Northern pike production in managed spawning and rearing marshes. No. 96 1977

Fago, Don
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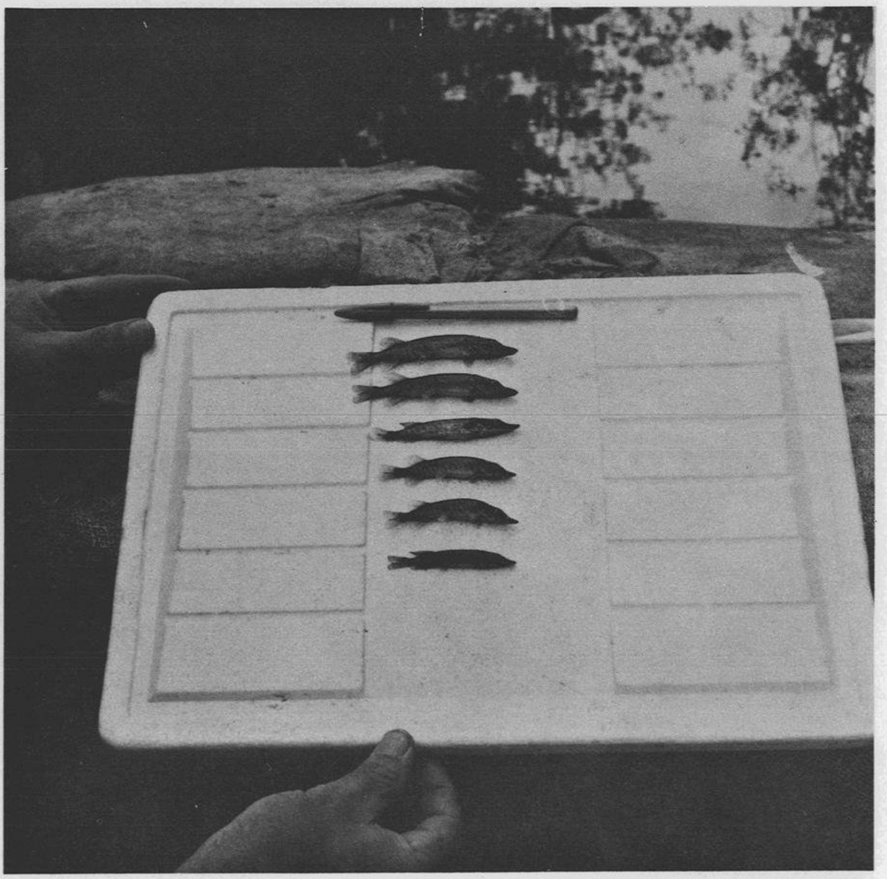
NORTHERN PIKE PRODUCTION IN MANAGED SPAWNING AND REARING MARSHES



TECHNICAL BULLETIN NO. 96
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1977

ABSTRACT

From 1969 through 1973, the 3.7-acre (1.5 hectare) Pleasant Lake Marsh was stocked each spring with adult northern pike (*Esox lucius* Linnaeus) in an effort to determine the factors that influence the production of fingerlings from managed spawning and rearing marshes. In 1971 and 1972, the 18.5-acre (7.5 hectare) Pabst Marsh was also studied. The annual production from the Pleasant Lake Marsh varied from 324 to 3,243 fingerlings per acre (131 to 1,312 per hectare). The Pabst Marsh produced 681 and 1,052 fish per acre (276 and 426 per hectare) during the two years it was studied. These fingerlings were produced from an average of 12.1 and 11.0 lbs/acre (13.6 and 12.3 kg/ha) of adult females and males, respectively.

The average production for both marshes at the time of draining was 1,332 fingerlings per acre (539 per hectare) having an average length of 3.5 inches (88.9 mm), and a length range from 1.5 to 6.8 inches (38 to 173 mm). The pounds per acre of fingerlings produced varied from 2.2 to 16.4 (2.5 to 18.3 kg/ha) with a mean of 10.6 lbs/acre (11.9 kg/ha). Estimated survival from egg deposition until the time of draining varied from 0.15 to 2.69 percent with an average of 1.09 percent.

Factors suspected of influencing the production of northern pike from managed marshes were studied. However, sufficient data for making quantitative predictions on the number of northern pike produced from these factors were not obtained. Nevertheless, it was observed that water temperature and dissolved oxygen during the draining of the marsh, cannibalism during the fingerling stage, and zooplankton composition during the fry stage were some of the most important factors influencing the production of northern pike.

A Fortran computer program was developed to handle the analyses of all northern pike stomach, zooplankton, and benthic samples.

NORTHERN PIKE
PRODUCTION IN MANAGED SPAWNING AND REARING MARSHES

By
Don M. Fago

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INTRODUCTION

Because of man's activities around many of the lakes in Wisconsin, marshy, low-lying areas have been lost at a rapid rate (Brynildson 1958). These areas quite often are known or suspected to be northern pike (*Esox lucius* Linnaeus) spawning sites. One report of this loss of spawning habitat (Threinen 1969) described detrimental activities such as ditching, filling, and diking in relation to northern pike populations, and gave some possible solutions. While a complete evaluation of the effects of spawning habitat loss on northern pike populations has not been conducted to date, it seems likely that it can only be harmful. In order to be better able to assess these losses and then take measures to ameliorate their effects, an understanding of the factors that influence northern pike production in marshes is needed. Researchers from other states who have studied various aspects of northern pike production from marshes include: Carbine (1941, 1943), DiAngelo (1961), and Williams (1963) in Michigan; Forney (1968) in New York; Franklin and Smith (1963), Jarvenpa (1962) and Bryan (1967) in Minnesota; and McCarraher (1957) in Nebraska. Their work investigated many phases of the factors that determine northern pike production in managed marshes but nevertheless left many questions unanswered.

In order to obtain a better understanding of these factors and be able to offset losses of marsh lands, the Wisconsin Department of Natural Resources initiated a study on two marshes. The purpose of this study was to assess fingerling production in managed spawning and rearing areas created by flooding low-lying areas near or adjacent to lakes and to evaluate some of the factors which might influence that production. This study was conducted in southeastern Wisconsin from 1969 through 1973 at one marsh, and during 1971 and 1972 at the other. The extent to which production actually improved the northern pike fishery in the adjacent lakes was the subject of another study.

DESCRIPTION OF STUDY AREAS

One study site, the Pleasant Lake Marsh, is a 3.7-acre marsh adjacent to Pleasant Lake in Walworth County (Fig. 1). In 1969 and 1970, a sand bag dam was used to control the water level in the marsh. However, during the summer of 1970, a concrete dam was constructed. The structure had two concrete sides each 5½ ft by 5 ft by 10 inches with space for two-foot long control boards in the middle (Fig. 2).*

The marsh was flooded to a depth of from 2 to 4 ft and was used as a managed spawning marsh from 1969 through 1973. The marsh is completely surrounded by a high steep wooded ridge, except where it connects with the lake. A very dense stand of leatherleaf (*Chamaedaphne calyculata*) is located in the center of the marsh, occupying over 50 percent of the surface area. The leatherleaf's top growth extends considerably above the surface of the water even at the highest levels. During the winter, the entire marsh freezes. In the spring, (after pumping has been completed), the leatherleaf mat gradually thaws and sinks a foot or two below the surface of the water.

However, after several weeks, the mat gradually rises and by May a good deal of the mat is either above the surface of the water or has less than six inches of water over it. The rest of the marsh is covered with cattail (*Typha* sp.) and a few patches of various sedges (*Carex* sp.). In July 1970 after drawdown, the leatherleaf was burned off using fuel oil in an attempt to increase the living space for the northern pike fingerlings, and reed canary grass (*Phalaris arundinacea*) was planted on the mat area. However, the growth of the grass in the following years was poor. The leatherleaf began a slow regrowth, but by 1973 it had not reached its previous height or density.

The other study site, the Pabst Marsh, is located in Waukesha County. This site is an 18.5-acre monotypic marsh of reed canary grass.

In the fall of 1970, a concrete control structure was also constructed at the outlet of this marsh. This dam consisted of two concrete sides each 8 ft by 6 ft by 10 inches with space for two-foot long control boards in the middle (Fig. 3).

This marsh was also flooded to a depth of from 2 to 4 ft. Most of the land surrounding the marsh is used for agricultural purposes, including cattle grazing and crop growing. The marsh drains into a slough connected with Oconomowoc Lake (Fig. 4).

*Table 12 in the Appendix gives pertinent English-Metric conversion factors for data presented in this report.

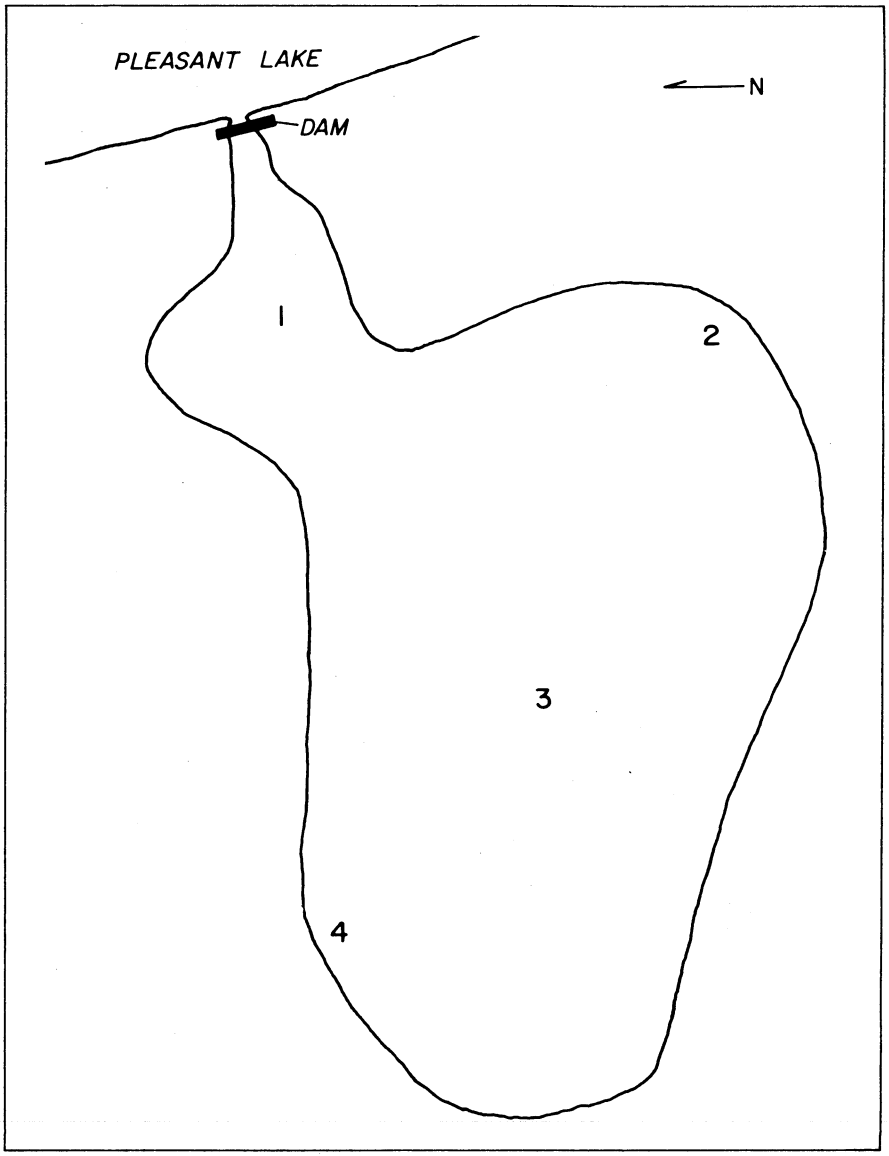


FIGURE 1. *Sampling stations at the 3.7-acre Pleasant Lake Marsh.*

FIGURE 2. *Concrete outlet structure at Pleasant Lake with the marsh in the background.*

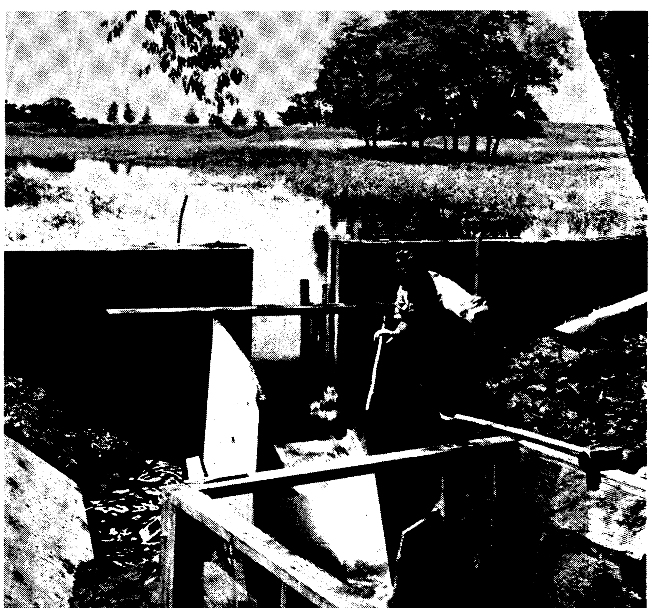


FIGURE 3. *Draining of Pabst Marsh and collection of northern pike fingerlings in a wiremesh pen.*

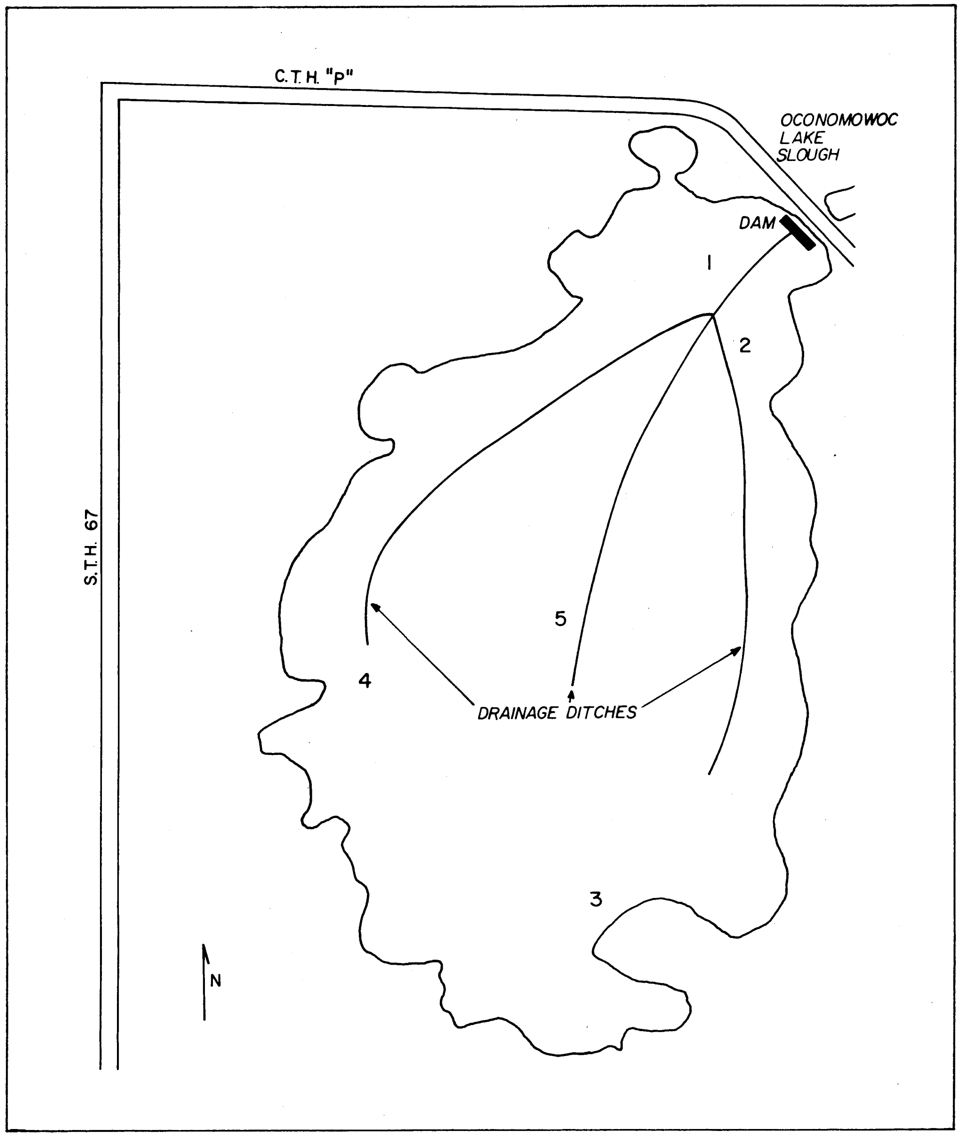


FIGURE 4. *Sampling stations at the 18.5-acre Pabst Marsh.*

METHODS

WATER LEVEL CONTROL

Both the Pleasant Lake and Pabst marshes were pumped full of water at the end of March with a 12- or 16-inch Crisafulli pump. The pumps were powered by a tractor or a 40-horsepower electric motor. The water levels were then maintained over an approximately nine-week period until the time of draining by periodically pumping water into the marshes with a 6-inch gasoline-powered "Pumper Buoy" pump at the Pleasant Lake Marsh and a 12-inch Crisafulli pump at the Pabst Marsh.

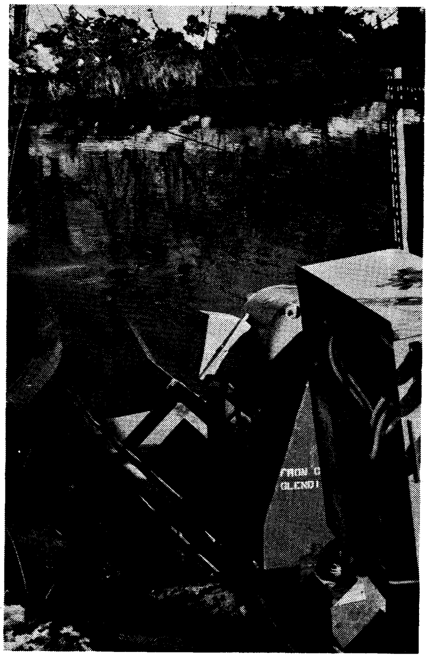
STOCKING OF ADULT SPAWNERS

The spawning stock was obtained primarily from Fox Lake in Dodge County, but one year, part of the stock was obtained from Rush Lake in Winnebago County and Beaver Dam Lake in Dodge County. The females were weighed to the nearest tenth of a pound. The males and females were measured to the nearest tenth of an inch. They were then hauled in live tanks and immediately released into the marshes. As soon as spawning had been completed, removal of all spawners was attempted using fyke nets to prevent predation of spawners on the young fingerlings.

