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**LARVAL WALLEYE AND YELLOW PERCH POPULATION DYNAMICS  
IN SPIRIT LAKE AND THE CONTRIBUTION OF  
STOCKED SAC-FRY TO THE LARVAL WALLEYE DENSITY**

STATE CONSERVATION COMMISSION

FISHERIES SECTION  
300 FOURTH STREET  
DES MOINES, IOWA 50319

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Fisheries Section  
Iowa Conservation Commission

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## ABSTRACT

Larval walleye and yellow perch populations in Spirit Lake, IA, were sampled using standardized tow net hauls in 9 weekly intervals during May-July, 1973-75. Annual catch means were 2.6, .9 and 1.7 larval walleye and 117, 23 and 81 larval yellow perch per tow, respectively. The annual maximum larval yellow perch density probably varied less than indicated. Seasonal catch of both fish species was unimodal, characterized by systematic declines in larval abundance after the modal density. Both fish species were randomly distributed. Annual survival ranged from 5-51% for walleye and 18-46% for yellow perch. Estimates of the contribution of stocked walleye fry to the larval population each year were 81%, 90% and 85%. Estimates by an alternate method ranged from about 23% to nearly 100%. The base of the larval walleye population was formed by stocked fry, with natural reproduction additionally strengthening year class abundance; with survival the determining factor in establishing year class strengths of both walleye and yellow perch. No significant correlations were found between the abundance or survival of larval walleye or yellow perch and six water quality parameters. Interspecific competition for zooplankton food between larval walleye and yellow perch did not influence survival or growth of either species. Two genera of Copepoda (*Diaptomus* and *Cyclops*) and three genera of Cladocera (*Daphnia*, *Chydorus* and *Bosmina*) were identified and enumerated. The abundance and distribution of all genera, except *Bosmina*, was highly variable. *Diaptomus* and *Daphnia* were codominant genera, nearly twice as abundant as *Cyclops* and nearly 15 times more abundant than *Chydorus* or *Bosmina*. *Cyclops*, *Diaptomus* and *Daphnia* were consumed by both fish species with yellow perch utilizing *Chydorus* and *Bosmina*. *Cyclops* and *Diaptomus* were generally utilized by smaller larvae and *Daphnia* by larger larvae (walleye 15 mm TL or greater; yellow perch 11 mm TL or greater).

The perch harvest.

Both hatchery prepared walleye sac-fry larvae and fingerlings (juveniles) have been released in Spirit Lake to increase year class abundance, while the population density of yellow perch is wholly dependent upon natural reproduction. Intensive evaluations of walleye fingerling plantings by Rose (1959) and Jennings (1966) disclosed the contribution to year class abundance ranged from 1% to nearly 100%. The magnitude of the contribution was partially dependent upon stocking density and other factors, such as fingerling survival, were also important.

Hatchery produced larvae from wild trapped walleye stocks in Spirit Lake and East and West Okoboji Lakes have been planted in Spirit Lake over several decades to maintain the fishery. Stocking density has varied widely from about 1,380 sac-fry/m<sup>2</sup> (360/ac) in 1964 and 1965 to over 2,400 sac-fry/m<sup>2</sup> (3,300/ac) in 1967 and 1969-73 were stocked. An early assessment of the program by Rose (1959) showed fingerling walleye populations were linear when no fry were stocked when compared to years with stocking indicating fry plantings contributed to year class abundance. However, Rose (1966) reported a decline in the white bass abundance during this period, and noted the possibility of a compensatory relationship between the predaceous bass and stocked walleye larvae survival. The relationship was never resolved because the white bass population continued to decline and has since remained at relatively low density levels.

## INTRODUCTION

Yellow perch and walleye are major sport fish species in Spirit Lake usually ranking second and third in the numerical harvest. Only black bullhead are caught in greater numbers, ranking first in 22 of the 28 years (1946-73) surveys were conducted. A 1975 telephone survey of Iowa anglers revealed the catch by resident fishermen in the Northwest District, who caught one or more fish, was comprised of 14% yellow perch and 4% walleye. However, 3% of the respondents sought yellow perch and 32% sought walleye (Fishing in Iowa, A Survey of Iowa Anglers; May 1976). In comparison, an interview-type survey conducted during 1972-73 showed nearly 12% of the fish caught at Spirit Lake were perch and 3% walleye, with slightly over 3% of the contacted anglers preferring perch and 7% walleye (McWilliams 1973).

Previous research at Spirit Lake has been, for the most part, devoted to adult walleye populations, and walleye fry stocking rates. Numerical estimates indicated the adult population fluctuated widely, from about 27,000 (Moen 1961) to nearly 80,000 (Jennings 1965). The fishery for walleye likewise varied considerably ranging from approximately 5,500 in 1969 to over 42,000 in 1960.

Although yellow perch usually ranked second in the catch, little information has been compiled about their life history. The only previous study was an age and growth assessment by Jennings (1970). Catch statistics compiled during annual surveys showed harvests ranged from approximately 6,000 in 1961 to 109,000 in 1971. Yellow perch ranked as the principal species in 6 of the 28 years surveyed; however, this was usually due to a significant decrease in the bullhead harvest rather than from an increase in the perch harvest.

Both hatchery propagated walleye sac-fry (larvae) and fingerlings (juveniles) have been released in Spirit Lake to increase year class abundance, while the population density of yellow perch is wholly dependent upon natural reproduction. Intensive evaluations of walleye fingerling plantings by Rose (1959) and Jennings (1970a) disclosed the contribution to year class abundance ranged from < 1% to nearly 13%. The magnitude of the contribution was partially dependent upon stocking density although other factors, such as fingerling survival, were also important.

Hatchery produced larvae from wild trapped walleye stocks in Spirit Lake and East and West Okoboji Lakes have been planted in Spirit Lake over several decades to maintain the fishery. Stocking density has varied widely from about 1,380 sac-fry/ha (560/ac) in 1964 and 1965 to over 8,300 sac-fry/ha (3,300/ac) in 1967 and 1969-73 were stocked. An early assessment of the program by Rose (1955) showed fingerling walleye populations were lower when no fry were stocked when compared to years with stocking indicating fry plantings contributed to year class abundances. However, Rose (ibid) reported a decline in the white bass abundance during this period, and noted the possibility of a compensatory relationship between the predacious bass and stocked walleye larvae survival. The relationship was never resolved because the white bass population continued to decline and has since remained at relatively low density levels.

Table 1. Concentrations of six water quality parameters at Spirit Lake from 1973-75.

	pH	Total hardness (mg/l)	Alkalinity (mg/l)	Dissolved oxygen (mg/l)	Temperature (°C)	Secchi disc (m)
1973						
Mean	8.5	243	217	8.9	17.9	2.1
Range	8.5-8.6	205-256	188-256	8.0-10.1	10.5-24.0	.9-3.7
1974						
Mean	8.6	227	190 <sup>a</sup>	8.9	17.8	1.8
Range	8.5-8.7	220-250		7.6-11.2	12.0-22.6	1.0-4.6
1975						
Mean	8.7	217	194	9.9	17.9	1.5
Range	8.5-9.3	215-235	180-225	7.2-13.0	11.5-25.6	.9-2.4

<sup>a</sup>Values were 190 mg/l.

Fish larvae samples were collected with a conically shaped tow net, approximately 3 m (9.8 ft) long, constructed of .79 mm (.03 in) nylon mesh attached to a .75 m (2.4 ft) diameter metal ring. Surface samples were collected by towing the net about 12.1 m (40 ft) directly behind an outboard powered boat. A stabilizing weight attached to the towing bridle hung below and behind the ring perimeter. Subsurface samples were collected by attaching the towing bridle to a support pipe fixed on the boat gunwale.

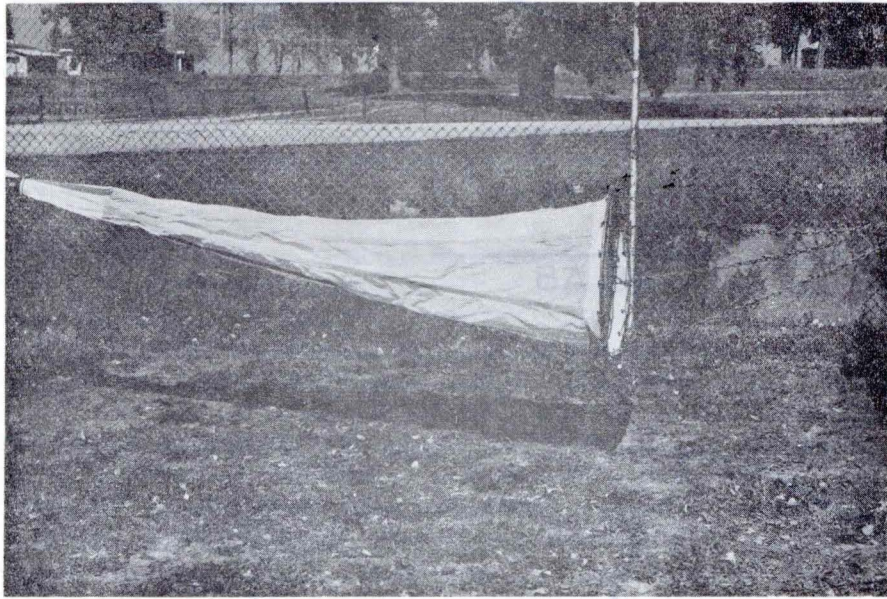
Larval walleye and yellow perch populations were sampled in nine weekly intervals, commencing the first week in May each year. Standardized tows were made at eight sampling stations located in varied habitats. Six sampling stations were located in shallow water along the shoreline and designated Stations 1-6 (Figure 1). Two midwater stations, Stations 7 (A and B) and 8 (A and B), were sampled at the surface and at a depth of 3.1 m (10 ft).

Each tow lasted five minutes with the tow length measured by attaching a General Oceanics Digital Flowmeter (Model 2030) to the center of the bridle. The number of larval fish was adjusted to a standard tow net haul of 1,000 m<sup>3</sup>.

Fish were preserved in 10% buffered formalin for later identification and sorting. After sorting, larval fish were preserved in 4% buffered formalin. Identification of walleye and yellow perch larvae was based on taxonomic keys by May and Gasaway (1967), Norden (1961), Nelson (1968), Mansueti (1964) and Fish (1932). After identification larvae were individually measured in body length, weighed in aggregate and several preserved for examination of stomach contents.

Sources of variation in the numerical catch data of each species were determined by least squares analysis of variance from transformed catch data in a fixed effects model. Catch in number per standardized net haul were transformed by the function





A 3/4 meter diameter tow net was used to sample larval fish populations.

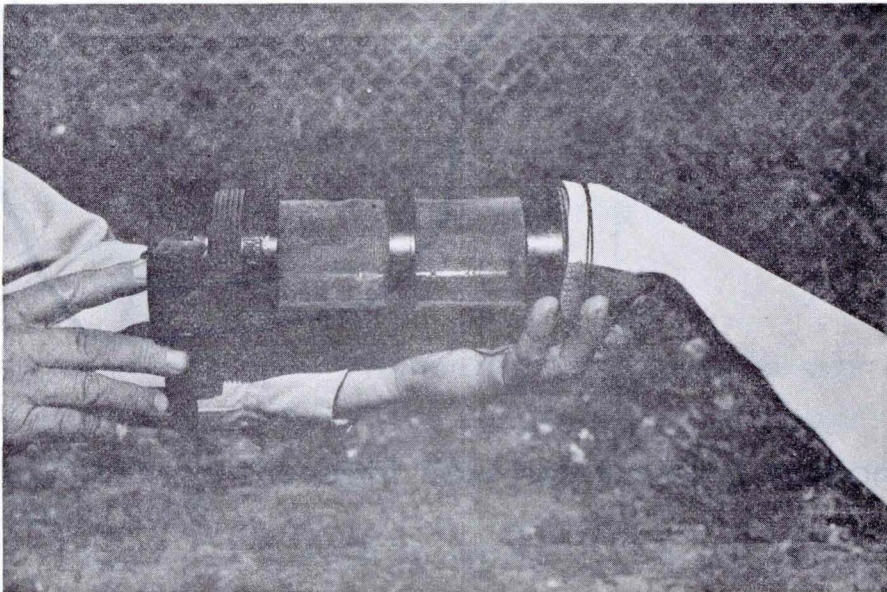


Figure 1.

Larval fish were collected in this type net bucket for emptying.

