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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

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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 Cylcops) 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).

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 rathern than from an incre 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 depensatory 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.

Interspecific competition between fish species has been poorly defined in Spirit Lake, particularly for those exhibiting close systematic relationships and environmental requirements like yellow perch and walleye. The objectives of this study were to refine the previous knowledge on the contribution of stocked walleye fry to the larval population density by examining survival from embryonic development through larval stages, and to define the level of competition between the larval stages of these members of the Percidae family by determination of the food requirements for larval fishes. An associated objective was to identify the environmental factors influencing abundance and survival of stocked and naturally produced walleye and yellow perch.

DESCRIPTION OF SPIRIT LAKE

Spirit Lake is the largest natural lake in Iowa with a surface area of 2,168 ha (5,300 ac). It is located in Dickinson County, and forms part of a chain of lakes along the Iowa-Minnesota border. The lake is bowl-shaped with a gradually sloping basin. Maximum depth is 7.3 m (24 ft) and mean depth 5.2 m (17 ft). Rocky shoals lie along much of the eastern, northern and western shorelines, with several prominent rock reefs. Extensive mud flats commence at a depth of about 6 m (20 ft).

The watershed contains about 18,000 ha (44,460 ac) which includes adjacent watersheds of adjoining lakes that drain into Spirit Lake (Bachmann and Jones 1974). The terrain is flat to gently rolling and intensively row-cropped.

Four chemical and two physical parameters were measured weekly concurrent with fish sampling. Those components monitored were pH, hardness, alkalinity, dissolved oxygen (DO), water temperature and water clarity.

During the study, pH changed slightly, with annual means of 8.5, 8.6 and 8.7 (Table 1). In 1973, hardness and alkalinity water samples were analyzed with a Hach Model AL-30 VR kit, and later with a Hach Colormetric kit, Model DR-EL. Average total hardness was 243 mg/ℓ in 1973, 227 mg/ℓ in 1974 and 217 mg/ℓ in 1975, with the decrease between the first two years attributed to the procedure change. Total hardness in 1973 was highest in May and early June, then declined through the remainder of the sampling period. However, there were no apparent seasonal trends during the last two years. Total alkalinity averaged 217 mg/ℓ in 1973, 190 mg/ℓ in 1974 and 194 mg/ℓ in 1975. There were no seasonal trends in alkalinity concentrations.

Dissolved oxygen was always adequate to maintain aquatic life. Annual means ranged from 8.9 mg/ℓ in 1973 and 1974 to 9.9 mg/ℓ in 1975. The minimum and maximum DO values were 7.2 mg/ℓ and 13.0 mg/ℓ, with the highest dissolved oxygen concentrations usually measured during May.

Water clarity in Spirit Lake was primarily a reflection of the plankton density rather than turbidity. Secchi disc reading between 1973 and 1975 showed decreasing clarity with annual means of 2.1 m, 1.8 m and 1.5 m, respectively. Water clarity was highest during May, with maximum readings of 3.7 m, 4.6 m and 2.1 m from 1973-75, respecitvely, followed by generally decreasing values, with measurements generally < 2 m after the second week in June annually.

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 [a]	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

[a]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^3.