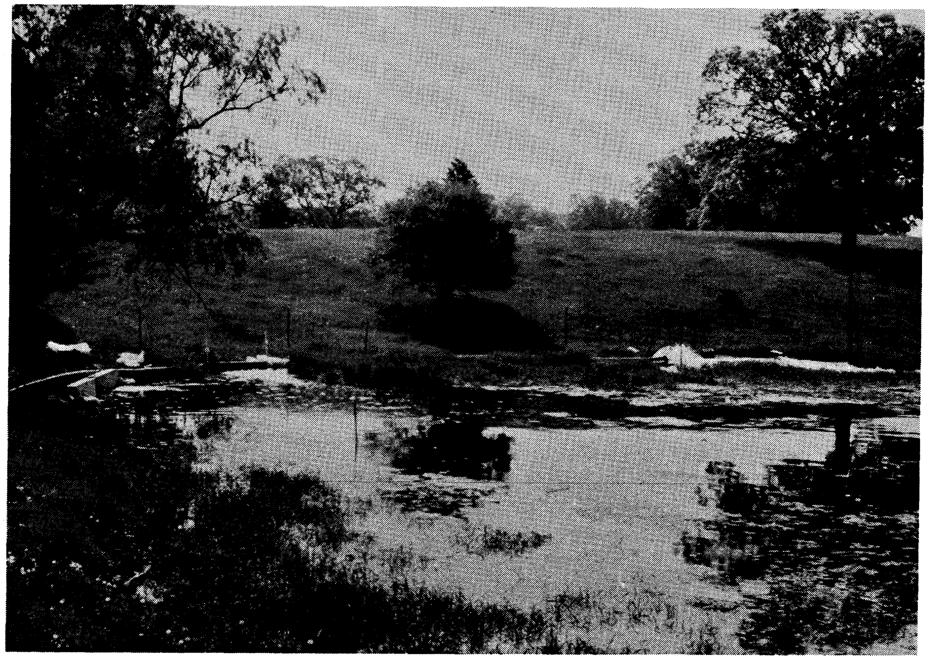
NORTHERN PIKE STUDIES

Egg Sampling

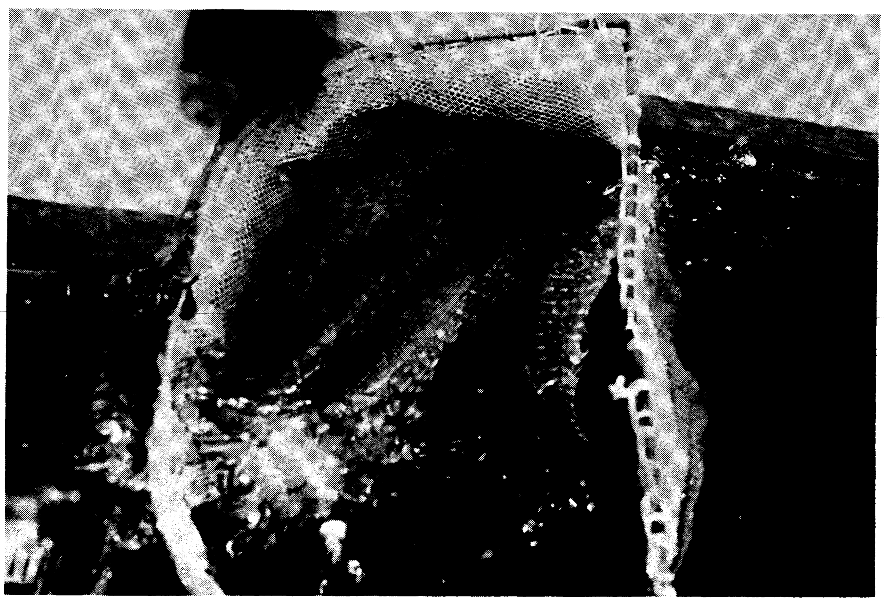
The number of eggs per female that could be deposited in the marsh for each of the years of this study was calculated from a linear regression of the number of eggs versus the total length of the female.



A 12-inch in diameter Crisafulli pump powered by a 40-horsepower electric motor used in filling the Pabst Marsh.



The Pabst Marsh being filled by the Crisafulli pump.



Stocking the managed marsh with the spawning fish.

Data for the regression were obtained by using a volumetric method to estimate the number of eggs from the 27 females obtained from Fox Lake in March of 1972, and measuring the females to the nearest tenth of an inch in total length. These fish had an average length of 29.1 inches with a range of 24.4 to 35.3 inches. The number of eggs in each female was estimated by first counting the number of eggs that displaced 10 ml of water. This procedure was done for six replicates for each fish and an average and 95 percent confidence limit were determined. The second step was to continue to make 10-ml displacements with the remaining eggs and the average number for each female determined in step one was used instead of counting the eggs. A linear regression was generated using the estimates of the number of eggs and the length of each of the 27 females. A 95 percent confidence limit of the estimated number of eggs from an average female whose length is equal to the mean length of the stocked fish was also calculated. Furthermore, 95 percent confidence limits of the predicted number of eggs produced by hypothetical females of several lengths were computed (Mendenhall 1965). Both types of confidence limits for numbers of eggs produced reported by other researchers were also determined. Finally, the total eggs potentially deposited in each marsh each year was calculated by taking the average length of the females in the marsh, and using the linear regression, estimating the number of eggs (with its 95 percent confidence limit) produced by an average female. This number was then multiplied by the number of females stocked.

To estimate egg survival in the marshes, in 1972, fertilized eggs were placed on one-foot-square nylon mats which had been divided into two-inch squares and covered with a plastic screen. Five mats were placed on the bottom of the Pabst Marsh. An attempt to have five densities of eggs was made using 50, 100, 200, 400, and 800 eggs per square foot.

In 1973, fertilized eggs were placed in 8.62-square-inch plastic petri dishes, prepared for the study by cutting 4.9-square-inch circular holes out of the tops and bottoms of the petri dishes, and glueing plastic window screen with a mesh size of 16 per inch over these holes. An attempt to have five densities of eggs was made by placing 32, 16, 8, 4 and 2 eggs in each of five different petri dishes which would give egg densities of 3.7, 1.9, 0.9, and 0.5, and 0.2 eggs per square inch, respectively. Six replicates of each of the five densities were placed in the marsh. The petri dishes containing the eggs were suspended in the water just below the surface by placing the dishes on wire mesh screens which formed shelves that were attached to steel stakes. There were five shelves on a stake, one for each of the egg densities. The condition of the eggs was checked on an average of every other day. A visual assessment of viability was made in the field on the basis of opaqueness and presence of fungus.

Growth Determination

Approximately 25 northern pike fry and fingerlings which were collected weekly for stomach analyses were measured to the nearest millimeter. At draining, the number of fish in the sample at the Pleasant Lake Marsh (1969-73) varied from 96 to 375 (average of 251) and at the Pabst Marsh (1971-72) from 348 to 375. The linear regressions for growth of the northerns in each marsh were calculated for each year by using an approximately equal number of fish from each week's sample. However, any weekly samples that averaged less than 19 mm were not used since the growth curve is not linear during this early period as will be shown later in Figures 5 and 6. At the time of draining in 1972 and 1973, a subsample of the fingerlings measured were also weighed to the nearest gram. From these fingerlings that were both weighed and measured, a weight-length equation and the 95 percent confidence limit for the expected weight of an average fingerling whose length is equal to the sample mean was derived. A common log transformation was used on the lengths and weights so that they would be linearly related. The numbers of fingerlings both weighed and measured at the Pleasant Lake Marsh in 1972 and 1973 and at the Pabst Marsh in 1972 were: 303, 74, and 59, respectively. Average weights of the fingerlings produced at the Pleasant Lake Marsh in 1969 through 1971 were determined by using the weight versus length equation derived from the combined 1972 and 1973 measurements at the Pleasant Lake Marsh. Average weights for the fingerlings produced at the Pabst Marsh in 1971 were determined by using the weight-length equation from the 1972 Pabst data. By using the average length of all fingerlings measured at a marsh during draining and the appropriate weight-length equation, the biomass of fingerlings produced was estimated with its 95 percent confidence limit.

Stomach Analyses

Weekly samples of approximately 25 northern pike were taken with a dip net or fine mesh seine and preserved in a 10-percent Formalin solution (Lagler 1956). The fish were measured to the nearest millimeter in total length. The entire stomach contents (whole and fragments) of those fish whose stomachs contained at least one food organism were identified and counted.

A Fortran computer program was developed that performed the analysis not only of the stomach contents and length of the fish, but also of the composition of zooplankton and benthic samples. A sample printout from this program is shown in Figure 11, Appendix. The number of each organism identified in each fish, zooplankton, or benthic sample for each date and each marsh was recorded on IBM cards. For the fish samples, the fingerling's length was also recorded. The program computed the arithmetic mean, its variance, and its 95 percent confidence limit, frequency of occurrence, and percent of the total number of organisms. In the case of zooplankton and benthic samples, it also calculated the numbers per gallon and numbers per 100 square centimeters. When it was found through test runs of the data that a transformation was necessary, this also was done by the program. Various groupings of the data with respect to organisms, date, or size range of fish was also easily accomplished through the program.

Counts of organisms in the stomachs had a distribution that was contagious since the variances for the counts of each of the organisms on a given day were greater than the mean. Therefore, a common log (x+1) transformation was used (Elliott 1971). The geometric mean, percent of total organisms, percent occurrence, and corrected mean (derived plus adjustment) were calculated by the computer program for each of the various groupings of organisms. By using the 95 percent confidence limits, a conservative ranking of the most numerous organisms on a given day was made in view of the extreme variability of the food content. Thus if the lower 95 percent confidence limit for an organism was higher than the upper confidence limits for any other, it would be given a rank of one. The organism whose lower limit was above all the remaining upper limits was given a rank of two. If the confidence limits of one organism overlapped with those of another, they were each given the same rank.

Production Determination

The beginning date for draining the marshes for the various years varied from 25 May to 8 June. At both marshes, the center boards on the concrete dams were pulled and a wire mesh pen measuring 10 ft by 5 ft by 3 ft deep was placed near the outlet to collect the fingerlings. In 1973 at the Pleasant Lake Marsh, due to the extremely high levels of water in the lake, most of the water in the marsh had to be pumped out. This was accomplished by placing the wire mesh pen in the marsh about 10 ft in front of the dam and building a coffer dam on either side of the entrance to the pen. The two 3-inch and one 2-inch Homelite pumps were then placed between the two dams, and the fingerlings, which were attracted to the current, were captured before they reached the pumps.

The production of northern pike fingerlings from the managed marshes was determined by making actual counts of every fingerling that was captured as the marshes were drained, except for a partial estimate that was necessary at the Pleasant Lake Marsh in 1973 when the marsh could not be completely drained. After the counting of the fingerlings captured in the pen was completed, an estimate of those remaining in the marsh was made by walking around the shore of the marsh and making counts of the fingerlings observed. The estimate used is considered minimal since visual observations were limited to the immediate shoreline.

SAMPLING OF OTHER ORGANISMS

Zooplankton

Three sampling stations were set up at the Pleasant Lake Marsh from 1969 through 1971 and one at the Pabst Marsh in 1971. Weekly samples of 15 to 25 gallons of water were collected in a 1.5-gallon bucket and strained through a number 10 plankton net and cup. Samples were preserved with a 10-percent Formalin solution or an Acetic-Formalin Alcohol (A.F.A.) solution. Each sample was analyzed by taking three subsamples of 3 ml each and identifying all organisms.

In 1972, zooplankton samples were collected weekly and in 1973, twice weekly. A Homelite (Model XLS1½-1A) pump connected to a Badger (Model 40) water meter was used to pump at a rate of approximately 35 gallons per minute through a number 10 plankton net and cup (Fago 1975). A route was followed from the center of the marsh to the shoreline and then along the shoreline until approximately 400 gallons had been pumped. The intake level was varied in order to collect a composite sample from all depths. The samples were preserved in A.F.A. solution and later analyzed by taking from six to ten subsamples of 3 ml each.

Counts from each subsample collected by means of the methods used in 1969-71 and 1972-73 were transformed using the common log (x+1). Since the variances of the counts were larger than the means, the zooplankton would have had a contagious distribution, but with the transformation, the counts were normalized. They were then converted to number per liter. The geometric means of the subsamples for a day, 95 percent confidence limits, percent of the total organisms and corrected mean were calculated, using the computer program previously described. The organisms were then ranked for each sampling day in relation to their 95 percent confidence limits.

Benthic Fauna

Benthic samples were taken in 1971 using an Ekman dredge (6 inches by 6 inches by 9 inches) with a five-foot steel rod extension. Three stations at the Pleasant Lake Marsh and one at the Pabst Marsh were sampled weekly and at each station four samples were taken and analyzed separately. Each sample was preserved with A.F.A., to which approximately 100 mg/l of the stain phloxine B was added. Complete samples were later washed in a number 35 screen, sorted, and identified. Since the counts of the benthic organisms, like the zooplankton samples, had a contagious distribution, a common log (x+1) transformation was used on the counts. They were then converted to number per 100 square cm. The geometric mean of the counts for all samples at a marsh for a given day, 95 percent confidence limits, percent of the total organisms, and corrected mean were calculated for each of the major groupings of organisms.

Since the Ekman dredge was unable to penetrate into the dense mat of grass roots at the Pabst Marsh or the leatherleaf bog at the Pleasant Lake Marsh, a new type of sampler was used in 1972 that consisted of a core sampler made from an aluminum pipe with an inside diameter of 52 mm. Four sampling stations were used at the Pleasant Lake Marsh, and five at the Pabst Marsh. Two samples from each station were taken weekly. Methods used to preserve and analyze the samples were similar to those previously described for the 1971 sample.

PHYSICAL AND CHEMICAL MEASUREMENTS

From 1969 through 1971 at the Pleasant Lake Marsh, four sampling stations, and in 1971, five stations at the Pabst Marsh were sampled twice weekly for dissolved oxygen, pH, alkalinity, and minimum-maximum temperatures. The minimum-maximum temperatures reported represent the average minimum and maximum temperatures of the water on the bottom of the marsh at the various stations since the last time the thermometers were checked. The average temperature of the dissolved oxygen samples that were taken at the water surface was also determined. Dissolved oxygen was determined using the Winkler method. More complete water chemistries were performed each year when the marshes were flooded and again just before draining to determine the concentrations of the following: nitrite, nitrate, ammonia, organic and total nitrogen, dissolved and total phosphorous, calcium, magnesium, sodium, potassium, iron, manganese, sulfate, chloride, and conductivity.

In 1972, ten stations were established at the Pabst Marsh and five stations at the Pleasant Lake Marsh. Samples for complete water chemistries were collected weekly and analyzed at the Delafield Laboratory. After several weeks, the number of stations at the Pabst Marsh was reduced to five, and at the Pleasant Lake Marsh, to four (Figs. 1 and 4) since differences in water chemistries between stations were found to be negligible.

In 1973, the same stations at the Pleasant Lake Marsh were used as in 1972. Station 3 at the Pleasant Lake Marsh was only sampled from 29 March to 24 April 1973, since the floating mat later made the readings meaningless.

During all years, a Taylor seven-day continuous thermograph was also used at one of the stations at each of the marshes. In 1972 and 1973, a combination of the Yellow Spring (Model 51A) dissolved oxygen analyzer and the Winkler method were used to determine the dissolved oxygen levels twice weekly.

RESULTS AND DISCUSSION

SPAWNING STOCK

The time of stocking varied from 16 March to 5 April for the various years. Yearly averages for the total length of the females ranged from 20.3 to 31.5 inches with an average of 21.8 inches. The corresponding weight of females stocked ranged from 2.3 to 9.0 lbs. with an average of 4.7 lbs. The stocking rates of females ranged from 10.4 to 14.3 lbs/acre during the study, averaging 12.1 lbs/acre. The numerical ratio of stocked males to females varied from 2.8:1 to 4.0:1 for the various years and averaged 3.2:1. The yearly averages for the total length of the males ranged from 13.2 to 22.2 inches with an average of 18.7 inches (Table 1).

McCarraher (1957) and DiAngelo (1961) used a stocking rate of 5 females/acre and 2 males for every female. Royen (1971) used between 15 and 32 pounds of female/acre of marsh and 1.6 to 2.4 males per female but found

An adult northern pike spawner in the Pleasant Lake Marsh.

no relationship between number of females stocked and number of fingerlings produced. Jarvenpa (1963) reported stocking rates of 3.6 to 20 pounds of female/acre and two males for every female.

EGG DEPOSITION

The linear regression for the number of eggs versus the total length of the female from this study was: E = 4,417 L − 62,555 where E is the number of eggs and L is the total length of the female in inches. The estimated number of eggs of each of the 27 females used to generate this regression had an average 95 percent confidence limit of ±1.9 percent. The size range of the northerns was from 24.4 to 35.3 inches, with a mean of 29 inches. However, this is not highly significant when compared to the 95 percent confidence limit of the number of eggs expected from the linear regression of an average female, even when its length is the same as the sample mean. This confidence limit of the expected number of eggs was ± 6 percent. Other researchers' equations, with my calculations of their 95 percent confidence limits of the expected number of eggs from an average female are: Smith, Franklin, and Kramer (1958), $E = 4{,}401.4\ L - 66{,}245$ (±13 percent) based on a sample size of 6 fish; Forney (1968), $E = 4{,}378\ L - 65{,}720$ (data not available to generate confidence limits), based on a sample of 11 fish; Carbine (1943), $E = 3{,}797.5\ L - 57{,}256$ (±10 percent), based on a sample of 30 fish; and Priegel and Krohn (1975), $E = 4{,}980\ L - 74{,}885$, (±13 percent), based on a sample of 11 fish.

By using the regression generated by this study, the annual number of eggs deposited in the Pleasant Lake Marsh was estimated to range from 383,000 in 1973 to 800,000 in 1970 with an average of 539,000 and at the Pabst Marsh the number of eggs deposited was 2,467,000 and 2,339,000 for 1971 and 1972, respectively (Table 1). These estimates had 95 percent confidence limits that ranged from 5.9 to 6.9 percent.

If one wanted to predict the number of eggs of a particular female northern for any given length, then the 95 percent confidence limits are greatly expanded. For this study it would be increased to about ± 31 percent, as compared to the ±6 percent for an average fish, as previously stated. Similarly, the confidence limits calculated for other researchers' data would be increased to: ± 34 percent (Smith, Franklin, and Kramer 1958); ± 55 percent (Carbine 1943); and ± 46 percent (Priegel and Krohn 1975).

TABLE 1. *Northern pike brood fish stocked in managed spawning marshes.*

	Statistics Grouped by Planting Year and Date						
	Pleasant Lake					Pabst	
Stocking Statistic	1969 (3/28)	1970 (4/3)	1971 (4/1)	1972 (4/5)	1973 (3/16)	1971 (4/2)	1972 (3/30)
Number of females	18	19	16	7	5	91	40
No. females/acre	4.9	5.1	4.3	1.9	1.4	4.9	2.2
Avg. length of females (inches)	21.2	23.7	21.3	28.6	31.5	20.3	27.4
Avg. lbs/female	2.3	*	2.9	5.5	9.0	2.9	5.6
Lbs female/acre	11.2	*	12.5	10.4	12.2	14.3	12.1
Total no. eggs (x 1000)	560	800	504	446	383	2,467	2,339
95% confidence limit**	7	7	7	6	6	7	6
Number of males	50	53	56	28	15	273	136
Avg. length of males (inches)	18.0	15.5	18.7	22.2	21.7	13.2	21.7
Avg. lbs/male	*	0.9	2.0	2.4	2.3	0.5	2.3
Ratio of males to females	2.8:1	2.8:1	3.5:1	4.0:1	3.0:1	3.0:1	3.4:1

* Weights not taken
**In percent of mean

Draining the Pleasant Lake Marsh in order to collect the northern pike produced.