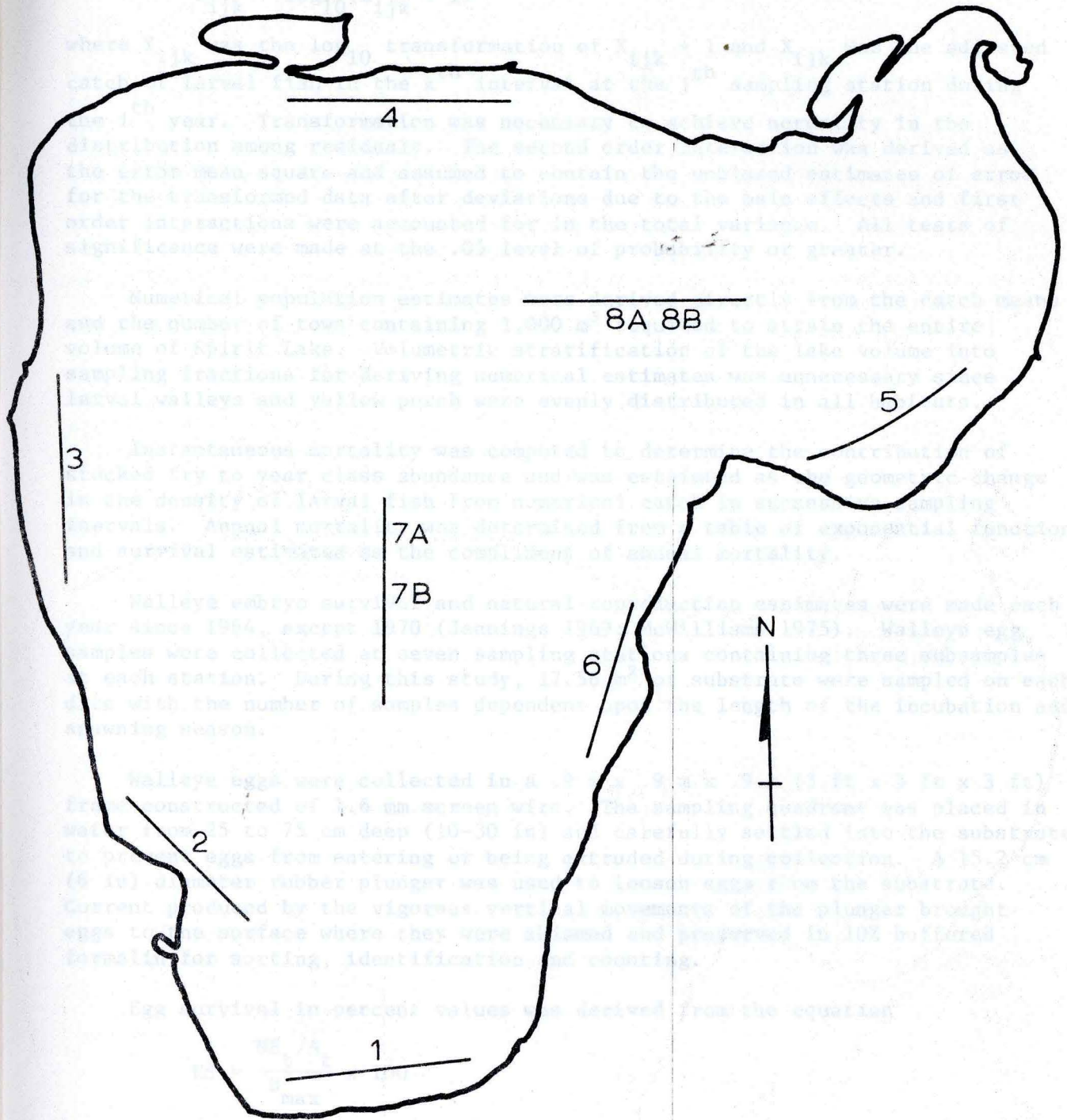


Figure 1. Location of the eight tow net sampling stations in Spirit Lake.

$$Y_{ijk} = \log_{10}(X_{ijk} + 1)$$

where  $Y_{ijk}$  was the  $\log_{10}$  transformation of  $X_{ijk} + 1$  and  $X_{ijk}$  was the adjusted catch of larval fish in the  $k^{\text{th}}$  interval at the  $j^{\text{th}}$  sampling station during the  $i^{\text{th}}$  year. Transformation was necessary to achieve normality in the distribution among residuals. The second order interaction was derived as the error mean square and assumed to contain the unbiased estimates of error for the transformed data after deviations due to the main effects and first order interactions were accounted for in the total variance. All tests of significance were made at the .05 level of probability or greater.

Numerical population estimates were derived directly from the catch means and the number of tows containing 1,000  $\text{m}^3$  required to strain the entire volume of Spirit Lake. Volumetric stratification of the lake volume into sampling fractions for deriving numerical estimates was unnecessary since larval walleye and yellow perch were evenly distributed in all habitats.

Instantaneous mortality was computed to determine the contribution of stocked fry to year class abundance and was estimated as the geometric change in the density of larval fish from numerical catch in successive sampling intervals. Annual mortality was determined from a table of exponential functions and survival estimated as the complement of annual mortality.

Walleye embryo survival and natural reproduction estimates were made each year since 1964, except 1970 (Jennings 1969; McWilliams 1975). Walleye egg samples were collected at seven sampling stations containing three subsamples at each station. During this study, 17.56  $\text{m}^2$  of substrate were sampled on each date with the number of samples dependent upon the length of the incubation and spawning season.

Walleye eggs were collected in a .9 m x .9 m x .9 m (3 ft x 3 ft x 3 ft) frame constructed of 1.6 mm screen wire. The sampling quadrant was placed in water from 25 to 75 cm deep (10-30 in) and carefully settled into the substrate to prevent eggs from entering or being extruded during collection. A 15.2 cm (6 in) diameter rubber plunger was used to loosen eggs from the substrate. Current produced by the vigorous vertical movements of the plunger brought eggs to the surface where they were skimmed and preserved in 10% buffered formalin for sorting, identification and counting.

Egg survival in percent values was derived from the equation

$$ES = \frac{NE_t / A_t}{D_{\max}} \times 100$$

where ES was percent egg survival,  $NE_t$  was the number of viable eggs on the last sampling date;  $A_t$  the total area sampled on the last sampling date and  $D_{\max}$  the maximum density of eggs per  $\text{m}^2$ .

The number of walleye produced was estimated from the number of eyed eggs on the last sampling date divided by the total area sampled on that date, assuming all eyed eggs hatched.

The contribution of stocked walleye sac-fry to the larval walleye population was estimated by two methods. First, a ratio was derived between the number of stocked walleye larvae surviving on the last stocking date to the number of stocked walleye larvae surviving plus the estimated number of naturally produced larvae surviving on that date. Natural reproduction was derived by multiplying the estimated number of fry hatched per  $m^2$  by the area within the 3.1 m (10 ft) contours (292 ha, 720 ac), which was considered the maximum area used by spawning walleye. Second, as the ratio of the estimated number of stocked fry surviving on the first sampling date to the estimated numerical density of the larval fish population on that date; where the number of surviving stocked larvae was determined by extrapolating the numbers stocked daily using estimated instantaneous mortality. Estimated contribution in succeeding intervals was assumed constant since factors influencing survival would act alike on both stocked and naturally produced walleye larvae.

Zooplankton population density was established by collecting 8-liters of water with a 2-liter Kemmerer water bottle and strained through a plankton net. These concentrated samples were preserved in 10% buffered formalin for identification and enumeration.

In 1973, plankton samples were concentrated to 6-15 ml. Four, 1-ml aliquots of the concentrated sample were placed in a Sedgwick-Rafter counting cell and the zooplankton identified and enumerated. The mean number of zooplankton per ml was then extrapolated to obtain the density of zooplankton per liter (N/l). Plankton samples in 1974 and 1975 were concentrated to exactly 8 ml. Four, 1-ml aliquots were counted in 1974 and three 1-ml aliquots in 1975, and the density estimated as before. Zooplankton were identified to genus with keys by Pennack (1953) and Eddy and Hodson (1950).

Analytical treatment of the numerical catch data followed the same procedures used for larval fish. Variation in the catch due to non-random distribution was examined by orthogonal contrasts. All tests of significance were made at the .05 level of probability or greater.

Utilization of zooplankton for food was determined by direct examination of larval walleye and yellow perch stomach contents during each sampling interval. Larvae of both species were washed and rinsed three times before dissection to flush off adhering organisms. The alimentary tract was carefully teased from the body and the contents examined and identified. The Ivlev (1961) electivity index was used to determine food selectivity. Index values may range from -1 to +1, with selection for a taxa expressed by positive values and non-preference by negative values.

#### ABUNDANCE, DISTRIBUTION AND SURVIVAL OF LARVAL WALLEYE

Annual catch means of larval walleye per standardized tow net haul were 2.6 in 1973, .9 in 1974 and 1.7 in 1975 (Table 2). Analysis of variance disclosed highly significant differences among the annual means; however, examination of the stocking dates and catch distribution made total acceptance of this analysis questionable. Spawning and brood stock collection in 1974 occurred early when compared with other years, and walleye fry stocking was completed before sampling of the larval populations commenced. Thus, there

concentrations in subsurface samples, but stated the concentrations varied widely from lake to lake and suggested turbidity might be a major factor influencing distribution.

Walleye larvae survival for the nine week sampling period varied widely, with estimates of 31% in 1973, 5% in 1974 and 19% in 1975. Survival during the first two weeks following natal occurrence was lower than in succeeding intervals with estimates of 28%, 5% and 7% in comparison, Robie (1972) also noted larval walleye survival was lower during early season samples Oneida Lac, NY, with estimates of about 5%.

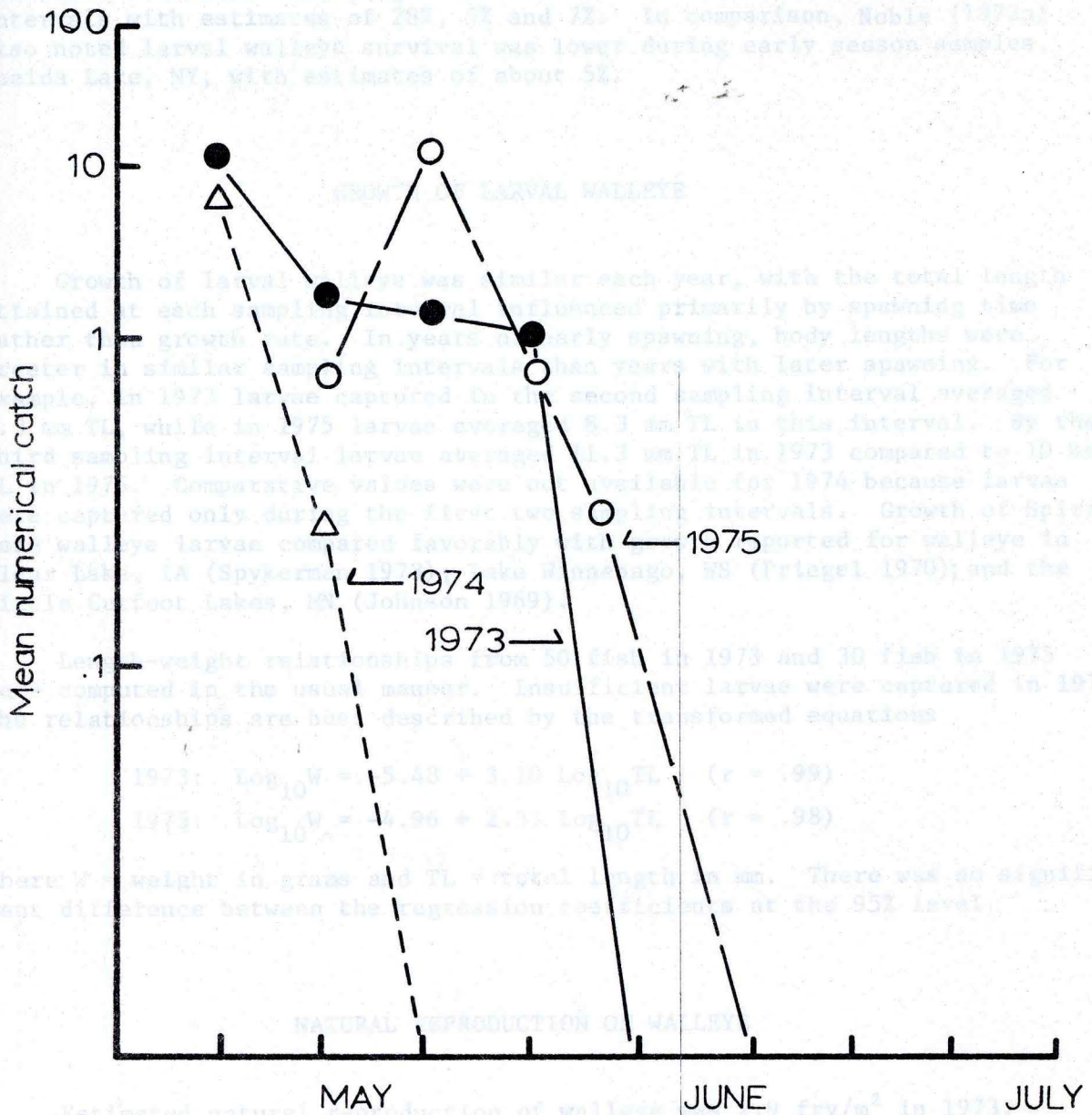


Figure 2. Mean numerical catch of walleye larvae in standardized tow net samples in Spirit Lake, 1973-75.