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
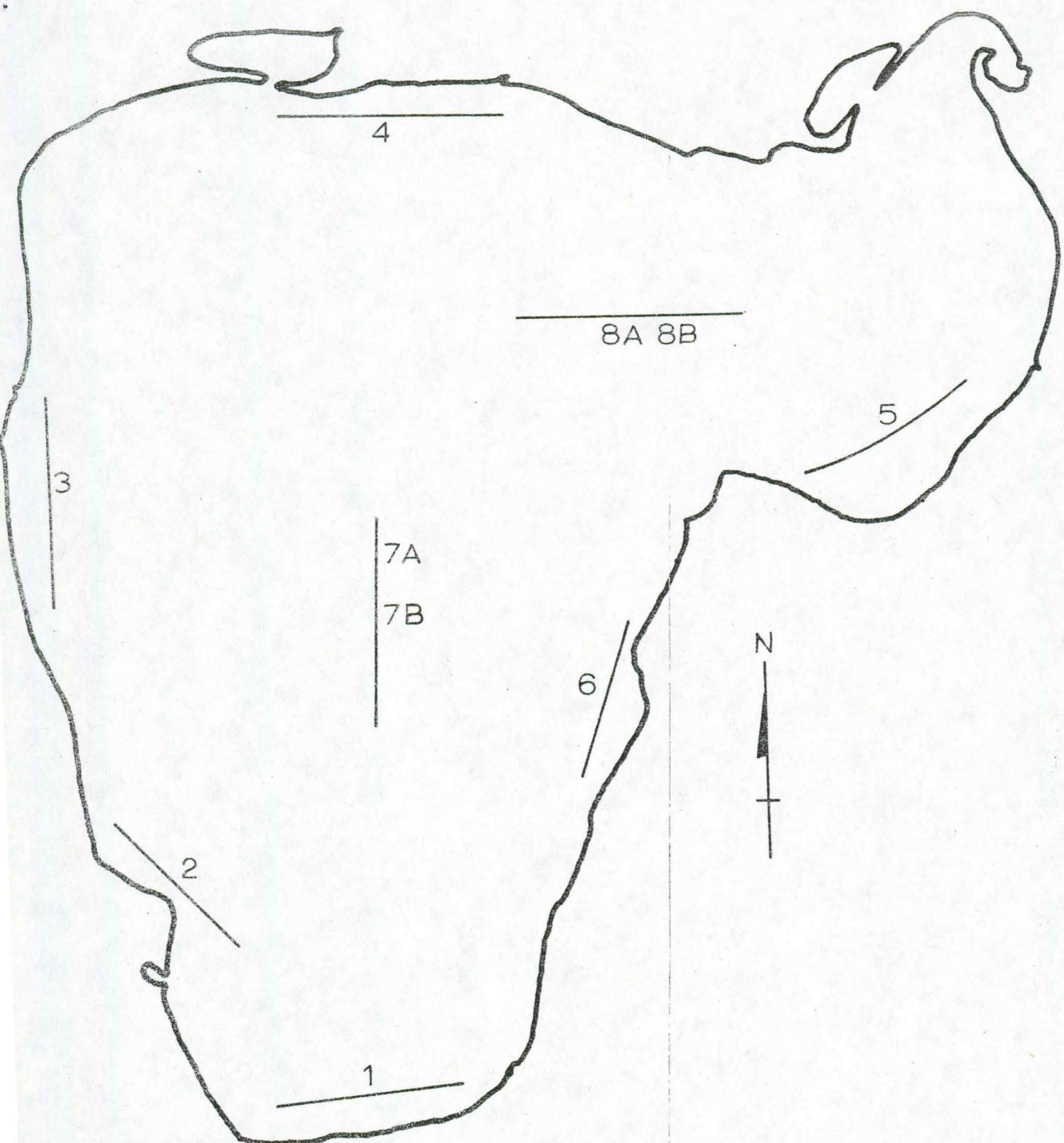
Figure 1. Location of the eight tow net sampling stations in
Spirit Lake.
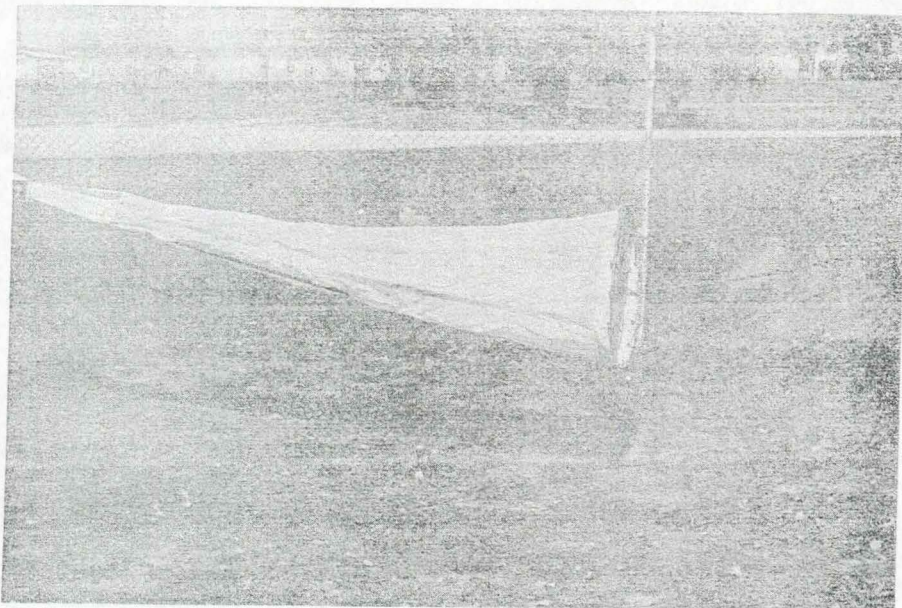
A 3/4 meter diameter tow net was used to sample larval fish populations.
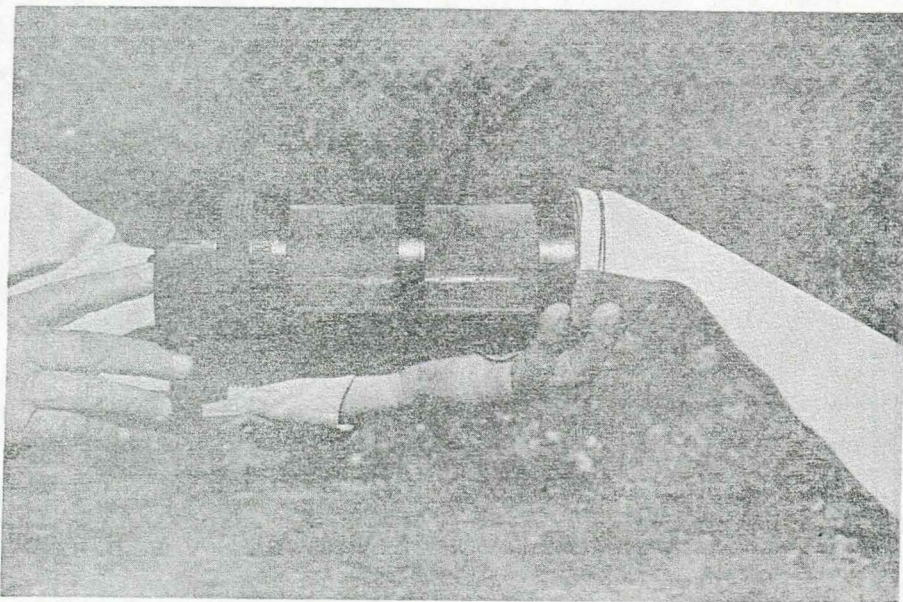
Larval fish were collected in this type net bucket for emptying.

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

where Y_{ijk} was the $\log_{10}$ transformation of $X_{ijk} + 1$ and X_{ijk} was the adjusted catch of larval fish in the kth interval at the jth sampling station during the ith 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 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 estaimted as the geometric change in the density of larval fish from numerical catch in successive sampling inervals. Annual mortality was determined from a table of exponential functions and survival estimated as the compliment 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 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 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 ot 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 numers 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 vlaues 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 varaiance 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

Table 2. Catch means of larval walleye in standardized tow net hauls expressed in number per 1,000 m^3 at Spirit Lake, 1973-75. Catch values in 1974 are the mean of two consecutive tows.

	Annual mean	May				June				July
1973	2.6	13.9	3.9	3.4	1.8	0	0	0	0	0
1974	.9	8.0	.4	0	0	0	0	0	0	0
1975	1.7	0	.8	13.2	1.0	.4	0	0	0	0

is a high probabilty the maximum population density occurred before sampling began. If this postulation is correct, the maximum population density in 1974 probably approached the 13-14 larvae per tow found in other years indicating a rather stable initial larval population density.

Estimated maximum population density was 718 walleye larvae per ha (N/ha) (291 larvae/ac) in 1973, 418 N/ha (169 N/ac) in 1974 and 676 N/ha (273 N/ac) in 1975, with minimum density values of 93 N/ha (38 N/ac), 21 N/ha (8 N/ac) and 22 N/ha (9 N/ac). Minimum population density estimate in 1973 was nearly four times of the estimated density in 1974 and 1975, indicating the presence of significantly higher larval abundance during early June in 1973.

Configuration of the catch distribution was similar in all years, except for temporal distribution (Figure 2). Frequency distribution was unimodal with the peak density occurring in May. Walleye larvae were not captured after the first week in June probably due to gear avoidance rather than low larval density. Noble (1971) found walleye larvae capable of avoiding capture in Miller high speed samplers starting at about 10 mm TL with avoidance increasing rapidly as body size increased. Larvae greater than about 18 mm TL (.7 in) were not captured in Spirit Lake, with the exception of one larvae measuring 31 mm TL (1.2 in). Spykerman (1973) also reported difficulty in capturing larger larvae, with only one larvae captured after the second week of June in Clear Lake, IA.

