# IOWA
# CONSERVATION COMMISSION
# FISHERIES SECTION

ANNUAL PERFORMANCE REPORT

COLD SPRINGS AND SPIRIT LAKE
RESEARCH STATIONS



Study No. 101-3: 0-Age Production and Survival in Spirit Lake

Study No. 402-3: Dynamics of Predator-Prey Relationship in DeSoto Bend Lake

## PERIOD COVERED
## 1 JULY, 74 - 30 JUNE, 75

ANNUAL PERFORMANCE REPORT

COLD SPRINGS AND SPIRIT LAKE
RESEARCH STATIONS

Study No. 101-3: 0-Age Production and Survival in Spirit Lake

Study No. 402-3: Dynamics of Predator-Prey Relationship in DeSoto Bend Lake

# TABLE OF CONTENTS

# ANNUAL PERFORMANCE REPORT

## RESEARCH PROJECT SEGMENT

STATE: Iowa

STUDY NO.: 101-3

JOB NO.: 1

STUDY TITLE: 0-Age Production and Survival in Spirit Lake

JOB TITLE: Abundance, distribution, mortality and production of larval walleye and yellow perch

Period Covered: May, 1973 through July, 1974

*ABSTRACT: 0-age walleye and yellow perch populations at Spirit Lake were sampled using standardized tow net hauls for 9 weekly intervals commencing in May, 1973 and 1974. 0-age walleye and yellow perch abundance decreased significantly between 1973 and 1974, with catch means of 2.5 and .9 larval walleye and 116.6 and 33.0 larval yellow perch per tow. Both species were randomly distributed. Estimated contribution of stocked walleye fry to year class abundance was 100% in 1973 and 23% in 1974 based upon extrapolation of stocked walleye larvae alive on the first sampling date annually and total population density, and 81% and 90% annually based upon the survival of stocked walleye sac fry and natural reproductive potential. Length-weight relationship for walleye was $Log_{10}W = -5.48 + 3.10\ Log_{10}L$ in 1973. Catch data were insufficient to compute the relationship in 1974. For larval yellow perch, relationships were $Log_{10}W = -5.94 + 3.67\ Log_{10}L$ in 1973 and $Log_{10}W = -6.23 + 3.86\ Log_{10}L$ in 1974. Production of larval walleye was 2.0 gm/ha in 1973 and < .1 gm/ha in 1974. Yellow perch production was 149.5 gm/ha in 1973 and 7.9 gm/ha in 1974.*

Author: Dick McWilliams
Fisheries Research Biologist

Date Prepared: 1 July, 1974

Approved by: James Mayhew
Fisheries Research Supervisor

## *STUDY OBJECTIVE*

*To determine the unique contribution of natural production and stocked larvae to the 0-age walleye population in Spirit Lake and identify the factors which influence the abundance and distribution, production, and survival of embryonic, larval and juvenile walleye and yellow perch.*

## *JOB 1 OBJECTIVE*

*To determine the numerical abundance, distribution, survival and reproduction of larval walleye and yellow perch in Spirit Lake.*

## INTRODUCTION AND STUDY BACKGROUND

Walleye and yellow perch are important sport fish species in Spirit Lake ranking third and second in harvest surveys. Maintenance of a productive walleye and yellow perch fishery, which has intense angler pressure, is dependent upon continual development and eventual recruitment of year classes into the fishery. In turn, year class abundance is dependent upon the extent and magnitude of natural production and/or supplemental stockings of larval and juvenile fishes, and survival through critical life stages.

Previous walleye studies at Spirit Lake have for the most part concentrated on adult populations. Population estimates were made in 1947, 1954, 1961-63 and 1967-72. Numerical estimates showed the adult walleye population fluctuated widely, ranging from 27,645 (Moen, 1961) to nearly 80,000 in 1973 (Jennings, 1965). Exploitation of the walleye sport fishery ranged from 11% in 1954 to 50% in 1963, averaging nearly 29% annually. Walleye catch ranged from 5,674 in 1969 to over 42,000 in 1960, with nearly 23,000 harvested annually from 1956 through 1973.

Annual stockings of larval walleye have been conducted for several decades at Spirit Lake, although the unique contribution of these larvae to the 0-age population was never ascertained. Rose (1954) found that years when no larval walleye were stocked, from 1944 to 1948, there was a paucity of fingerling walleye compared to years when approximately 7,500 larvae/ha (3,000 per acre) were stocked, indicating larval walleye plantings directly affected year class abundance. However, during the same period Rose found a dramatic decrease in the white bass population, and the effect of the declining predacious bass on the survival and abundance of 0-age walleye could not be determined.

In addition to the annual sac fry stockings, fingerling walleye have been stocked periodically in Spirit Lake. Rose (1959) evaluated a 1956 fingerling stocking and found they contributed 11.8% to year class strength. Jennings (1970) reported fingerling walleye stocked from 1964 through 1967 comprised 3.2%, 12.9%, 1.3% and .7% of their respective year classes. The stocking of fingerling walleye to supplement natural reproduction in Spirit Lake was not considered completely successful.

Yellow perch is the second most important sport fish species in total harvest statistics. Creel surveys conducted between 1956 and 1973 showed yellow perch harvest ranged from about 6,000 in 1961 to over 109,000 in 1971, averaging nearly 45,000 yearly. Annual population surveys indicated high abundances of young perch occurred in 1954, 1956, 1968 and 1969. Harvest records showed above average catches of perch were recorded in 1958, 1959, 1962, 1963, 1969, 1970 and 1971, roughly corresponding to the peak population survey numbers, indicating direct association between year class abundance and harvest.

The overall objective of this study was to determine the unique contribution of stocked larval walleye to the 0-age walleye population and to determine the abundance, distribution, survival and production of 0-age walleye and yellow perch with emphasis on the interrelationship between these closely related fishes.

## DESCRIPTION SPIRIT LAKE

### *PHYSICAL CHARACTERISTICS*

Spirit Lake is a shallow, eutrophic lake located in Dickinson County. It is the largest natural lake in Iowa encompassing a surface area of 2,168 ha (5,280 ac) with a maximum depth of 7.3 m (24 ft) and a mean depth of 5.2 m (17 ft). The basin is bowl-shaped, with gradually sloping sides, and at a depth of approximately 6 m (20 ft) has extensive muck flats. Rocky shoals line much of the eastern, northern and western shores, and there are several prominent rock reefs. The lake is homothermous, with dissolved oxygen adequate to support aquatic life at all depths.

Total watershed area of Spirit Lake is about 13,500 ha (32,893 ac), including individual watersheds of lakes draining into Spirit Lake, in addition to 3,500 ha (8,523 ac) in lakes and marshes. The surrounding topography is flat or gently rolling with much of the land intensively row cropped.

### *CHEMICAL PARAMETERS*

Chemical parameters were measured at weekly intervals in conjunction with the sampling of 0-age fish populations. Six parameters were monitored; pH, alkalinity, hardness, dissolved oxygen, water clarity using a Secchi disc, and temperature.

There was little change in pH, either horizontally or vertically, throughout the study. In 1973, pH values ranged from 8.5 to 8.6 with a mean of 8.5 (Table 1). The next year pH values varied from 8.5 to 8.7, with a mean of 8.6. Analytical procedures for determining hardness, and alkalinity were changed between years to obtain more accurate and precise readings. The first year sample was processed with a Hach Model AL-30VR and the second year with a Hach Colorimetric kit. Total alkalinity ranged from 188 mg/l-256 mg/l in 1973 with a mean of 217 mg/l, with no apparent seasonal trend (Table 1). In 1974, alkalinity remained at 190 mg/l throughout the sampling period, probably due to the improved technique for measuring the component.

Table 1. Chemical characteristics for six water quality parameters based on weekly samples from Spirit Lake, 1973-1974.

| Parameter | 1973 Mean | 1973 Range | 1974 Mean | 1974 Range |
|---|---|---|---|---|
| pH | 8.5 | 8.5- 8.6 | 8.6 | 8.5- 8.7 |
| Total hardness (mg/l) | 243 | 205 -256 | 227 | 220 -250 |
| Alkalinity (mg/l) | 217 | 188 -256 | 190 | |
| Dissolved oxygen (mg/l) | 8.9 | 8.0- 10.1 | 8.9 | 7.6- 11.2 |
| Temperature (°C) | 17.9 | 10.5- 24.0 | 17.8 | 12.0- 22.6 |
| Secchi disc (m) | 2.1 | .9- 3.7 | 1.8 | 1.0- 4.6 |

Total hardness values ranged from 205 mg/l-256 mg/l in 1973, with a mean of 243 mg/l. In 1974, hardness values ranged from 220 to 250 mg/l, with a mean of 227 mg/l. Total hardness in 1973 during May and early June remained near 256 mg/l, subsequently dropping to 205-239 mg/l in late June and early July. During 1974, hardness values did not show a similar seasonal decrease.