Estimated natural reproduction of walleye in Spirit Lake was 1.1 fry/m<sup>2</sup> in 1974 and 4.3 fry/m<sup>2</sup> in 1975 (Table 3). Natural reproduction of walleye larvae in Spirit Lake was estimated to be about 10 to 49 fry/m<sup>2</sup> (Johnson 1961).

Maximum egg density fluctuated widely, with 116 eggs/m<sup>2</sup>, 27 eggs/m<sup>2</sup> and 123 eggs/m<sup>2</sup> from 1973-1975, respectively. Previous findings at Spirit Lake revealed maximum egg deposition ranged from 4 to over 5,000 eggs/m<sup>2</sup>.

concentrations in subsurface samples, but stated the concentration varied widely from lake to lake and suggested turbidity might be a major factor influencing distribution.

Walleye larvae survival for the nine week sampling period varied widely, with estimates of 51% in 1973, 5% in 1974 and 19% in 1975. Survival during the first two weeks following modal occurrence was lower than in succeeding intervals with estimates of 28%, 5% and 7%. In comparison, Noble (1972a) also noted larval walleye survival was lower during early season samples, Oneida Lake, NY, with estimates of about 5%.

#### GROWTH OF LARVAL WALLEYE

Growth of larval walleye was similar each year, with the total length attained at each sampling interval influenced primarily by spawning time rather than growth rate. In years of early spawning, body lengths were greater in similar sampling intervals than years with later spawning. For example, in 1973 larvae captured in the second sampling interval averaged 9.3 mm TL, while in 1975 larvae averaged 8.3 mm TL in this interval. By the third sampling interval larvae averaged 11.3 mm TL in 1973 compared to 10 mm TL in 1975. Comparative values were not available for 1974 because larvae were captured only during the first two sampling intervals. Growth of Spirit Lake walleye larvae compared favorably with growth reported for walleye in Clear Lake, IA (Spykerman 1973); Lake Winnebago, WS (Priegel 1970); and the Little Cutfoot Lakes, MN (Johnson 1969).

Length-weight relationships from 50 fish in 1973 and 30 fish in 1975 were computed in the usual manner. Insufficient larvae were captured in 1974. The relationships are best described by the transformed equations

$$1973: \text{Log}_{10} W = -5.48 + 3.10 \text{Log}_{10} \text{TL} \quad (r = .99)$$

$$1975: \text{Log}_{10} W = -4.96 + 2.53 \text{Log}_{10} \text{TL} \quad (r = .98)$$

where W = weight in grams and TL = total length in mm. There was no significant difference between the regression coefficients at the 95% level.

#### NATURAL REPRODUCTION OF WALLEYE

Estimated natural reproduction of walleye was 2.9 fry/m<sup>2</sup> in 1973, 1.1 fry/m<sup>2</sup> in 1974 and 4.3 fry/m<sup>2</sup> in 1975 (Table 3). Natural reproduction from 1973-75 was similar to previous estimates at Spirit Lake (Jennings 1969; McWilliams 1975), although considerably below reported natural reproduction at Lake Winnigigoshish, MN, on similar substrate which ranged from about 10 to 49 fry/m<sup>2</sup> (Johnson 1961).

Maximum egg density fluctuated widely, with 116 eggs/m<sup>2</sup>, 27 eggs/m<sup>2</sup> and 125 eggs/m<sup>2</sup> from 1973-1975, respectively. Previous findings at Spirit Lake revealed maximum egg deposition ranged from 4 to over 6,000 eggs/m<sup>2</sup>

Table 3. Estimated natural walleye fry production and egg survival along the western shoreline of Spirit Lake.

	1964 <sup>a</sup>	1965 <sup>a</sup>	1966 <sup>a</sup>	1967 <sup>a</sup>	1968 <sup>a</sup>	1969 <sup>a</sup>	1971	1972	1973	1974	1975
Maximum egg density per m <sup>2</sup>	300	24	6,041	79	5	4	695	127	116	27	125
Number of eggs collected on last sampling date	55	161	572	18	6	47	1,606	16	130	119	139
Number of viable eggs on last sampling date	2	44	10	2	16	2	40	2	51	19	76
Average number of fry per m <sup>2</sup>	.2	6.6	2.0	.3	1.6	.1	2.3	.1	2.9	1.1	4.3
Percent egg survival	< .1	27.0	< .1	.4	34.4	3.3	.3	< .1	2.5	4.0	3.5

<sup>a</sup>Jennings, 1969.

Configuration of catch curves between 1973 and 1975 were similar with the exception of seasonal distributions (Figure 3). Catch distribution was unimodal each year with the maximum density occurring in early May. The limited number of larvae captured during late June and early July was probably due to net avoidance rather than to low population density.

Larval yellow perch were uniformly distributed in Spirit Lake. Individual station catch means ranged from 0 to 927 larvae per tow in 1973, 0 to 838 per tow in 1974 and 0 to 2,115 per tow in 1975 (Appendix B). The spatial distribution of perch larvae in Spirit Lake agreed closely with the distribution reported in a bay at Oneida Lake, NY, where larval perch were uniformly distributed in the upper 3.7 m of water (Noble 1972). However, in contrast Noble (1968) reported in the open lake perch fry tended to concentrate in the upper 1.5 m of water.

Estimated survival of yellow perch larvae during the nine week sampling period was 46% in 1973, 18% in 1974 and 23% in 1975.

#### GROWTH OF LARVAL YELLOW PERCH

Body length of yellow perch was also influenced more by the time of spawning than by growth. Larval length in the second sampling interval was 5.8 mm TL in 1973, 9.1 mm TL in 1974 and 6.2 mm TL in 1975, with differences in total body lengths existing throughout May and June.

Length-weight relationships were computed from 398 fish in 1973, 129 larvae in 1974 and 105 larvae in 1975. Regression coefficients were computed using normal procedures and are best described by the equations

$$\begin{aligned} 1973: \log_{10} W &= -5.94 + 3.67 \log_{10} TL & (r = .99) \\ 1974: \log_{10} W &= -6.23 + 3.86 \log_{10} TL & (r = .99) \\ 1975: \log_{10} W &= -5.66 + 3.48 \log_{10} TL & (r = .99) \end{aligned}$$

with weight in g and total lengths in mm. Differences between the regression coefficients were not significantly different at the 95% level.

#### ABUNDANCE AND DISTRIBUTION OF ZOOPLANKTON

Zooplankton populations were sampled in conjunction with larval fish sampling to determine their abundance and distribution; and to ascertain food preference and utilization of selected zooplankton taxa by larval walleye and yellow perch. Two genera of *Copepoda* (*Diaptomus* and *Cyclops*) and three genera of *Cladocera* (*Daphnia*, *Chydorus* and *Bosmina*) were identified and enumerated.

*Diaptomus* and *Daphnia* were the codominant genera in all years, about twice as abundant as *Cyclops* and nearly 15 times as abundant as *Chydorus* or *Bosmina*. Annual abundance of all genera, except *Bosmina*, was highly variable. *Cyclops* and *Daphnia* were most abundant in May and during the early



ABUNDANCE AND DISTRIBUTION OF COPEPODA

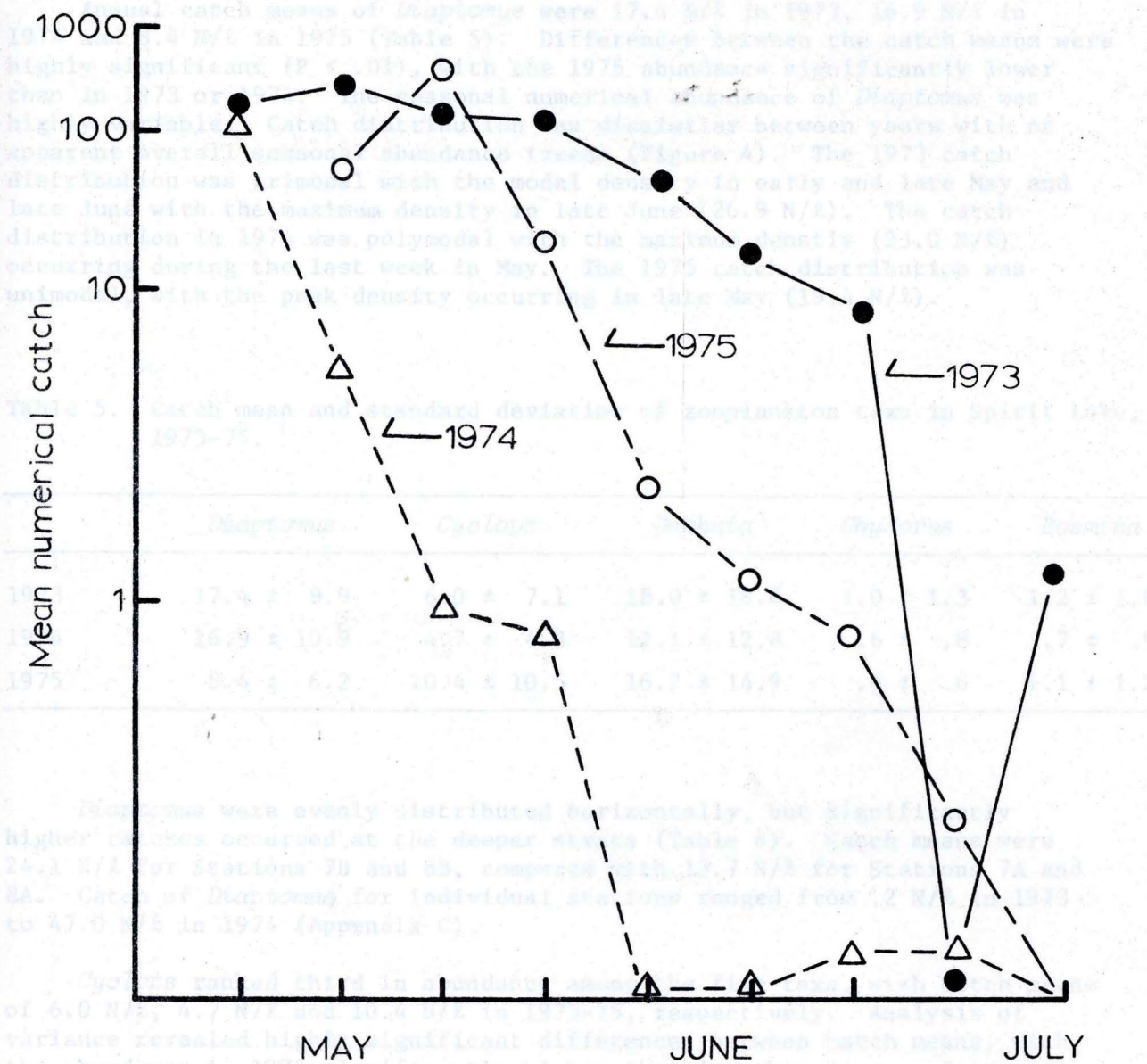


Figure 3. Mean numerical catch of yellow perch larvae in standardized tow net samples in Spirit Lake, 1973-1975.

part of June, with the peak numerical density of *Diaptomus* and *Bosmina* occurring at varying intervals, and the peak density of *Chydorus* usually occurring during mid-June.

#### ABUNDANCE AND DISTRIBUTION OF COPEPODA

Annual catch means of *Diaptomus* were 17.4 N/l in 1973, 16.9 N/l in 1974 and 8.4 N/l in 1975 (Table 5). Differences between the catch means were highly significant ( $P < .01$ ), with the 1975 abundance significantly lower than in 1973 or 1974. The seasonal numerical abundance of *Diaptomus* was highly variable. Catch distribution was dissimilar between years with no apparent overall seasonal abundance trends (Figure 4). The 1973 catch distribution was trimodal with the modal density in early and late May and late June with the maximum density in late June (26.9 N/l). The catch distribution in 1974 was polymodal with the maximum density (23.0 N/l) occurring during the last week in May. The 1975 catch distribution was unimodal, with the peak density occurring in late May (19.4 N/l).

Table 5. Catch mean and standard deviation of zooplankton taxa in Spirit Lake, 1973-75.