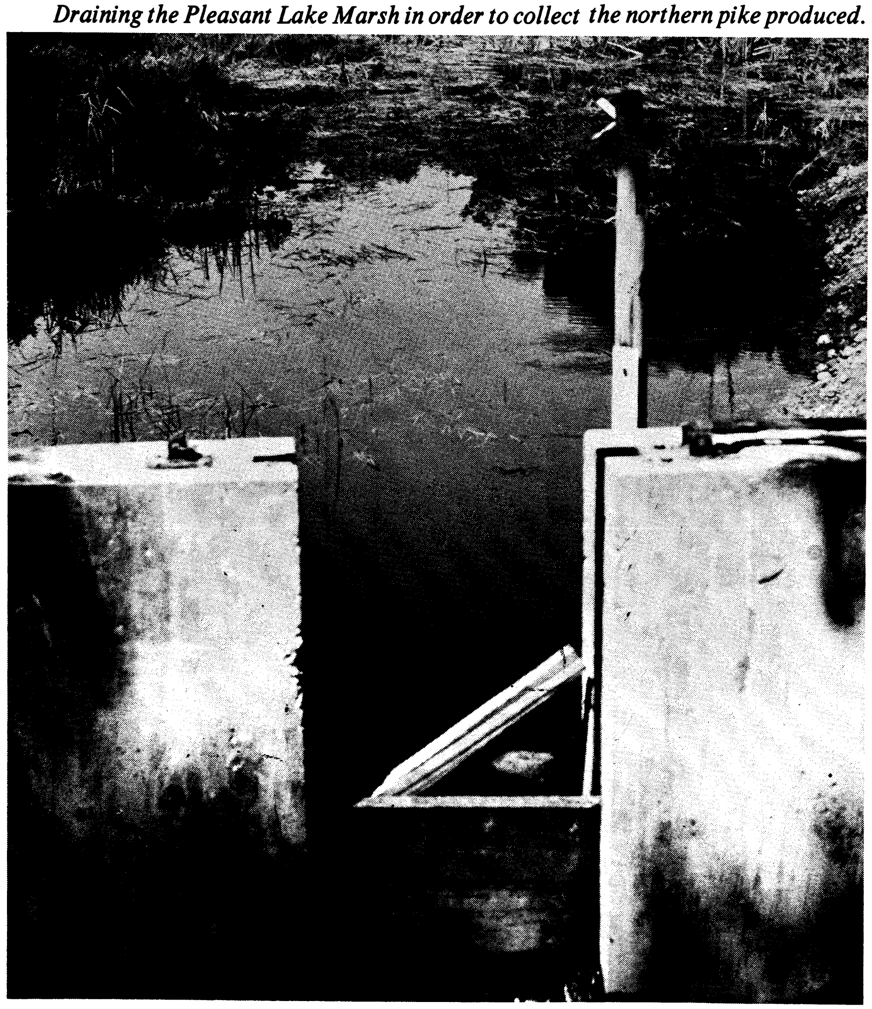


TABLE 2. *Northern pike fingerling production from the Pleasant Lake and Pabst managed marshes (95 percent confidence limits shown in parentheses).*

	Production Figures Grouped by Year and Draining Date						
	Pleasant Lake					Pabst	
Production Figures	1969 (6/3-7)	1970 (6/8-11)	1971 (6/1-4)	1972 (5/25-26)	1973 (5/29-6/2)	1971 (6/7-13)	1972 (5/30-6/3)
Total number fingerlings	3,730	1,200	2,000	12,000	9,150***	12,600	19,460
Percent survival	0.67	0.15	0.40	2.69	2.39	0.51	0.83
Number/acre	1,009	324	541	3,243	2,473	681	1,052
Avg. length (mm)	91(±1.5)	81(±2.3)	100(±5.1)	70(±1.2)	78(±1.2)	96(±2.3)	108(±1.4)
Length range (mm)	41-137	38-125	41-155	53-131	48-130	48-173	38-152
Avg. length (inches)	3.6(±.05)	3.2(±.11)	3.9(±.24)	2.8(±.05)	3.1(±.05)	3.8(±.11)	4.3(±.05)
Avg. weight (g)	4.6*	3.1*	6.2*	1.9	3.0	4.7**	6.3
Lbs/acre	10.1*	2.2*	7.4*	13.6	16.1	7.0**	14.6

*based upon length vs. weight equation derived from 1972 and 1973 Pleasant Lake Marsh data.
**based upon length vs. weight equation derived from 1972 Pabst Marsh data.
***only 6,650 actually counted (see text).

FINGERLING PRODUCTION

Survival

The best overall production from either marsh for any of the years studied was in 1973 at the Pleasant Lake Marsh when a total of 6,650 northern pike fingerlings were counted. In addition to this count, an estimated 2,500 fish emigrated from the marsh after the pumping was stopped, for a total production of approximately 9,150 fingerlings (2,473 fish/acre). These fish averaged 78 mm ± 1.2 mm (3.1 inches ± 0.05) with a length range of 48 to 130 mm (1.9 to 5.1 inches) (Table 2). This production in 1973 represents a 24-percent decline in the number of fingerlings produced over 1972 (which averaged only 70 mm), but nevertheless a 93-percent increase over the average number produced for the previous four years. The weight (and 95 percent confidence limits in parentheses) of the fingerlings averaged 3.0 grams (± 2 percent) [0.104 ounces (± 2 percent)] and amounted to 16.1 lbs/acre (± 2 percent) [18.0 kg/ha (± 2 percent)]. This represents an 18-percent increase in pounds per acre over 1972 production, and a 93-percent increase over the average pounds per acre for the previous four years (Table 2). This seemingly paradoxical increase in pounds per acre with a decrease in the number of fingerlings for 1973 is explained by the 58 percent increase over the average weight of the fingerlings in 1972. Forney (1968) is one of the few researchers who took weights of the northern pike produced from his managed marshes. He reported weights of 6.8, 3.2, and 6.1 lbs/acre for northern pike produced in each of three years in which a managed marsh was studied.

It was evident in all years, especially 1973, that the fingerlings were not able to make use of the mat area in the center of the Pleasant Lake Marsh once the mat had floated to the surface, near the end of April. Since the leatherleaf comprises approximately 50 percent of the area of the marsh, the production on an acreage basis could actually have been as high as 32.2 lbs/acre (36 kg/ha).

The percent survival of the estimated number of eggs deposited to the number of fingerlings produced from the two study marshes varied from 0.15 to 2.69 (Table 2). However, it must be remembered that the confidence limits on the estimated number of eggs deposited can be significant (see earlier discussion of Egg Deposition). Other researchers have reported survival rates as high as 29.25 percent from Mission Lake Pond Number 1 in 1962 in Minnesota (Jarvenpa 1962) and 6.6 percent from Lower Townline Lake in Michigan (Williams 1963); however, the average length of the fingerlings produced was only 51 and 66 mm, respectively. The highest percent survival reported from a marsh for fingerlings averaging 76 mm or larger was 1.63 percent from the St. Croix Park pond in 1962 in Minnesota (Jarvenpa 1962) (Table 3). Therefore, the 2.39-percent survival to an average length of 78 mm (3.1 inches) in the Pleasant Lake Marsh in 1973 was extremely high.

A multiple regression was run with the number of fingerlings per acre as the dependent variable and the average length of the fingerlings at the time of draining and the number of eggs deposited per acre as the independent variables using sixty marsh-years of managed spawning marsh data from a combination of work done in New York, Michigan, Minnesota, Nebraska, and Wisconsin (Table 3). This regression had a multiple correlation coefficient of only 0.313. The r^2 value of 0.10 suggests that many other factors may also have affected production. Intuitively, one would expect factors such as water temperature and food supply to influence the numbers of fingerlings produced.

It must be remembered when making conclusions from this analysis that the regression is subject to any biases in techniques of estimating the number of eggs, in counting or estimating the number of fingerlings produced, and in estimating the average length of the fingerlings. Thus, it is possible that one or both of the independent variables may be highly influential in determining the numbers of fingerlings produced but is masked by one or more of the errors and biases mentioned.

TABLE 3. *Northern pike fry and fingerling production from managed spawning and rearing marshes in six states.*

Location	Marsh Size (Acres)	Year	Eggs Deposited Acre (X 1000)	Fingerlings: No. Per Acre	Fingerlings: Average Length (mm)	Fingerlings: Size Range (mm) Min.	Fingerlings: Size Range (mm) Max.	% Survival	Reference
New York									
Oneida Lake	7.3	1964	151	6,181	≈36	18		4.1	Forney (1968)
		1965	171	5,554	≈36	18		3.2	
		1966	92	2,557	≈46	18		2.8	
Michigan									
Houghton Lake	≈4	1939	1,006	1,810				0.18	Carbine (1941)
(Peterson's Ditches)		1940	523	374				0.07	
		1942	451	≈2,000				0.44	
Townline Lake (Lower)	4.2	1958	60	3,976	66	48	99	6.6	Williams (1963)
		1959	21	425	51	33	79	2.0	
		1960	490	196	30	18	46	0.04	
		1961		6,262	30				
Ostego Lake	31.0	1959	72	43	69	36	132	0.06	
		1960	28	1,242	58	41	112	4.4	
		1961	84	3,027	58	23	114	3.6	
		1962	470	470	79	33	142	0.1	
		1963	162	1,459	43	25	84	0.9	
Rose Lake	2.0	1961		2,067	48				DiAngelo (1961)
Halls Lake	10.0	1961		1,983	43				
Crooked Lake (Lower)	1.9	1961		1,132	56				
Bertha Lake	0.5	1961		237	56				
Schoolsection Lake	3.2	1961		2,329	41				
Townline Lake (Upper)	8.0	1961		1,059	38				
Eagle Lake	7.0	1961		553	46				
Minnesota									
I.W.L.A. Pond #1	20.0	1962	180	6,679	51			3.71	Jarvenpa (1962 & 1963)
		1963	5,957	2,740		25	51	0.046	
Mission Lake Pond #1	20.0	1962	100	29,205	51			29.25	
		1963	998	4,293		25	76	0.043	
St. Croix Park Pond	5.0	1962	209	3,400	76			1.63	
		1963	10,213	9,600				0.094	
St. Paul Pond #4	0.5	1963	14,286	2,000				0.014	
Sabre Lake	5.0	1962	297	1,100	51			0.37	
		1963	25,000	25	38			0.0001	
Waterville Pond #2	9.0	1962	407	2,567	64			0.63	
		1963	17,600	352	51			0.002	
Rose Lake	2.0	1963	14,286	1,000		38	51	0.007	
Whitehead	4.5	1963	4,010	3,689		51	102	0.092	
Hutchenson Pond	11.9	1963	981	1,079	89			0.11	
Shetek Pond #1	10.2	1962	120	24	76			0.02	
		1963	8,333	5		32	44	0.00006	
Shetek Pond #2	7.4	1962	171	24	89			0.014	
Jacobs Pond	2.0	1962	107	630	51			0.59	
		1963	8,685	1,737	56			0.020	
Cannon R. (I.W.L.A.)	1.0	1962	258	103	76			0.04	
		1963	52,250	1,045	38			0.002	
Pine Island Lake	2.0	1963	8,250	495	86			0.006	
Laitimer Lake Pond	2.0	1962	1,883	3,578		25	38	0.19	
		1963	8,750	350	89			0.004	
Ann Lake	1.0	1963	12,763	5,616	46			0.044	
Wilkoske Pond	2.0	1962	1,129	10,500	64			0.93	
Harriet Lake	17.0	1962	63	2,056	64			3.25	
Fox Lake	4.5	1962	67	447	127			0.67	
Kiester Pond	30.9	1962	24	184	127			0.76	
Lieuna Lake	10.0	1962	124	21				0.017	
Miss. River (Brainerd)	20.0	1962	55	11	102			0.02	
Coyote Creek	20.0	1962	75	3				0.004	
Phalen Pond	2.9	1965	375	≈3,000				0.8	Bryan (1967)
Lake George	9.0	1955		≈377					Franklin & Smith (1963)
		1956	234	≈10,327				4.62	
		1957	152	455				0.30	
Nebraska									
Valentine Pond A	2.6	1955	57	1,885	43			3.3	McCarraher (1957)
Valentine Pond B	1	1955	58	1,946	58			3.3	
Valentine Pond C	1	1956	330	1,700	66	38	79	0.5	
Valentine Pond D	1.5	1956	160	3,367	38			2.1	
Bluestem	325	1971		45		51	104		Morris (1974)
		1972		88		38	117		
		1973		261		38	91		
Wisconsin									
Lake Ripley	10	1964	174	70	53			0.4	Kleinert (1970)
		1966	533	52	48			0.1	
Pleasant Lake	3.7	1969	151	1,009	91	41	137	0.67	Present study
		1970	216	324	81	38	124	0.15	
		1971	136	541	99	41	155	0.40	
		1972	121	3,243	71	53	132	2.69	
		1973	104	2,473	79	48	130	2.39	
Pabst Marsh	18.5	1971	133	681	97	48	173	0.51	Present study
		1972	126	1,052	109	38	152	0.83	
South Dakota									
North Dimock	0.5	1957		3,260	43				Boussu (1958)
South Dimock	0.4	1957		2,285	43				
Hanson	0.3	1957		22,600	43				
Clear	4.1	1957		292	91				
French	1.6	1957		No est.	69				

Growth

The linear regression for growth of the fingerlings in 1969 through 1973 in Pleasant Lake Marsh is:

$$L = -245.1 + 2.12\ S$$
$$L = -381.2 + 2.94\ S$$
$$L = -313.8 + 2.69\ S$$
$$L = -433.7 + 3.42\ S$$
and
$$L = -233.8 + 2.05\ S$$

where L is expressed in millimeters and S in day of the year. The equations for growth at the Pabst Marsh in 1971 and 1972 are:

$$L = -308.4 + 2.59\ S$$
and
$$L = -469.8 + 3.74\ S$$

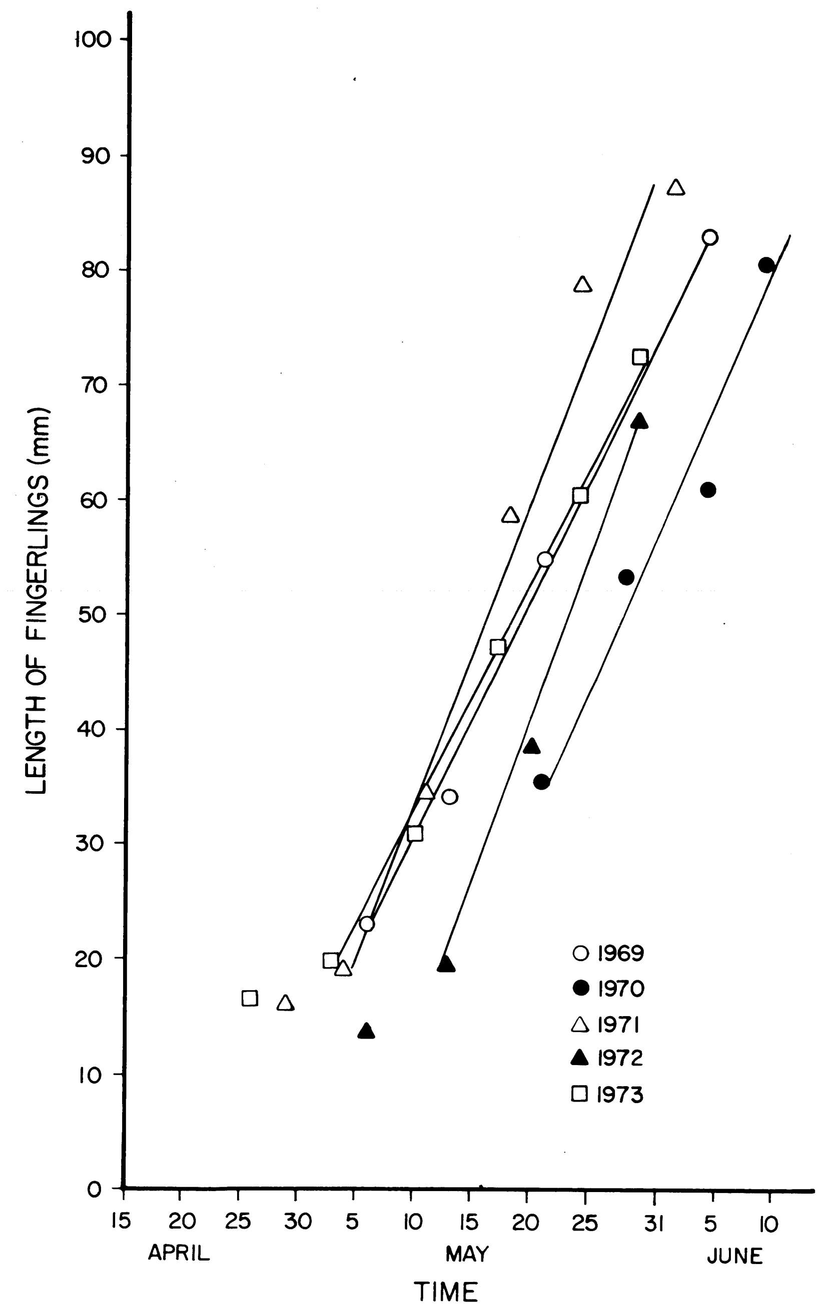
Figures 5 and 6 show growth curves and indicate that the fastest to the slowest growing fish were: 1972 Pabst; 1972, 1970 and 1971 Pleasant Lake; 1971 Pabst; 1973 and 1969 Pleasant Lake fish, respectively. Northern pike from the Pleasant Lake and Pabst Marshes had average growth rates of 2.64 and 3.17 mm/day, respectively. Forney (1968) reports growth rates of 2.4 mm/day for fish over 20 mm in length from his managed marsh. Franklin and Smith (1963) give growth rates that range from 0.5 to 2.3 mm/day depending on what portion of the growth curve is considered for the northern pike fingerlings from their marsh. Bryan (1967) found growth rates of 0.67 mm/day; however, this was only for fry up to approximately 22 mm in length. Carbine (1941) reports an average growth rate from his marsh of approximately 2.6 and 1.6 mm/day for fish over 20 mm in length during two years studied. Thus, the growth of 3.74 mm/day at the Pabst Marsh in 1972 is the highest rate reported. However, all of these rates are approximations since the hatching period of eggs occurs over an extended period and therefore the exact age of a particular fish in a marsh is never known.

The length of the fingerlings at the time of draining at the Pleasant Lake and Pabst Marshes ranged from 38 to 173 mm (1.34-6.10 inches) (Table 1), with annual averages of 70 and 108 mm, respectively.