Dissolved oxygen was always adequate to maintain aquatic life throughout Spirit Lake. In 1973, dissolved oxygen ranged from 8.0-10.1 mg/l, with a mean of 8.9 mg/l. In 1974, dissolved oxygen ranged from 7.6-11.2 mg/l and had a mean of 8.9 mg/l.

Secchi disc measurements in Spirit Lake reflected mostly changes in plankton abundance, since silt turbidity was not a problem. Measurements in 1973 showed heavy presence of plankton early in May, in contrast to a lack of plankton during early May in 1974. Measurements in late May and June showed plankton fairly abundant in both years. Overall mean Secchi disc readings averaged 2.1 m in 1973 and 1.8 m in 1974.

Temperature profiles showed homothermic characteristics in Spirit Lake with little or no differences found between surface and subsurface readings. The mean temperature in 1973 was 17.9°C with a range of 10.5-24.0°C from early May through mid-July. In 1974 the mean temperature was 17.8°C with a range of 12.0-22.6°C in the same time period. The large divergence occurred in early May between years, with the temperatures in 1974 much higher in early spring.

## METHODS AND PROCEDURES

Sampling of 0-age fish populations was conducted in 9 weekly intervals commencing on the week of 7 May, 1973 and 6 May, 1974, at 8 stations. Sampling stations were located in a variety of habitats, (Figure 1) including shallow water and midwater areas. Six stations were located in shallow water and designated Stations 1-6. Two midwater stations were sampled at the surface and at a depth of 3.1 m (10 ft) and designated Stations 7A and 8A for the surface tows and 7B and 8B for deep water tows.

The tow net was conically-shaped, approximately 3 m long (9.8 ft) constructed of .79 mm (.03 inches) nylon mesh. A .75 m (2.4 ft) diameter metal ring was used to maintain the opening and provide rigid support for the towing bridle.

Surface samples were collected by towing the net about 12 m (40 ft) directly behind the boat. A weight attached to one of the towing bridle chains hung below and behind the ring perimeter and maintained net stability and proper depth. Subsurface samples were collected by attaching the towing bridle to a stand pipe fixed at the side of the boat at 3.1 m depth (10 ft).

Tows were 5 minutes in duration. Length of each tow was measured using a General Oceanics Digital Flowmeter (Model 2030) attached to the towing bridle with the flowmeter centered in the net. The volume of water strained during each tow was adjusted to 1,000 $m^3$.

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

Catch per standardized net haul were transformed by the function

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

where $Y_{ijk}$ was the $\log_{10}$ transformation of $X_{ijk} + 1$ and $X_{ijk}$ was the adjusted catch in the $k^{th}$ interval at the $j^{th}$ statioon in the $i^{th}$ year. Transformation was necessary to achieve uniform variance among residuals.

Sources of variation in the numerical catch data of each species were determined by factorial analysis of variance of the transformed catch data in a fixed effects model. The station-interval and year-station-interval interactions were pooled to derive the error mean square sinxe neither interaction was of practical use in the analysis. Residual mean squares were unbiased estimates of error for the transformed data after deviations due to the main effects and interactions were accounted for in the total variance. All tests of significance were at the .05 level of probability.

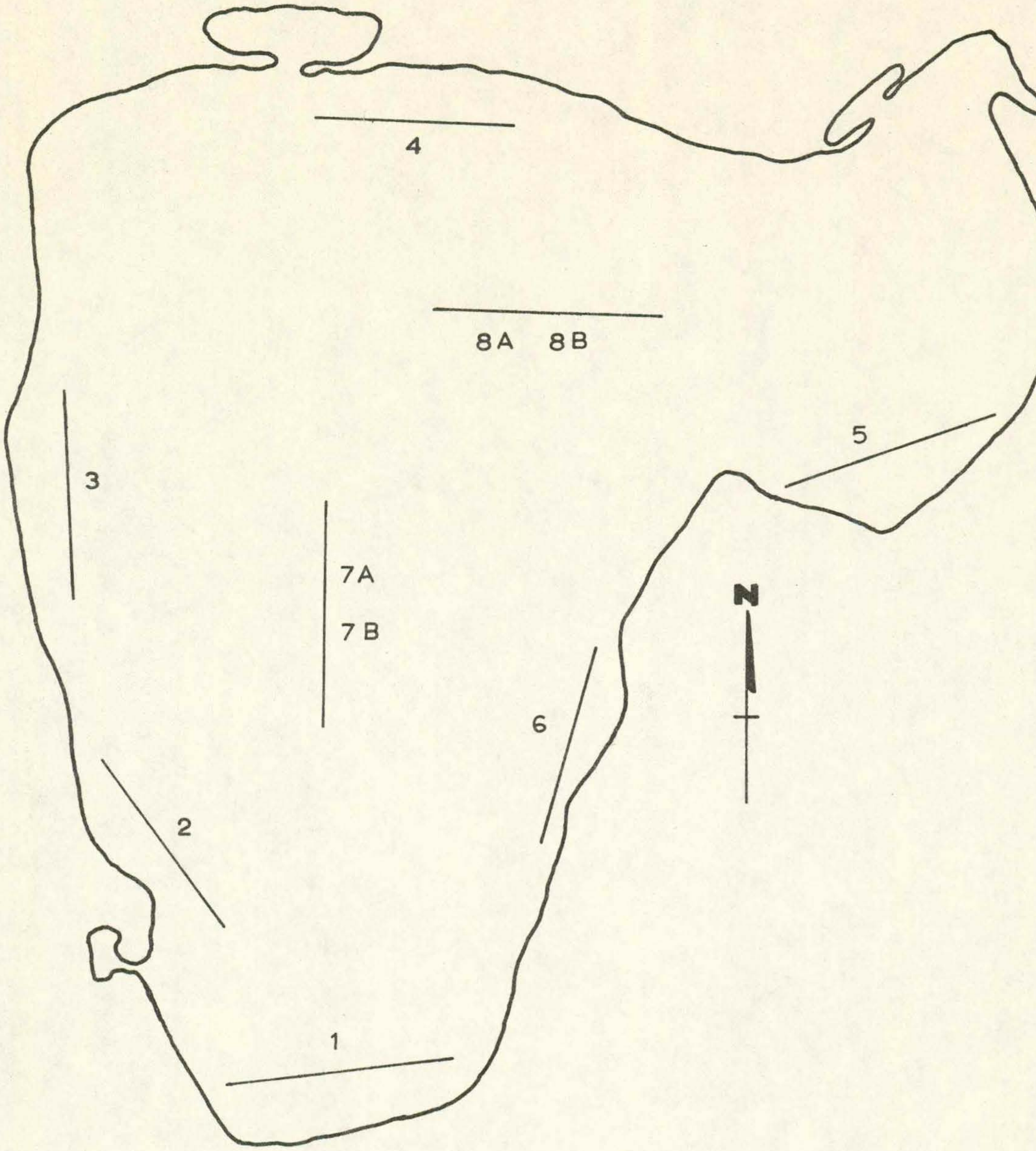


Figure 1. Location of sampling stations at Spirit Lake.

The numerical density of 0-age walleye and yellow perch was derived for each sampling interval for use in production estimates by volumetric extrapolation. The mean number of larval fish caught per sampling interval was multiplied by the number of tows containing 1,000 $m^3$ required to strain the entire lake volume. Volumetric stratification of Spirit Lake into sampling fractions was unnecessary in deriving numerical estimates because 0-age fish were distributed uniformly.

Production of 0-age walleye and yellow perch was computed by the function described by Ricker (see Chapman, 1968),

$$P = G\overline{B}$$

where P, represented total production, G equalled instantaneous growth and $\overline{B}$ mean biomass.

Mean biomass was computed as the mean body weight of the 0-age fish populations at the same sampling intervals.

Instantaneous growth was computed as the geometric change in body weight between sampling intervals from the equation

$$G = \frac{\log_e(wt_{n+1}) - \log_e(wt_n)}{\Delta t}$$

where G was the instantaneous growth coefficient, $wt_{n+1}$ was the mean weight in interval n + 1 and $wt_n$ was the mean weight in the preceeding interval.