	<i>Diaptomus</i>	<i>Cyclops</i>	<i>Daphnia</i>	<i>Chydorus</i>	<i>Bosmina</i>
1973	17.4 ± 9.9	6.0 ± 7.1	18.0 ± 16.6	1.0 ± 1.3	1.2 ± 1.8
1974	16.9 ± 10.9	4.7 ± 4.3	12.1 ± 12.8	.6 ± .8	.7 ± .9
1975	8.4 ± 6.2	10.4 ± 10.5	16.2 ± 14.9	.6 ± .6	1.1 ± 1.2

*Diaptomus* were evenly distributed horizontally, but significantly higher catches occurred at the deeper strata (Table 6). Catch means were 24.1 N/l for Stations 7B and 8B, compared with 13.7 N/l for Stations 7A and 8A. Catch of *Diaptomus* for individual stations ranged from .2 N/l in 1973 to 47.0 N/l in 1974 (Appendix C).

*Cyclops* ranked third in abundance among the five taxa, with catch means of 6.0 N/l, 4.7 N/l and 10.4 N/l in 1973-75, respectively. Analysis of variance revealed highly significant differences between catch means, with the abundance in 1975 significantly higher than in other years. Seasonal distribution of the *Cyclops* catch showed peak abundance occurred during May. Maximum concentrations were 18.8 N/l in 1973, 10.1 N/l in 1974 and 27.6 N/l in 1975. Population density within succeeding intervals were  $< 7$  N/l except in 1975, with the density during May 14.6 N/l, 14.9 N/l and 15.2 N/l before declining in June to less than 7 N/l. Configuration of catch curves were similar after peak density occurred, with the population density usually decreasing through the first part of June and remaining relatively low through late June and early July (Figure 5).

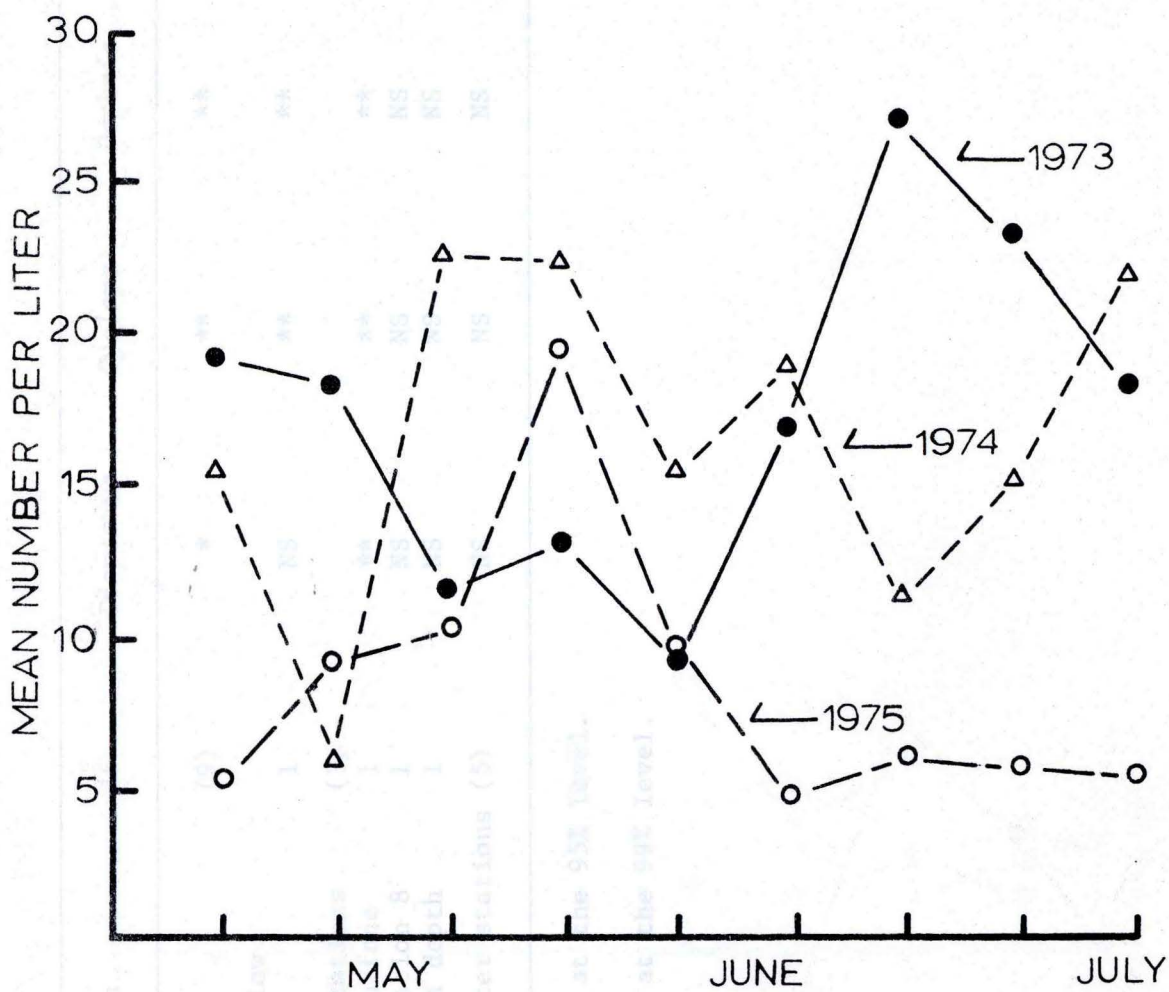


Figure 4. Seasonal distribution of the Diaptomus catch in plankton samples at Spirit Lake, 1973-1975.



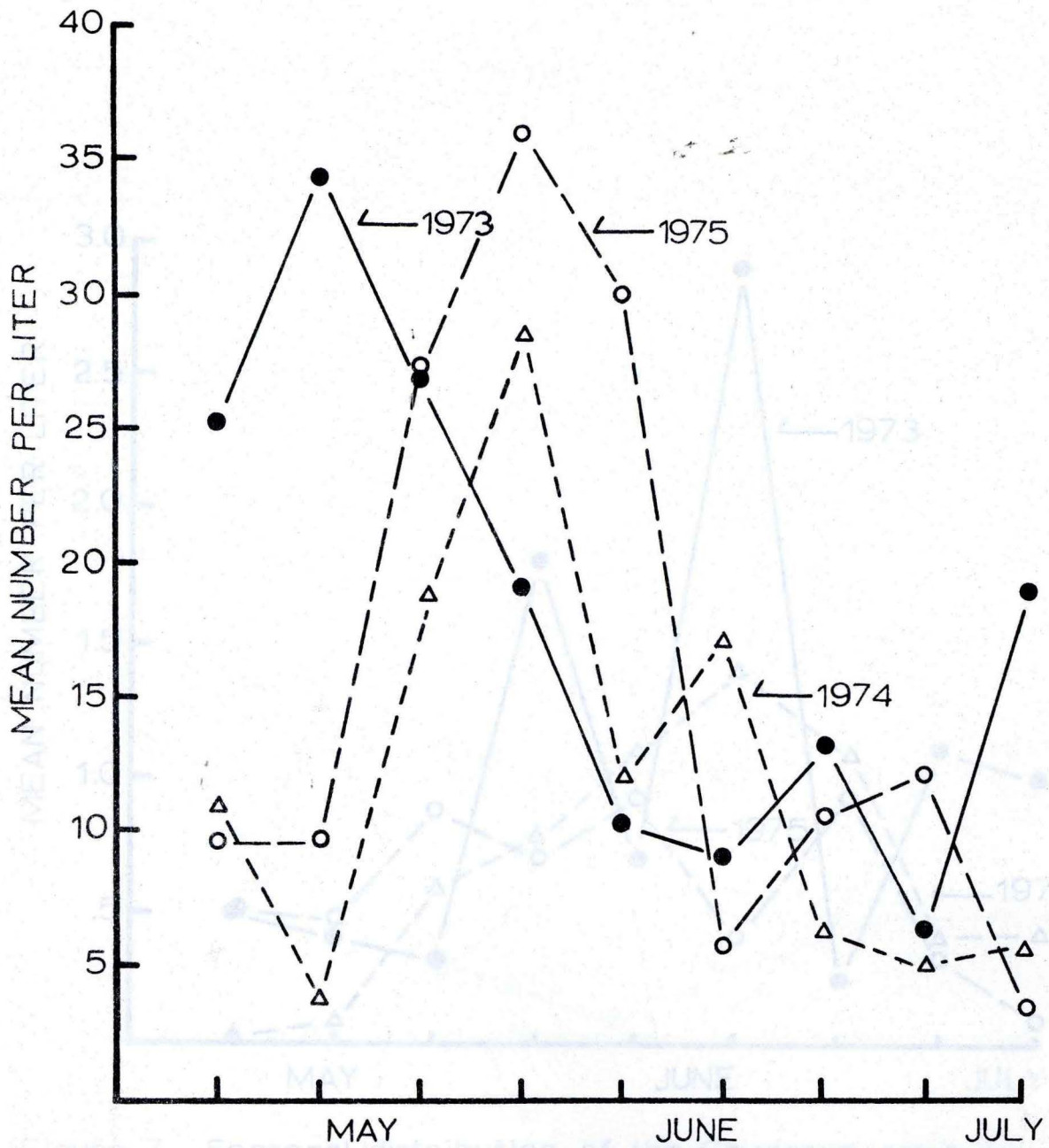


Figure 6. Seasonal distribution of the *Daphnia* catch in plankton samples at Spirit Lake, 1973-1975.

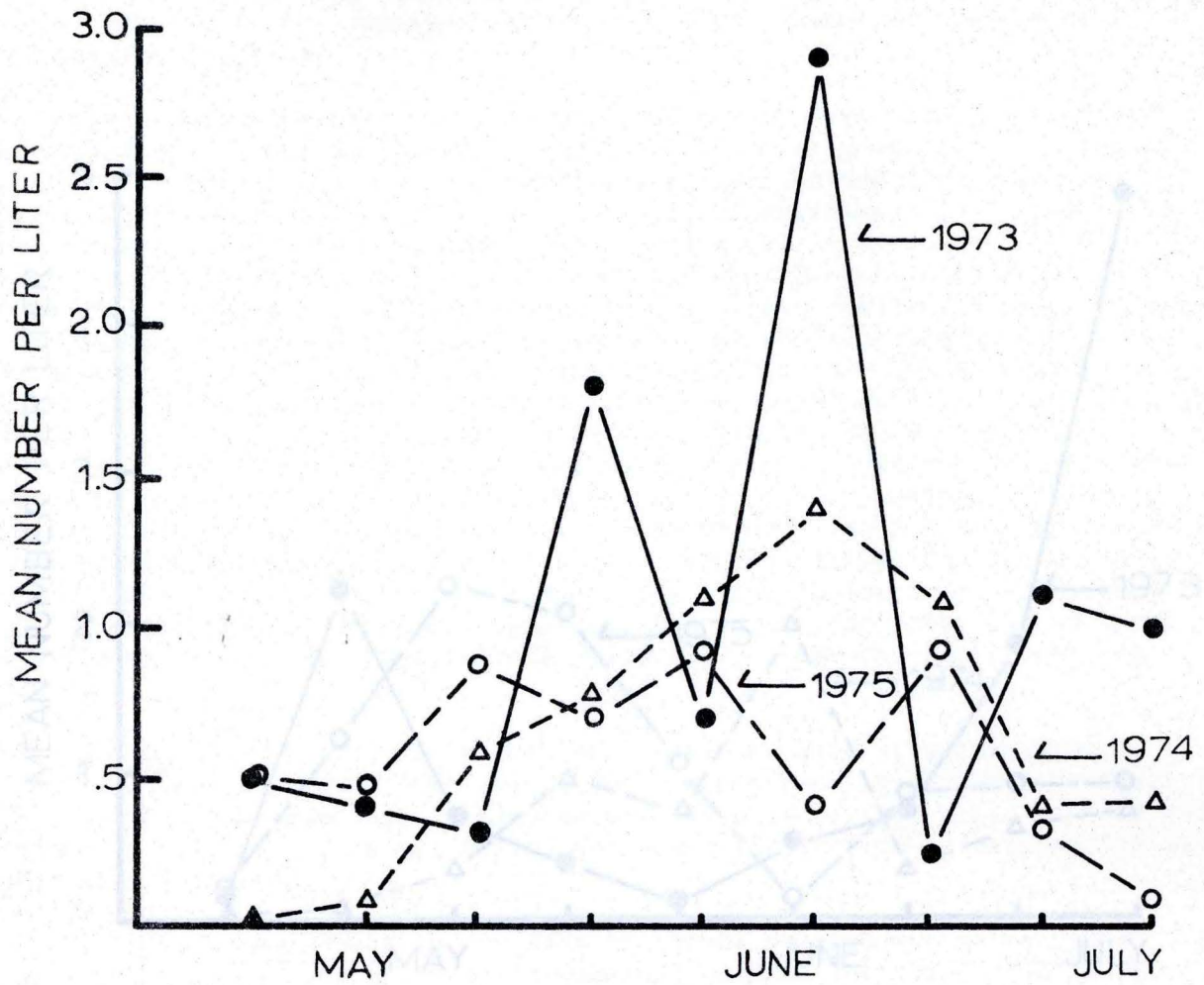


Figure 7. Seasonal distribution of the *Chydorus* catch in plankton samples at Spirit Lake, 1973-1975.