The weight-length equations for the fingerlings from the Pleasant Lake Marsh in 1972 and 1973 and Pabst Marsh in 1972 are:

$$W = 1.92 \times 10^{-6}\ L^{3.252}$$
$$W = 22.08 \times 10^{-5}\ L^{2.722}$$
and
$$W = 3.75 \times 10^{-5}\ L^{2.571}$$

FIGURE 5. *Growth curves of northern pike fingerlings in the Pleasant Lake managed spawning marsh, 1969-73.*



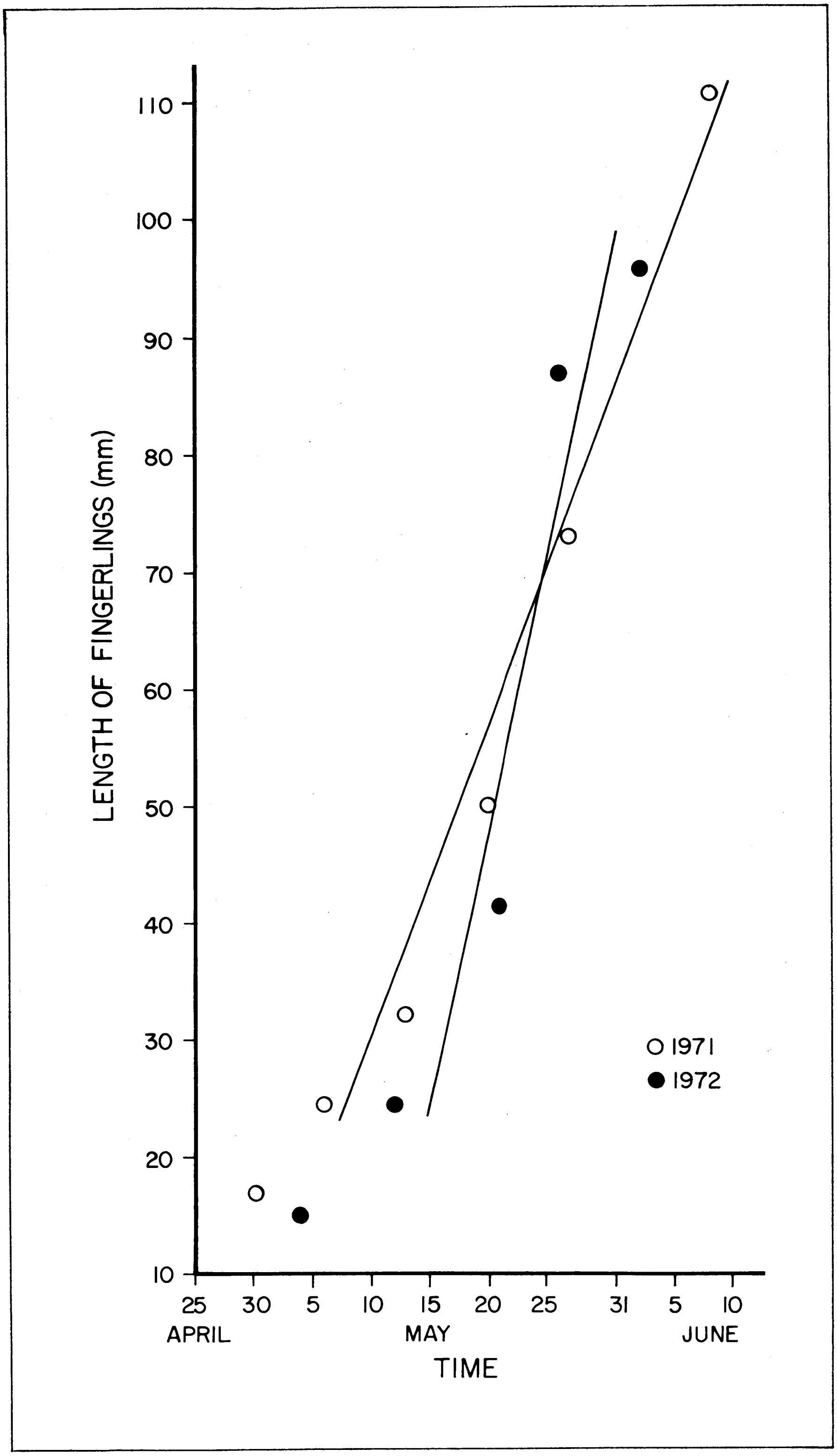


FIGURE 6. *Growth curves of northern pike fingerlings in the Pabst managed spawning marsh, 1971-72.*

where W is expressed in grams and L in millimeters. All had an average ±95 percent confidence limit of ± 2 percent and correlation coefficients of 0.93, 0.86, and 0.94, respectively. The weight-length equation of the combined 1972 and 1973 Pleasant Lake Marsh data that was used to estimate the weights of the fingerlings produced at Pleasant Lake between 1969 and 1971 is $W = 2.14 \times 10^{-6} L^{3.23}$ with a 95 percent confidence limit of ± 2 percent and a correlation coefficient of 0.92. Franklin and Smith (1963) give equations of:

$$W = 2.2 \times 10^{-5} L^{2.693}$$
$$W = 7.59 \times 10^{-6} L^{2.940}$$
and
$$W = 6.6 \times 10^{-6} L^{2.996}$$

for the years 1955 through 1957, respectively, from their Lake George study. Lake George, Pleasant Lake, and Pabst marshes are all in relatively close agreement when the 95 percent confidence limits are taken into account with the possible exception of the 1957 equation from Lake George.

FACTORS THAT AFFECT FINGERLING PRODUCTION

Stocking Rates

The relationship between the stocking rates of spawners and the optimum production of northern pike fingerlings in the Pleasant Lake or Pabst marshes, was not quantitatively defined, nor has it been defined by other researchers in this field. However, it is my thought that the female spawners should preferably be large (over 25 inches) so that fewer are needed to supply the necessary eggs. This reduces the number of males needed, and also reduces the total number of spawners which need to be removed after spawning. Based on stocking rates cited in the literature and those used at the Pleasant Lake and Pabst marshes, the females should probably be stocked at a rate of 10 to 15 lbs/acre and the number of males (at least 20 inches in total length) should be two to three per female. All spawners should be removed from the marsh as soon as possible after spawning has been completed to prevent predation on the young.

Aquatic Vegetation

The dominant aquatic vegetation in the Pleasant Lake Marsh was leatherleaf, which occupied the center of the marsh. However, cattails and a few patches of sedges occurred along the perimeter of the marsh. At the Pabst Marsh, reed canary grass occupied over 99 percent of the marsh's area. The use of different vegetation types and the survival of eggs on these types was not measured due to the lack of manpower needed to make a statistically sound assessment. However, spawning activity was dominant in the Pleasant Lake Marsh along the edge of the marsh in the dense mats of dead sedges and cattails.

Other researchers such as McCarraher and Thomas (1972) have reported that mowed hay or broken hay bales were attractive to spawning northern pike. Carbine (1941) stated that northern pike in the drainage ditches flowing into Houghton Lake used marsh grass, *Calamagrostis canadensis*, for spawning. Forney (1968) has reported northerns spawned on seeded plots of winter wheat as well as natural vegetation consisting of grasses (*Spartina*), sedges (*Carex*), and water plantain (*Alisma*). Fabricius and Gustafson (1958) also found that pike preferred spawning over meadows of sedge grasses. Priegel and Krohn (1975) are still other researchers who believe that pike prefer dense mats of sedge and wild celery for spawning.

It would seem from these observations that the most suitable vegetation for a spawning marsh would be a sedge or grass type that forms a mat beneath the surface to which the eggs can adhere, thus keeping them out of the bottom sediments where the dissolved oxygen levels are low.

Egg Survival

In 1972, less than one percent of the artificially fertilized eggs placed on nylon mats in the marsh hatched. The cause or causes of mortality could not be determined, but high siltation on the eggs and the related blockage of dissolved oxygen into the eggs probably were influential.

In 1973, mortality of artificially fertilized eggs was 100 percent, and the causes were again indeterminable. The eggs were placed in the petri dishes on 22 March, and by 25 March most of the eggs looked unhealthy. Most of the eggs had started to develop, but never went much farther than the formation of a blastodermal cap. By 1 April, over 95 percent of the eggs were opaque and fungus was present. Some possible causes for the mortality include toxicity of materials used to hold the eggs, low dissolved oxygen levels immediately around the eggs due to insufficient flow of water through the petri dishes, injury due to handling, and low water temperatures. Survival of the eggs naturally deposited in the marshes during 1972 and 1973 must have been relatively high, since very large numbers of fingerlings were produced (Table 2).

There has been little quantitative work on the survival of eggs in a marsh. Carbine (1941) had estimates of the survival of the number of eggs deposited to emigration of the young that ranged from 0.07 to 0.44 percent. Franklin and Smith (1963) had estimates based on a live-to-dead egg ratio of the survival to hatching of the number of eggs deposited that ranged from 63.6 to 89.6 percent. Bryan (1967) estimates the survival of the eggs to hatching at 90 percent. He used a live-to-dead egg ratio to obtain his estimate from the eggs he collected from the marsh. Forney (1968), in his work on the survival of eggs to the fry stage, estimated survival at 77 percent if a live-to-dead egg ratio is used, and at 18 percent if a population estimate based on the number of eggs and fry per square foot in the marsh is used. He calculated that, with his later method, both the estimates of the numbers of eggs and fry per square foot had a standard error of about 20 percent.

The problem with using a live-to-dead egg method to determine egg survival is that it does not take into account loss of eggs from predation, or rapid decomposition. Those who have used this method in the past have also failed to report confidence limits about their estimates.

Thus, there is a great deal of work that is still needed, first, to obtain better estimates of survival rates of the eggs in the marsh; and second, to design experiments to determine the factors which influence their survival.

Food Supply

Zooplankton. Analyses of the zooplankton samples collected between 1969 and 1971 indicate that the zooplankton had a spatial dispersion that was contagious, since the variances were usually greater than their means (Elliott 1971). Since a sampling scheme that would have allowed differences between stations to be determined was beyond the manpower available, one sample that strained a much larger volume of water and sampled a greater number of habitats in the marsh was used in 1972 and 1973. This, hopefully, would give a fairly good estimate of the mean populations of zooplankton in the marsh on a sampling date. However, in both 1972 and 1973, due to the problems associated with subsampling of the strained zooplankton sample, variances of the counts between subsamples on a given day were greater than the mean. One of the major problems involved filamentous algae, which were also collected in the zooplankton sample, trapping large numbers of zooplankton and insects and causing a clumping effect. This resulted in the distribution of zooplankton in the storage jar also having a contagious distribution. In order for comparisons to be made between sampling dates, a common log (x+1) transformation was used on all samples from 1969 through 1973. These problems made comparisons of zooplankton populations between marshes, sampling dates, and years very difficult, since the 95 percent confidence limits about the means were usually very wide.

The average ranking for 1973 at the Pleasant Lake Marsh for the four major groupings of organisms collected is given in Figure 7. Copepoda, principally *Cyclops* sp., dominated the sample until the end of May when Cladocera, principally *Chydorus* sp. surpassed the numbers of Copepoda collected. Tables 4 and 5 give the rank, percent of the total for a day, and numbers per liter for Cladocera, Copepoda, Ostracoda, and Insecta at Pleasant Lake and Pabst marshes for the various years of this study. A complete breakdown of organisms, giving 95-percent confidence limits for each estimate is provided in Table 13 in the Appendix. This table clearly shows the wide confidence intervals about the estimated population densities of the individual organisms. A number of researchers have reported on their samples of the plankton and insects in a northern pike spawning marsh. However, no one has published a statistically sound picture on a quantitative basis of individual groupings of these populations over the period of approximately two months that the pike are present.

Benthic Fauna. The core sampler used in 1972 was able to penetrate the dense mat of grass roots at the Pabst Marsh and the floating mat at the Pleasant Lake Marsh. The Eckman dredge which was used in 1971 was unable to do this, thus the samples collected were not representative of the benthos. Therefore, a comparison between years was not attempted.

A quantitative comparison of the benthic fauna in 1972 between sampling dates failed to show any significant differences due to the wide confidence limits about the mean numbers of each of the species for a sampling date (Tables 6 and 7). A tremendous increase in the number of sampling stations and the number of samples taken at each station would be required in order for this type of comparison to be made. This, however, was beyond the available manpower. Other researchers who have worked on managed northern pike spawning marshes have not attempted a quantitative study of the benthic fauna. In fact, Smith, Franklin, and Kramer (1958) are one of the few who conducted any type of benthic study. Thus, there is little information on the benthos in relation to northern pike feeding habits.

Insects that were commonly found in both marshes in 1972 were members of the Culicidae, Tendipedidae, and Dytiscidae families. Members of the order Trichoptera were common in the Pleasant Lake Marsh but very rare in the Pabst Marsh. Tables 6 and 7 give the geometric mean of the number per 100 cm and the 95 percent confidence limits for each of the major groupings of organisms found in the benthos at the two marshes. A complete breakdown of the population densities of each organism with their 95-percent confidence limit is given in Table 14 in the Appendix.

Stomach Content. By using the ranking method, stomach samples indicate that the northern pike fry ate predominantly Copepoda (mostly *Cyclops* sp.) the first two weeks after hatching. From the second week through the sixth week, Insecta (mostly Chironomidae) were the most numerous in the diet of the fry, with Cladocera (mostly *Ceriodaphnia* sp. and *Scapholeberis* sp.) also being important.

In our study during the sixth week, northern pike were one of the most important food items in the diet of other fingerlings, in terms of biomass (Fig. 8). Cannibalism was verified to have occurred in northern pike as small as 38 mm in length. Hunt and Carbine (1950) report it occurring at 21 mm. Attempts of one northern pike trying to capture and eat another were often observed in this study. However, attempts were many times unsuccessful, which left the prey injured and possibly dying without being of nutrient value to the surviving fish. The effect of this on the northern pike population size as a whole, however, was not quantitatively assessed. Bryan (1967) noted similar cannibalism, but also was unable to define its effect on the population size. Franklin and Smith (1963), however, found the incidence of cannibalism very low.

McCarraher (1957) found that northern pike up to 1.2 inches in length fed primarily upon Copepoda, upon Odonata and Tendipedidae when the fish were 33 to 66 mm, and upon fish after they were over 66 mm. Franklin and Smith (1963) noted that for pike up to 119 mm in length, Cladocera (especially *Daphnia* sp. and *Ceriodaphnia* sp.) were an important food item. They also stated that Copepoda (mostly *Cyclops* sp.) were important in the diet up to the time the northerns reached 45 mm, after which *Hyalella* sp. dominated. They found Tendipedidae larvae and Ephemeroptera and Zygoptera nymphs also important food items after the fish had reached 20 mm or more in length. Both McCarraher and Franklin and Smith found Ostracoda seldom utilized, which basically agrees with the Pleasant Lake and Pabst Marsh data. Bryan (1967) states that northerns up to 18 to 19 mm fed mainly on plankton (chiefly *Daphnia* sp. and rotifers) after which time Tendipedidae became increasingly more important. Frost (1954) found in Lake Windermere that northern pike under 35 mm fed predominantly on Entomostraca (principally Cladocera) while fish from 35 to 200 mm fed primarily on perch fry.

Tables 8 and 9 give the rank, the percent of the total number of food organisms present in all northern pike stomachs in which food organisms occurred for Cladocera, Ostracoda, Insecta and fish (northern pike fingerlings) at the Pleasant Lake and Pabst marshes for the various years of the study.

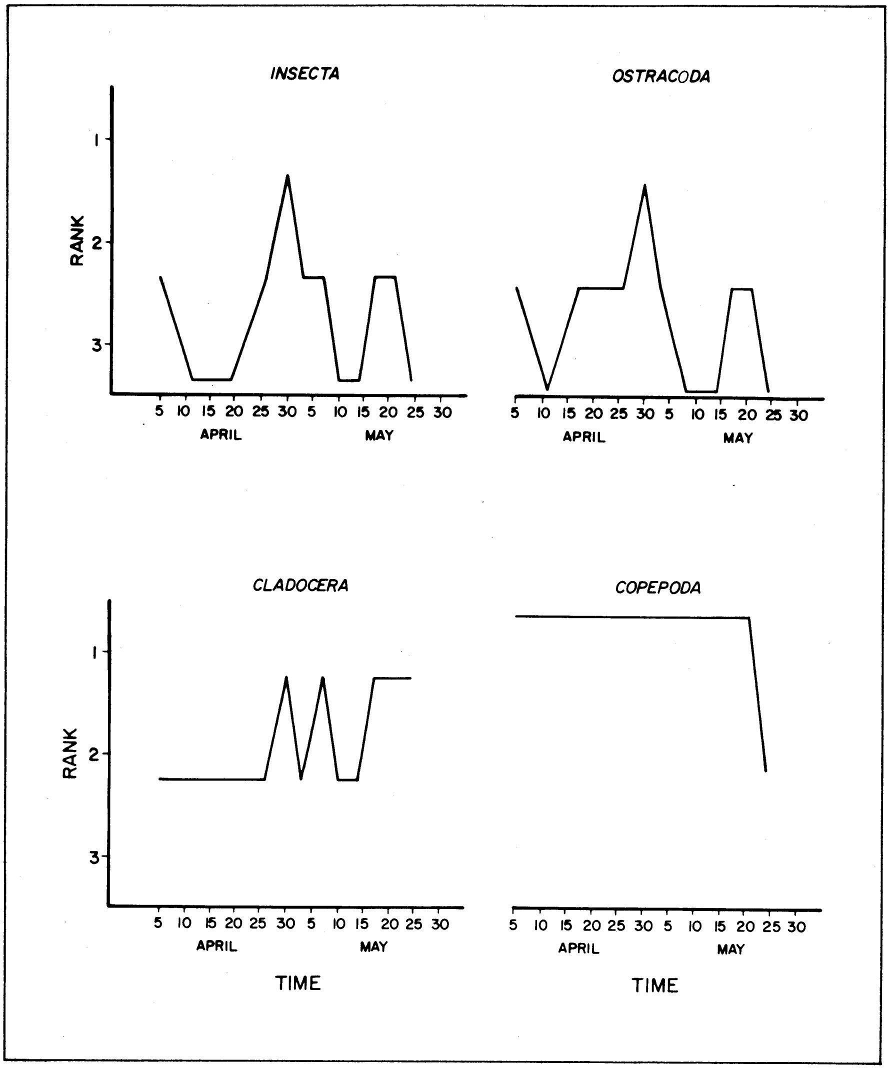


FIGURE 7. *Average change in the insect and zooplankton composition in the Pleasant Lake Marsh, 1973.*

Analysis of the food habits of northern pike fry and fingerlings through the method of electivity indices (Ivlev 1961) was intended. However, the problems already discussed with the zooplankton and benthic samples and their respective wide confidence limits also occurred with the analyses of stomach content and precluded use of this analytical technique. The problems associated with obtaining a reliable picture of the fluctuations in densities of the various organisms can be more clearly seen in Table 15 in the Appendix. This table gives a complete breakdown of the estimated population densities and their 95 percent confidence limits for each organism. When this table is used in conjunction with Tables 13 and 14, the problem of trying to calculate meaningful electivity indices becomes apparent. Although a number of researchers have done some work on selection of particular food items by northern pike fingerlings in a marsh in relation to their food supply, a sound statistical approach is still needed.