Walleye larvae were evenly distributed in Spirit Lake. Catch means at indvidual stations varied from 0 to 4.6 larvae per tow in 1973, 0 to 4.1 larvae per tow in 1974 and 0 to 4.2 larvae per tow in 1975 (Appendix A). Eschmeyer (1950) first suggested larval walleye were pelagic shortly after hatching, returning to littoral zones after growing to approximately 25 mm TL (1 in). Similar horizontal movement of larval walleye was also found in several eastern and Midwestern lakes (Johnson 1969: Spykerman 1973). Few larvae captured in Spirit Lake were longer than 18 mm TL (.7 in) partially negating any conclusion concerning the return of larvae to the littoral zones. However, examination of the catch means by individual stations indicated a demersal larval movement occurred in early and mid-May. In contrast to the even vertical distribution of larval walleye in Spirit Lake, Noble (1972) and Spykerman (1973) reported higher walleye larval density in subsurface samples than in surface samples. Johnson (1969) also reported higher
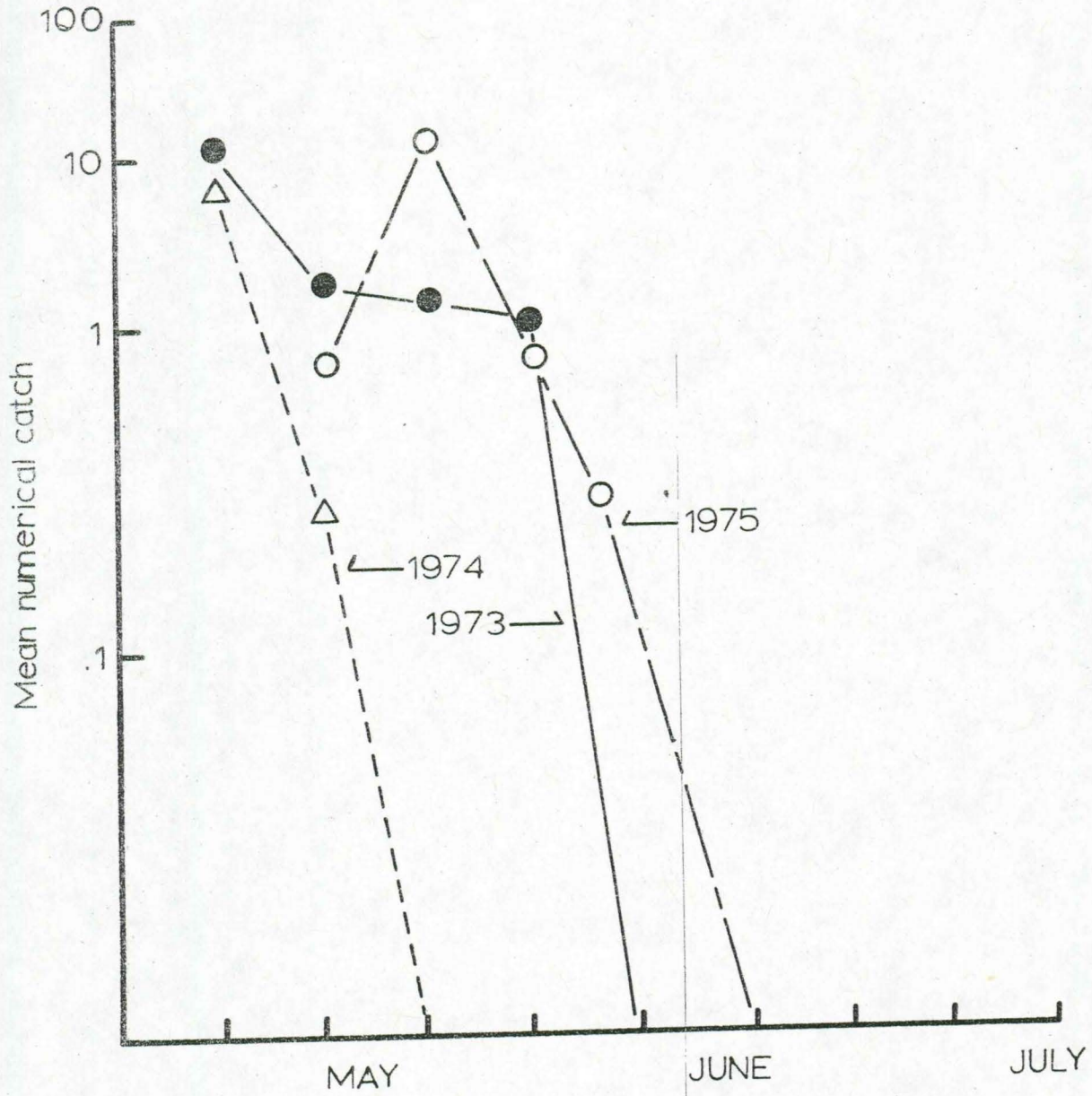
Figure 2. Mean numerical catch of walleye larvae in standard-
ized tow net samples in Spirit Lake, 1973-75.

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

$$1973: \quad \log_{10}W = -5.48 + 3.10 \log_{10}TL \quad (r = .99)$$
$$1975: \quad \log_{10}W = -4.96 + 2.53 \log_{10}TL \quad (r = .98)$$

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^2 in 1973, 1.1 fry/m^2 in 1974 and 4.3 fry/m^2 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^2 (Johnson 1961).

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

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

	1964[a]	1965[a]	1966[a]	1967[a]	1968[a]	1969[a]	1971	1972	1973	1974	1975
Maximum egg density per m^2	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^2	.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

[a]Jennings, 1969.

. (Jennings 1969; McWilliams 1975). Wide ranges in maximum egg density at Lake Winnibigoshish was also reported (Johnson 1961), although similar density was reported in both alkes.

Embryonic survival was estimated at 2.5%, 4.0% and 3.5% during the study period, considerably below previous estimates that averaged 8% from 1964-72. By comparison, Johnson (1961) reported about 18% survival of walleye embryo at Lake Winnibigoshish, MN. These data indicate embryo survival is a key factor in determining the extent of natural production in Spirit Lake.

CONTRIBUTION OF STOCKED WALLEYE SAC-FRY TO THE LARVAL WALLEYE POPULATION

The estimated contribution of stocked walleye fry to the larval walleye population by the first method was 81% in 1973, 90% in 1974 and 85% in 1975. By the second method the percent contribution ranged from nearly 100% in 1973 to 23% in 1974. However, confidence intervals for the 1974 estimate showed the contribution might range from 12% to over 100%. In comparison, contributions of stocked walleye larvae to year class abundance in West Blue Lake, Manitoba, ranged from 43% to 100% (Ward and Clayton 1974).

ABUNDANCE, DISTRIBUTION AND SURVIVAL OF LARVAL YELLOW PERCH

Annual catch means of larval yellow perch in the tow net samples were 117 in 1973, 23 in 1974 and 81 in 1975 (Table 4). Analysis of variance of the numerical catch revealed differences among the annual catch means were significant; however, examination of the catch means indicated total acceptance of the analysis was also questionable for the same reason as stated previously for walleye.