*Bosmina* was the only genus that was equally distributed in all habitats. Catches at individual sampling stations showed *Bosmina* present in only limited numbers throughout Spirit Lake, ranging up to a maximum catch of 9.2 N/L in 1975 (Appendix G).

#### ZOOPLANKTON UTILIZATION AND FOOD PREFERENCE OF LARVAL WALLEYE AND YELLOW PERCH

Competition for food between larval walleye and yellow perch was determined by examining zooplankton utilization and food preferences. Alimentary tracts were examined to ascertain the number and genera of zooplankton ingested.

Thirty-seven walleye larvae alimentary tracts were examined from fish ranging from 8 to 31 mm TL. During the first two seasons (1973-74) larvae < 10 mm TL contained at least some yolk material and had not commenced feeding with only 3 of 34 examined containing identifiable food fragments. In contrast, larvae in 1975 began feeding actively at approximately 9 mm TL and some larvae up to 10 mm TL did contain some yolk material. Spycherman (1973) found walleye actively feeding at about 10 mm TL. (1966) and Paulus (1969) found larvae commenced feeding on diatoms at about 8 mm TL, with zooplankton becoming common in the diet after walleye 10 mm TL. Onondaga Lake, NY, commenced feeding on zooplankton at about 7 mm TL. (1973) presented at the 44th Midwest Fish and Wildlife Conference, (1973) found stocked walleye larvae did not begin to feed until five to seven days after stocking at approximately 10 mm TL. During 1973, none of the stocked walleye would have reached this transitional stage during the first sampling interval. Stocked larvae in 1974 would have reached the transitional stage during the first sampling interval. Larvae contained identifiable zooplankton as prey items. Larvae that had not all stocked larvae would have reached the transitional stage during the first sampling interval.

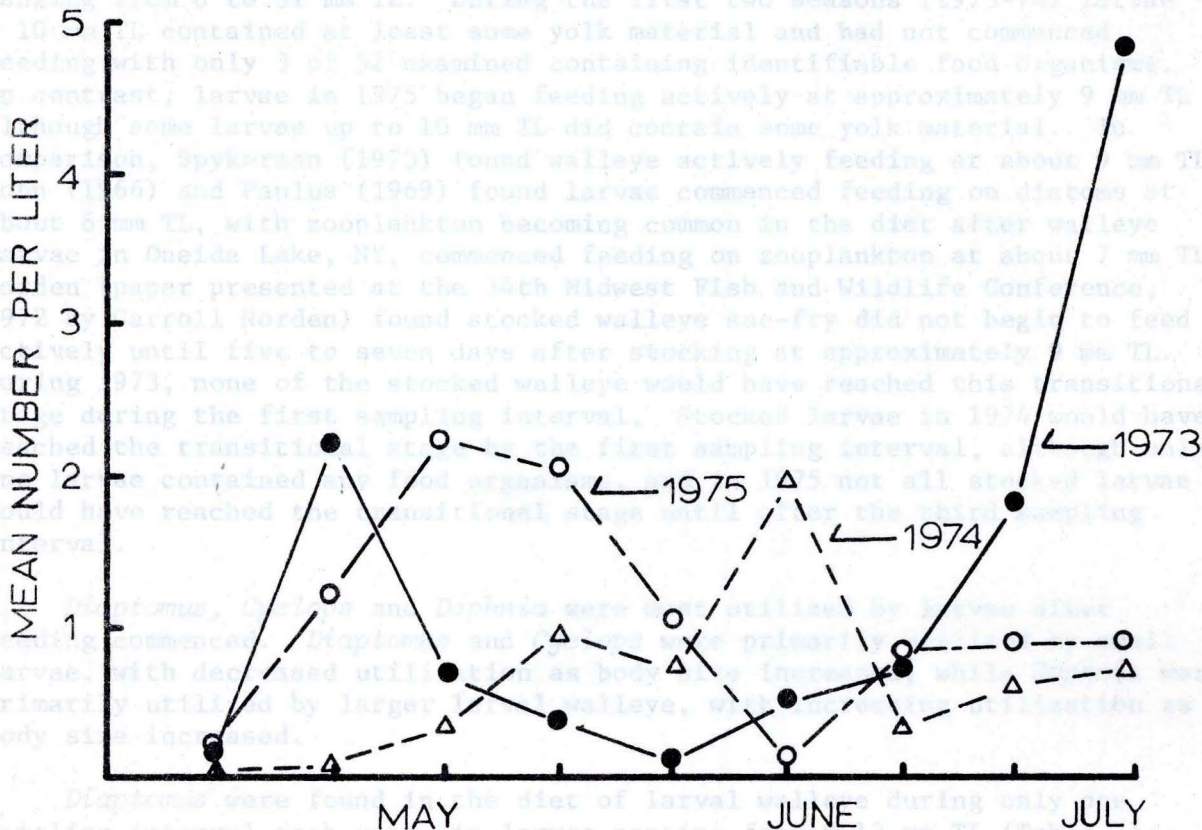


Figure 8. Seasonal distribution of the *Bosmina* catch in plankton samples at Spirit Lake, 1973-1975.

*Cyclops* was a primary food of smaller larvae. In 1973 and 1975, *Cyclops* comprised over 27% of the food ingested in each sampling interval that they were consumed, with larvae ranging from 8-12 mm TL. No *Cyclops* were utilized in 1974. *Cyclops* decreased in importance as body size increased, from 50-100% of the food ingested by larvae 8-10 mm TL to 27.3% of the food consumed by

*Bosmina* was the only genus that was equally distributed in all habitats. Catches at individual sampling stations showed *Bosmina* present in only limited numbers throughout Spirit Lake, ranging up to a maximum catch of 9.2 N/l in 1973 (Appendix G).

#### ZOOPLANKTON UTILIZATION AND FOOD PREFERENCE OF LARVAL WALLEYE AND YELLOW PERCH

Competition for food between larval walleye and yellow perch was determined by examining zooplankton utilization and food preferences. Alimentary tracts were examined to ascertain the number and genera of zooplankton ingested.

Ninety-seven walleye larvae alimentary tracts were examined from fish ranging from 8 to 31 mm TL. During the first two seasons (1973-74) larvae < 10 mm TL contained at least some yolk material and had not commenced feeding with only 3 of 52 examined containing identifiable food organisms. In contrast, larvae in 1975 began feeding actively at approximately 9 mm TL although some larvae up to 10 mm TL did contain some yolk material. In comparison, Spykerman (1973) found walleye actively feeding at about 9 mm TL. Hohn (1966) and Paulus (1969) found larvae commenced feeding on diatoms at about 6 mm TL, with zooplankton becoming common in the diet after walleye larvae in Oneida Lake, NY, commenced feeding on zooplankton at about 7 mm TL. Norden (paper presented at the 34th Midwest Fish and Wildlife Conference, 1972 by Carroll Norden) found stocked walleye sac-fry did not begin to feed actively until five to seven days after stocking at approximately 9 mm TL. During 1973, none of the stocked walleye would have reached this transitional stage during the first sampling interval. Stocked larvae in 1974 would have reached the transitional stage by the first sampling interval, although only one larvae contained any food organisms, and in 1975 not all stocked larvae would have reached the transitional stage until after the third sampling interval.

*Diaptomus*, *Cyclops* and *Daphnia* were most utilized by larvae after feeding commenced. *Diaptomus* and *Cyclops* were primarily utilized by small larvae, with decreased utilization as body size increased, while *Daphnia* were primarily utilized by larger larval walleye, with increasing utilization as body size increased.

*Diaptomus* were found in the diet of larval walleye during only one sampling interval each year, in larvae ranging from 9-12 mm TL (Table 7). *Diaptomus* constituted 27.3%, 100.0% and 11.8% of the food organisms ingested although the contribution in 1974 (100%) is considered biased, since only one larvae contained discernable food items. Electivity indices revealed a slight overall preference for *Diaptomus* with indices of +.06, +.40 and -.35 in 1973-75, respectively (Table 8).

*Cyclops* was a primary food of smaller larvae. In 1973 and 1975, *Cyclops* comprised over 27% of the food ingested in each sampling interval that they were consumed, with larvae ranging from 8-12 mm TL. No *Cyclops* were utilized in 1974. *Cyclops* decreased in importance as body size increased, from 50-100% of the food ingested by larvae 8-10 mm TL to 27.3% of the food consumed by



Table 7. Number of stomachs examined, body length range and percent composition of zooplankton in larval walleye in Spirit Lake, 1973-75.

	Size range (mm)	Stomachs examined	Empty stomachs	<i>Diaptomus</i>		<i>Cyclops</i>		<i>Daphnia</i>	
				N	%	N	%	N	%
1973	8-10	26	25			1	50.0		
	9-10	9	8			1	100.0		
	11-12	7	1	3	27.3	3	27.3	1	9.1
	14-16	4	1					7	87.5
1974	9-11	21	20	1	100.0				
	10	1	1						
1975	a	a							
	8	1	1						
	9-11	26	4	4	11.8	11	32.3	5	14.7
	18	1						1	50.0
	31	1						1	33.3
	a	a							

<sup>a</sup>No larval walleye captured during the sampling interval.

Table 8. Electivity of zooplankton for food by larval walleye at Spirit Lake, 1973-75.

	Size range (mm)		<i>Diaptomus</i>	<i>Cyclops</i>	<i>Daphnia</i>
1973	8-10	Early May		+ .36	
	9-10	Mid-May		+ .60	
	11-12	Late May	+ .06	+ .31	-.73
	14-16				+ .50
1974	9-11	Mid-May	+ .40		
1975	9-11	Mid-May	-.35	-.12	-.30
	18	Late May			+ .02
	31	Early May			-.18

larvae, 11-12 mm TL. Despite the decrease, *Cyclops* were highly preferred as food in 1973, with indices of +31 to +.60, but were not preferred in 1975 with an indice of -.12, although larvae were approximately the same size in both years.

*Daphnia* were generally absent in the diet of walleye larvae 11 mm TL or less, but increased in numerical abundance as larval size increased. Among larvae from 9-12 mm TL, *Daphnia* constituted 9.1% and 14.7% of the food consumed. However, for larvae 12 mm TL or greater, *Daphnia* contributed 87.5% of the diet in 1973 and 50.0% and 33.3% in 1975. No *Daphnia* were consumed in 1974. Despite the importance of *Daphnia* in the diet, particularly among the larger larvae, they were preferred only by larvae ranging from about 14-18 mm TL, with indices of +.50 and +.02. A major change in the diet of walleye occurred in 1975, with fish, primarily yellow perch, a major food item in larvae > 9.5 mm TL. Results of the change may also be partially responsible for the decrease in preferences shown by larvae walleye for zooplankton in 1975.

*Diaptomus* and *Cyclops* were preferred food items of larval walleye at Clear Lake, IA, although *Daphnia* was the most numerous organism consumed, and the most important genus in the diet (Spykerman 1973). Houde (1967) and Priegel (1970) found walleye larvae preferred *Cyclops*, but not *Diaptomus*. In contrast, Smith and Moyle (1943) reported rotifers were the major food of walleye in rearing ponds with larvae ranging from about 6-9 mm TL, with *Diaptomus* and *Cyclops* becoming dominant in the diet of larvae 9 mm TL or greater. In agreement, Johnson (1969) also found rotifers were consumed by walleye larvae in the Little Cutfoot Lakes, MN.

The alimentary tracts of 464 larval yellow perch were examined in fish ranging from 4-43 mm TL. Larval perch 6 mm TL or less in 1973 had not commenced feeding with only 4 of 66 containing food. Similarly, larvae 7 mm TL or smaller in 1974 or 1975 did not forage with only 3 of 44 in 1974 and

none of the 44 examined in 1975 containing food organisms. In contrast, Siefert (1972) reported larval yellow perch in Park Lake and Greenwood Lake, MN fed actively at about 6 mm TL.