Instantaneous mortality was computed from the geometric change in 0-age fish density from the peak numerical catch and each following interval by the function

$$Z = \frac{-(\log_e 2 - \log_e 1)}{\Delta t}$$

where $\log_e 2$ and 1 are the transformed catch means and $\Delta t$ the sample interval. Annual mortality (A) was computed in the usual fashion from a table of exponential functions. Survival was estimated as the compliment of annual mortality, where S = 1 - A.

Estimated contributions of stocked walleye to the 0-age walleye populations were measured by two methods. First, the contribution was determined as the percent of surviving stocked larvae to the estimated numerical population on the first sampling date. Second, the contribution was derived as a percent of stocked sac fry to the estimated survival of stocked fry plus naturally produced walleye larvae on the last day of stocking. Natural reproductive potential was estimated by multiplying the number of fry hatched per $m^2$ by 292 ha (720 ac), the area within the 3.1 m (10 ft) contours. Percent estimates of the contribution in succeeding intervals were constant, since factors influencing mortality would act on stocked and naturally produced laval walleye alike.

# FINDINGS

## *0-AGE WALLEYE ABUNDANCE AND DISTRIBUTION*

Abundance of 0-age walleye in the net tows decreased significantly between 1973 and 1974. Overall catch mean was 2.5 larvae per standardized tow haul in 1973 and .9 per tow in 1974. Seasonally, maximum catches of walleye larvae occurred during the first sampling interval both years and thereafter systematically decreased (Figure 2). The highest catch mean per tow net haul in 1973 was 13.9 fish per haul, decreasing to 3.9 fish in the next interval, followed by 3.4 fish in the third interval and 1.8 fish in the fourth sampling interval (Table 2).

In 1974, a similar decrease in catch occurred between the first and second sampling intervals, from 8.0 larvae in the first sampling interval to .4 larvae in the following interval (Table 2). No larval walleye were captured after the second sampling interval.

Walleye larvae were uniformly distributed throughout Spirit Lake both years (Table 3). Lack of significant variation precluded dividing the lake into volumetric fractions for computation of population density. Density of larval fish populations was computed directly from the mean catch in each sampling interval.

## *0-AGE WALLEYE SURVIVAL AND MORTALITY*

The instantaneous mortality in 1973 was estimated at .68 and in 1974 it was 2.99. Annual mortality was 49% and 95% for these seasons, respectively. Survival of walleye larvae was 51% and 5%.

Mortality during thefirst two sampling intervals was higher than other periods. In 1973 it was 72% and 94.9% in 1974. Noble (1972) found mortality of 95% and 96% among Oneida Lake walleye larvae for a two week period. Larval walleye at Oneida Lake were slightly larger ranging from 10-18 mm TL with larvae at Spirit Lake ranging from 9-15 mm TL during the two week period.

## *0-AGE WALLEYE GROWTH*

Total length of larval walleye was measured from 50 fish in 1973 and 30 fish in 1974. Weekly mean body length in 1973 was 8.8, 9.2, 11.3 and 15.4 mm TL from early through late May (Table 4). The length-weight relationship for larval walleye in 1973 was $\log_{10}W = -5.48 + 3.10 \log_{10}L$ ($r = .99$).

Total length of larval walleye in 1974 was 9.5 and 9.4 mm TL in the first two sampling intervals. Catch data were insufficient for computation of the length-weight relationship.

Growth of larval walleye during 1973 compared favorably with growth of 0-age walleye in the Little Cutfoot Sioux Lakes, Minnesota (Johnson, 1969) and in Oneida Lake, New York (Forney, 1966). Growth of Spirit Lake larval walleye also

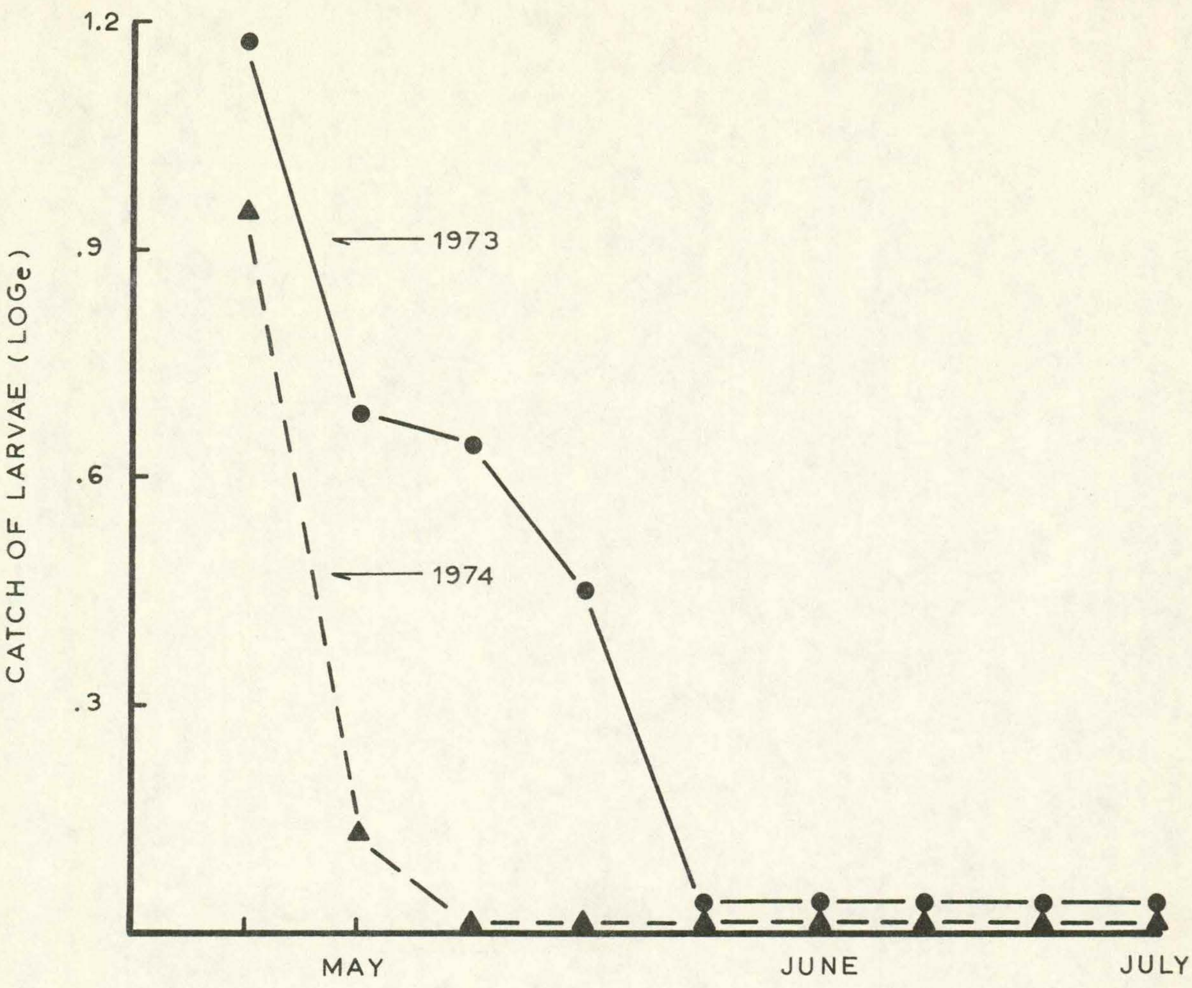


Figure 2. Mean catch of 0-age walleye in standardized .75 meter tow net hauls at Spirit Lake, 1973-1974.