Table 4. Catch mean of larval yellow perch in standardized tow net hauls expressed in number per $1,000 \text{ m}^3$ at Spirit Lake, 1973-75. Catch values in 1974 are the mean of two consecutive tows.

	Annual mean	Sampling interval								
		May				June				July
1973	117	263	405	182	115	53	21	8	0	2
1974	23	197	8	1	1	0	0	1	1	0
1975	81	0	59	636	27	3	1	1	1	0

Maximum population density of yellow perch was estimated at 20,923 N/ha (8,471 N/ac) in 1973, 10,190 N/ha (4,126 N/ac) in 1974 and 32,519 N/ha (13,166 N/ac) in 1975. Minimum population density occurred during late June and early July each year, with estimates of 83 N/ha (34 N/ac), 10 N/ha (4 N/ac) and 20 N/ha (8 N/ac) from 1973-75, respectively.

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

$$1973: \quad Log_{10}W = -5.94 + 3.67 \ Log_{10}TL \quad (r = .99)$$
$$1974: \quad Log_{10}W = -6.23 + 3.86 \ Log_{10}TL \quad (r = .99)$$
$$1975: \quad Log_{10}W = -5.66 + 3.48 \ Log_{10}TL \quad (r = .99)$$

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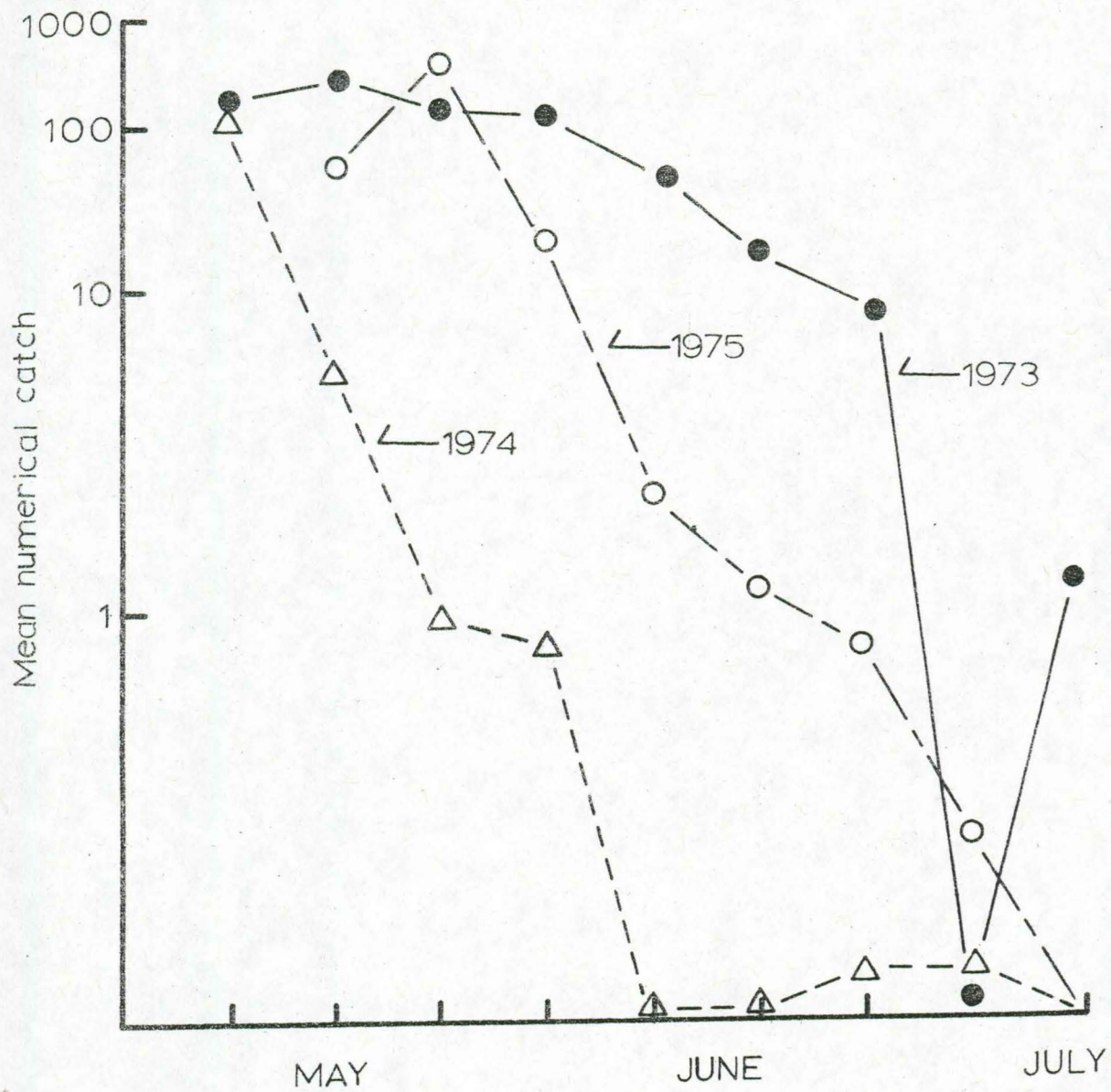
Figure 3. Mean numerical catch of yellow perch larvae in standardized tow net samples in Spirit Lake, 1973-1975.

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 denstiy (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.