All five zooplankton taxa were utilized for food by larval yellow perch, with *Diaptomus* and *Cyclops* generally most important as food in small larvae and *Daphnia*, *Chydorus* and *Bosmina* more important in the diet of larger larvae.

*Diaptomus* were consumed by larval perch of all sizes, except in 1973 and 1975 when larvae 37 mm TL or larger contained no *Diaptomus* (Table 9). *Diaptomus* comprised between 12.5% and 82.3% of the food of larvae ranging from 7-22 mm TL. *Diaptomus* generally decreased in importance comprising between 8.7% and 17.4% of the food in larvae from about 12-30 mm TL. Electivity indices revealed *Diaptomus* was preferred by larvae ranging from 7-13 mm TL, with positive indices ranging from +.29 in 1974 to +.41 in 1973 (Table 10). Larvae ranging from about 13-30 mm TL did not prefer *Diaptomus* with indices ranging from -.01 to -.68. In contrast, during 1975 larvae from 7-9 mm TL did not prefer *Diaptomus*, while larvae ranging from 8-26 mm TL showed positive preferences for *Diaptomus* with indices of +.16 and +.29, before becoming a non-selected food organism again.

*Cyclops* were also a major food source for smaller yellow perch, but decreased in importance as body size increased. *Cyclops* constituted between 34.8% and 71.4% of the food in larvae ranging from 5-11 mm TL in 1973 and 1975, then decreased, comprising generally less than 15.2% of the food ingested by larvae larger than 11 mm TL. There was little change in the percent composition of *Cyclops* in the diet of larvae in 1974, comprising between 11.1% and 23.1% of the food organism, little evidence indicated a preference for this taxa. In 1973 and 1975, larvae ranging from about 5-13 mm TL preferred *Cyclops* with positive indices from +.01 to +.48. However, similar sized larvae in 1974 indicated no preference. Similarly, larvae in 1973 and 1975, ranging from approximately 10-22 mm TL, did not select *Cyclops*, but in 1974 the index was +.48 indicating a definite preference for *Cyclops*. *Cyclops* was also preferred by larvae greater than about 25 mm TL, with positive values from +.11 to +.61, although no *Cyclops* were consumed by similar sized larvae in 1975.

*Daphnia* became increasingly important as a food source as larvae size increased. In larvae ranging from 7-13 mm TL, *Daphnia* comprised between 1.4-3.8% of the organisms ingested. In larvae ranging from 25-43 mm TL they comprised between 50.0-80.0% of the diet. Electivity indices showed despite the importance of *Daphnia* in the diet, it was not a preferred food organism. No preference for *Daphnia* were shown in either 1974 or 1975 until perch were about 26 mm TL, when index values ranged from +.17 to +.49. In contrast, larvae in 1973 indicated continual non-selection of *Daphnia* with indices ranging from -.01 to -.95.

*Chydorus* made up only a minor portion of the larval perch diet comprising between 2.9-7.7%. The feeding chronology showed no trends for larvae ranging between 11-27 mm TL between 1973 and 1975. There were also no preferences indicated between years among perch of similar sizes.

*Bosmina* were absent from the diet of small larval perch, but were important for larvae 11 mm TL or larger. *Bosmina* comprised up to 26.7% of the food in larvae ranging from 11-26 mm TL, with occurrence increasing as body size increased. *Bosmina* were also absent from the diet of larvae greater than

Table 9. Number of stomachs examined, body length range and percent composition of zooplankton in larval yellow perch at Spirit Lake, 1973-75.

	Size range (mm)	Stomachs examined	Empty stomachs	<i>Diaptomus</i>		<i>Cyclops</i>		<i>Daphnia</i>		<i>Chydorus</i>		<i>Bosmina</i>	
				N	%	N	%	N	%	N	%	N	%
1973													
May	4- 6	20	20										
	5- 7	46	40			5	71.4						
	7-11	50	12	32	46.4	24	34.8	1	1.4				
	10-14	83	7	102	82.3	8	6.5	9	7.3				
June	11-17	40	10	46	39.6	8	6.9	41	35.3			6	5.2
	11-22	21	1	48	25.1	7	3.7	55	28.8	8	4.2	51	26.7
	11-30	18	2	4	8.7	7	15.2	18	39.1			11	23.9
	a												
July	37-43	3	0			7	6.1	98	86.0				
1974													
May	5- 8	44	41										
	7-12	25	7	19	73.1	4	15.4	1	3.8				
	8-11	5	0	7	77.8	1	11.1						
	16-17	2	0	3	23.1	3	23.1			1	7.7	3	23.1
June	a												
	a												
	26	1	0	2	10.0			10	50.0			5	25.0
	26	1	0	4	17.4	3	13.0	14	60.9			1	4.3
1975													
May	a												
	5- 7	44	44										
	7- 9	25	16	2	12.5	11	68.7						
	8-13	27	2	27	24.5	45	40.9	4	3.6			1	.9
June	11-13	3	0	2	40.0	1	20.0	1	20.0			1	20.0
	19-26	3	0	15	32.6	6	13.1	16	34.8			1	2.2
	25-28	2	0	4	11.4			25	71.4	1	2.9		
	38	1	0					5	55.6				
July	a												

<sup>a</sup>No larval yellow perch captured during the sampling period.

reported larval perch in Park Lake, MN, utilized *Copepoda nauplii* after the commencement of feeding, with *Bosmina* the dominant food item in larvae 11 mm TL or greater. However, in contrast, Siefert (1972) also reported larval perch in Greenwood Lake, MN, commenced feeding upon rotifers, and to a lesser extent upon *Copepoda nauplii*, with *Cyclopoid copepoda* becoming the dominant food item as larval size increased. As with larval walleye, larval yellow perch have reported utilized a variety of food organisms, indicating food preference probably plays only a minor role in determining total food utilization.

#### ACCOMPLISHMENTS, NEEDS AND IMPLICATIONS

Previous investigations in Spirit Lake as well as other natural lakes in Iowa and other states have clearly documented the significant impact of walleye sac-fry plantings on the numerical density of larval walleye populations (Rose 1955; Carlander et al. 1960; Forney 1975; Payne 1975; and others). However, in most instances the exact contribution of the stocked fry remained unknown, primarily because of the difficulty in defining the separate effects of the stocked and naturally produced fry on larval populations.

Findings in Spirit Lake, based on the ratio of stocked density of walleye sac-fry and natural reproduction, showed stocked larvae contributed from 81% to 90% of the larval population from 1973-75. Secondary estimates, based on the survival curves of stocked fry in relation to larval densities in Spirit Lake on the first sampling date annually were also high, ranging from 23% to 100%. However, the low estimate, 23%, had extremely wide confidence intervals with estimates ranging up to 100%, also.

The magnitude of the contribution of stocked walleye fry was further clarified by examination of the estimated total natural reproduction of larvae, based upon the density and survival of walleye eggs in Spirit Lake. Natural production was an estimated 8.5 million larvae in 1973, 3.2 million in 1974 and 12.6 million in 1975. In comparison the number of stocked fry was nearly twice the natural production in 1973 and 1975 and about six-fold the 1974 production. The implications from these findings seems contrary to the original intent of the supplemental walleye fry stocking program, with the larval walleye population base in Spirit Lake formed by stocked fry, and fluctuations in year class abundance due to variations in the magnitude of natural reproduction.

Despite the nearly constant stocking density of walleye sac-fry during the three year study period, the annual catch of larval walleye in the net tows were significantly different with means varying from .9 to 2.7 larvae per tow. Total acceptance of the analysis is questionable since the maximum density of larval walleye in 1974 might have occurred prior to the initial sampling. If this were true, the peak population density in 1974 was probably similar to other years (13-14 larvae per tow) revealing the initial population density was relatively static, with eventual year class abundance primarily dependent upon survival. If this postulation is true, it also provides additional evidence reflecting the magnitude of the contribution of stocked fry to the larval population.

Annual catch means of larval yellow perch also varied significantly, from 23 larvae per tow in 1974 to 117 larvae per tow in 1973. However, similar to the analysis of the walleye catch data, total acceptance of the analysis is questionable, and the probability that the maximum density in 1974 was similar to either 1973 or 1975 is high. If this were true, year class abundance would probably be more dependent on larval survival than initial population density. Larvae density in late June and early July also indicated survival was a major factor in determining year class abundance, with the density in 1973 from 4 to 8 times the larval density in 1974 or 1975, even though the highest initial larval density was recorded in 1975.

The postulation that stocked walleye fry form the base of the larval population suggests the abundance might be altered for fisheries management purposes by manipulating the numbers stocked. However, wide fluctuations in larval survival, from 5% in 1974 to 50% in 1973, revealed an obvious lack in the predictability of the stocking density to the eventual population abundance. In years of high survival, population density may be markedly increased by increased stocking, but during years of high mortality little increase might be expected. For example, if the survival were 50%, as found in 1973, the larval population could have been doubled by increasing the stocking density two-fold. In contrast, in 1974, with an annual survival of 5%, the stocking density would have to have been 20 times the number stocked to achieve a two-fold increase in the larval population. Even if survival were comparable to 1975, with about 20% survival, to double the larval population density would require a five-fold increase in stocking density. Cost benefits in the latter examples would be prohibitive at this time.

Payne (1975) reported a significant positive correlation between the number of walleye sac-fry stocked and eventual year class abundance in Clear Lake, IA. He suggested stocking 24,000-36,000 sac-fry per ha (10,000-15,000 per ac) would result in a larval density which would approach the maximum level of abundance of what might be expected for Clear Lake, a lake similar to Spirit Lake. These stocking densities are from three to five times the current stocking rates in Spirit Lake, and at this time unobtainable on an annual basis.

No significant correlations were found between water quality and the annual or seasonal abundance or survival of either larval walleye or yellow perch. Lack of any association indicated factors other than those measured or a combination of factors influenced survival and consequently larval density. However, the findings indicated a strong positive association between the length of the spawning season and larval abundance. The association between the spawning season length and walleye larval abundance was also noted at Lake Winnibigoshish, MN by Johnson (1961). Shorter spawning seasons resulting in higher survival are usually devoid of periods of precipitous declines in water temperatures following spring storms or intense cold fronts. The adverse effect of cold weather on walleye spawning was also reported by Derback (1947), with a poor hatch of walleye after cessation of spawning activity due to the onset of cold weather. Since factors influencing walleye fry survival are identical for both stocked and naturally produced fry, larval abundances could be manipulated to the greatest degree following the shorter spawning seasons, other factors constant, by adjusting stocking density.

Natural production in Spirit Lake between 1973-75 ranged from 1.1 to 4.3 larvae per square mile, similar to previous estimates at Spirit Lake, but from 3 to 20 times below the natural production in Lake Winnibigoshish, MN

(Johnson 1961). Maximum egg despositions at Spirit Lake and at Lake Winnibigoshish, MN varied widely, indicating natural production in Spirit Lake has the potential of producing an adequate year class of walleye. However, embryonic survival averaged less than 4% in the three year period (below the average 8% from 1964-72), and considerably below the approximately 17% survival in Lake Winnibigoshish, MN (Johnson 1961). Embryonic survival appears to be a paramount factor in the development of natural larval populations, although the identity and overall effects of factors influencing success or failure are not understood.

Egg survival was associated with several factors in Lake Winnibigoshish, MN. Among them were wave action and substrate type. Johnson (1961) reported about a 50% decrease in the number of walleye eggs after high winds, and reported substantial numbers of dead eggs entangled in clumps of filamentous algae following another period of wave action. In Lake Winnebago, WS, substantial numbers of eggs were found in windrows after moderate wind and wave action (Priegel 1970). Limited observations at Spirit Lake revealed walleye eggs on the shore following spring storms, indicating at times wave action is an important factor in egg survival. Substrate type was also associated with egg survival in Lake Winnibigoshish, MN (Johnson 1961), with survival best on clean rubble-gravel substrates, intermediate on firm clean sand and poorest on a soft detritus muck bottom. Based on these criteria the primary walleye spawning area in Spirit Lake should provide good habitat, in terms of substrate size and composition, however, detritus materials are present in most areas and may degrade these areas into poorer habitat than would be expected, and be reflected in the poor embryonic survival in Spirit Lake.

Johnson (1961) found a dramatic improvement in egg survival and production of walleye larvae after improving one spawning area by the addition of clean suitable sized rock and rubble, indicating a possibility of increasing the overall natural reproduction by the maintenance or improvement of walleye spawning sites. The areas in Spirit Lake falling into the rubble-gravel substrate classification as previously mentioned have detritus materials throughout. Addition of clean rubble-gravel to these areas and/or to other areas may increase egg survival and consequently larval production. There is a need to investigate this alternative and to define the increase in production which would be reasonably expected by habitat manipulation versus the economic feasibility, if it is desirable to significantly increase larval populations in Spirit Lake.