Table 2. Catch of 0-age walleye in standardized .75 meter tow net hauls expressed in number per 1,000 $m^3$ at Spirit Lake, 1973-74. Catch values in each cell are the mean of two simultaneous tows in 1974.

| Year | 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 |

Table 3. Factorial analysis of variance in the numberical catch of 0-age walleye in Spirit Lake, 1973-74.

| Source of variation | df | SS | MS |
|---|---|---|---|
| Year | 1 | .97 | .97** |
| Station | 9 | .48 | .05 |
| Year x station | 9 | .87 | .01 |
| Interval | 8 | 10.00 | 1.25** |
| Year x interval | 8 | 1.27 | .16 |
| Residual | 144 | 11.80 | .08 |
| Total (corrected) | 179 | 25.40 | |

**Significant at the 99% level.

Table 4. Mean total length and length range of 0-age walleye in Spirit Lake, 1973-74.

| 1973 | | | | 1974 | | | |
|---|---|---|---|---|---|---|---|
| Sampling interval | Mean total length (mm) | Range (mm) | Number | Sampling interval | Mean total length (mm) | Range (mm) | Number |
| 5/7 -5/11 | 8.8 | 7.6-10.1 | 30 | 5/6 -5/10 | 9.5 | 8.3-10.7 | 29 |
| 5/14-5/18 | 9.2 | 8.5-10.0 | 9 | 5/13-5/17 | 9.4 | | 1 |
| 5/21-5/25 | 11.3 | 10.8-11.5 | 7 | 5/20-5/24 | [a] | | |
| 5/28-6/1 | 15.4 | 14.1-16.1 | 4 | 5/27-5/31 | [a] | | |
| 6/4 -6/8 | [a] | | | 6/3 -6/7 | [a] | | |
| 6/11-6/15 | [a] | | | 6/10-6/14 | [a] | | |
| 6/18-6/22 | [a] | | | 6/17-6/21 | [a] | | |
| 6/25-6/29 | [a] | | | 6/24-6/28 | [a] | | |
| 7/2 -7/6 | [a] | | | 7/1 -7/5 | [a] | | |

[a]No larval walleye captured.

compares closely with that at Clear Lake, Iowa for the first three weeks of May (Spykerman, 1973). However, larval walleye growth at Spirit Lake was considerably less than was found at Clear Lake during later May.

*PRODUCTION OF 0-AGE WALLEYE*

Total production of 0-age walleye in 1973 was 2.0 gms per hectare (gms/ha), decreasing to < .1 gms/ha in 1974. Production by sampling interval increased systematically from .3 gms/ha to 1.0 gms/ha in the first year (Table 5). In 1974, walleye larvae were captured during the first two sampling intervals, with total production of the two sampling intervals < .1 gms/ha.

The highest population density of larval walleye in 1973 was 718 per hectare (N/ha) (291 N/ac) in early May. Population density declining systematically to a minimum of 93 N/ha (38 N/ac) in the late May sampling interval. Maximum numerical density in 1974 was 418 N/ha (169 N/ac) in the early May sampling interval and decreased to 21 N/ha (8.0 N/ac) in the next period.

The total standing crop in 1973 decreased from 4 kg in the second sampling interval to 1.4 kg in mid-May followed by a steady increase thereafter. The total standing crop in 1974 paralleled the decrease in numerical density, declining from 2.8 kg in the first sampling interval to .2 kg in mid-May.

*CONTRIBUTION OF STOCKED WALLEYE LARVAE TO THE 0-AGE WALLEYE POPULATION*

During 1973, 18,000,000 walleye sac fry (8,300/ha, 3,360/ac) were planted in Spirit Lake from 6-9 May, with approximately equal daily distribution. The estimated numerical population on 10 May, based on tow net samples, was 718 ± 426 fry per ha (291 ± 175 fry per ac). On 10 May, by extrapolation, 6,475 ± 4,174 stocked larvae per ha (2,621 ± 1,690 per ac) survived, indicating the entire year class was stocked fish. Natural reproductive potential in 1973 was 8,468,000 (3,906 fry per ha, 1,581 per ac), of which 1,559 per ha (631 per ac) survived on 10 May. Based on these estimates stocked fry contributed 81% of the year class strength.

Nearly 9,225 larval walleye per ha (3,735 per ac) were stocked between 30 April and 3 May, 1974, with equal numbers released daily. The 0-age walleye population on 10 May was 418 ± 353 per ha (169 ± 142 per ac) of which 97 per ha (39 per ac) was estimated to be stocked fry. By division, stocked larvae comprised 23% of the 0-age walleye population, although the wide confidence limits revealed stocked fry could compose from 13% to the entire year class abundance. Estimates based upon the natural reproductive potential in 1974 revealed stocked fry composed 90% of the year class strength, with an estimated survival of 279 naturally produced fry/ha (113 fry/ac) and 2,761 stocked fry per ha (1,118 fry per ac) on the last stocking date.

*0-AGE YELLOW PERCH ABUNDANCE AND DISTRIBUTION*

The abundance of yellow perch decreased significantly ($P < .01$), from 116.6 fish per tow in 1973 to 23.0 fish per tow in 1974. Seasonally, catches of larval yellow perch declined significantly ($P < .01$), but the catch curves were similar each year (Figure 3). In 1973, catch mean increased from 263.1 larvae in early May to 405.3 per tow in the mid-May sampling interval, then declined sharply to

Table 5. Production of 0-age walleye at Spirit Lake, 1973-74.

| Sampling interval | Mean weight (g) | Instantaneous growth coefficient | Population size (N/ha) | Population biomass (kg) | Mean biomass (kg) | Production (gms/ha) |
|---|---|---|---|---|---|---|
| 1973 | | | | | | |
| 5/7 -5/11 | .026 | | 718 | 4.0 | | |
| | | .25 | | | 2.7 | .3 |
| 5/14-5/17 | .033 | | 201 | 1.4 | | |
| | | .71 | | | 2.0 | .7 |
| 5/21-5/25 | .067 | | 176 | 2.6 | | |
| | | .81 | | | 2.8 | 1.0 |
| 5/28-6/1 | .151 | | 93 | 3.1 | | |
| 6/4 -7/6 | [a] | | | | | |
| | | | | | Total production = 2.0 gms/ha | |
| 1974 | | | | | | |
| 5/6 -5/10 | .031 | | 418 | 2.8 | | |
| | | .06 | | | 1.4 | < .1 |
| 5/13-5/17 | .032 | | 21 | .2 | | |
| 5/20-7/5 | [a] | | | | | |
| | | | | | Total production = < .1 gms/ha | |

[a] One or fewer larval walleye captured.

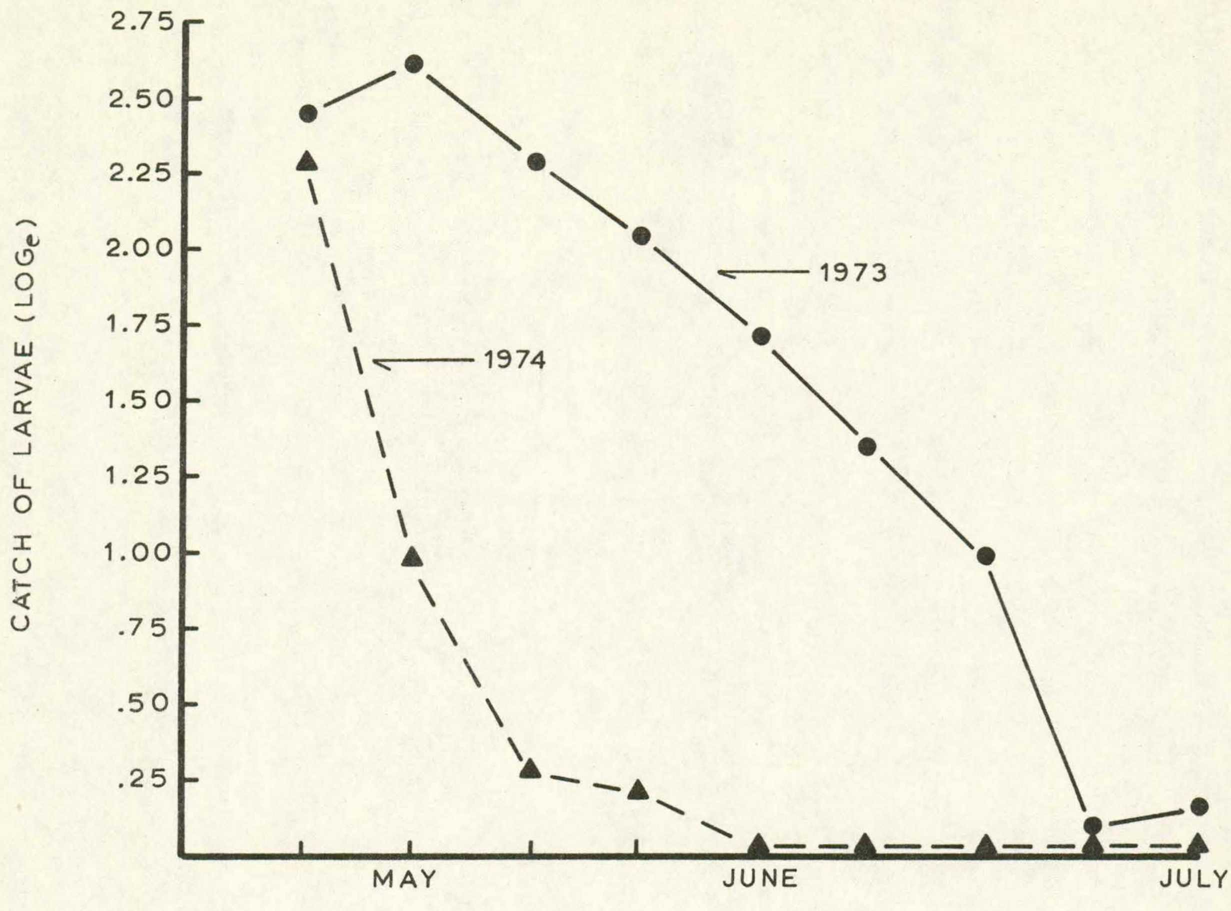


Figure 3. Catch means of 0-age yellow perch in standardized .75 meter tow net hauls at Spirit Lake, 1973-1974.