	Diaptomus	Cyclops	Daphnia	Chydorus	Bosmina
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 *Cylcops* 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).
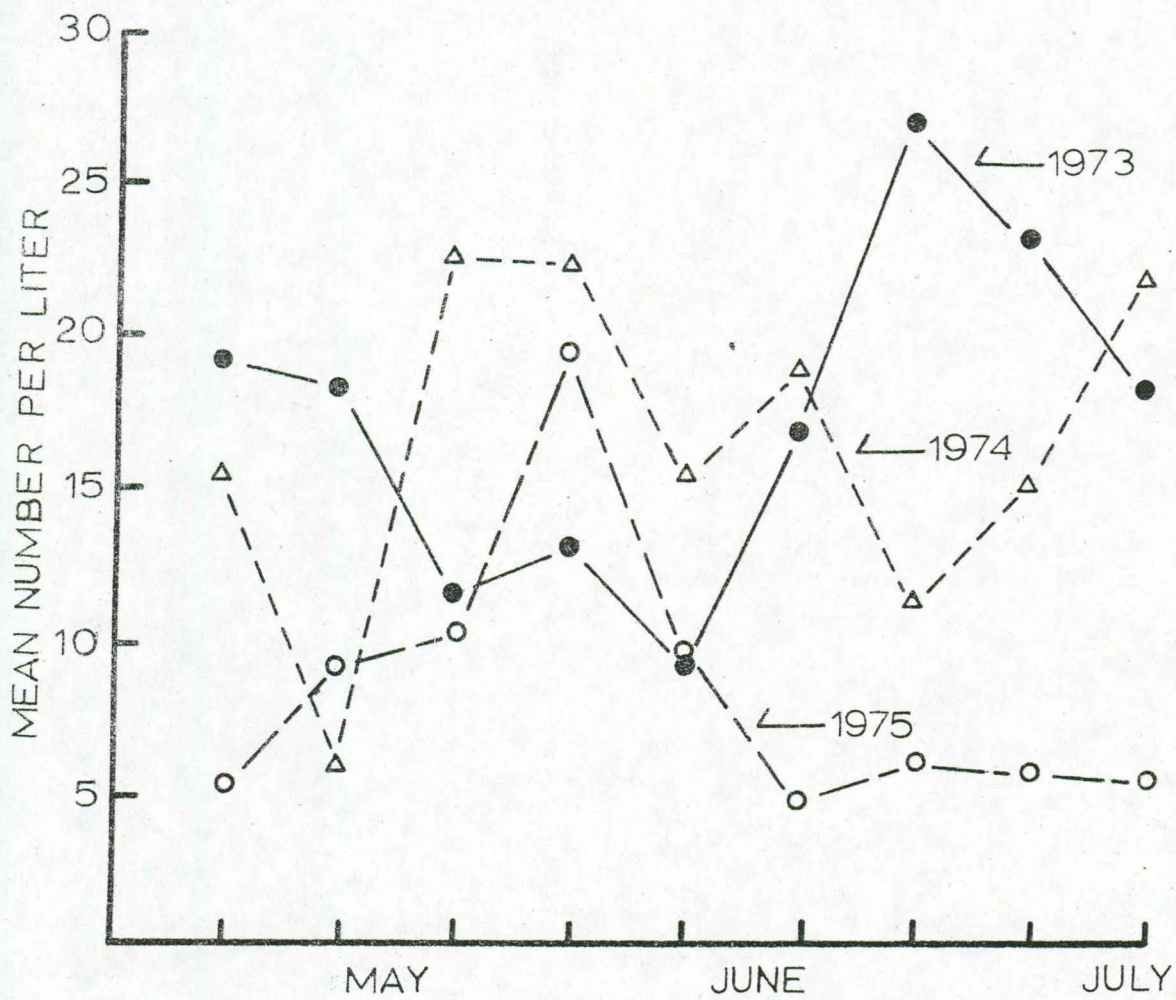
Figure 4. Seasonal distribution of the _Diaptomus_ catch in plankton samples at Spirit Lake, 1973-1975.

Table 6. Partitioned factorial analysis of variance due to sampling station effect in the numerical catch of zooplankton at Spirit Lake, 1973-75.

Source of variation	df	*Diaptomus*	*Cyclops*	*Daphnia*	*Chydorus*	*Bosmina*
Station	(9)	*	**	**	**	NS
Midwater vs shallow water stations	1	NS	**	**	**	NS
Among midwater stations	(3)					
Surface vs subsurface	1	**	**	**	NS	NS
Station 7 vs Station 8	1	NS	NS	NS	NS	NS
Interaction with depth	1	NS	NS	NS	NS	NS
Among shallow water stations	(5)	NS	NS	NS	NS	NS

* Significant at the 95% level.

** Significant at the 99% level.

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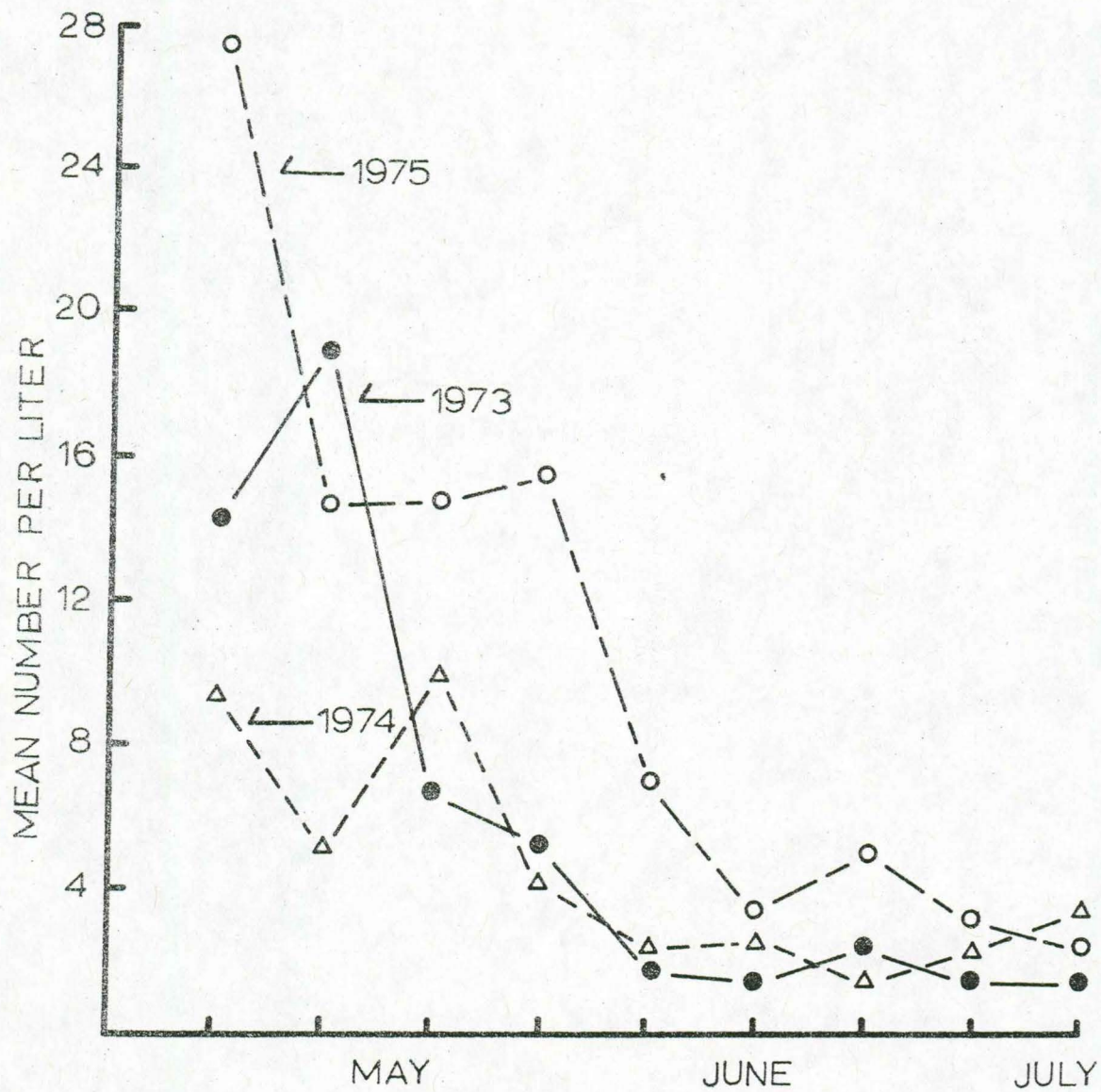
Figure 5. Seasonal distribution of the Cyclops catch in plankton samples at Spirit Lake, 1973-1975.