Interspecific competition for zooplankton food between walleye and yellow perch larvae did not influence survival or growth of either species, although both species consumed identical taxa during the same time periods each year. The primary genera consumed by both species were *Cyclops*, *Diaptomus* and *Daphnia*. *Cyclops* and *Diaptomus* were utilized as feeding activity commenced. Larval yellow perch commenced feeding at a smaller size (6-7 mm TL) than walleye (9-10 mm TL), with no discernable impact on the numerical densities of the zooplankton populations observed. *Cyclops* and *Diaptomus* became less important in the diets of larvae as body size increased, while *Daphnia* became more important (walleye, 15 mm TL or greater; yellow perch, 11 mm TL or greater). In the larger sized fish *Daphnia* increased in importance, comprising a maximum of 87.5% of the food of larval walleye and 86.0% of the food items of larval perch. *Daphnia* size was probably important in precluding its selection as food by the smaller larvae. Further evidence supporting this postulation is recognized in that *Daphnia* was not selected as a food item until perch larvae were about 17 mm TL or greater, and walleye larvae selected *Daphnia* only after reaching approximately 14 mm TL. Houde (1967) also noted the probability that

selection of food organisms was dependent upon prey size as well as the size of larval walleye in Oneida Lake, NY. Walleye larvae in Spirit Lake in 1973 utilized other fish larvae during only sampling interval, and no larvae were consumed by walleye larvae in 1974. In contrast, during 1975, fish larvae were consumed by larval walleye 9.5 mm TL or greater, and comprised a major portion of the diet, although the reasons for the change in food habits between years are unknown. In comparison, larval walleye in Oneida Lake, NY, as small as 9.0 mm TL were also found to feed actively upon larval perch (Houde, 1967). Competition for food between larval walleye and yellow perch is prevalent in Spirit Lake, but the abundance of all zooplankton taxa utilized is so great the level of competition is unimportant for the survival of either species.

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## APPENDIX

Table A. Larval walleye catch in standardized tow net samples expressed in number per 1,000 m<sup>3</sup> at Spirit Lake, 1973-75. Catch values in 1974 are the mean of two consecutive tows.

Sampling station	Sampling interval									
	5/7- 5/11	5/14- 5/18	5/21- 5/25	5/28- 6/1	6/4- 6/8	6/11- 6/15	6/18- 6/22	6/25- 6/29	7/2- 7/6	
1973										
1	0	6.8	0	4.6	0	0	0	0	0	0
2	6.8	9.0	0	0	0	0	0	0	0	0
3	4.6	0	0	0	0	0	0	0	0	0
4	25.1	4.6	0	0	0	0	0	0	0	0
5	11.4	9.1	6.8	0	0	0	0	0	0	0
6	27.3	0	0	0	0	0	0	0	0	0
7A	9.1	0	0	0	0	0	0	0	0	0
7B	0	9.1	15.9	9.1	0	0	0	0	0	0
8A	41.0	0	0	0	0	0	0	0	0	0
8B	13.7	0	11.4	4.6	0	0	0	0	0	0
Mean	13.9	3.9	3.4	1.8	0	0	0	0	0	0
1974										
	5/6- 5/10	5/13- 5/17	5/20- 5/24	5/27- 5/31	6/3- 6/7	6/10- 6/14	6/17- 6/21	6/24- 6/28	7/1- 7/5	
1	6.8	0	0	0	0	0	0	0	0	0
2	15.8	0	0	0	0	0	0	0	0	0
3	33.2	4.1	0	0	0	0	0	0	0	0
4	7.2	0	0	0	0	0	0	0	0	0
5	16.9	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0
7A	0	0	0	0	0	0	0	0	0	0
7B	0	0	0	0	0	0	0	0	0	0
8A	0	0	0	0	0	0	0	0	0	0
8B	0	0	0	0	0	0	0	0	0	0
Mean	8.0	.4	0	0	0	0	0	0	0	0
1975										
	5/5- 5/9	5/12- 5/16	5/19- 5/23	5/26- 5/30	6/2- 6/6	6/9- 6/13	6/16- 6/20	6/23- 6/27	6/30- 7/4	
1	0	0	0	0	0	0	0	0	0	0
2	0	0	8.6	0	4.5	0	0	0	0	0
3	0	0	4.6	0	0	0	0	0	0	0
4	0	4.0	9.0	0	0	0	0	0	0	0
5	0	0	30.2	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0
7A	0	0	13.5	0	0	0	0	0	0	0
7B	0	0	27.2	0	0	0	0	0	0	0
8A	0	4.0	29.4	4.6	0	0	0	0	0	0
8B	0	0	9.8	5.0	0	0	0	0	0	0
Mean	0	.8	13.2	1.0	.4	0	0	0	0	0

Table B. Catch of larval yellow perch in tow net samples expressed in numbers per 1,000 m<sup>3</sup> at Spirit Lake, 1973-75. Catch values in 1974 are the mean of two consecutive tows.

Sampling station	Sampling interval								
	5/7- 5/11	5/14- 5/18	5/21- 5/25	5/28- 6/1	6/4- 6/8	6/11- 6/15	6/18- 6/22	6/25- 6/29	7/2- 7/6
1973									
1	104.8	942.9	4.6	132.1	0	0	13.7	0	0
2	539.8	488.7	31.9	50.1	0	0	6.8	0	0
3	29.6	13.7	4.6	47.8	0	157.2	6.8	0	0
4	241.4	293.8	0	4.6	0	9.1	0	0	0
5	264.2	202.7	100.2	59.2	161.7	13.7	29.6	0	0
6	11.4	628.6	0	27.3	230.0	0	27.3	0	0
7A	4.6	29.6	47.8	86.5	13.7	4.6	0	0	0
7B	107.0	858.6	248.2	252.8	25.0	25.0	0	0	15.9
8A	521.6	0	453.2	159.4	4.6	0	0	0	0
8B	806.2	594.4	926.9	330.2	95.7	0	0	0	0
Mean	263.1	405.3	181.7	115.0	53.1	21.0	8.4	0	1.6
1974									
	5/6- 5/10	5/13- 5/17	5/20- 5/24	5/27- 5/31	6/3- 6/7	6/10- 6/14	6/17- 6/21	6/24- 6/28	7/1- 7/5
1	118.8	1.8	0	2.7	0	0	0	0	0
2	197.2	4.6	2.6	5.0	0	0	0	0	0
3	837.7	7.8	0	0	0	0	0	2.0	0
4	117.1	23.2	0	0	0	0	2.2	0	0
5	204.5	8.6	0	0	0	0	0	0	0
6	350.3	2.3	5.1	0	0	0	0	0	0
7A	15.5	2.3	2.6	0	0	0	0	0	0
7B	0	0	0	0	0	0	0	0	0
8A	26.9	15.9	0	0	0	0	0	0	0
8B	106.6	11.8	0	0	0	0	0	0	0
Mean	197.4	7.8	1.0	.8	0	0	.2	.2	0
1975									
	5/5- 5/9	5/12- 5/16	5/19- 5/23	5/26- 5/30	6/2- 6/6	6/9- 6/13	6/16- 6/20	6/23- 6/27	6/30- 7/4
1	0	17.4	281.8	4.7	0	0	0	0	0
2	0	20.8	12.9	18.4	0	0	4.2	4.1	0
3	0	41.5	13.9	65.2	17.3	9.4	0	0	0
4	0	299.5	357.1	67.1	4.1	4.4	0	0	0
5	0	144.2	798.9	4.6	0	0	0	0	0
6	0	4.6	278.2	28.6	0	0	0	0	0
7A	0	12.2	437.5	36.4	0	0	0	0	0
7B	0	24.4	756.2	37.9	0	0	0	0	0
8A	0	12.1	2,114.6	0	0	0	4.2	0	0
8B	0	14.9	1,304.4	10.0	5.2	0	0	0	0
Mean	0	59.2	635.6	27.3	2.7	1.4	.8	.4	0

Table C. *Diaptomus* catch expressed in number per liter in standardized plankton samples in Spirit Lake, 1973-75.

Sampling station	Sampling interval								
	5/7- 5/11	5/14- 5/18	5/21- 5/25	5/28- 6/1	6/4- 6/8	6/11- 6/15	6/18- 6/22	6/25- 6/29	7/2- 7/6
1973									
1	11.6	13.5	.2	4.2	14.2	5.8	36.5	38.3	10.1
2	8.4	13.8	4.0	6.0	16.9	18.2	32.3	30.2	44.2
3	26.6	17.8	1.5	7.3	13.6	22.3	45.7	14.9	16.4
4	20.1	11.0	25.5	18.4	2.4	21.5	25.4	19.9	12.0
5	27.5	19.1	18.5	16.5	5.3	14.2	23.4	12.3	3.1
6	19.7	18.0	6.2	20.1	9.6	10.1	24.5	10.7	10.7
7A	15.5	18.5	5.3	4.6	2.0	16.2	24.1	26.5	19.5
7B	17.2	27.8	20.0	18.4	19.0	24.9	23.9	48.0	27.6
8A	16.5	13.8	13.2	11.8	2.4	12.4	10.9	16.2	20.6
8B	31.0	29.8	20.0	30.2	6.6	24.0	22.3	16.9	6.1
Mean	19.4	18.3	11.4	13.8	9.2	17.0	26.9	23.4	17.0
1974									
1	16.0	14.5	25.7	22.7	25.0	15.3	7.7	3.7	13.7
2	45.0	2.3	16.7	38.3	9.3	12.3	2.3	13.3	27.0
3	15.3	9.0	14.7	20.3	7.3	20.0	2.3	6.3	13.7
4	3.0	4.6	21.0	7.0	13.0	21.3	1.0	4.7	25.3
5	40.5	4.7	41.0	18.3	18.7	18.3	11.0	12.7	16.7
6	7.5	13.3	28.3	8.3	9.3	21.3	19.7	14.7	15.7
7A	1.3	7.3	26.3	34.3	11.0	27.0	15.3	28.3	36.3
7B	17.8	3.7	19.0	39.7	31.0	21.0	24.7	47.0	34.0
8A	.8	2.3	17.7	8.0	8.3	10.0	4.7	12.7	17.0
8B	14.8	3.7	20.0	31.0	29.3	20.7	22.7	11.0	22.0
Mean	16.2	6.5	23.0	22.8	16.2	18.7	11.1	15.4	22.1
1975									
1	1.3	5.7	25.7	33.3	12.3	6.0	10.7	7.0	9.3
2	1.0	3.0	8.0	11.7	14.3	2.3	12.3	3.7	4.0
3	2.3	8.3	7.0	5.3	7.0	5.0	5.3	4.0	7.3
4	4.3	8.7	11.7	24.3	3.3	5.0	2.3	6.7	5.7
5	2.3	10.3	11.0	20.7	8.7	2.7	9.0	8.7	3.3
6	8.0	7.7	5.0	13.7	7.7	6.0	11.7	4.0	3.3
7A	2.7	10.0	4.3	22.0	10.0	10.3	4.0	3.3	3.7
7B	8.0	14.3	6.0	17.3	11.0	3.7	4.7	2.7	2.0
8A	4.7	8.0	10.7	28.3	8.7	3.0	1.7	11.3	5.3
8B	21.0	9.7	11.7	17.3	10.0	4.7	2.7	12.0	7.3
Mean	5.6	8.6	10.1	19.4	9.3	4.9	6.4	6.3	5.1

Table D. *Cyclops* catch expressed in number per liter in standardized plankton samples at Spirit Lake, 1973-75.