Physical and Chemical Factors

Adequate data are not available for predicting the critical values of dissolved oxygen and temperature with respect to time on northern pike eggs, fry, and fingerlings. Even though dissolved oxygen levels reached very low levels (below 3 ppm) during the rearing period, no significant mortalities were observed (Table 10, Appendix). However, during draining, dissolved oxygen levels fell below 2 ppm, and toward the end of the draining period, significant mortalities amounting to approximately 32 and 20 percent of the total production in the Pabst Marsh in 1971 and 1972, respectively, occurred. However, high water temperatures in the high 70's and even up to the mid 80's were reached and stranding of the fingerlings in the marsh at the time of draining in both years may have actually been the most significant

TABLE 4. *Zooplankton analysis at the Pleasant Lake marsh in percent of total organisms and numbers per liter for each date, 1969-1973.*

	Cladocera			Copepoda			Ostracoda			Insecta			Total
Date	Rank	% T.	No./l	Rank	% T.	No./l	Rank	% T.	No./l	Rank	% T.	No./l	No./l
1969													
8 April	2	4.4	1.6	1	88.6	32.0	2	7.0	2.5				36.1
15 April	2	1.6	1.7	1	90.0	94.6	2	8.4	8.8				105.1
22 April	2	2.7	3.9	1	90.0	126.5	2	7.2	10.1				140.5
29 April	2	10.5	17.9	1	83.4	142.0	2	6.1	10.4				170.4
6 May	1	22.2	30.2	1	64.0	86.8	1	13.8	18.7				135.7
13 May	1	51.6	88.4	1	43.5	74.5	2	4.8	8.3				171.2
21 May	1	74.6	258.9	2	24.0	83.4	3	1.4	5.0				347.2
1970													
21 May	1	38.3	34.3	1	58.8	52.7	2	2.9	2.6				89.6
26 May	1	29.2	15.7	1	68.9	36.9	2	1.8	1.0				53.6
28 May	1	57.1	57.9	1	41.1	41.7	2	1.9	1.9				101.5
4 June	1	57.6	27.4	1	35.8	17.0	1	6.6	3.1				47.6
1971													
29 April	1	5.9	0.9	1	82.9	12.9	1	10.1	1.6				10.5
4 May	1	15.9	0.2	1	53.1	0.8	1	13.0	0.2				1.5
11 May	1	40.8	2.3	1	22.0	1.2	1	15.8	0.9				5.6
18 May	1	44.6	3.6	1	30.8	2.5	1	14.1	1.1				8.1
24 May	1	79.8	30.2	2	14.2	5.4	3	4.5	1.7				37.9
1972													
4 May	2	18.4	6.9	1	67.4	25.1	2	13.9	5.2	3	0.3	0.1	37.3
12 May	2	19.7	5.5	1	72.6	20.2	3	7.1	2.0	4	0.6	0.2	27.8
18 May	2	23.2	47.5	1	75.5	154.4	3	0.7	1.4	3	0.6	1.1	204.5
23 May	1	89.1	239.7	2	9.7	26.2	3	0.8	2.0	3	0.4	1.1	269.0
1973													
5 April	2	2.4	1.0	1	89.7	34.9	2	6.0	2.3	2	0.9	0.4	39.0
11 April	2	7.0	1.3	1	86.3	15.6	3	4.2	0.8	3	2.3	0.4	18.1
17 April	2	9.4	6.2	1	71.3	47.2	2	18.1	12.0	3	1.1	0.7	66.3
19 April	2	17.1	7.5	1	67.6	29.6	2	12.6	5.5	3	2.1	0.9	43.8
26 April	2	27.7	8.7	1	52.7	16.6	2	15.5	4.9	2	3.8	1.2	31.4
30 April	1	20.5	3.8	1	42.4	7.9	1	26.8	5.0	1	9.4	1.7	18.6
3 May	3	2.4	1.5	1	84.0	53.3	2	7.5	4.8	2	5.9	3.8	63.4
7 May	1	29.3	37.2	1	63.4	80.4	3	1.4	1.8	2	5.7	7.2	126.9
10 May	2	20.6	27.4	1	75.9	101.2	4	0.7	0.9	3	2.8	3.8	133.3
14 May	2	24.4	11.3	1	71.1	33.1	3	3.1	1.5	3	1.3	0.6	46.6
17 May	1	52.1	26.4	1	43.5	22.1	2	2.7	1.4	2	1.3	0.7	50.7
21 May	1	61.6	18.6	1	34.7	10.5	2	2.2	0.7	2	1.4	0.4	30.2
24 May	1	74.6	41.6	2	21.0	11.7	3	1.0	0.6	3	2.9	1.6	55.8

TABLE 5. *Zooplankton analysis at the Pabst Marsh in percent of total organisms and numbers per liter for each date, 1971–72.*

	Cladocera			Copepoda			Ostracoda			Insecta			Total
Date	Rank	% T.	No./l	Rank	% T.	No./l	Rank	% T.	No./l	Rank	% T.	No./l	No./l
1971													
30 April	1	40.6	1.3	1	32.3	1.1	1	20.5	0.7				3.3
6 May	1	36.5	6.3	1	13.3	2.3	1	50.2	8.7				17.3
13 May	1	32.2	1.9	1	30.4	1.8	1	35.3	2.0				5.8
20 May	1	39.7	7.3	1	37.5	6.9	1	22.8	4.2				18.5
1972													
2 May	2	16.9	7.7	1	81.8	37.1	3	1.3	0.6				45.4
10 May	2	32.4	67.6	1	52.5	109.7	3	14.9	31.1	4	0.2	0.4	208.9
19 May	2	6.0	8.7	1	92.6	134.8	3	1.1	1.6	4	0.3	0.4	145.5
24 May	1	71.7	222.9	2	19.8	61.5	2	8.2	25.6	3	0.3	1.0	311.1

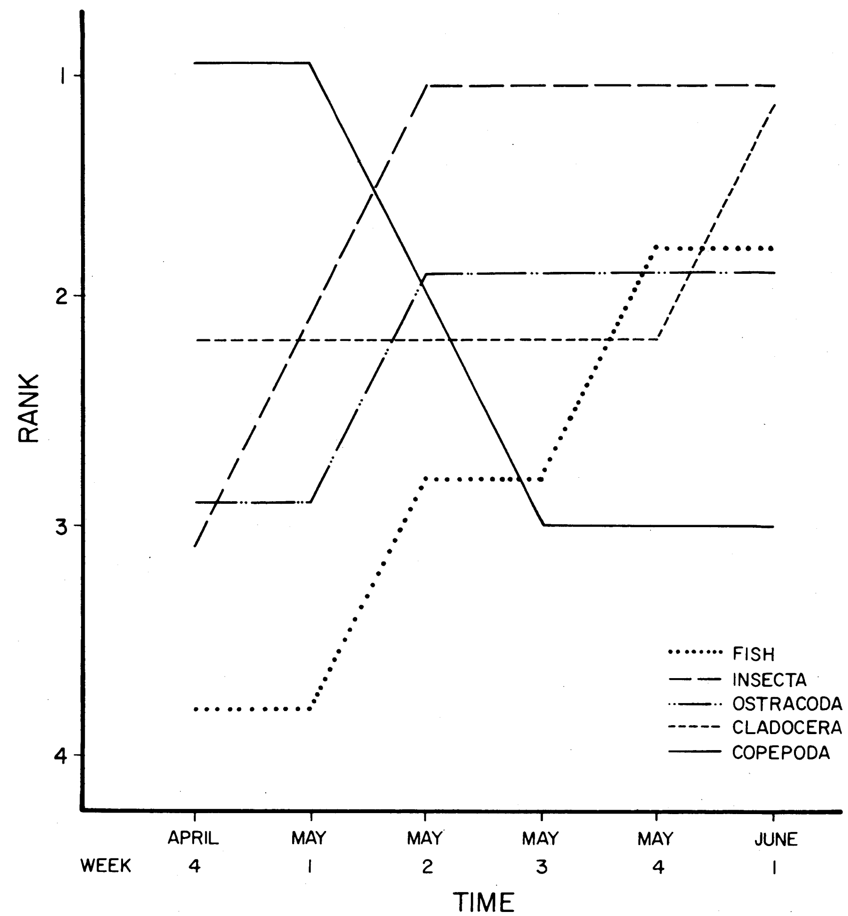


FIGURE 8. *Average change in northern pike stomach content at the Pleasant Lake Marsh, 1969 and 1971-73.*

cause of death. Figures 9 and 10 give the average hourly water temperatures from March through June in the spawning marshes. During several years, accurate readings from the Taylor thermographs could not be obtained in the first week after flooding and from time to time during the rearing period.

It is my opinion that draining the marsh at a time when water temperatures are relatively low (preferably below 70°F) and dissolved oxygen levels are relatively high (about 5 ppm) is probably of prime importance in successfully harvesting the northern pike crop from rearing marshes.

There does not appear to be any correlation between the production of northern pike and the minor fluctuations in the levels of nitrates, nitrites, ammonia, organic and total nitrogen, dissolved and total phosphorous, calcium, magnesium, sodium, potassium, iron, manganese, sulfate, chloride, alkalinity, conductivity, and pH encountered in this study. The results of the complete water analyses are given in Table 11 in the Appendix. Although a few of the researchers such as Smith, Franklin, and Kramer (1958) and Bryan (1967) have studied environmental characteristics such as water temperature, pH, alkalinity, dissolved oxygen, and ammonia and iron content, a quantitative relationship of these parameters to survival of the young pike in the marsh has not been defined.

TABLE 6. *Major groups of benthic fauna at the Pleasant Lake Marsh in numbers per square centimeter, 1972.*

	May 11			May 18			May 24		
Organism	Mean	% T	% 0	Mean	% T	% 0	Mean	% T	% 0
Insecta	5.4	8.7	75	4.4	9.6	63	3.5	11.1	63
Coleoptera	2.0	3.2	38	0.8	1.9	25	0	–	–
Diptera	2.6	4.1	38	3.0	6.5	50	3.5	11.1	63
Trichoptera	0.4	0.7	13	0.4	0.9	13	0	–	–
Oligochaeta	18.8	30.4	100	5.7	12.5	63	4.7	14.8	75
Ostracoda	19.3	31.2	100	11.8	26.1	100	7.0	22.2	75
Eubranchiopoda	0.7	1.1	13	0	–	–	0	–	–
Hirudinea	0	–	–	1.3	3.0	25	0	–	–
Cladocera	4.4	7.1	63	0.4	0.9	13	10.2	32.4	75
Copepoda	12.9	20.8	75	20.5	45.4	100	6.2	19.6	38
TOTAL	61.5			44.1			31.6		

TABLE 7. *Major groups of benthic fauna at the Pabst Marsh in numbers per square centimeter, 1972.*

	May 10			May 19			May 24		
Organism	Mean	% T	% 0	Mean	% T	% 0	Mean	% T	% 0
Insecta	3.0	8.6	50	3.5	6.5	60	4.4	12.8	50
Coleoptera	0	–	–	0	–	–	0.5	1.5	10
Diptera	3.0	8.6	50	2.7	5.0	50	3.5	10.1	40
Oligochaeta	6.3	18.3	80	6.7	12.3	60	7.4	21.5	80
Ostracoda	11.5	33.2	100	14.1	26.0	80	3.1	9.0	30
Eubranchiopoda	1.3	3.7	30	2.3	4.3	40	2.3	6.8	30
Hirudinea	2.1	6.2	40	4.1	7.6	50	10.4	30.2	90
Cladocera	0.1	0.9	10	2.3	4.3	30	0.1	0.9	10
Copepoda	10.0	29.0	90	20.3	37.4	90	6.5	18.8	80
TOTAL	34.3			53.3			34.2		

TABLE 8. *Northern pike fingerling stomach analysis at the Pleasant Lake Marsh in percent of the total number of food organisms present in all fish stomachs and percent of the total number of stomachs in which a food organism occurred, 1969 and 1971-73.*

	Fish Sampled			Stomach Contents														
				Cladocera			Copepoda			Ostracoda			Insecta			Fish		
Date	Average Length of Fish (mm)	No. of Stomachs	Avg. No. Organisms	Rank	% T.	% 0.	Rank	% T.	% 0.	Rank	% T.	% 0.	Rank	% T.	% 0.	Rank	% T.	% 0.
1969																		
6 May	22.9	47	8.0	1	27.8	76.6	2	35.5	76.6				2	36.3	78.7	3	0.4	4.3
13 May	34.4	41	6.3	1	38.2	65.9	2	6.6	22.0	3	3.7	22.0	1	51.3	82.9	3	0.3	2.4
21 May	54.8	30	14.0	1	27.3	80.0	3	0.7	10.0	2	3.7	30.0	1	68.1	96.7	3	0.2	3.3
4 June	83.3	85	7.0	1	49.6	70.6	2	2.2	14.1	2	1.7	9.4	1	44.8	84.7	2	1.6	15.3
1971																		
29 April	16.2	24	41.6	2	28.1	100	1	71.4	100	3	0.5	25.0						
4 May	19.2	25	43.9	2	18.4	100	1	72.9	96.0	4	1.7	40.0	3	7.0	88.0			
11 May	34.4	24	13.4	2	3.1	37.5	2	4.2	41.7	2	3.3	25.0	1	89.1	100	3	0.2	4.2
18 May	58.8	24	10.1	2	3.8	20.8				2	3.1	20.8	1	92.8	100	3	0.3	4.2
24 May	78.8	21	2.9	1	51.5	52.4	2	1.2	4.8	1	11.3	28.6	1	32.4	57.1	2	3.6	14.3
1 June	87.5	15	12.6	1	45.6	80.0				2	6.4	33.3	1	46.0	93.3	2	2.1	33.3
1972																		
4 May	13.7	24	9.5	2	25.9	87.5	1	69.4	95.8	3	4.3	33.3	4	0.3	4.2			
11 May	19.1	25	22.6	2	27.4	96.0	1	68.4	100	3	1.4	28.0	3	2.7	48.0			
18 May	38.6	26	5.3	1	30.1	65.4	2	7.1	30.8	1	36.8	65.4	1	22.1	69.2	3	3.9	26.9
27 May	67.3	16	1.1										2	19.4	25.0	1	80.6	93.8
1973																		
17 April	11.0	24	0.0															
26 April	16.3	25	13.3	2	19.4	76.0	1	52.9	96.0	3	1.6	20.0	2	26.1	96.0			
3 May	19.9	20	31.3	2	5.7	65.0	1	82.9	100	3	0.6	20.0	2	10.9	80.0			
10 May	30.9	23	14.9	2	10.1	65.2	1	44.9	91.3	3	1.5	21.7	1	43.6	100			
17 May	47.1	25	8.3	1	20.2	68.0	1	21.6	56.0	1	24.4	60.0	1	32.5	76.0			
24 May	60.5	26	7.1	1	45.7	88.5	1	35.0	69.2	1	5.0	26.9	1	13.2	50.0			
29 May	72.5	24	13.8	1	36.1	75.0	2	0.9	8.3	2	1.3	16.7	1	61.6	95.8	2	0.2	4.2

TABLE 9. *Northern pike fingerling stomach analysis at the Pabst Marsh in percent of the total number of food organisms present in all fish stomachs and percent of the total number of stomachs in which a food organisms occurred, 1971-72.*

	Fish Sampled			Stomach Contents														
				Cladocera			Copepoda			Ostracoda			Insecta			Fish		
Date	Average Length of Fish (mm)	No. of Stomachs	Avg. No. Organisms	Rank	% T.	% 0.	Rank	% T.	% 0.	Rank	% T.	% 0.	Rank	% T.	% 0.	Rank	% T.	% 0.
1971																		
30 April	16.9	28	34.9	2	10.7	92.9	1	89.3	100	3	0.1	3.6						
6 May	24.5	25	63.3	2	1.2	48.0	1	98.1	100	3	0.3	20.0	2	0.4	24.0			
13 May	32.2	25	17.9	1	79.3	100	2	11.3	80.0	2	5.8	64.0	2	3.6	52.0			
20 May	49.8	25	5.2	1	37.7	84.0	1	34.6	72.0	2	5.4	16.0	1	22.4	60.0			
27 May	73.4	22	15.2	1	37.5	81.8	3	0.2	4.5	2	4.7	40.9	1	56.5	100	3	1.1	22.7
8 June	110.8	41	11.8	2	31.3	68.3	2	0.2	2.4	2	0.7	7.3	1	67.0	100	2	0.7	12.2
1972																		
2 May	15.2	25	28.5	2	3.7	56.0	1	95.6	100	3	0.6	20.0	3	0.1	4.0			
10 May	24.5	24	29.0	1	44.6	100	1	53.1	100	2	1.2	25.0	2	1.1	33.3			
19 May	41.5	25	6.7	2	12.4	36.0	2	4.9	20.0	1	73.5	80.0	2	5.4	36.0	2	3.7	32.0
24 May	87.3	15	2.2							1	21.8	20.0	1	48.8	66.7	1	27.3	66.7
31 May	96.2	19	5.8	1	51.6	73.7	3	2.2	10.5	2	4.8	26.3	1	29.3	68.4	2	11.5	73.7

