spawning.

A comparison of sex ratios suggests that females were much more susceptible to angling than males. Of the tagged fish taken by anglers, the ratio of females to males was 1:1.1 while the ratio of females to males in the spawning population was 1:2.3. Since spawning males averaged smaller than spawning females, there was a possibility that anglers were catching more males but were returning them to the lake and not reporting them.

To investigate this possibility, it was assumed that all northern pike, 22 inches (55.9 cm) and larger, were acceptable to most anglers. Sex ratios were determined for the tagged fish recaptured by anglers and for those fish in the spawning population that were under 22 inches and those 22 inches and larger. These data also suggested that females were more susceptible to angling than males.

RECOVERIES BY PROJECT PERSONNEL

Project personnel recovered 136 tagged northern pike while netting during the 1969 spawning season. Fish tagged either in the lower or upper jaw showed little evidence of tag loss. Some tags on the lower jaw did cause a definite groove to form in the jaw of the larger fish; however, there was only minor irritation of the groove itself and of the tissue adjacent to the tag. The lower jaw tag on small fish caused little or no irritation or grooving.

The upper jaw tag (clamped around the maxillary bone) was securely anchored and showed little irritation. On many fish, the tissue had started growing over the tag and had to be cut away to observe the tag number. This condition was not noted on tags attached to the lower jaw.

In 1969, the 136 tagged northern pike recaptured by project personnel were measured after they had carried jaw tags over one growing season. Although the normal increment attained by the tagged fish varied widely, there was no marked retardation of growth (Table 14). However, the annual increment of untagged fish in the population is not known.

SUMMARY

From 11 May 1968 (opening date of the 1968 season) through 31 August 1970, anglers reported the capture of 131 tagged northern pike in Big Cedar Lake, for a minimum return of 17.6 percent of the number tagged (744 fish). The greatest number of tagged fish were caught in May and

TABLE 13. *Percentage of tagged northern pike caught by anglers in Big Cedar Lake, 1968-70.**

Months of Fishing Season**	1968			1969			1970			Grand Total		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
January	–	–	–	6.7	12.9	9.8	0	0	0	2.9	6.5	4.6
February	–	–	–	10.0	9.7	9.8	0	0	0	4.3	4.8	4.6
May	18.9	27.6	22.7	36.7	22.5	29.5	50.0	100.0	75.0	27.5	27.4	27.5
June	35.1	27.6	31.8	40.0	45.2	42.6	50.0	0	25.0	37.7	35.5	36.6
July	10.8	13.8	12.1	3.3	9.7	6.5	0	0	0	7.2	11.3	9.2
August	10.8	3.4	7.6	0	0	0	0	0	0	5.8	1.6	3.8
September	2.7	3.4	3.0	0	0	0	0	0	0	1.5	1.6	1.5
October	16.2	17.2	16.7	3.3	0	1.6	0	0	0	10.1	8.1	9.2
November	2.7	3.4	3.0	0	0	0	0	0	0	1.5	1.6	1.5
December	2.7	3.4	3.0	0	0	0	0	0	0	1.5	1.6	1.5
No. Fish	37	29	66	30	31	61	2	2	4	69	62	131

*Returns are based on 744 fish tagged in Gilbert Lake from March through May 1968.

**The season on Big Cedar Lake extended from the second Saturday in May of one year through 15 February of the next year.

TABLE 14. *Growth of tagged northern pike recovered by project personnel after one complete growing season**

Length Groups (in Inches)**		Number of Fish	Average Total Length (in inches)		Growth Increments (in Inches)	
			At Release	At Recapture	Average	Range
14.0–14.9	(35.6–37.8)	1	14.2 (36.1)	17.6 (44.7)	+3.4 (8.6)	–
15.0–15.9	(38.1–40.4)	1	15.0 (38.1)	17.0 (43.2)	+2.0 (5.1)	–
16.0–16.9	(40.6–42.9)	1	16.2 (41.1)	21.1 (53.6)	+4.9 (12.4)	–
17.0–17.9	(43.2–45.5)	4	17.7 (45.0)	19.1 (48.6)	+1.4 (3.6)	0–2.5 (0 –6.4)
18.0–18.9	(45.7–48.0)	10	18.5 (47.0)	19.8 (50.3)	+1.3 (3.3)	0.3–1.8 (0.8–4.6)
19.0–19.9	(48.3–50.5)	9	19.5 (49.5)	20.8 (52.8)	+1.3 (3.3)	0.3–2.4 (0.8–6.1)
20.0–20.9	(50.8–53.1)	11	20.4 (51.8)	21.8 (55.4)	+1.4 (3.6)	0.1–3.7 (0.3–9.4)
21.0–21.9	(53.3–55.6)	11	21.4 (54.4)	22.3 (56.6)	+0.9 (2.3)	0.2–2.5 (0.5–6.4)
22.0–22.9	(55.9–58.2)	18	22.4 (56.9)	23.5 (59.7)	+1.1 (2.8)	0.3–2.0 (0.8–5.1)
23.0–23.9	(58.4–60.7)	13	23.4 (59.4)	24.4 (62.0)	+1.0 (2.5)	-0.2–3.2 (0.5–8.1)
24.0–24.9	(61.0–63.2)	13	24.4 (62.0)	25.0 (63.5)	+0.6 (1.5)	-0.2–1.4 (0.5–3.6)
25.0–25.9	(63.5–65.8)	7	25.5 (64.8)	26.6 (67.6)	+1.1 (2.8)	0.1–2.9 (0.3–7.4)
26.0–26.9	(66.0–68.3)	11	26.4 (67.1)	27.0 (68.6)	+0.6 (1.5)	0.1–2.4 (0.3–6.1)
27.0–27.9	(68.6–70.9)	5	27.3 (69.3)	27.7 (70.3)	+0.4 (1.0)	0.1–0.7 (0.3–1.8)
28.0–28.9	(71.1–73.4)	8	28.4 (72.1)	29.2 (74.2)	+0.8 (2.0)	-0.2–1.3 (0.5–3.3)
29.0–29.9	(73.7–75.9)	2	29.5 (74.9)	31.9 (81.0)	+2.4 (6.1)	–
30.0–30.9	(76.2–78.4)	4	30.3 (76.9)	31.8 (80.7)	+1.5 (3.8)	1.2–1.7 (3.0–4.3)
31.0–31.9	(78.7–81.0)	4	31.6 (80.2)	32.6 (82.8)	+1.0 (2.5)	0.2–1.7 (0.5–4.3)
34.0–34.9	(86.3–88.6)	2	34.6 (87.8)	35.1 (89.1)	+0.5 (1.3)	0.4–0.6 (1.0–1.5)
37.0–37.9	(93.9–96.2)	1	37.5 (95.2)	37.0 (93.9)	-0.5 (1.3)	–