Cyclops were unequally distributed in Spirit Lake both horizontally and vertically. *Cylcops* were most abundant at midwater stations. Catch means were 7.6 N/ℓ for Stations 7 and 8 and 6.6 N/ℓ for Stations 1-6. *Cyclops* were more abundant at 3.1 m (10 ft) than at the surface, with overall catch means of 9.4 N/ℓ for Stations 7B and 8B and 5.8 N/ℓ for Stations 7A and 8A.

ABUNDANCE AND DISTRIBUTION OF CLADOCERA

Annual catch means of *Daphnia* were 18.0 N/ℓ, 12.1 N/ℓ and 16.2 N/ℓ in 1973-75, respectively. Catch of *Daphnia* at individual sampling stations varied widely ranging up to 80.0 N/ℓ in 1973 (Appendix E). Differences among catch means were highly significant. The seasonal peak density always occurred during May. Maximum counts were 34.5 N/ℓ in 1973, 28.9 N/ℓ in 1974 and 36.1 N/ℓ in 1975. Although the abundance of *Daphnia* decreased in June, a secondary mode occurred with catch means of 13.0 N/ℓ, 17.0 N/ℓ and 12.2 N/ℓ in 1973-75, respectively. Configuration of the catch distributions were quite similar, except for temporal differences (Figure 6). All catch curves were bimodal, with the highest density occurring the second or fourth weeks in May followed by rapid decreases in abundance, with secondary modes occurring between mid- and late June.

The spatial distribution of *Daphnia* was highly variable. *Daphnia* were significantly more abundant in midwater with catch means of 18.7 N/ℓ for Stations 7 and 8 and 13.7 N/ℓ for Stations 1-6. *Daphnia* were also more abundant at 3.1 m (10 ft) than at the surface with a catch means of 12.0 N/ℓ at the surface sampling stations and 25.4 N/ℓ at the subsurface stations.

Chydorus ranked lowest in abundance with catch means of 1.0 N/ℓ, .6 N/ℓ and .6 N/ℓ in 1973-75. Seasonally, the numerical abundance of *Chydorus* remained at relatively low density each year during May with the average catch usually < 1 N/ℓ (Figure 7). Population abundance increased in June to a maximum density of 2.9 N/ℓ in 1973 and 1.4 N/ℓ in 1974, but remained below 1 N/ℓ in 1975. Configuration of seasonal catch distributions in 1974 and 1975 were similar except during the second week of June. The 1973 catch distribution revealed rapid changes occurred in the population density throughout the sampling period, although modes in 1973 and 1974 occurred during the same sampling interval.

Chydorus were evenly distributed vertically, but not horizontally with higher concentrations in midwater. Overall catch means were 1.0 N/ℓ for Stations 7 and 8 and .6 N/ℓ for Stations 1-6. Concentrations at individual stations were low in all years, ranging up to a maximum catch of 8.8 N/ℓ (Appendix F).