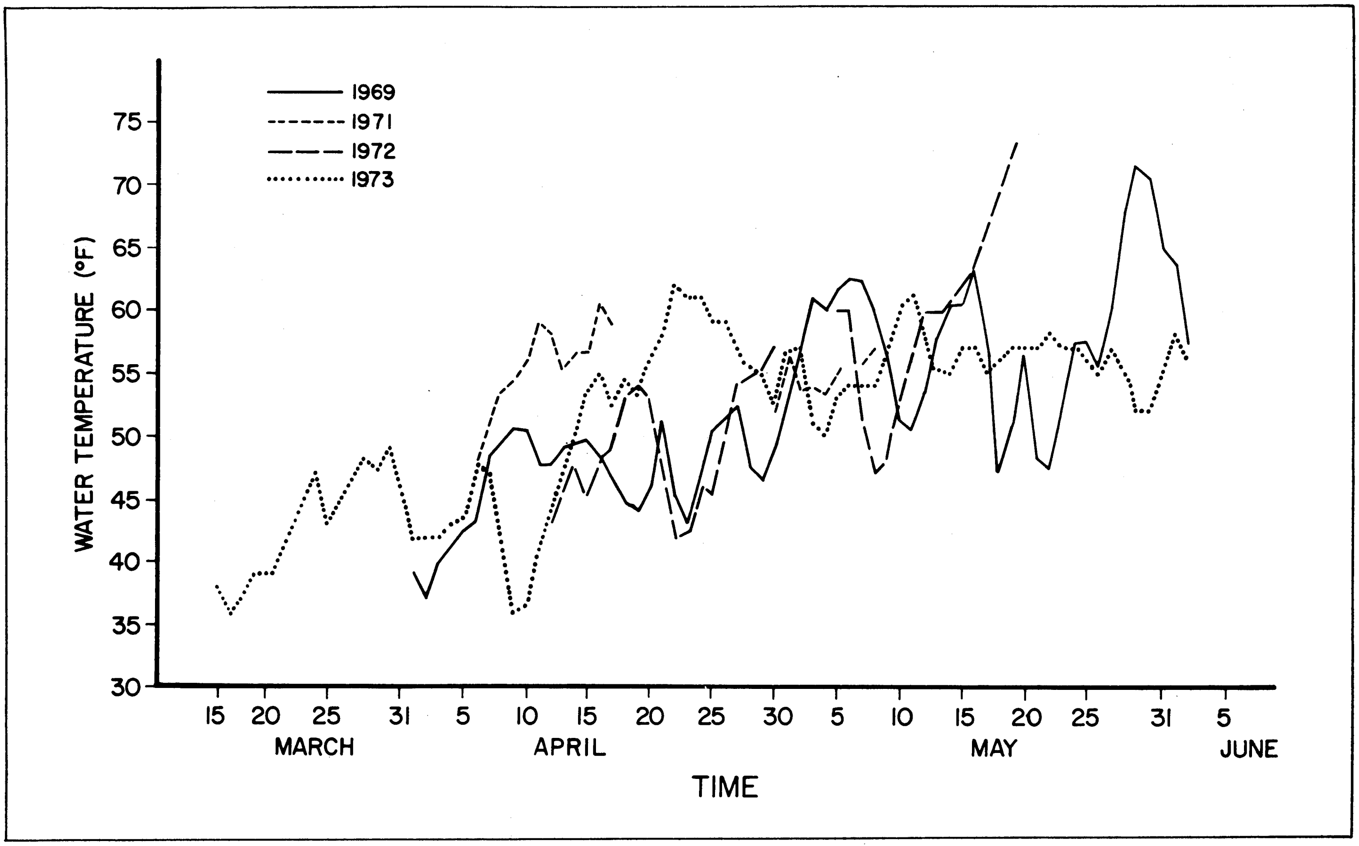
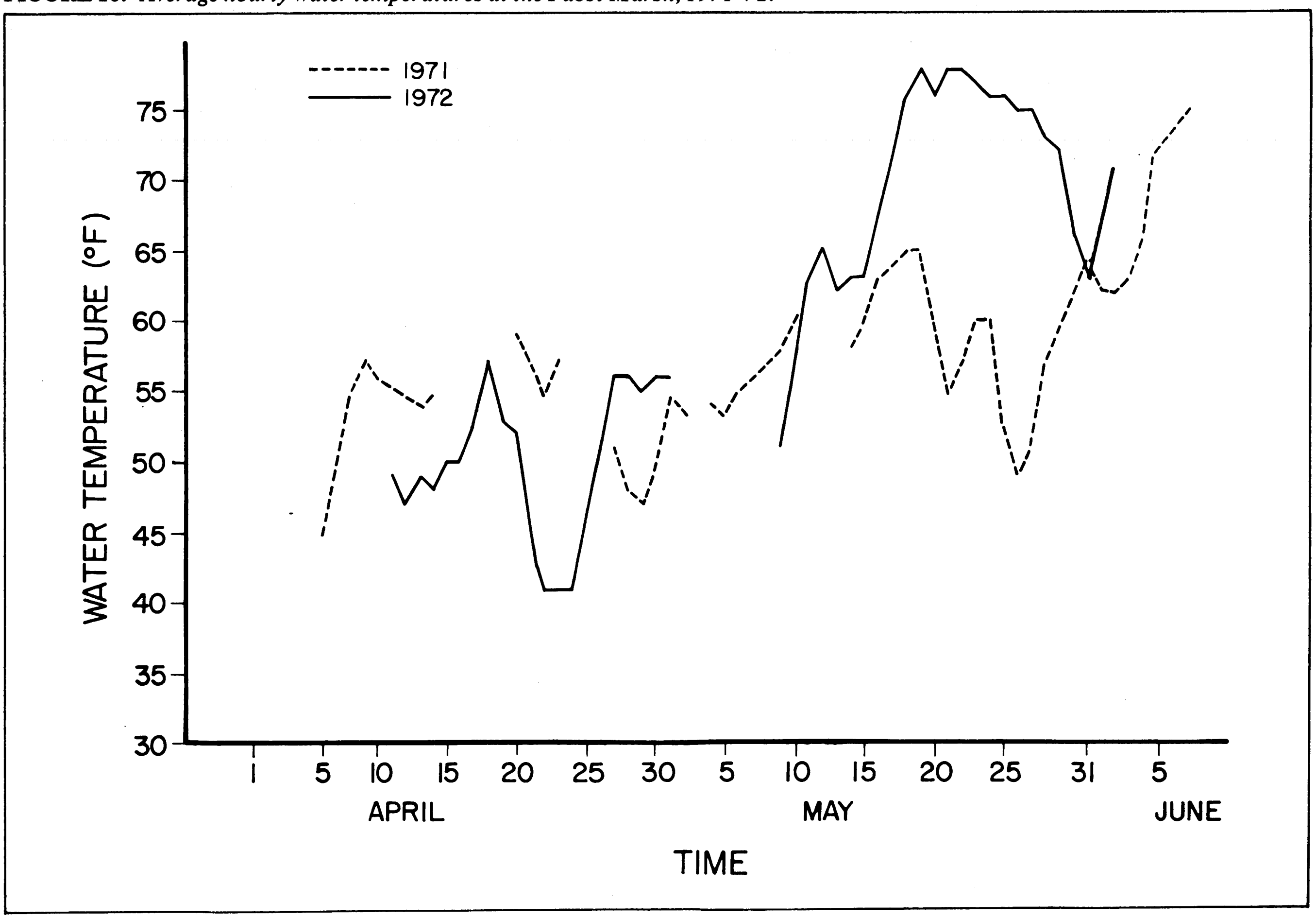


FIGURE 9. *Average hourly water temperatures at the Pleasant Lake Marsh, 1969 and 1971-73.*

FIGURE 10. *Average hourly water temperatures at the Pabst Marsh, 1971-72.*



RECOMMENDATIONS

Although many of the factors that influenced the production of northern pike fingerlings from the Pabst and Pleasant Lake marshes could not be quantitatively defined at each of the critical stages in the early life history of the fish, general procedures and considerations for the management of these types of marshes are now better understood. Three major considerations that must be taken into account when managing a northern pike spawning marsh are: (a) the characteristics of the spawning marsh, (b) the characteristics of the spawning stock, and (c) the time of draining.

Marsh Characteristics. Important characteristics of the spawning marsh include that it be completely drainable (preferably into the lake to be stocked), be close to a water supply, and have predominantly sedge and grass type vegetation. If this type of vegetation is not presently established in the proposed marsh, it is possible that reed canary grass seed, which is readily available, could be planted or that bailed hay could be spread over the bottom.

The inlet should be constructed as to allow water into the marsh only when needed, and should include a screen to prevent predators from entering. If the land contours do not lend themselves to this type of inlet structure, the necessary water may have to be pumped into the marsh. The outlet structure should allow surface drawdown of the marsh and the placement of a wire mesh pen downstream to collect the fingerlings if they are to be counted or marked.

Spawning Stock Characteristics. No researcher has yet been able to determine quantitatively a relationship between size, number, and ratio of female and male spawners to the production of fingerlings. However, from this study it is believed that the female spawners should preferably be large (over 25 inches) so that fewer are needed to supply the necessary eggs. This will also reduce the number of males needed and the total number of spawners which need to be removed after spawning. Ten to 15 pounds of females per acre and two to three males per female should be obtained. The males should be at least 20 inches in total length. All spawners should be removed as soon as possible after spawning to prevent their predation on the young fingerlings. This can be done through the use of fyke nets.

Draining Time. The time of draining should be governed by the water temperature during draining and the size of fingerlings desired. If water temperatures are in the 80's (Fahrenheit), significant mortalities due to temperature stress and low dissolved oxygen levels will most likely occur. The survival of a fingerling in a lake is probably directly proportional to its length (other factors in the lake being equal), and the number of fingerlings produced from a marsh is inversely proportioned to their length (primarily due to cannibalism). However, the two coefficients of these proportions are unknown. Therefore, the optimum time of draining cannot be determined. The fish manager must thus decide if he wants a larger number of smaller fingerlings or a smaller number of larger fingerlings. If he wants to mark them by fin clipping, he will have to use larger fingerlings (75 to 100 mm in average size) and thus drain at a later date. Although adequate data are not available on optimum size and number of fingerlings to assure high survival in a lake, it is believed that fish of this size would insure large numbers of fingerlings whose lake survival would be high.

In order to develop a clearer understanding of the food habits of the northern pike fry and fingerlings, the following appears to be necessary: (a) sampling of the stomachs, zooplankton, and benthos must occur twice weekly (or more often), (b) more sampling stations, especially for the benthos must be established, and (c) a minimum of half a dozen marshes must be selected in order to simultaneously study food habits over a period of years.

It is believed that a great deal of study is still needed in quantifying the relationships of the various factors that influence the survival of northern pike eggs from the time they are deposited in a marsh to their hatching. Apparatuses for monitoring the survival of eggs and the various related physical and chemical factors in a marsh environment still need to be developed. In addition, in order for a definitive answer to the question on the optimum number and size of spawners to be stocked in a marsh and for an understanding of the inverse relationship between the number and length of fingerlings produced from a marsh, a number of marshes (perhaps as many as a dozen) would have to be managed simultaneously over several years so that these different factors can by systematically varied and then statistically analyzed.

FINGERLING PRODUCTION

The 3.7-acre Pleasant Lake Marsh in Walworth County was stocked with adult northern pike spawners each spring from 1969 through 1973. This marsh, which is surrounded by a steep wooded ridge except at the outlet to the lake, has leatherleaf as the dominant aquatic vegetation. In 1971 and 1972, a second marsh, Pabst Marsh (18.5 acres) in Waukesha County was also studied. Reed canary grass is the dominant aquatic vegetation in this marsh.

The female spawners averaged 21.8 inches in total length and 4.7 lbs. The stocking rate averaged 12.1 lbs/acre. The numerical ratio of stocked males to females averaged 3.2:1 and the average total length of the males was 18.7 inches. The linear regression that was derived for the number of eggs versus total length of the female is: $E = 4{,}417\ L - 62{,}555$ where E is the number of eggs and L is the total length of the female in inches. This regression has a 95 percent confidence limit of ± 6 percent for estimating the fecundity of an average fish.

The following production rates indicate that management of the Pleasant Lake and Pabst marshes was highly successful in rearing large numbers per acre of fingerlings that were of large size: (a) the production of 2,473 fingerlings per acre averaging 79 mm from the Pleasant Lake Marsh in 1973, (b) the 1,052 fish per acre averaging 109 mm from the Pabst Marsh in 1972, and (c) the overall average of 1,332 fish per acre averaging 89 mm by the first week of June from both sites in all years. These rates are among the highest reported.

FACTORS AFFECTING FINGERLING PRODUCTION

The five catogories of factors thought to influence northern pike production were spawning stock, aquatic vegetation, egg survival, food supply, and physical and chemical factors. It was not possible from the data collected on these factors to make quantitative predictions on the number of northern pike produced. However, several useful relationships in connection with their food supply and physical and chemical requirements were observed.

A seasonal shift in zooplankton species composition occurred and was best defined at the Pleasant Lake Marsh in 1973. At that marsh, Copepoda (principally *Cyclops* sp.) dominated the zooplankton population until the end of May when Cladocera (principally *Chydorus* sp.) surpassed them in numbers.

The best picture of the benthic community was gained in 1972 when, at both marshes, members of the Culicidae, Tendipedidae, and Dytiscidae families were the most commonly occurring organisms in benthic samples.

The analyses of the data for the northern pike food habits study was accomplished through the use of a Fortran computer program which enabled each organism in the stomach samples as well as zooplankton and benthic samples to have its geometric mean [common log (x + 1) transformation used], variance, 95 percent confidence limit, percent occurrence, percent of total organisms, and corrected mean, calculated for each day. The conversions to number per liter and number per 100 square centimeters were also performed by the program for the zooplankton and benthic samples, respectively. These analyses showed that the number and species composition of organisms consumed are highly variable on a given day. Based on the averages form the weekly stomach content for 1969, 1971, 1972, and 1973 from Pleasant Lake and Pabst marshes, a generalized trend showed the dominance of Copepoda shifting to a combination of Cladocera, Insecta, and fish (other northern pike). However, numerical comparison of fish with other food organisms underestimates its importance, since fish have a much higher nutrient value. The rate at which cannibalism reduces the northern pike population could not be determined. Comparison between the zooplankton and benthos populations, such as in electivity indices, was hindered by problems associated with their tremendous variability, which resulted from: (a) an insufficient number of stations being sampled, (b) samples not being taken often enough, and (c) samples not being large enough (in volume).

Of the physical and chemical factors which might influence northern pike production in managed spawning marshes, water temperature and dissolved oxygen levels during draining appear to have a significant effect. While these two factors could not be documented to influence the survival of the eggs and northern pike during their rearing, intuitively one would expect them to have an influence. Chemical analyses of the water in the marsh during the years of the study showed only minor fluctuations and thus could not explain the variances in production.

TABLE 10. *Average dissolved oxygen and water temperature readings at northern pike managed spawning marshes, 1969-1973.*

Lake and Date	Time	Mean Dissolved Oxygen (ppm)	Mean Temperature (^{o}F)		
			D. O. Sample	Min. –	Max.
Pleasant Lake Marsh					
4/08/69	11:00	10.0	50	44	57
4/15/69	12:00	7.5	49	48	50
4/15/69	16:30	7.5	50	48	50
4/22/69	10:30	7.1	47	42	49
4/29/69	11:00	4.8	45	40	54
5/01/69	10:00	6.0	49	42	56
5/06/69	10:00	1.3	57	60	65
5/13/69	8:30	2.4	48	51	64
5/21/69	11:00	1.1	53	44	54
5/28/69	16:00	3.0	79	62	75
5/21/70	9:30	5.0	70	–	–
5/26/70	9:30	1.9	57	59	76
5/28/70	9:00	2.6	55	54	65
6/02/70	9:15	2.8	57	57	71
6/04/70	9:30	2.9	60	59	65
6/08/70	10:30	3.4	69	59	71
4/24/71	–	5.8	–	50	62
4/29/71	9:30	4.8	–	47	62
5/04/71	–	4.4	–	–	–
5/06/71	9:00	4.5	–	53	61
5/11/71	–	4.5	–	61	72
5/18/71	–	3.7	–	55	82
5/20/71	–	5.4	–	58	73
5/24/71	8:30	5.0	–	54	76
5/28/71	–	5.2	–	56	69
4/17/72	8:30	7.7	44	36	56
4/21/72	–	9.7	44	37	59
4/24/72	10:15	9.6	45	41	49
4/28/72	15:00	8.0	59	38	61
5/04/72	9:45	8.1	54	51	63
5/09/72	10:45	6.9	48	43	62
5/11/72	10:15	7.8	61	44	63
5/16/72	8:50	3.4	63	58	69
5/18/72	9:45	2.7	70	62	74
5/23/72	10:30	1.6	73	68	83
3/27/73	15:00	15.0	51.8	41	49
3/29/73	9:30	13.0	45.8	41	51
4/05/73	10:45	9.2	50.0	40	49
4/11/73	12:30	7.8	45.0	38	50
4/17/73	14:30	8.4	61.7	41	56
4/18/73	12:30	9.8	59.0	–	–
4/19/73	13:30	8.8	59.0	52	59
4/24/73	11:00	5.2	62.0	55	64
4/26/73	12:30	6.0	60.8	56	63
4/30/73	12:00	6.2	53.6	52	60
5/03/73	7:00	2.5	48.2	51	57
5/07/73	6:30	5.2	54.3	47	54
5/10/73	6:15	3.7	55.2	53	57
5/14/73	6:50	2.6	51.6	52	59
5/17/73	6:00	2.2	50.4	51	57
5/21/73	6:00	4.4	57.2	51	56
5/23/73	6:10	2.1	55.6	54	59
Pabst Marsh					
5/04/71	–	6.4	–	49	59
5/06/71	–	6.4	–	49	59
5/11/71	–	5.8	–	55	69
5/13/71	–	4.6	–	53	68
5/18/71	9:30	4.1	–	53	71
5/20/71	9:00	4.1	–	59	68
5/24/71	–	3.6	–	57	66
4/13/72	14:30	9.3	49	32	54
4/20/72	13:30	10.0	56	45	61
4/25/72	8:45	11.0	44	40	58
4/28/72	9:55	10.5	56	42	61
5/02/72	12:00	9.0	54	39	51
5/05/72	9:00	8.5	58	50	60
5/08/72	9:55	8.9	49	47	60
5/16/72	14:00	9.0	67	45	67
5/19/72	8:35	6.2	73	67	77
5/21/72	12:45	7.5	78	63	78

TABLE 11. *Average water chemistries for northern pike managed marshes.*

Lake and Date	NO_2-N (mg/l)	NO_3-N (mg/l)	NH_3-N (mg/l)	Org-N (mg/l)	TOT-N (mg/l)	P (Dis) (mg/l)	P (Tot) (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	Fe (mg/l)	Mn (mg/l)	SO_4 (mg/l)	Cl (mg/l)	Alka (Tot) (mg/l)	Cond. (μmhos/cm at 25°C)	pH
Pleasant Lake Marsh																		
4/08/69	0.004	0.10	0.03	0.47	0.60	0.09	0.30	8.4	16.0	2.4	1.8			12	7		200	
5/13/69	0.075	0.20	0.04	1.25	1.57	0.11	0.50	12.1	6.2	2.2	2.1			12	7	102		7.2
5/21/70	0.004	0.20	0.03	1.40	1.63	0.06	0.60	14.0	16.0	2.9	3.1			12	7	90		7.1
5/26/70	0.004	0.10	0.03	1.25	1.25	0.03	0.20	15.0	14.0	2.9	2.3			14	7	111		6.9
4/01/71	0.008	0.13	0.03	1.22	1.36	0.028	0.10	14.0	18.0	2.8	1.5			16	4	93		8.0
5/02/71		0.14	0.04	0.88	1.06	0.007	0.04	22.0	22.0	2.7	1.9			20	8			
4/17/72	0.010	0.12	0.11	0.89	1.13	0.012	0.06	26.0	29.1	2.4	1.5	0.35	0.06	11	9	101	283	7.2
3/22/73	0.011	0.16	0.15	0.65	0.97	0.091	0.07	29.0	52.0	9.0	1.6			13	11	144	283	7.4
5/24/73	0.005	0.13	0.05	0.89	1.07	0.027	0.08	28.0	25.0	7.0	0.2	0.46	0.26	10	10	158	283	7.5
Pabst Marsh																		
3/31/71	0.021	0.95	0.10	1.30	2.37	0.028	0.05	37.0	27.0	4.4	3.0			35	11	172		7.7
6/07/71	0.005	0.15	0.21	1.60	1.97	0.007	0.06	54.0	31.0	5.6	3.8			19	16			
4/12/72	0.008	0.34	0.23	1.07	1.65	0.014	0.06	72.0	32.4	9.4	4.5	0.42	0.01	28	18	214	567	7.9
5/30/72	0.001	0.08	0.08	1.29	1.45	0.009	0.05	77.4	37.0	7.0	2.3	0.60	0.07	27	21	238	520	8.0

TABLE 12. *English - metric conversion factors.*

To Convert	Multiply By	To Obtain
Inches	25.4	Millimeters
Millimeters	0.03937	Inches
Grams	0.03527	Ounces
Pounds	0.4536	Kilograms
Pounds per acre	1.121	Kilograms per hectare
Number per 100 square cm	9.29	Number per square foot
Fahrenheit	5/9(°F-32)	Centigrade
Acres	0.4047	Hectares

TABLE 13. *Analysis of the plankton sampled from the Pleasant Lake and Pabst Marshes in #/liter. (log_{10} transformation used)*