181.7 fish per haul in late May. The systematic decrease continued through the remaining sampling intervals (Table 6). Highest catch success in 1974 occurred during the early May sampling interval, 197.4 larvae per tow, then decreased sharply to 7.8 larval per tow net haul in the next period and continued decreasing to .8 larvae per tow in late May (Table 6). No larval yellow perch were captured during the first two periods in June and in early July, and only .2 larvae each were captured in mid- and late June intervals. The significant ($P < .05$) year-interval interaction showed high or low catch success in one interval during one year did not mean similar catches in the next year.

Yellow perch larvae were uniformly distributed throughout Spirit Lake, in both the horizontal and vertical attitudes (Table 7). High or low catches at a sampling station in one year did not mean it was always the same in the successive year.

## 0-AGE YELLOW PERCH SURVIVAL AND MORTALITY

In 1973, instantaneous mortality was .77 and in 1974 it was 1.69. Annual mortality was 54% and 82%, respectively. Survival, the complement of annual mortality, was 46% in 1973 and 18% in 1974.

## GROWTH OF 0-AGE YELLOW PERCH

Over the two seasons 527 larval yellow perch were measured for body length and weighed. The total in 1973 was 398 and 129 in 1974. Length-weight relationships for yellow perch were computed using linear regression;

$$\text{Log}_{10}W = a + \text{Log}_{10}L$$

where weight was in gms and length was in mm. The relationships were as follows:

$$1973 \quad - \text{Log}_{10}W = -5.94 + 3.67\ \text{Log}_{10}L \qquad (r = .99)$$

$$1974 \quad - \text{Log}_{10}W = -6.23 + 3.86\ \text{Log}_{10}L \qquad (r = .99)$$

Mean total length from early May through late June, 1973 was 5.4, 5.8, 8.3, 11.4, 13.1, 15.0 and 14.8 mm TL and 39.7 mm TL in the last period (Table 8). Size of captured perch during May, 1974 was greater than in 1973 reflecting earlier spawning. Mean total length was 6.1, 9.1, 9.5 and 15.0 mm TL in early May through late May with mean total length of 26.2 and 26.3 mm TL in the mid-June sampling intervals.

## 0-AGE YELLOW PERCH PRODUCTION

Total production of yellow perch was 149.4 gms/ha in 1973 and 8.1 gms/ha in 1974. Production for individual periods ranged up to a maximum of 38.5 gms/ha in mid-June (Table 9). In 1974, production ranged from .2 gms/ha in the last part of June to 5.8 gms/ha between the first and second sampling intervals (Table 10).

Table 6. Catch of 0-age yellow perch in .75 standardized meter tow net hauls expressed as number per 1,000 $m^3$ at Spirit Lake, 1973-74. Catch values in each cell are the mean of two simultaneous tows in 1974.

| Year | 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 | 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 |

Table 7. Factorial analysis of variance of 0-age yellow perch transformed catch data at Spirit Lake.

| Source of variation | df | SS | MS |
|---|---|---|---|
| Years | 1 | 25.67 | 25.67[**] |
| Station | 9 | 2.52 | .28 |
| Year x station | 9 | 5.85 | .65[*] |
| Interval | 8 | 70.27 | 8.78[**] |
| Year x interval | 8 | 15.52 | 1.94[**] |
| Residual | 144 | 46.64 | .32 |
| Total (corrected) | 179 | 166.46 | |

[*] Significant at the 95% level.

[**] Significant at the 99% level.

Table 8. Mean total length and length range of 0-age yellow perch in Spirit Lake, 1973-74.

| 1973 | | | | 1974 | | | |
|---|---|---|---|---|---|---|---|
| Sampling interval | Mean total length (mm) | Range (mm) | Number | Sampling interval | Mean total length (mm) | Range (mm) | Number |
| 5/7 -5/11 | 5.4 | 4.5- 6.6 | 81 | 5/6 -5/10 | 6.1 | 4.8- 7.7 | 87 |
| 5/14-5/18 | 5.8 | 4.9- 6.7 | 80 | 5/13-5/17 | 9.1 | 6.7-12.0 | 32 |
| 5/21-5/25 | 8.3 | 6.0- 9.6 | 59 | 5/20-5/24 | 9.5 | 8.0-10.7 | 5 |
| 5/28-6/1 | 11.4 | 8.2-13.8 | 87 | 5/27-5/31 | 15.0 | 13.8-17.0 | 3 |
| 6/4 -6/8 | 13.1 | 9.8-16.5 | 39 | 6/2 -6/7 | [a] | | |
| 6/11-6/15 | 15.0 | 10.9-22.6 | 21 | 6/10-6/14 | [a] | | |
| 6/18-6/22 | 14.8 | 11.1-29.8 | 18 | 6/17-6/21 | 26.2 | | 1 |
| 6/23-6/29 | [a] | | | 6/24-6/28 | 26.3 | | 1 |
| 7/2 -7/6 | 39.7 | 37.0-43.0 | 3 | 7/1 -7/6 | [a] | | |

[a] No larval yellow perch captured.

Table 9. Production of 0-age yellow perch at Spirit Lake, 1973.

| Sampling interval | Mean weight (g) | Instantaneous growth coefficient | Population size (N/ha) | Population biomass (kg) | Mean biomass (kg) | Production (gms/ha) |
|---|---|---|---|---|---|---|
| 5/7 -5/11 | .0069 | | 13,582 | 20.3 | | |
| | | - .21 | | | 22.9 | - 2.2 |
| 5/14-5/18 | .0056 | | 20,923 | 25.4 | | |
| | | 1.28 | | | 32.6 | 19.6 |
| 5/21-5/25 | .0202 | | 9,380 | 41.1 | | |
| | | 1.26 | | | 66.2 | 38.5 |
| 5/28-6/1 | .0710 | | 5,937 | 91.4 | | |
| | | .68 | | | 88.7 | 27.8 |
| 6/4 -6/8 | .1449 | | 2,741 | 86.1 | | |
| | | .84 | | | 81.2 | 31.5 |
| 6/11-6/15 | .3249 | | 1,084 | 76.4 | | |
| | | .09 | | | 53.8 | 2.2 |
| 6/18-6/22 | .3323 | | 434 | 31.2 | | |
| | | 1.46 | | | 47.5 | 32.0 |
| 6/25-6/29 | [a] | | | | | |
| 7/2 -7/6 | .6220 | | 83 | 11.4 | | |
| | | | | Total production = 149.4 gms/ha | | |

[a]No larval yellow perch captured.

Table 10. Production of 0-age yellow perch at Spirit Lake, 1974.

| Sampling interval | Mean weight (g) | Instantaneous growth coefficient | Population size (N/ha) | Population biomass (kg) | Mean biomass (kg) | Production (gms/ha) |
|---|---|---|---|---|---|---|
| 5/6 -5/10 | .0053 | | 10,190 | 11.7 | | |
| | | 1.74 | | | 7.2 | 5.8 |
| 5/13-5/17 | .0302 | | 403 | 2.6 | | |
| | | .48 | | | 1.6 | .4 |
| 5/20-5/24 | .0488 | | 52 | .5 | | |
| | | 1.94 | | | 1.2 | 1.1 |
| 5/27-5/31 | .2083 | | 41 | 18.6 | | |
| 6/3 -6/7 | [a] | | | | | |
| | | .68 | | | 1.8 | .6 |
| 6/10-6/14 | [a] | | | | | |
| 6/17-6/21 | 1.610 | | 11 | 36.0 | | |
| | | .09 | | | 3.8 | .2 |
| 6/24-6/28 | 1.761 | | 10 | 39.4 | | |
| 7/1 -7/5 | [a] | | | | | |

Total production = 8.1 gms/ha

[a]No larval yellow perch captured.