Sampling station	Sampling interval									
	5/7- 5/11	5/14- 5/18	5/21- 5/25	5/28- 6/1	6/4- 6/8	6/11- 6/15	6/18- 6/22	6/25- 6/29	7/2- 7/6	
1973										
1	3.1	11.0	.8	1.5	5.5	.3	.9	.9	.2	
2	3.3	23.4	3.0	2.3	1.5	1.1	1.3	3.1	1.3	
3	18.4	21.0	.8	1.0	2.4	3.3	3.8	.4	.9	
4	14.7	12.3	10.5	7.2	.7	2.3	6.6	.4	2.4	
5	23.1	15.9	18.5	3.8	0	.7	3.1	.4	.4	
6	17.8	18.8	2.0	5.0	.9	1.1	1.5	1.1	1.5	
7A	13.1	12.5	2.1	3.1	.4	1.1	1.5	2.0	2.4	
7B	10.1	25.0	8.4	6.8	5.5	2.4	2.6	4.8	5.0	
8A	14.0	17.8	10.7	4.6	.2	.8	1.3	1.1	1.1	
8B	22.5	30.5	10.1	14.7	2.0	1.3	3.3	1.3	1.1	
Mean	14.1	18.8	6.7	5.0	1.9	1.4	2.6	1.6	1.6	
1974										
	5/6- 5/10	5/13- 5/17	5/20- 5/24	5/27- 5/31	6/3- 6/7	6/10- 6/14	6/17- 6/21	6/24- 6/28	7/1- 7/5	
1	9.0	8.8	4.7	.7	1.3	.7	2.7	2.7	2.0	
2	17.8	4.4	6.7	7.0	0	2.3	.7	4.0	5.7	
3	4.3	7.0	10.0	1.0	1.0	3.3	0	1.3	2.0	
4	1.5	6.5	7.0	.7	1.3	10.0	.3	.7	5.3	
5	17.3	5.7	13.3	3.7	1.0	.7	1.7	3.3	6.7	
6	4.8	3.3	10.0	3.7	.3	2.3	.1	3.7	3.3	
7A	5.8	2.3	6.3	9.7	1.0	4.3	1.0	2.7	2.0	
7B	16.3	4.0	17.3	9.7	6.7	2.3	4.7	2.3	4.0	
8A	4.8	1.7	10.3	2.7	1.0	.3	.3	1.3	2.0	
8B	12.5	6.7	15.0	9.0	6.7	3.7	3.7	3.0	2.7	
Mean	9.4	5.0	10.1	4.8	2.0	3.0	1.6	2.5	3.6	
1975										
	5/5- 5/9	5/12- 5/16	5/19- 5/23	5/26- 5/30	6/2- 6/6	6/9- 6/13	6/16- 6/20	6/23- 6/27	6/30- 7/4	
1	24.0	7.7	21.3	34.7	2.0	3.3	6.3	4.0	1.0	
2	14.0	2.7	12.3	12.7	3.3	1.0	5.0	1.0	2.0	
3	17.0	19.3	13.3	10.7	5.3	2.0	4.0	1.3	1.0	
4	27.0	19.3	16.7	15.0	5.3	6.3	.7	2.0	3.7	
5	24.7	15.3	18.0	16.7	6.0	4.3	7.3	5.3	2.3	
6	76.0	6.3	10.3	5.7	5.3	3.0	12.3	5.0	3.7	
7A	24.0	11.0	13.3	9.7	9.0	3.0	6.7	2.3	1.7	
7B	26.7	25.0	14.0	14.7	9.0	4.7	4.0	.3	1.3	
8A	16.7	13.7	10.7	13.7	13.0	4.3	2.3	5.0	2.3	
8B	26.0	26.0	18.7	18.7	11.6	3.6	2.7	4.3	8.0	
Mean	27.6	14.6	14.9	15.2	7.0	3.6	5.1	3.0	2.7	

Table E. *Daphnia* catch expressed in number per liter in standardized plankton samples in Spirit Lake, 1973-75.

Sampling station	Sampling interval									
	5/7- 5/11	5/14- 5/18	5/21- 5/25	5/28- 6/1	6/4- 6/8	6/11- 6/15	6/18- 6/22	6/25- 6/29	7/2- 7/6	
1973										
1	30.6	46.3	.2	3.7	18.8	6.8	15.1	1.5	10.1	
2	8.4	18.9	7.8	4.7	10.9	10.9	5.5	1.3	12.5	
3	10.9	27.8	3.8	1.0	16.9	14.9	6.8	2.0	5.0	
4	19.4	25.0	46.5	29.1	.2	9.5	18.2	2.9	51.2	
5	37.8	22.8	45.8	6.6	2.4	5.7	6.4	5.0	8.5	
6	29.7	27.5	8.2	27.8	6.6	6.4	6.4	.4	37.9	
7A	18.3	24.5	5.4	3.7	5.0	10.1	22.3	6.8	10.3	
7B	21.9	58.3	50.4	35.0	29.1	17.5	18.8	11.0	28.0	
8A	22.8	14.3	31.5	15.1	2.4	.9	11.8	12.9	18.2	
8B	53.8	80.0	67.2	56.0	10.5	7.7	18.4	18.2	7.2	
Mean	25.4	34.5	26.7	18.3	10.3	9.0	13.0	6.2	19.0	
1974										
	5/6- 5/10	5/13- 5/17	5/20- 5/24	5/27- 5/31	6/3- 6/7	6/10- 6/14	6/17- 6/21	6/24- 6/28	7/1- 7/5	
1	15.8	1.8	19.0	19.0	3.3	5.7	9.0	3.0	.7	
2	22.8	2.5	14.9	59.3	3.0	9.0	1.0	8.7	9.7	
3	8.5	4.8	14.0	36.3	5.3	13.7	1.0	2.7	.7	
4	1.8	10.5	13.0	6.3	5.3	41.3	.3	5.0	4.7	
5	9.0	2.3	24.0	11.7	2.7	7.3	7.7	1.3	3.7	
6	1.5	7.0	34.0	26.7	1.0	26.0	1.0	2.0	3.3	
7A	1.5	0	10.7	38.0	8.0	18.7	4.3	2.0	6.7	
7B	23.0	6.0	28.7	48.0	48.3	19.3	20.7	15.0	9.7	
8A	2.5	1.7	5.3	5.3	6.0	3.3	2.7	2.0	5.7	
8B	27.5	4.3	23.3	38.0	37.0	25.2	16.0	8.3	8.7	
Mean	11.4	4.1	18.7	28.9	12.0	17.0	6.4	5.0	5.4	
1975										
	5/5- 5/9	5/12- 5/16	5/19- 5/23	5/26- 5/30	6/2- 6/6	6/9- 6/13	6/16- 6/20	6/23- 6/27	6/30- 7/4	
1	6.3	5.3	46.3	62.7	16.7	3.7	26.7	4.0	5.3	
2	2.7	2.3	19.3	69.3	6.3	1.7	16.7	4.0	3.3	
3	19.0	9.0	20.3	35.0	31.3	5.0	5.3	1.7	3.3	
4	11.3	9.3	14.7	32.7	29.7	7.3	3.0	6.3	2.0	
5	1.7	6.3	18.7	18.7	37.7	1.7	19.3	11.3	2.3	
6	1.7	5.7	24.7	20.3	54.7	4.7	11.7	4.0	2.3	
7A	5.0	11.3	16.7	29.0	39.3	3.3	8.0	11.3	2.0	
7B	18.7	23.3	21.7	42.0	23.7	12.3	8.7	9.3	4.0	
8A	10.3	11.7	44.0	18.0	25.7	9.3	3.3	34.3	3.0	
8B	20.3	11.7	43.7	33.0	37.7	15.7	5.3	36.3	8.3	
Mean	9.7	9.6	27.0	36.1	30.3	6.5	10.8	12.2	3.6	

Table F. *Chydorus* catch expressed in number per liter in standardized plankton samples in Spirit Lake, 1973-75.

Sampling station	Sampling interval								
	5/7- 5/11	5/14- 5/18	5/21- 5/25	5/28- 6/1	6/4- 6/8	6/11- 6/15	6/18- 6/22	6/25- 6/29	7/2- 7/6
1973									
1	0	.8	0	.9	1.8	1.0	0	.2	.2
2	0	0	0	2.8	1.5	.6	.4	.4	.2
3	.8	.5	.3	1.5	0	.4	.9	.4	.4
4	1.0	.5	.3	1.8	0	1.3	.7	.7	.7
5	.3	0	.5	.6	.2	.9	.2	1.3	.4
6	.6	0	0	2.4	.4	3.9	.2	.6	2.2
7A	.9	.5	.2	2.0	.8	8.8	0	.7	.9
7B	1.1	.5	.3	1.1	.8	7.3	.4	2.5	2.0
8A	.3	.3	.6	.9	.7	2.1	.4	1.3	1.1
8B	.3	1.0	.3	3.5	.9	2.3	1.5	2.9	1.5
Mean	.5	.4	.3	1.8	.7	2.9	.5	1.1	1.0
1974									
	5/6- 5/10	5/13- 5/17	5/20- 5/24	5/27- 5/31	6/3- 6/7	6/10- 6/14	6/17- 6/21	6/24- 6/28	7/1- 7/5
1	0	0	.7	.3	2.0	1.3	.7	0	0
2	0	0	0	.7	.3	.7	1.3	0	.3
3	0	0	0	.3	0	0	0	.3	0
4	0	0	0	0	1.0	3.3	3.3	1.0	1.0
5	0	.3	1.0	.7	2.0	1.3	.7	.3	.3
6	0	0	0	0	.3	2.3	.7	0	0
7A	0	0	1.0	2.3	1.3	1.0	1.0	.3	.3
7B	0	.3	.7	2.3	2.0	1.3	1.3	1.7	0
8A	0	0	2.0	1.0	1.0	1.0	0	0	1.0
8B	.3	.7	.3	0	.7	1.9	2.0	0	1.0
Mean	< .1	.1	.6	.8	1.1	1.4	1.1	.3	.4
1975									
	5/5- 5/9	5/12- 5/16	5/19- 5/23	5/26- 5/30	6/2- 6/6	6/9- 6/13	6/16- 6/20	6/23- 6/27	6/30- 7/4
1	0	.3	2.3	1.0	1.0	1.0	.7	0	0
2	0	.3	.7	.7	.3	0	1.0	.3	.7
3	0	1.0	.7	0	2.7	0	0	.3	.3
4	0	.7	.3	1.0	0	1.0	0	.7	.3
5	0	0	.7	.7	1.3	.7	1.0	.7	0
6	1.0	0	.7	.3	1.3	.3	.3	.3	0
7A	.7	.7	.3	0	.3	.7	0	.7	0
7B	.7	1.3	.7	2.0	1.0	0	1.7	0	.3
8A	.7	.3	1.7	0	.7	0	2.3	0	0
8B	2.0	0	.7	1.3	.3	.7	1.7	.7	0
Mean	.5	.5	.9	.7	.9	.4	.9	.4	.2



Table G. *Bosmina* catch expressed in number per liter in standardized plankton samples in Spirit Lake, 1973-75.

Sampling station	Sampling interval									
	5/7- 5/11	5/14- 5/18	5/21- 5/25	5/28- 6/1	6/4- 6/8	6/11- 6/15	6/18- 6/22	6/25- 6/29	7/2- 7/6	
1973										
1	0	.3	0	.7	.4	0	.8	.7	2.4	
2	0	6.2	.5	.6	0	0	0	1.1	6.4	
3	0	1.8	1.3	.3	0	1.8	1.1	.7	5.3	
4	0	3.3	.8	.7	0	.8	2.2	3.3	6.6	
5	0	0	.3	0	0	0	.9	.9	2.4	
6	0	.5	0	.2	.2	.2	.2	0	5.0	
7A	0	3.8	.2	0	0	1.1	.2	1.5	4.2	
7B	0	1.5	2.0	.2	0	.4	.4	3.0	2.3	
8A	0	1.3	.6	.7	0	.4	0	5.3	9.2	
8B	0	2.3	.3	.4	.2	.4	1.1	1.5	4.4	
Mean	0	2.1	.6	.4	.1	.5	.7	1.8	4.8	
1974										
1	.3	0	0	.7	0	1.7	0	.3	.3	
2	0	.3	.3	1.0	0	1.0	.3	2.3	0	
3	0	0	.7	.7	.7	3.0	0	0	.3	
4	0	0	0	0	.3	3.3	.7	0	1.7	
5	0	0	1.7	.7	.3	1.0	.3	1.0	.7	
6	.3	0	.3	0	0	2.3	.3	.3	.3	
7A	0	0	.3	3.0	1.0	4.0	1.0	0	1.7	
7B	0	.3	0	2.3	1.0	2.7	.7	1.3	.7	
8A	.3	0	.3	.3	1.0	.3	0	.7	.3	
8B	.5	0	.7	1.7	2.3	.8	.3	0	1.0	
Mean	.1	.1	.4	1.0	.7	2.0	.4	.6	.7	
1975										
1	.3	.7	3.0	6.3	.3	0	1.0	0	2.0	
2	0	.3	1.3	2.7	0	0	2.3	.3	1.7	
3	0	2.7	2.0	0	2.0	0	0	.3	1.3	
4	.3	1.3	2.0	1.0	2.0	0	.3	0	1.7	
5	1.0	1.0	1.3	.7	.7	.3	.7	.7	1.0	
6	0	.3	3.7	2.0	1.7	0	.7	1.0	0	
7A	0	1.7	1.7	2.3	1.0	0	.3	0	0	
7B	0	2.7	1.7	2.7	.7	.3	.7	.7	0	
8A	.3	1.0	2.7	1.7	1.0	.3	.7	0	.7	
8B	.3	.3	2.7	1.3	1.0	.3	1.0	5.7	1.3	
Mean	.2	1.2	2.2	2.1	1.0	.1	.8	.9	1.0	

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