		Pleasant Lake Marsh																			
		1969							1970				1971					1972			
Organism		4/8	4/15	4/22	4/29	5/6	5/13	5/21	5/21	5/26	5/28	6/4	4/29	5/4	5/11	5/18	5/24	5/4	5/12	5/18	5/23
Cladocera		1.6	1.7	3.9	17.9	30.2	88.4	258.9	34.3	15.7	57.9	27.4	1.0	0.2	2.3	3.6	30.2	6.9	5.5	47.5	239.7
95% C.L.	(U)	5.5	6.5	8.7	25.0	76.9	125.6	336.9	49.2	43.5	70.5	46.8	2.0	0.6	4.6	8.5	49.6	9.4	9.7	58.4	262.1
	(L)	0.1	–	1.5	12.8	11.5	62.1	198.8	23.8	5.3	47.6	15.8	0.3	–	1.0	1.3	18.3	5.0	3.0	38.7	219.2
Daphnia		0.6	0.9	1.9	7.1	4.5	6.9	3.9	0.7	0.2			0.1		0.2	0.1	0.4	0.2	0.1	0.2	2.1
95% C.L.	(U)	2.4	3.5	5.2	10.5	7.5	22.1	19.3	4.0	1.8			0.2		0.6	0.2	1.0	0.5	0.5	0.6	7.0
	(L)	–	–	0.4	4.8	2.6	1.8	0.3	–	–			–		–	–	–	–	–	–	0.4
Ceriodaphnia					0.1	0.1	0.1	0.3					0.2	0.1	0.1	0.1	1.2	0.1	0.4		1.4
95% C.L.	(U)				0.2	0.3	0.4	1.1					0.4	0.2	0.2	0.4	4.2	0.5	1.1		5.7
	(L)				–	–	–	–					–	–	–	–	–	–	–		0.1
Simocephalis				0.1	0.1	0.4	0.9	3.6		0.8	0.8	0.4			0.1	0.1			0.1	5.7	26.1
95% C.L.	(U)			0.5	0.2	1.3	1.8	11.9		0.8	4.2	3.5			0.2	0.5			0.3	11.1	42.8
	(L)			–	–	–	0.2	0.7		0.8	–	–			–	–			–	2.7	15.9
Alona														0.1	0.1	1.0			0.1	15.8	20.7
95% C.L.	(U)													0.4	0.3	3.1			0.5	18.8	58.4
	(L)													–	–	0.1			–	13.3	7.1
Scapholebris				0.1			0.1	9.7	1.2	0.4	13.5	10.7	0.1		0.3	1.2	11.0	1.4	1.6		1.4
95% C.L.	(U)			0.5			0.2	30.2	1.2	8.1	25.1	24.6	0.4		0.7	3.6	17.2	2.3	3.3		4.2
	(L)			–			–	2.7	1.2	–	7.0	4.2	–		–	0.2	7.0	0.7	0.6		0.3
Chydorus		0.6	0.4	0.9	3.5	13.7	33.9	91.8	31.1	14.2	42.1	14.9	0.3	0.1	1.2	0.2	14.0				
95% C.L.	(U)	2.2	1.4	3.3	11.1	62.9	125.5	321.7	45.6	34.6	45.9	33.3	0.7	0.2	3.3	0.7	29.5				
	(L)	–	–	–	0.8	2.4	8.7	25.8	21.0	5.5	38.6	6.2	0.1	–	0.2	–	6.4				
Bosmina			0.4	0.4	1.0	4.2	6.5	21.5	1.0		0.3	0.4						4.9	3.1	23.4	173.3
95% C.L.	(U)		1.4	1.0	2.2	8.4	8.7	59.1	7.6		3.1	3.5						7.0	4.7	25.7	191.5
	(L)		–	–	0.2	1.9	4.7	7.5	–		–	–						3.3	2.0	21.3	156.8
Eurycerus					0.2						0.3	0.4	0.2				0.1				
95% C.L.	(U)				1.2						3.1	3.5	0.5				0.2				
	(L)				–						–	–	–				–				
Unknown		0.2	0.1		0.4	0.5	0.3	0.5			0.3							0.1		1.6	1.3
95% C.L.	(U)	1.1	0.4		1.3	1.4	0.7	1.1			3.1							0.2		5.0	4.0
	(L)	–	–		–	–	–	–			–							–		0.3	0.2
Rotatoria		0.4	0.7	0.5	0.3	0.9	0.6	1.8	1.0	0.3	1.1	3.0	0.1	0.3	0.1	0.5	1.8				
95% C.L.	(U)	1.2	1.8	1.3	0.8	2.3	1.2	2.6	7.6	4.6	8.0	12.5	0.3	0.6	0.2	1.2	3.5				
	(L)	–	0.1	–	–	0.1	0.2	1.2	–	–	–	–	–	–	–	0.1	0.7				
Copepoda		32.0	94.6	126.5	142.0	86.8	74.5	83.4	52.7	36.9	41.7	17.0	12.9	0.8	1.2	2.5	5.4	25.1	20.2	154.4	26.2
95% C.L.	(U)	70.0	143.0	134.3	165.0	113.0	95.2	111.5	105.9	55.0	66.5	28.6	43.8	2.1	2.3	5.2	11.0	27.9	33.7	190.9	36.1
	(L)	14.3	62.4	119.1	122.3	66.5	58.3	62.3	25.9	24.7	25.9	9.9	3.5	0.1	0.6	1.0	2.4	22.7	12.0	124.9	19.0
Calanoida		6.2	8.4	7.7	4.6	7.3	6.0	2.2					12.6	0.5	0.3	0.5		1.5	1.5	3.2	
95% C.L.	(U)	33.4	13.9	16.1	9.2	12.7	7.8	5.6					43.5	1.3	0.7	1.3		2.9	2.6	5.1	
	(L)	0.6	4.9	3.4	2.1	4.1	4.5	0.6					3.4	–	–	–		0.7	0.8	2.0	
Cyclopidae		23.5	70.0	115.7	134.7	77.3	68.1	80.5	52.3	36.7	41.7	17.0	0.1	0.2	1.0	1.4	4.7	21.9	18.6	150.3	26.2
95% C.L.	(U)	40.3	136.5	119.3	158.1	103.8	88.2	106.7	105.4	53.4	66.5	28.6	0.2	0.7	1.6	3.2	9.5	25.5	31.4	186.6	36.1
	(L)	13.5	35.7	112.2	114.8	57.6	52.5	60.6	25.6	25.2	25.9	9.9	–	–	0.5	0.4	2.2	18.7	11.0	120.9	19.0
Nauplius			3.2	1.0	0.6				0.3	0.2			0.1	0.1		0.2	0.5	1.4		0.3	
95% C.L.	(U)		24.1	3.7	1.4				2.9	1.8			0.3	0.2		0.7	1.4	2.0		2.0	
	(L)		–	–	–				–	–			–	–		–	–	1.0		–	
Ostracoda		2.5	8.8	10.1	10.4	18.7	8.3	5.0	2.6	1.0	1.9	3.1	1.6	0.2	0.9	1.1	1.7	5.2	2.0	1.4	2.0
95% C.L.	(U)	9.9	15.8	19.2	13.9	25.6	10.9	7.1	10.6	2.4	23.2	10.9	7.6	0.6	2.2	3.6	3.1	7.0	2.6	4.5	3.8
	(L)	0.2	4.8	5.1	7.8	13.7	6.3	3.4	–	0.2	–	0.3	–	–	0.2	0.1	0.8	3.8	1.5	0.2	1.0
Hydracarina													0.2	0.3	1.2	0.9	0.6				
95% C.L.	(U)												0.4	0.7	3.6	2.9	1.6				
	(L)												–	–	0.1	–	–				
Eubranchiopoda																					
95% C.L.	(U)																				
	(L)																				
Insecta																		0.1	0.2	1.1	1.1
95% C.L.	(U)																	0.4	0.8	3.2	2.4
	(L)																	–	–	0.2	0.3
Ephemeroptera																				0.1	0.1
95% C.L.	(U)																			0.4	0.4
	(L)																			–	–
Coleoptera																		0.1			
95% C.L.	(U)																	0.2			
	(L)																	–			
Diptera																			0.1		0.2
95% C.L.	(U)																		0.3		0.6
	(L)																		–		–
Trichoptera																		0.1	0.1	0.9	0.5
95% C.L.	(U)																	0.2	0.1	3.2	1.5
	(L)																	–	–	–	–

– equals < 0.05

TABLE 13. *Continued.*

		Pleasant Lake Marsh 1973													Pabst Marsh 1971				Pabst Marsh 1972			
Organism		4/5	4/11	4/17	4/19	4/26	4/30	5/3	5/7	5/10	5/14	5/17	5/21	5/24	4/30	5/6	5/13	5/20	5/2	5/10	5/19	5/24
Cladocera		1.0	1.3	6.2	7.5	8.7	3.8	1.5	37.2	27.4	11.3	26.4	18.6	41.6	1.3	6.3	1.9	7.3	7.7	67.6	8.7	222.9
95% C.L.	(U)	2.4	2.0	12.8	10.5	10.9	6.9	2.4	95.8	69.2	20.0	28.4	33.8	48.2	3.0	16.1	3.4	10.6	9.1	93.8	10.5	275.3
	(L)	0.3	0.7	3.0	5.3	6.9	2.1	0.9	14.3	10.8	6.4	24.7	10.2	35.9	0.4	2.2	0.9	5.0	6.5	48.7	7.2	180.5
Daphnia		0.6	0.4	1.4	0.6	1.0	0.3			0.3			0.2	0.2	0.8	3.2	0.7	2.0	1.4	44.1	0.7	1.2
95% C.L.	(U)	1.5	1.0	4.1	1.8	1.7	1.1			0.9			0.8	0.9	0.8	10.0	2.7	4.3	2.4	74.9	1.6	2.2
	(L)	0.2	0.1	0.4	0.1	0.5	–			–			–	–	0.8	0.7	–	0.7	0.8	25.9	0.2	0.6
Ceriodaphnia		–		0.1	0.2		–	0.1		0.1	0.1	0.2	0.2	–		0.6		0.7	0.3		0.2	1.9
95% C.L.	(U)			0.3	0.5			0.3		0.3	0.3	0.4	0.5			4.9		6.1	0.8		0.4	5.7
	(L)			–	–			–		–	–	–	–			–		–	–		–	0.4
Simocephalis		–						–			–		0.1	0.1					0.3		0.2	212.3
95% C.L.	(U)												0.4	0.4					0.7		0.5	262.2
	(L)												–	–					–		–	171.9
Alona		0.1	0.1	1.0	0.4	2.6		0.1	0.6	1.0	1.2	0.2	0.4	1.4	0.2			1.3		0.3	0.3	
95% C.L.	(U)	0.3	0.2	3.6	1.2	6.0		0.3	3.6	7.5	4.2	0.9	1.2	12.8	2.0			19.3		0.7	0.6	
	(L)	–	–	0.2	–	1.0		–	–	–	–	–	–	–	–			–		–	0.1	
Scapholebris		–												0.1					3.0	10.4	1.4	1.3
95% C.L.	(U)													0.5					3.9	19.4	2.4	3.1
	(L)													–					2.3	5.5	0.7	0.4
Chydorus					0.6	0.2	0.5		3.7	3.9	5.1	0.1	0.4	22.1	0.2		0.1	0.4				
95% C.L.	(U)				3.2	0.6	3.5		84.4	45.9	9.2	0.4	1.7	46.6	2.0		1.1	7.1				
	(L)				–	–	–		–	0.1	2.8	–	–	10.4	–		–	–				
Bosmina		0.1	0.7	2.4	1.8	0.8	0.4	1.3	0.2	0.2	0.9	0.7	1.1	0.4		2.2	0.9	1.8	0.6	6.7	4.1	4.6
95% C.L.	(U)	0.3	1.0	3.9	3.3	2.2	1.1	2.0	0.8	0.7	3.0	1.9	2.2	1.7		7.3	2.8	8.5	1.2	11.4	5.4	7.9
	(L)	–	0.5	1.4	0.9	0.2	–	0.8	–	–	0.1	0.2	0.5	–		0.3	0.1	–	0.3	3.8	3.1	2.6
Eurycerus						–																
95% C.L.	(U)																					
	(L)																					
Unknown		–	–	0.4	0.9	1.1	0.7		1.2	2.5	1.0	24.8	9.8	1.9							–	
95% C.L.	(U)			2.2	4.3	7.9	3.7		24.3	39.5	8.0	26.1	64.3	22.6								
	(L)			–	0.1	–	–		–	–	–	23.5	1.3	–								
Rotatoria																		2.0				
95% C.L.	(U)																	10.7				
	(L)																	–				
Copepoda		34.9	15.6	47.2	29.6	16.6	7.9	53.3	80.4	101.2	33.1	22.1	10.5	11.7	1.1	2.3	1.8	6.9	37.1	109.7	134.8	61.5
95% C.L.	(U)	74.0	19.4	61.7	32.6	22.6	14.2	64.3	106.9	112.8	39.8	28.9	11.9	16.5	2.5	5.0	6.0	7.9	40.8	119.6	159.8	73.2
	(L)	16.5	12.5	36.1	26.8	12.1	4.3	44.2	60.5	90.7	–	16.9	9.2	8.3	0.2	0.8	0.3	6.0	33.7	100.7	113.7	51.7
Calanoida		1.8	0.3			–		0.2					0.1				0.1					
95% C.L.	(U)	3.1	0.6					1.4					0.4				1.1					
	(L)	1.1	0.1					–					–				–					
Cyclopidae		32.8	13.3	46.2	29.6	15.3	7.9	46.1	80.4	101.2	32.2	21.6	10.0	11.7	1.1	2.3	1.6	6.9	36.4	109.4	132.8	61.5
95% C.L.	(U)	71.0	18.5	60.6	32.6	21.7	14.2	56.3	106.9	112.8	38.2	28.3	11.6	16.5	2.5	5.0	4.7	7.9	40.2	119.4	157.0	73.2
	(L)	15.1	9.5	35.3	26.8	10.8	4.3	37.7	60.5	90.7	27.1	16.5	8.7	8.3	0.2	0.8	0.4	6.0	33.0	100.2	112.3	51.7
Nauplius		–	0.9	0.8		0.9		6.1			0.7	0.4	0.2						0.4	0.2	1.2	
95% C.L.	(U)		2.5	2.1		2.4		8.0			2.2	1.1	0.5						0.8	0.6	2.5	
	(L)		0.3	0.2		0.3		4.7			0.1	–	–						0.2	–	0.5	
Ostracoda		2.3	0.8	12.0	5.5	4.9	5.0	4.8	1.8	0.9	1.5	1.4	0.7	0.6	0.7	8.7	2.0	4.2	0.6	31.1	1.6	25.6
95% C.L.	(U)	5.3	1.3	16.5	6.9	7.9	6.7	8.4	2.9	1.7	5.4	2.2	1.9	2.0	5.1	10.8	2.8	28.0	1.3	33.1	2.4	53.4
	(L)	1.0	0.4	8.7	4.4	3.0	3.7	2.7	1.1	0.4	0.3	0.8	0.1	–	–	6.9	1.5	0.2	0.1	29.2	1.1	12.2
Hydracarina		–	–	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.2	–	0.2	0.3		0.1					
95% C.L.	(U)			0.2	0.4	0.3	0.3	0.2	0.6	0.4	0.3	0.4		0.6	2.0		1.1					
	(L)			–	–	–	–	–	–	–	–	–		–	–		–					
Eubranchiopoda		0.4			0.1		–					–										
95% C.L.	(U)	0.8			0.2																	
	(L)	0.1			–																	
Insecta		0.4	0.4	0.7	0.9	1.2	1.7	3.8	7.2	3.8	0.6	0.7	0.4	1.6					–	0.4	0.4	1.0
95% C.L.	(U)	0.8	0.7	1.2	1.5	3.6	2.8	6.7	11.9	7.6	1.5	1.8	1.4	3.1						1.0	0.7	2.9
	(L)	0.1	0.2	0.4	0.6	0.3	1.0	2.0	4.3	1.8	0.2	0.1	–	0.8						0.1	0.2	0.2
Ephemeroptera														0.2						0.3	0.2	0.3
95% C.L.	(U)													1.0						0.6	0.4	0.7
	(L)													–						0.1	–	–
Coleoptera			0.1			–			–			0.1	–	0.1								
95% C.L.	(U)		0.2									0.2		0.3								
	(L)		–									–		–								
Diptera		0.3	0.2	0.7	0.9	1.2	1.7	3.8	7.2	3.8	0.6	0.6	0.4	1.2								
95% C.L.	(U)	0.5	0.7	1.1	1.5	3.5	2.8	6.7	11.9	7.6	1.5	1.6	1.3	2.0								
	(L)	0.1	–	0.4	0.6	0.3	1.0	2.0	4.3	1.8	0.2	0.1	–	0.7								
Trichoptera		0.1	–	–															–	0.2	0.2	0.6
95% C.L.	(U)	0.3																		0.4	0.4	2.4
	(L)	–																		–	–	–

– equals < 0.05

TABLE 14. *Analysis of the benthic sampler showing major groupings of organisms from the Pleasant Lake and Pabst Marshes in 1971 and 1972 with their mean number/100 sq. cm. and upper and lower 95% confidence limit. (log_{10} transformation used)*