*Based on 136 fish recovered in 1969.

**Centimeters in parenthesis.

June. Females were considerably more susceptible to angling than males.

In 1969, the 136 tagged northern pike recaptured by project personnel were measured after they had carried jaw tags over one growing season. Although the normal increment attained by the tagged fish varied widely, tags apparently caused no marked retardation of growth; however, the annual increment of untagged fish in the population was not known.

CONCLUSIONS AND IMPLICATIONS

The combined northern pike spawning population in Gilbert and Big Cedar lakes consisted of 2,500-3,000 fish. Over a period of at least 16 days, about one-half of the fish in Big Cedar Lake entered Gilbert Lake to spawn. Certain characteristics of the spawning population were found: (1) Relative to the total number of males in the spawning run, males tended to move into and out of the spawning area faster than females. The average sex ratio ranged from 1 female to 2.0-2.3 males. (2) As the run progressed, the average size of males increased and after the peak, their size declined. Size of female northern pike showed no such trend. (3) Fecundity was roughly proportional to the weight of the female northern pike sampled. There were an average of 10,300 eggs per pound of fish. (4) Immigration into the spawning areas began in mid-March. Major spawning activity occurred from late March through early April. Peak emigration took place in early April, but continued through early May.

Several characteristics of spawning habitat were also found: (1) The intensity of immigration varied directly with water temperatures and coincided with the ice breakup on Gilbert Lake. Peak immigration occurred at water temperatures between 38 and 51°F (3.4-10.6° C). (2) Egg densities and, hence, spawning activity were associated with vegetation type--egg densities were greatest where dense sedge mats and wild celery remains were present.

The growth rate of northern pike in Big Cedar Lake is exceptionally good compared to the growth of northern pike in other state waters. Currently, there is no size limit on northern pike and the age and growth data would indicate that a size limit is not justified in these waters.

Information was collected on the early life history of the northern pike in the two study lakes. Eggs were collected throughout Gilbert Lake, with greater densities in the southern half. Following a 13- to 16-day incubation period, eggs hatched, but survival appeared to be quite low in the early stages of development inasmuch as few fry were observed in 1968. Fry did not eat prior to yolk sac absorption which occurred at 12.5 mm. The major food items consumed were cladocerans and insects.

Harvest data showed that from 11 May 1968 through 31 August 1970, 131 tagged fish were taken by anglers in Big Cedar Lake. Of the 744 fish originally tagged, this harvest constituted a 17.6-percent return. The greatest number of tagged fish were caught in May and June, 27.5 and 36.6 percent, respectively, for all years combined. Females were considerably more susceptible to angling than males. If a 22-inch (55.9 cm) minimum size limit was imposed on this population, female northern pike on the average would be legal size during their third growing season, while males wouldn't attain 22 inches until the end of their fourth year of life. Even without a size limit, females were more susceptible to angling and with a size limit, the harvest of females would increase.

Angler exploitation of the tagged northern pike (17.6 percent) was not considered high because of the good growth rate and size ranges of the population. Snow and Beard (1972) reported that in Bucks Lake, northwestern Wisconsin, after the 18-inch (45.7 cm) size limit was imposed, 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-inch limit, the exploitation rates dropped to 3 and 2 percent, respectively. The decline was largely the result of the 18-inch limit, but it was also related to a concurrent drop in fishing pressure and standing crop of larger fish. Total annual mortality of northern pike in Bucks Lake averaged 64 percent from 1961 to 1969 and ranged from a low of 35 percent to a high of 84 percent (Snow and Beard 1972). High total annual mortality is a normal characteristic of northern pike populations.

Gilbert Lake is clearly an important spawning area for northern pike from Big Cedar Lake and development within the lake basin should be severely restricted. Vegetation such as wild celery, grasses, and sedges that break down to form a dense mat are preferred by northern pike for spawning. For northern pike, marshes with this type of vegetation should receive priority consideration for protection as natural spawning areas and development as controlled spawning and rearing areas.

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