Bosmina were also low in abundance. Annual catch means were 1.2 N/ℓ, .7 N/ℓ and 1.1 N/ℓ in 1973-75, respectively. Numerical density of *Bosmina* rarely exceeded 2 N/ℓ in any year, although in 1973, the maximum density was 4.8 N/ℓ in early July. Catch distribution, although basically bimodal each year, were dissimilar temporally (Figure 8). Modes occurred between early May and early June, with secondary modes occurring between mid-June and early July, except in 1973 when the reverse occurred with the greatest concentration in early July.
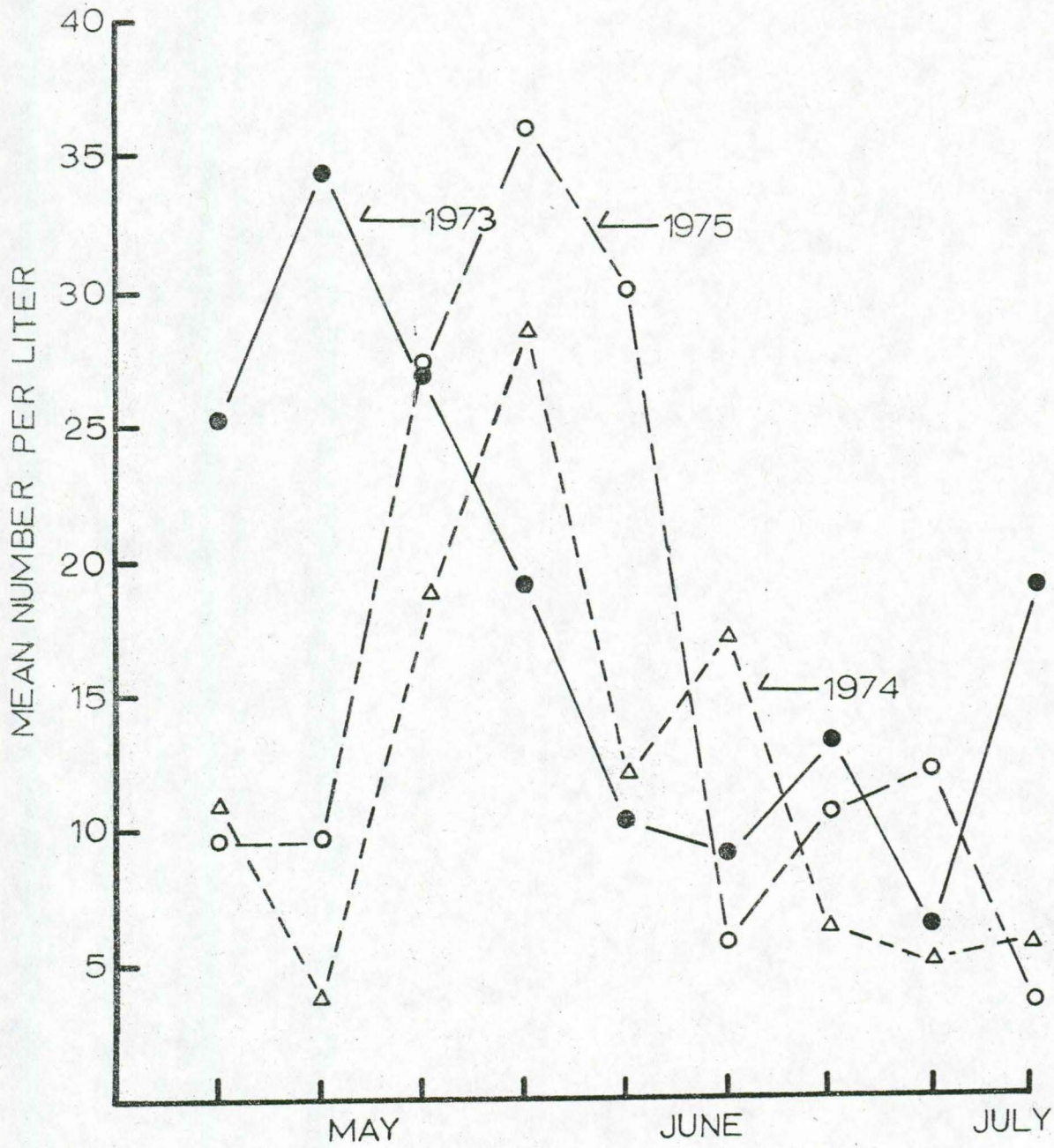
Figure 6. Seasonal distribution of the _Daphnia_ catch in plankton samples at Spirit Lake, 1973-1975.
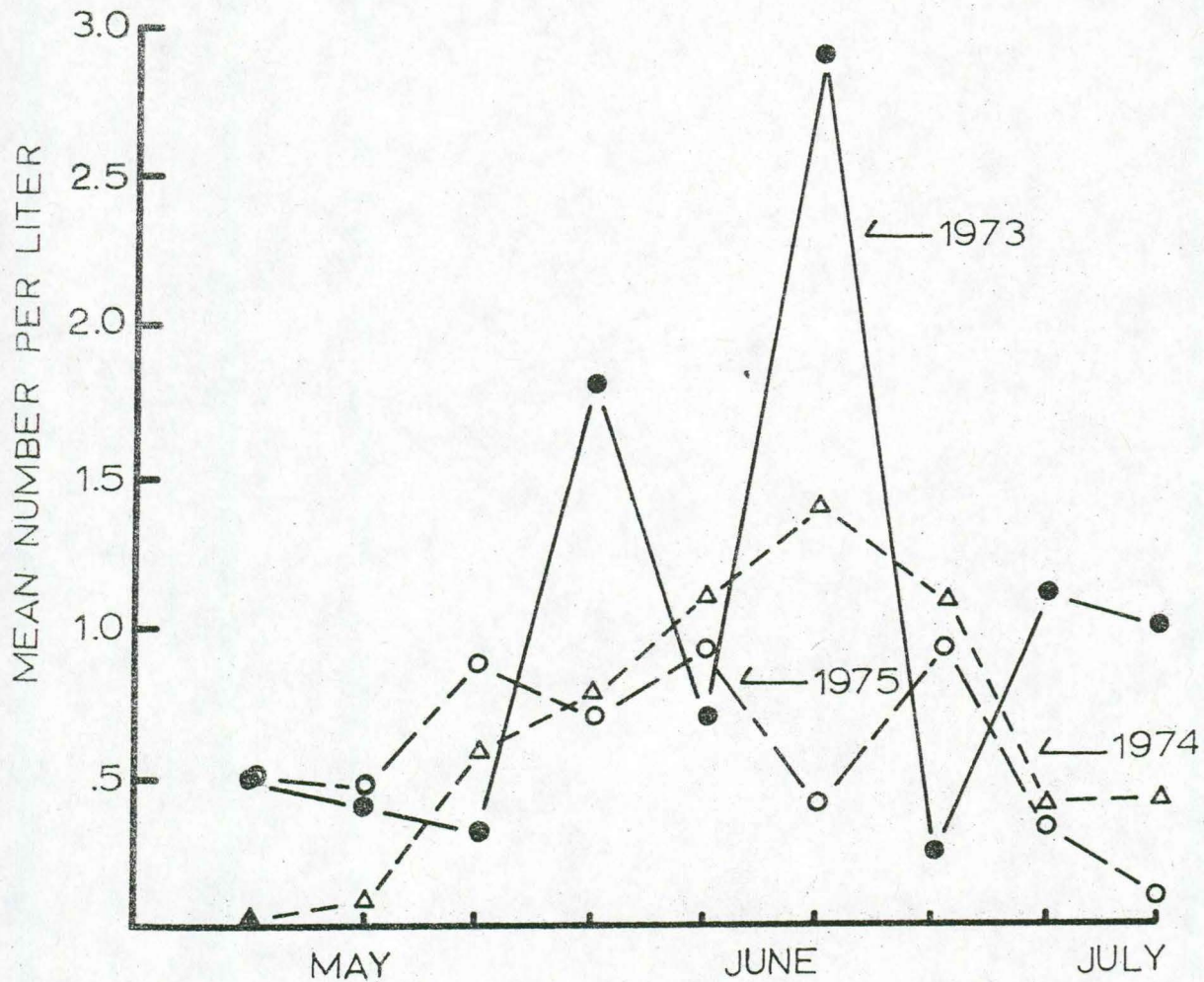
Figure 7. Seasonal distribution of the Chydorus catch in plankton samples at Spirit Lake, 1973-1975.
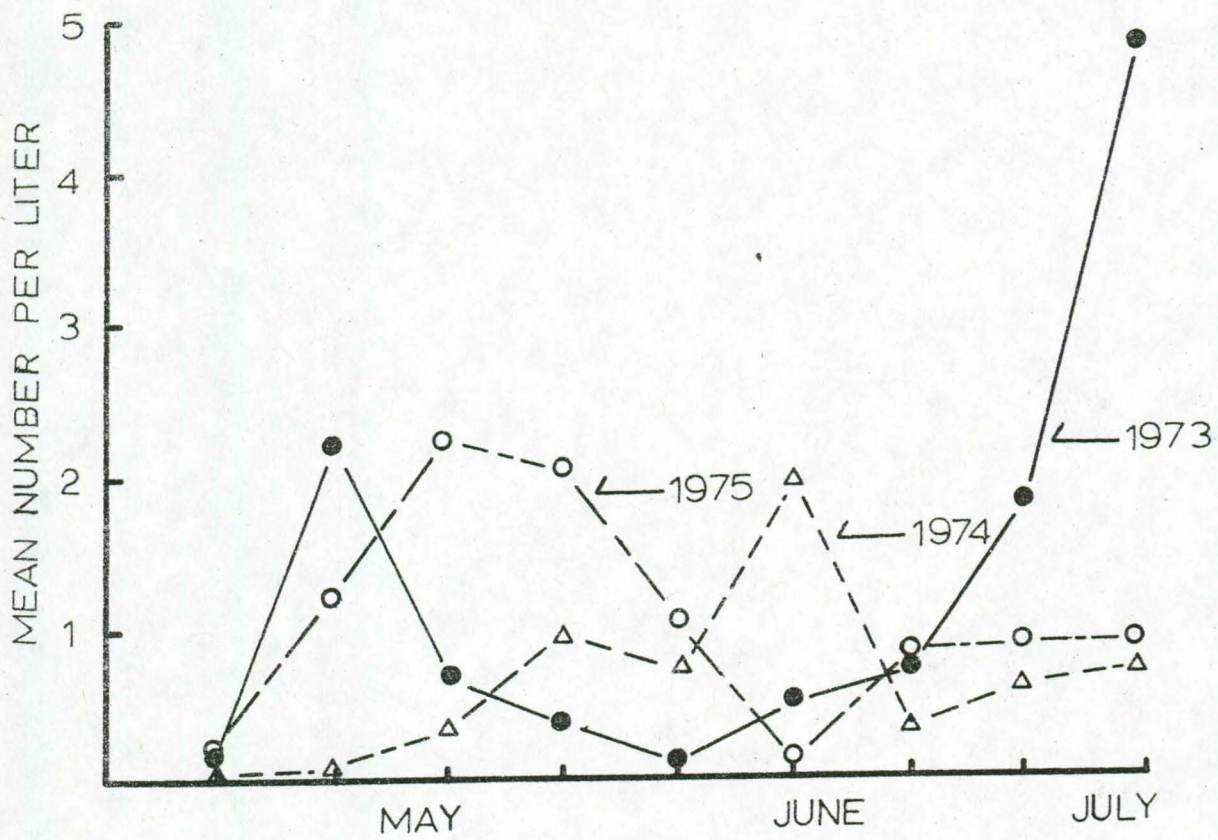
Figure 8. Seasonal distribution of the Bosmina catch in plankton samples at Spirit Lake, 1973-1975.