		Pleasant Lake Marsh								Pabst Marsh							
		1971					1972			1971					1972		
Organism		4/29	5/4	5/11	5/18	5/24	5/11	5/18	5/23	4/24	4/30	5/6	5/13	5/20	5/10	5/19	5/24
Cladocera							4.4	0.4	10.2						0.3	2.3	0.3
95% C.L.	(U)						11.5	1.5	27.9						1.1	7.1	1.1
	(L)						0.4	–	2.1						–	–	–
Copepoda		1.0	0.7	1.8	1.8	1.0	12.9	20.5	6.2	1.7	4.3	0.7	4.5	2.3	10.0	20.3	6.5
95% C.L.	(U)	1.7	1.6	3.3	3.9	2.4	36.1	68.7	29.7	10.9	8.5	3.5	13.4	6.7	20.2	36.7	12.2
	(L)	0.5	0.1	0.9	0.7	0.3	2.9	4.1	–	–	2.0	–	1.3	0.6	4.1	10.5	2.7
Calanoida		0.4	0.1				0.4		0.4								
95% C.L.	(U)	0.7	0.2				1.5		1.5								
	(L)	0.2	–				–		–								
Cyclopidae		0.5	0.6	1.8	1.2	1.0	10.9	20.5	3.5	1.7	4.3	0.7	4.5	2.3	10.0	20.3	5.7
95% C.L.	(U)	1.1	1.5	3.3	1.9	2.4	28.2	68.7	12.1	10.9	8.5	3.5	13.4	6.7	20.2	36.7	11.8
	(L)	0.2	0.1	0.9	0.8	0.3	2.7	4.1	–	–	2.0	–	1.3	0.6	4.1	10.5	1.9
Unknown							1.8		4.4								0.3
95% C.L.	(U)						6.7		21.3								1.1
	(L)						–		–								–
Ostracoda		4.9	4.9	2.4	3.1	1.2	19.3	11.8	7.0	1.0	2.1	3.0	1.1	1.8	11.5	14.1	3.1
95% C.L.	(U)	8.7	13.8	6.6	4.7	2.1	33.9	19.3	17.0	4.8	3.7	13.6	6.1	3.8	16.8	30.0	9.8
	(L)	2.7	1.6	0.7	2.0	0.6	10.2	6.7	1.6	–	1.1	0.4	–	0.8	7.5	5.5	–
Hydracarina							0.4									0.9	
95% C.L.	(U)						1.5									2.6	
	(L)						–									–	
Eubranchiopoda					0.1		0.7			1.0	0.6	1.4	1.2	1.5	1.3	2.3	2.3
95% C.L.	(U)				0.3		2.7			4.8	2.5	8.3	7.7	3.4	3.3	5.9	7.1
	(L)				–		–			–	–	–	–	0.5	–	–	–
Insecta		3.9	4.3	6.3	7.7	11.8	5.4	4.4	3.5	0.1	0.3	0.7	11.5	14.2	3.0	3.5	4.4
95% C.L.	(U)	5.8	7.5	11.1	14.4	18.0	14.0	11.5	7.9	0.9	2.1	1.5	33.8	22.5	7.1	7.2	11.0
	(L)	2.6	2.4	3.5	4.1	7.7	0.8	0.4	0.6	–	–	0.2	3.7	8.9	0.3	1.0	0.6
Ephemeroptera		0.1	0.1													0.5	0.3
95% C.L.	(U)	0.2	0.2													1.9	1.1
	(L)	–	–													–	–
Odonata		0.1	0.2	0.2	0.3	0.3											
95% C.L.	(U)	0.3	0.6	0.6	0.6	0.7											
	(L)	–	–	–	0.1	–											
Coleoptera				0.1			2.0	0.9			0.1			0.1			0.5
95% C.L.	(U)			0.2			5.4	2.5			0.9			0.5			1.9
	(L)			–			–	–			–			–			–
Diptera		3.3	3.5	5.7	6.4	11.4	2.6	3.0	3.5	0.1	0.2	0.7	11.5	14.0	3.0	2.7	3.5
95% C.L.	(U)	5.0	6.5	10.2	13.9	17.2	9.0	8.6	7.9	0.9	1.2	1.5	33.8	23.0	7.1	5.9	9.1
	(L)	2.1	1.8	3.2	2.8	7.5	–	–	0.6	–	–	0.2	3.7	8.5	0.3	0.5	0.2
Trichoptera		0.2	0.1	0.2	0.2	0.1	0.4	0.4									
95% C.L.	(U)	0.4	0.3	0.4	0.5	0.1	1.5	1.5									
	(L)	–	–	–	–	–	–	–									
Nematoda		0.1	0.1														
95% C.L.	(U)	0.4	0.3														
	(L)	–	–														
Gastropoda		0.2	0.2	0.2	0.5	0.5						0.2	0.1	0.2		0.3	
95% C.L.	(U)	0.5	0.4	0.5	1.1	1.1						0.7	0.5	0.7		1.1	
	(L)	–	–	–	0.1	0.2						–	–	–		–	
Hirudinea		0.1	0.1		0.2	0.2		1.3		0.1					2.1	4.1	10.4
95% C.L.	(U)	0.2	0.3		0.5	0.3		4.5		0.5					5.6	11.0	19.6
	(L)	–	–		–	–		–		–					–	3.0	4.7
Oligochaeta		6.0	6.6	3.2	5.2	4.2	18.8	5.7	4.7	11.1	4.2	2.3	1.1	19.5	6.3	6.7	7.4
95% C.L.	(U)	12.0	17.7	10.6	10.2	7.9	29.3	13.9	9.4	61.4	13.2	20.3	6.1	26.0	13.9	17.1	15.4
	(L)	2.9	2.3	0.8	2.5	2.2	11.6	1.1	1.5	1.7	1.2	–	–	14.6	1.9	1.3	2.6
Pelecypoda		3.7	3.4	5.7	5.7	3.6		1.1									
95% C.L.	(U)	9.2	6.9	13.9	18.1	9.5		3.6									
	(L)	1.4	1.6	2.2	1.6	1.2		–									

– equals < 0.05

TABLE 15. *Analysis of the averaged northern pike fingerling stomach content showing major groupings of organisms from the Pleasant and Pabst Marshes with their mean number and upper and lower 95% confidence limit (log_{10} transformation used).*

		Pleasant Lake Marsh													
		1969				1971						1972			
Organism		5/6	5/13	5/21	6/4	4/29	5/4	5/11	5/18	5/24	6/1	5/4	5/11	5/18	5/27
Cladocera		2.2	2.4	3.8	3.5	11.7	8.1	0.4	0.4	1.5	5.7	2.5	6.2	1.6	
95% C.L.	(U)	3.2	4.4	6.8	5.0	15.6	12.0	0.8	1.0	2.8	17.0	3.7	9.7	2.7	
	(L)	1.4	1.1	2.0	2.3	8.7	5.4	0.2	–	0.6	1.5	1.6	3.8	0.8	
Daphnia		2.2	2.4	3.8	3.2	7.7	0.9	0.1	0.1	–		0.1	0.6	0.1	
95% C.L.	(U)	3.2	4.4	6.8	4.6	10.5	1.5	0.2	0.2			0.2	1.4	0.1	
	(L)	1.4	1.1	2.0	2.1	5.6	0.4	–	–			–	0.1	–	
Ceriodaphnia							–	–			1.4	0.3	0.9	1.3	
95% C.L.	(U)										3.2	0.5	1.7	2.4	
	(L)										0.4	0.1	0.4	0.6	
Simocephalis								0.1		0.2			0.1		
95% C.L.	(U)							0.2		0.4			0.3		
	(L)							–		–			–		
Alona							0.1								
95% C.L.	(U)						0.2								
	(L)						–								
Scapholebris					0.2	1.7	1.4		0.2	0.1		–		–	
95% C.L.	(U)				0.3	3.1	2.5		0.7	0.2					
	(L)				–	0.8	0.6		–	–					
Chydorus						0.5	2.4		–	0.5					
95% C.L.	(U)					0.8	3.8			1.1					
	(L)					0.2	1.4			0.1					
Bosmina						0.1	1.6	–				2.1	1.6	–	
95% C.L.	(U)					0.3	2.9					3.1	3.4		
	(L)					–	0.7					1.4	0.5		
Eurycerus											0.6				
95% C.L.	(U)										3.1				
	(L)										–				
Unknown			–		0.1		–	0.1	0.1	0.6	2.3				
95% C.L.	(U)				0.2			0.3	0.2	1.2	5.2				
	(L)				–			–	–	0.1	0.7				
Copepoda		2.8	0.4	0.1	0.2	29.7	32.0	0.6		–		6.6	15.4	0.4	
95% C.L.	(U)	4.3	0.8	0.2	0.3	42.0	50.6	1.1				9.4	20.2	0.7	
	(L)	1.8	0.1	–	0.1	21.0	20.1	0.2				4.5	11.7	0.1	
Calanoida						0.2	0.3								
95% C.L.	(U)					0.4	0.6								
	(L)						0.1								
Cyclopidae		2.8	0.4	0.1	0.2	26.8	29.7	0.5		–		5.9	14.7	0.4	
95% C.L.	(U)	4.3	0.8	0.2	0.3	38.9	47.0	1.0				8.5	19.3	0.7	
	(L)	1.8	0.1	–	0.1	18.4	18.6	0.2				4.0	11.1	0.1	
(Nauplius)						1.3	1.2					0.6	0.4		
95% C.L.	(U)					2.2	2.1					1.0	0.8		
	(L)					0.6	0.5					0.2	0.1		
Ostracoda			0.2	0.5	0.1	0.2	0.7	0.4	0.3	0.3	0.8	0.4	0.3	1.9	
95% C.L.	(U)		0.4	1.0	0.2	0.4	1.4	1.0	0.7	0.7	2.1	0.8	0.6	3.4	
	(L)		0.1	0.1	–	–	0.3	–	–	0.1	.0.1	0.1	0.1	1.0	
Insecta		2.9	3.2	9.5	3.1		3.1	12.0	9.4	0.9	5.8	–	0.6	1.2	0.2
95% C.L.	(U)	4.2	4.7	14.6	4.2		4.7	21.3	12.7	1.7	9.8		1.0	1.8	0.5
	(L)	1.9	2.1	6.1	2.3		1.9	6.5	6.9	0.4	3.3		0.3	0.7	–
Ephemeroptera			–	0.1	0.3			0.7	0.2	0.4	1.7		–	0.1	
95% C.L.	(U)			0.3	0.5			2.5	0.4	0.8	3.8			0.1	
	(L)			–	0.2			–	–	0.1	0.5			–	
Odonata				0.1					0.3					0.1	–
95% C.L.	(U)			0.2					0.6					0.3	
	(L)			–					–					–	
Hemiptera				0.1	0.1					0.1	0.4			0.1	
95% C.L.	(U)			0.2	0.2					0.4	1.2			0.3	
	(L)			–	0.1					–	–			–	
Coleoptera								0.4	0.2						
95% C.L.	(U)							0.8	0.4						
	(L)							0.1	–						
Diptera		0.1			0.1						–				
95% C.L.	(U)	0.1			0.2										
	(L)	–			–										
Trichoptera		2.8	3.1	8.6	1.9		3.1	7.0	8.4	0.3	1.8	–	0.6	0.8	0.2
95% C.L.	(U)	4.1	4.7	13.7	2.8		4.7	9.8	11.3	0.7	3.6		1.0	1.3	0.4
	(L)	1.9	2.0	5.2	1.3		1.9	4.9	6.3	0.1	0.8		0.2	0.4	–
Fish		–	–	–	0.1			–	–	0.1	0.3			0.2	0.9
95% C.L.	(U)				0.2					0.2	0.5			0.4	1.1
	(L)				0.1					–	–			0.1	0.7

– equals < 0.05

TABLE 15. *Continued.*

		Pleasant Lake Marsh						Pabst Marsh										
		1973						1971						1972				
Organism		4/26	5/3	5/10	5/17	5/24	5/29	4/30	5/6	5/13	5/20	5/27	6/8	5/2	5/10	5/19	5/24	5/31
Cladocera		2.6	1.8	1.5	1.7	3.2	5.0	3.7	0.7	14.2	2.0	5.7	3.7	1.1	12.9	0.8		3.0
95% C.L.	(U)	4.4	3.5	3.0	2.9	5.4	9.6	5.2	1.3	21.0	3.1	10.5	6.2	1.9	17.5	1.7		5.7
	(L)	1.4	0.7	0.6	0.8	1.8	2.4	2.6	0.3	9.4	1.2	2.9	2.1	0.5	9.5	0.3		1.4
Daphnia		0.5				0.1	0.7	2.8	0.4	9.4	0.2	0.6	0.1	0.5	7.4			
95% C.L.	(U)	1.0				0.1	1.5	4.3	0.8	14.4	0.5	1.3	0.4	1.1	11.3			
	(L)	0.2				–	0.2	1.7	0.1	6.0	–	–	–	0.1	4.8			
Ceriodaphnia		0.2	0.1	–	0.7	1.9	0.4					0.1	0.8	0.3	3.0	0.3		1.3
95% C.L.	(U)	0.6	0.3		1.3	3.0	0.8					0.2	1.4	0.6	5.1	0.5		2.8
	(L)		–		0.3	1.1	–					–	0.4	0.1	1.6	–		0.4
Simocephalis							0.3				0.3	2.1				0.5		0.3
95% C.L.	(U)						0.8				0.6	3.7				1.1		0.8
	(L)						–				0.1	1.0				–		–
Alona		0.3	1.1	0.8			0.1									–		0.8
95% C.L.	(U)	0.8	2.5	1.9			0.4											1.8
	(L)	–	0.3	0.1			–											0.2
Scapholebris		0.1	0.2	0.4			1.8					0.1						
95% C.L.	(U)	0.2	0.5	0.8			4.1					0.2						
	(L)	–	–	0.1			0.6					–						
Chydorus								0.3			0.3	0.2						
95% C.L.	(U)							0.6			0.6	0.6						
	(L)							0.1			0.1	–						
Bosmina		0.7	0.1		0.1	–	0.1	0.1	0.3	–	–			0.1				
95% C.L.	(U)	1.4	0.3		0.2		0.3	0.3	0.6					0.2				
	(L)	0.2	–		–		–	–	–					–				
Eurycerus					0.6	1.1												
95% C.L.	(U)				1.3	2.2												
	(L)				0.2	0.3												
Unknown		–			–					3.4	0.6	1.4	2.5		–			–
95% C.L.	(U)									5.5	1.2	2.9	4.2					
	(L)									2.0	0.2	0.5	1.3					
Copepoda		7.0	25.9	6.7	1.8	2.5	0.1	31.1	62.1	2.0	1.8	–	–	27.3	15.4	0.3		0.1
95% C.L.	(U)	9.8	37.9	11.5	3.3	4.5	0.3	39.1	79.4	3.3	3.2			33.2	20.0	0.7		0.4
	(L)	4.9	17.7	3.7	0.8	1.2	–	24.7	48.5	1.1	0.9			22.4	11.8	–		–
Calanoida											–							
95% C.L.	(U)																	
	(L)																	
Cyclopidae		7.0	25.9	6.7	1.8	2.5	0.1	31.1	62.1	2.0	1.8	–	–	26.4	15.2	0.3		0.1
95% C.L.	(U)	9.8	37.9	11.5	3.3	4.5	0.3	39.1	79.4	3.3	3.1			32.2	19.8	0.7		0.4
	(L)	4.9	17.7	3.7	0.8	1.2	–	24.7	48.5	1.1	0.9			21.7	11.6	–		–
(Nauplius)														0.2	0.1			
95% C.L.	(U)													0.6	0.3			
	(L)													–	–			
Ostracoda		0.2	0.2	0.2	2.0	0.3	0.2	–	0.2	1.0	0.3	0.7	0.1	0.2	0.3	4.9	0.5	0.3
95% C.L.	(U)	0.4	0.4	0.5	3.9	0.7	0.4		0.4	1.7	0.7	1.4	0.2	0.3	0.7	9.2	1.5	0.6
	(L)	–	–	–	0.9	0.1	–		–	0.5	–	0.2	–	–	0.1	2.4	–	–
Insecta		3.5	3.4	6.5	2.7	0.9	8.5		0.3	0.6	1.2	8.6	7.9	–	0.3	0.4	1.1	1.7
95% C.L.	(U)	5.0	5.5	9.3	4.4	1.6	14.6		0.5	1.1	2.0	12.4	10.2		0.6	0.6	2.0	3.1
	(L)	2.3	2.0	4.4	1.5	0.4	4.8		0.1	0.3	0.6	5.9	6.1		0.1	0.1	0.4	0.8
Ephemeroptera			0.1		0.5	0.2					0.1	0.5	5.9					–
95% C.L.	(U)		0.2		0.8	0.5					0.3	1.0	8.1					
	(L)		–		0.2	–					–	0.2	4.2					
Odonata																0.1	0.3	0.1
95% C.L.	(U)															0.1	0.8	0.2
	(L)															–	–	–
Hemiptera												–	–			0.1	–	0.2
95% C.L.	(U)															0.2		0.4
	(L)															–		–
Coleoptera			0.1		–	–					–		–				–	–
95% C.L.	(U)		0.2															
	(L)		–															
Diptera		3.5	3.2	6.5	2.0	0.6	8.5					0.1	0.1			–	0.1	0.2
95% C.L.	(U)	5.0	5.2	9.3	3.5	1.1	14.6					0.3	0.2				0.3	0.5
	(L)	2.3	1.9	4.4	1.0	0.3	4.8					–	–				–	–
Trichoptera									0.3	0.6	1.0	6.1	0.7	–	0.3	0.2	0.4	1.1
95% C.L.	(U)								0.5	1.1	1.7	10.6	1.2		0.6	0.4	0.8	2.2
	(L)								0.1	0.3	0.5	3.3	0.4		0.1	–	0.1	0.4
Fish							–					0.2	0.1			0.2	0.6	0.7
95% C.L.	(U)											0.3	0.2			0.4	0.9	0.9
	(L)											–	–			0.1	0.3	0.4

– equals < 0.05

DAY = 116
SAMPLE = 25.
#EMPTY = 0
MEAN #ORG. 13.25

	L. MM.	CLAD.	DAPH.	CERI.	SIMO.	ALON.	SCAP.	CHYD.	BOSM.	SIDA.	UNKN.	EURY.	ROTA.
MEAN/UNIT	16.320	2.571	0.537	0.245		0.311	0.087		0.719		0.028		
VAR. =	2.727	0.186	0.086	0.071		0.095	0.018		0.136		0.004		
95% C.L. (U)	17.000	4.379	1.030	0.603		0.757	0.232		1.438		0.089		
95% C.L. (L)	15.640	1.371	0.163						0.212				
% OCCUR.	100.000	76.000	36.000	16.000		16.000	8.000		36.000		4.000		
% T. ORG.		19.400	4.048	1.850		2.343	0.654		5.424		0.212		
COR. MEAN		4.850	0.930	0.502		0.687	0.138		1.463		0.038		

	COPE.	CALA.	CYCL.	NAUP.	UNKN.	OSTR.	HYDR.	AMPH.	EUBR.
MEAN/UNIT	7.014		7.014			0.211			
VAR. =	0.100		0.100			0.034			
95% C.L. (U)	9.815		9.815			0.442			
95% C.L. (L)	4.938		4.938			0.017			
% OCCUR.	96.000		96.000			20.000			
% T. ORG.	52.922		52.922			1.593			
COR. MEAN	9.440		9.440			0.325			

	T. INS.	EPHE.	ODON.	HEMI.	COLE.	DIPTE.	TRIC.	NEMA.	GAST.	HIRU.	OLIG.	PELE.	FISH.
MEAN/UNIT	3.457					3.457							
VAR. =	0.094					0.094							
95% C.L. (U)	4.961					4.961							
95% C.L. (L)	2.333					2.333							
% OCCUR.	96.000					96.000							
% T. ORG.	26.086					26.086							
COR. MEAN	4.716					4.716							

Abbreviations: L.MM. = length in millimeters; CLAD. = Cladocera; DAPH. = Daphnia; CERI. = Ceriodaphnia; SIMO. = Simocephalus; ALON. = Alona; SCAP. = Scapholeberis; CHYD. = Chydorus; BOSM. = Bosmina; SIDA. = Sida; UNKN. = unknown Cladocera; EURY. = Eurycerus; ROTA. = Rotatonia; COPE. = Copepoda; CALA. = Calanoida; CYCL. = Cyclopoida; NAUP. = nauplius; UNKN. = unknown; OSTR. = Ostracoda; HYDR. = Hydracarina; AMPH. = Amphipoda; EUBR. = Eubranchiopoda; T. INS. = Total Insecta; EPHE. = Ephemeroptera; ODON. = Odonata; HEMI. = Hemiptera; COLE. = Coleoptera; DIPTE. = Diptera; TRIC. = Trichoptera; NEMA. = Nematoda; GAST. = Gastropoda; HIRU. = Hirudinea; OLIG. = Oligochaeta; PELE. = Pelecypoda; FISH. = Fish; · = space is available for other groups; VAR. = variance; 95% C.L. (U) = upper 95% confidence limit; 95% C.L. (L) = lower 95% confidence limit; % OCCUR. = percent occurrence; % T. ORG. = percent of total organisms; COR. MEAN = corrected mean.

FIGURE 11. *Computer printout of stomach analysis at the Pleasant Lake Marsh on 26 April 1973.*

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ABOUT THE AUTHOR

The author is a Fishery Biologist in the Bureau of Research, Department of Natural Resources, Madison Area Headquarters, Route 4, Madison, Wisconsin 53711.

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