The highest numerical population in 1973 was 20,923 N/ha in the mid-June sampling interval. Standing crop increased steadily during May, from 20.3 kg to 91.4 kg, decreased until the last sampling interval when standing crop increased to 11.4 kg.

The maximum numerical population in 1974 was 10,190 N/ha in the first sampling interval. Population size decreased systematically to 10 N/ha in the late June sampling interval. Standing crop decreased from 11.7 kg in the first sampling interval, to .5 kg in mid-June sampling interval, then increased systematically to 39.4 kg in the late June period.

## DISCUSSION OF FINDINGS

Stocking of larval walleye to supplement natural reproduction in Spirit Lake has been conducted for several decades. Rose (1955), Carlander, et al. (1960) and Forney (1975) found fry stockings significantly increased population densities and year class abundance. Findings in this study revealed contributions of stocked fry to year class abundance were 100% in 1973 and 23% in 1974, based upon extrapolation of stocked fry to population density. In 1974, sampling of the 0-age fish populations commenced nearly a week after the last stocking date, with larval walleye captured during the first two sampling intervals. The catch curve based upon the two week period may represent only the tail portion of the entire catch curve. Estimates of the contribution of stocked fry to year class abundance in 1974 would therefore be biased, particularly if high mortality occurred, as suspected, prior to commencement of sampling. Estimates of the contribution of stocked walleye larvae to year class abundance utilizing natural reproductive potential were 81% in 1973 and 90% in 1974. In both years the number of walleye fry stocked was over twice the estimated reproductive potential.

Estimates of the contribution of stocked walleye fry to year class abundance for both years were over 80%, indicating fry stocking in Spirit Lake formed the year class base, with natural reproduction additionally strengthening year class abundance, which seems contrary to the original intent of these plantings. In this management regimen it is quite conceivable that the population density of walleye could be altered by merely changing the fry stocking density, except the main problem of stocking density remains unknown. In comparison, Ward and Clayton (1974) found the contribution of walleye fry significantly increased year class abundance in West Blue Lake, Manitoba, with estimates of 43% and 100%.

Production of larval walleye was nearly 100 times greater in 1973 than in 1974, with production of 0-age yellow perch nearly 20 times greater in 1973 than 1974. It was apparent from estimated standing crops and growth, production of walleye and yellow perch was generally influenced more by body weight than by numerical density.

Larval walleye were uniformally distributed throughout Spirit Lake. In contrast, Houde and Forney (1970) found walleye pro-larvae tended to drift passively with prevailing currents, then tended to concentrate in littoral zones.

Johnson (1969) also observed walleye larvae in limnetic zones shortly after hatching, returning to littoral zones after reaching 30-40 mm TL. Catch data from Spirit Lake showed few larvae were captured after reaching 16 mm TL, partially negating any conclusion concerning the movement of the larger walleye larvae.

0-age yellow perch abundance also decreased significantly between 1973 and 1974 also reflecting higher mortality and lower production. Yellow perch larvae were randomly distributed both horizontally and vertically in Spirit Lake. In contrast Noble (1972a) found yellow perch varied in horizontal distribution, with more fry found inshore than offshore, but were fairly uniformly vertically distributed.

## RECOMMENDATIONS

Sampling of the 0-age fish populations should continue using the same procedures during 1975.

## LITERATURE CITED

Carlander, K., R. Whitney, E. Speaker and K. Madden. 1960. Evaluation of walleye fry stocking in Clear Lake, Iowa by alternate year stocking. Trans. Am. Fish. Soc. 89(3):249-254.

Chapman, D. 1968. Production. IN Methods for Assessment of Fish Production in Fresh Waters. I.B.P. Handbook No. 3. Blackwell Scientific Publications.

Fish, M. 1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters. U.S. Bur. Fish. Bull. 47(10):293-398.

Forney, J. 1966. Factors affecting first-year growth of walleyes in Oneida Lake, New York. N.Y. Fish and Game J. 13(2):147-167.

________. 1975. Contribution of stocked fry to walleye fry populations in New York lakes. Prog. Fish. Cult. 37(1):20-25.

Houde, E. and J. Forney. 1970. Effects of water currents on the distribution of walleye larvae in Oneida Lake, New York. J. Fish. Res. Bd. Can. 27(3): 445-456.

Jennings, T. 1965. Spirit Lake walleye study, 1963. Ia. Cons. Comm., Quart. Biol. Rpts. Vol. XVII (1):28-32.

________. 1970. Progress report of Spirit Lake walleye studies, status of marked fingerling stocking study. Ia. Cons. Comm., Quart. Biol. Rpts. Vol. XXI (2):49-56.

Johnson, F. 1969. Environmental and species associations of the walleye in Lake Winnibigeshish and connecting waters, including observations of food habits and predator-prey relationships. Minn. Fish. Invest. No. 5:5-36.

Mansueti, A. 1964. Early development of the yellow perch, *Perca flavescens*. Cheasapeake Sci. Vol. 5, No. 1-2:46-66.

May, E. and C. Gasaway. 1967. A preliminary key to the identification of larval fishes of Oklahoma, with particular reference to Canton Reservoir, including a selected bibliography. Okla. Dept. Wildl. Conserv., Okla. Fish. Res. Lab., Bull. 5. 33 p.

Moen, T. 1961. Walleye population studies, Spirit Lake, 1961-62. Ia. Cons. Comm., Quart. Biol. Rpts., Vol. XIV(1):21-24.

Nelson, W. 1968. Embryo and larval characteristics of sauger, walleye and their reciprocal hybrids. Trans. Am. Fish. Soc. 97(2):167-197.

Noble, R. 1972. Mortality rates of walleye fry in a bay of Oneida Lake, New York. Trans. Am. Fish. Soc. 101(4):720-723.

__________. 1972a. Distribution of walleye and yellow perch fry in a bay of Oneida Lake. N.Y. Fish and Game J. 19(2):168-177.

Norden, C. 1961. The identification of larval yellow perch, *Perca flavescens*, and walleye, *Stizostedion vitreum*. Copeia 1961(3):282-288.

Ricker, W. 1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Bd. Can. Bull. No. 119.

Rose, E. 1965. The fluctuations in abundance of walleyes in Spirit Lake. Ia. Cons. Comm., Quart. Biol. Rpts. Vol. VI(4):27-35.

__________. 1959. The contribution of stocked fingerling walleyes to the adult population in Spirit Lake. Ia. Cons. Comm., Quart. Biol. Rpts. Vol. XI (2):21-23.

Spykerman, V. 1973. Food habits, growth, and distribution of larval walleye in Clear Lake, Iowa. M.S. Thesis, Iowa State University.

Ward, F. and J. Clayton. 1974. Initial effects of fry introduction on year-class strengths of West Blue Lake walleye, *Stizostedion vitreum vitreum*, (Mitchell) using fry with distinctive malate dehydrogenase isoyme phenotypes as an identifying mark. Dept. of Zool., Univ. of Manitoba, Canada.

ANNUAL PERFORMANCE REPORT

RESEARCH PROJECT SEGMENT

STATE: Iowa

STUDY NO.: 101-3

JOB NO.: 2

STUDY TITLE: 0-Age Production and Survival in Spirit Lake

JOB TITLE: Food utilization and competition by larval walleye and yellow perch

Period Covered: May, 1973 through July, 1974

ABSTRACT: Zooplankton samples were collected at the same time as samples of 0-age fish. Three genera of Cladocera and two genera of Copepoda were evaluated. Diaptomus were the most abundant organism, followed closely by Daphnia. These organisms were about 10 times more abundant than Chydorus, Bosmina, and Cyclops in Spirit Lake. There were no significant changes in the yearly abundances of Diaptomus or Cyclops; however, Daphnia, Bosmina and Chydorus had significant decrease in abundance between 1973 and 1974. Seasonal catch of all taxa, except Diaptomus, was highly variable. Cyclops and Daphnia were most numerous in May, with Chydorus and Bosmina most abundant in June. Horizontal distribution of all genera was variable, with higher density generally found at midwater sampling stations. Only Diaptomus and Daphnia had unequal vertical distribution, with higher density at subsurface stations. 0-age walleye utilized three genera, Diaptomus, Daphnia and Cyclops. Small walleye larvae (> 15.0 mm TL) showed a strong preference for Cyclops, and later in life they preferred Daphnia. 0-age yellow perch utilized all genera. Small yellow perch (13.0 mm TL or less) preferred Cyclops and Diaptomus, with larger fish preferring other genera at varying times.