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 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	Diaptomus N	%	Cyclops N	%	Daphnia 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						
		a							
1975		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] 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)		Diaptomus	Cyclops	Daphnia
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 or 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.

Cylcops 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, comrpising 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 definate 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	Diaptomus		Cyclops		Daphnia		Chydorus		Bosmina	
			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												

[a] No larval yellow perch captured during the sampling period.

Table 10. Electivity for zooplankton for food by larval yellow perch at Spirit Lake, 1973-75.

	Size range (mm)	Diaptomus	Cyclops	Daphnia	Chydorus	Bosmina
1973						
May	4- 6	--	--	--	--	--
	5- 7	--	+.48	--	--	--
	7-11	+.31	+.41	-.95	--	--
	10-14	+.41	-.32	-.73	--	--
June	11-17	-.01	-.01	-.12	--	+.87
	11-22	-.36	-.10	-.01	-.37	+.89
	11-30	-.63	+.61	-.05	--	+.37
	a					
July	37-43	--	+.24	-.33	--	--
1974						
May	5- 8	--	--	--	--	--
	7-12	+.30	-.32	-.73	--	--
	8-11	+.29	-.25	--	--	--
	16-17	-.25	+.48	` --	+.71	+.86
June	a					
	a					
	26	-.68	--	+.24	--	+.87
July	26	-.57	+.11	+.49	--	+.28
	a					
1975						
May	a					
	5- 7	--	--	--	--	--
	7- 9	-.32	+.24	--	--	--
	8-13	+.16	+.22	-.86	--	+.62
June	11-13	+.22	+.01	-.41	--	+.76
	19-26	+.29	-.01	-.25	--	+.04
	25-28	-.44	--	+.29	+.04	--
	38	--	--	+.17	--	--
July	a					

[a]No larval yellow perch captured during the sampling interval.

27 mm TL. Electivity indices showed *Boxmina* was preferred for food in all instances, with indices of +.37 to +.89 in 1973; +.28 to +.87 in 1974; and +.04 to +.76 in 1975.

In agreement with these findings larval perch in the Red Lakes, MN fed upon a variety of zooplankton genera (Pycha and Smith 1954), including the five genera utilized by larvae in Spirit Lake. In comparison, Siefert (1972)

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 *Copoeoda 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 estiamted 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 thenatural 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 questionalbe, and the probability that the maximum density in 1974 was similar to either 1973 or 1975 is high. If this were ture, 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 prveious 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 or 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^3 at Spirit Lake, 1973-75. Catch values in 1974
are the mean of two consecutive tows.

Sampling station	Sampling interval								
1973	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
1	0	6.8	0	4.6	0	0	0	0	0
2	6.8	9.0	0	0	0	0	0	0	0
3	4.6	0	0	0	0	0	0	0	0
4	25.1	4.6	0	0	0	0	0	0	0
5	11.4	9.1	6.8	0	0	0	0	0	0
6	27.3	0	0	0	0	0	0	0	0
7A	9.1	0	0	0	0	0	0	0	0
7B	0	9.1	15.9	9.1	0	0	0	0	0
8A	41.0	0	0	0	0	0	0	0	0
8B	13.7	0	11.4	4.6	0	0	0	0	0
Mean	13.9	3.9	3.4	1.8	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
2	15.8	0	0	0	0	0	0	0	0
3	33.2	4.1	0	0	0	0	0	0	0
4	7.2	0	0	0	0	0	0	0	0
5	16.9	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7A	0	0	0	0	0	0	0	0	0
7B	0	0	0	0	0	0	0	0	0
8A	0	0	0	0	0	0	0	0	0
8B	0	0	0	0	0	0	0	0	0
Mean	8.0	.4	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
2	0	0	8.6	0	4.5	0	0	0	0
3	0	0	4.6	0	0	0	0	0	0
4	0	4.0	9.0	0	0	0	0	0	0
5	0	0	30.2	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7A	0	0	13.5	0	0	0	0	0	0
7B	0	0	27.2	0	0	0	0	0	0
8A	0	4.0	29.4	4.6	0	0	0	0	0
8B	0	0	9.8	5.0	0	0	0	0	0
Mean	0	.8	13.2	1.0	.4	0	0	0	0

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

Sampling station				Sampling interval					
1973	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
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								
1973	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
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	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	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	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	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					
1973	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
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								
1973		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
	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								
1973	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
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								
1973	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
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	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	.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	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	.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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