Author: Dick McWilliams
Fisheries Research Biologist

Date Prepared: 1 July, 1974

Approved by: James Mayhew
Fisheries Research Supervisor

## *JOB 2 OBJECTIVE*

*To measure the abundance, distribution, utilization and competition for planktonic fish food organisms by larval and post-larval walleye and yellow perch.*

## INTRODUCTION AND STUDY BACKGROUND

One of the primary requirements for survival and development of year class abundance of fish is an adequate food supply. During early life stages the primary food of walleye and yellow perch are planktonic organisms, particularly zooplankton. For survival of larval fishes, zooplankton must be available and vulnerable. Marr (1956) suggested the lack of available fish food organisms, or other factors, may cause catastrophic mortality during critical periods in the early life history of fishes.

Three genera of *Cladocera* (*Daphnia*, *Bosmina* and *Chydorus*) and two genera of *Copepoda* (*Diaptomus* or *Cyclops*) were evaluated at Spirit Lake to determine their abundance, distribution, utilization and selectivity as food by 0-age yellow perch and walleye.

## METHODS AND PROCEDURES

Plankton samples were collected using a 2-liter Kemmerer water bottle with a total of 8 liters of water strained through a size 000 plankton net and preserved in 10% formalin for identification and enumeration.

In 1973, plankton samples were concentrated to 8 ml, but ranged from 6 to 15 ml. Four, 1 ml aliquots were placed in a Sedgewick-Rafter counting cell and the total number of zooplankton identified and enumerated. The mean number per ml was computed and extrapolated to obtain the total number of organisms per liter. Plankton samples in 1974 were concentrated to exactly 8 ml. Four, 1 ml aliquots were counted. The mean number of zooplankton per ml was estimated as number of organisms per liter (N/1). Zooplankton were identified to genus with keys by Pennack (1953) and Eddy and Hodson (1950).

Treatment of numerical catch data for each zooplankton genus followed the same procedures as used for catch data of 0-age fish. Variation in the catch attributable to non-random distribution of individual zooplankton genera was examined by linear comparisons. All tests of significance were made at the 95% level or higher.

Zooplankton utilization and selectivity by 0-age walleye and yellow perch was determined by examination of stomach contents. Sub-samples of walleye and yellow perch larvae from each sampling interval were preserved in 4% formalin after sorting and identification. Larvae of both species were washed and rinsed three times before dissection to flush off any organisms adhering to the body. The alimentary tract was teased away from the body and examined under a dissecting microscope.

An electivity index described by Ivlev (1961) was used to determine feeding selectivity. The indices, E, was calculated by

$$E = \frac{r_1 - p_1}{r_1 + p_1}$$

where $r_1$ was the relative occurrence of organisms expressed as a percentage in the stomach contents, and $p_1$ was the percent occurrence of the organisms in the samples. Values of E may range between ± 1, where selection of a taxa was expressed by index values from 0 to +1 and non-preferenece from 0 to -1.

## FINDINGS

### *ABUNDANCE AND DISTRIBUTION OF DIAPTOMUS*

There was nonsignificant ($P > .05$) change in the abundance of *Diaptomus* between years. Annual catch means were 17.4 N/l in 1973 (Table 11) and 16.9 N/l in 1974 (Table 12). Change in the seasonal abundance of *Diaptomus* was not significant, although the significant ($P < .05$) year-interval interaction revealed disperity in the catch of *Diaptomus* at different intervals each year. The peak mode in numerical abundance in 1973 was 34.5 N/l occurring in mid-May followed by a gradual decrease to 9.0 N/l in mid-June, then fluctuating through the last sampling interval (Figure 4). Numerical abundance in 1974 declined from 11.4 N/l to 4.1 N/l between the first and second sampling intervals then increased to the peak mode of 28.9 N/l in late May, followed by declining catches to 5.0 N/l and 5.4 N/l in the last two intervals. The peak mode in the numerical abundance of *Diaptomus* was approximately 14 days later in 1974.

Analysis of variance in the catch of *Diaptomus* among sampling stations revealed a highly significant ($P < .01$) difference in the vertical distribution (Table 13). Catch means were significantly greater at Stations 7B and 8B than at the surface. There was also significant ($P < .05$) horizontal variation among midwater stations with greater numbers found at Station 7 than Station 8. Catch means were 17.7, 25.8, 11.1, and 20.1 N/l at Stations 7A, 7B, 8A and 8B, respectively. *Diaptomus* was equally distributed among shallow water stations.

### *ABUNDANCE AND DISTRIBUTION OF CYCLOPS*

Overall catch means of *Cyclops* were 6.0 N/l in 1973 and 4.7 N/l in 1974, with no significant difference in population density ($P > .05$). Seasonal abundance of *Cyclops* was highly variable with significant differences among intervals ($P < .01$). The highly significant F-values for the year-interval interaction indicated population density changed at different intervals of each year. Seasonal

Table 11. Catch of *Diaptomus* in number per liter in standardized plankton samples at Spirit Lake, 1973.

| 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 |
| 1 | 11.6 | 13.5 | 0.2 | 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 | 25.4 | 34.5 | 26.7 | 18.3 | 10.3 | 9.0 | 13.0 | 6.2 | 18.9 |

Table 12. Catch of *Diaptomus* in number per liter in standardized plankton samples at Spirit Lake, 1974.

| Sampling station | Sampling interval 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 | 11.4 | 4.1 | 18.7 | 28.9 | 12.0 | 17.0 | 6.4 | 5.0 | 5.4 |

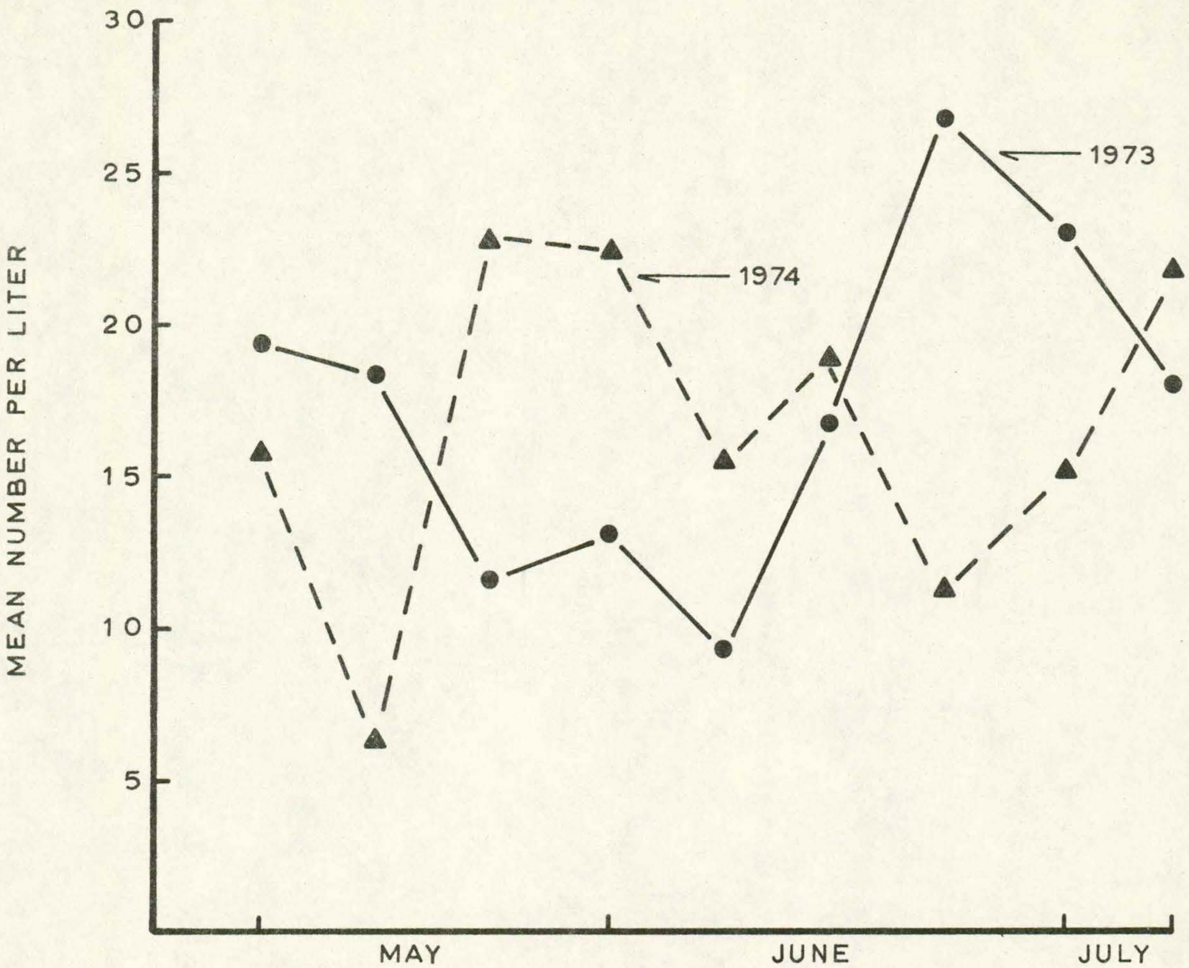


Figure 4. Seasonal distribution of *Diaptomus* at Spirit Lake, 1973-74.

Table 13. Factorial analysis of variance in the numerical catch of *Diaptomus* at Spirit Lake, 1973-74.

| Source of variation | df | SS | MS |
|---|---|---|---|
| Year | 1 | .040 | .040 |
| Station | (9) | (1.788) | (.199)** |
| Midwater vs shallow water | 1 | .156 | .156 |
| Among midwater | 3 | 1.412 | .450** |
| Among shallow water | 5 | .220 | .044 |
| Year x station | 9 | .748 | .083 |
| Interval | 8 | 1.007 | .126 |
| Year x interval | 8 | 4.389 | .549** |
| Residual | 144 | 9.492 | .066 |
| Total (corrected) | 179 | 17.456 | |

**Significant at the 99% level.

catch curves for both years revealed *Cyclops* was most abundant during May, and decreased during June and the first part of July (Figure 5). In 1973, the catch was unimodal increasing from 14.1 N/1 in early May to 18.8 N/1 in the following interval, then decreasing sharply to 6.7 N/1 by late May and gradually declining thereafter (Table 14). In 1974, the catch curve was bimodal with 9.4 N/1 during the first sampling interval, decreasing to 5.0 N/1 in the second sampling interval, increasing slightly to 10.0 N/1 in the third interval, and finally declining and maintaining approximately 2.5 N/1 during June and the first part of July (Table 15).

*Cyclops* was unequally distributed both horizontally and vertically in Spirit Lake. Catch means of shallow water stations were significantly ($P < .01$) lower than midwater station means (Table 16) with catch means at deep strata significantly higher ($P < .01$) than surface catch means. *Cyclops* were equally distributed among the shallow water stations. Catch means were 3.1, 4.9, 4.5, 5.0, 6.6 and 4.5 N/1 for Stations 1-6, and 4.1, 7.7, 4.2 and 8.3 N/1 for Stations 7A, 7B, 8A and 8B.

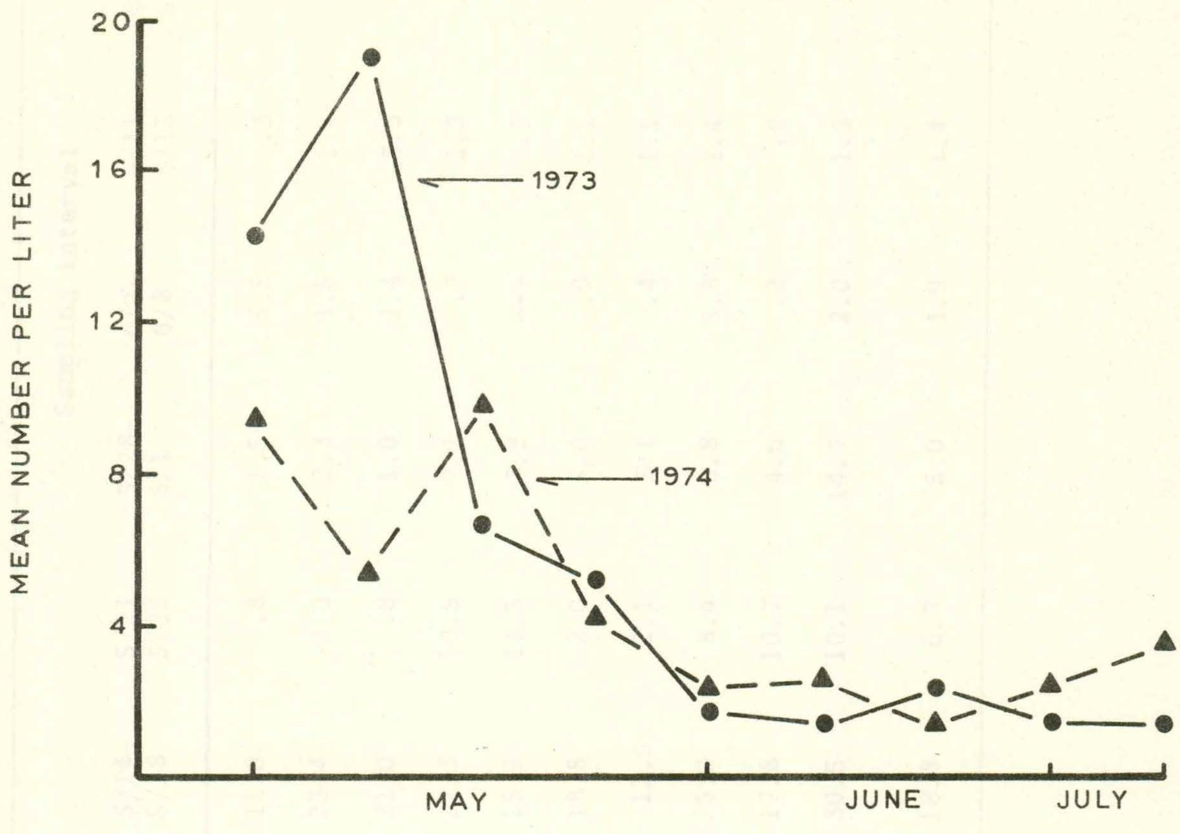


Figure 5. Seasonal distribution of *Cyclops* at Spirit Lake, 1973-74.

Table 15. Catch of *Cyclops* in number per liter in standardized plankton samples at Spirit Lake, 1974.

| Sampling station | Sampling interval | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 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 | --- | 2.3 | .7 | 4.0 | 5.7 |
| 3 | 4.3 | 7.0 | 10.0 | 1.0 | 1.0 | 3.3 | --- | 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 |

Table 16. Factorial analysis of variance in the numerical catch of *Cyclops* at Spirit Lake, 1973-74.

| Source of variation | df | SS | MS |
|---|---|---|---|
| Year | 1 | .003 | .003 |
| Station | (9) | (2.115) | (.235)** |
| Midwater vs shallow water | 1 | .491 | .491 |
| Among midwater | 3 | 1.268 | .423** |
| Among shallow water | 5 | .356 | .071 |
| Year x station | 9 | .466 | .052 |
| Interval | 8 | 11.229 | 1.404** |
| Year x interval | 8 | 2.647 | .331** |
| Residual | 144 | 6.929 | .048 |
| Total (corrected) | 179 | 22.970 | |

**Significant at the 99% level.

### *ABUNDANCE AND DISTRIBUTION OF DAPHNIA*

Mean population density of *Daphnia* decreased significantly (P < .01) from 18.0 N/l in 1973 to 12.1 N/l in 1974. Seasonal abundance also varied significantly (P < .01) both within years and between years (Figure 6). Catch means in 1973 showed the highest population density of *Daphnia* occurred in May, with a peak mode of 34.5 N/l during the mid-month interval, decreasing steadily through the last half of May and first part of June to 9.0 N/l in the mid-June sampling interval then fluctuating slightly during the last three sampling intervals (Table 17). During 1974, catch mean decreased from 11.4 N/l in early May to the lowest mean of 4.1 N/l in the second sampling interval. Catch increased steadily reaching a peak of 28.9 N/l in late May samples, with a smaller peak of 17.0 N/l in the mid-June samples (Table 18).

The analysis of variance in the catch of *Daphnia* among sampling stations revealed unequal horizontal and vertical distribution. Catch means between shallow water and midwater stations were significantly different at the 99% level with highest density in midwater stations (Table 19). *Daphnia* density was significantly higher at deeper strata than in surface samples. Catch mean for midwater stations were 10.9 N/l at Station 7A, 9.1 N/l at Station 8A, 27.1 N/l at Station 7B and 28.2 N/l at Station 8B. *Daphnia* were uniformily distributed among shallow water stations.

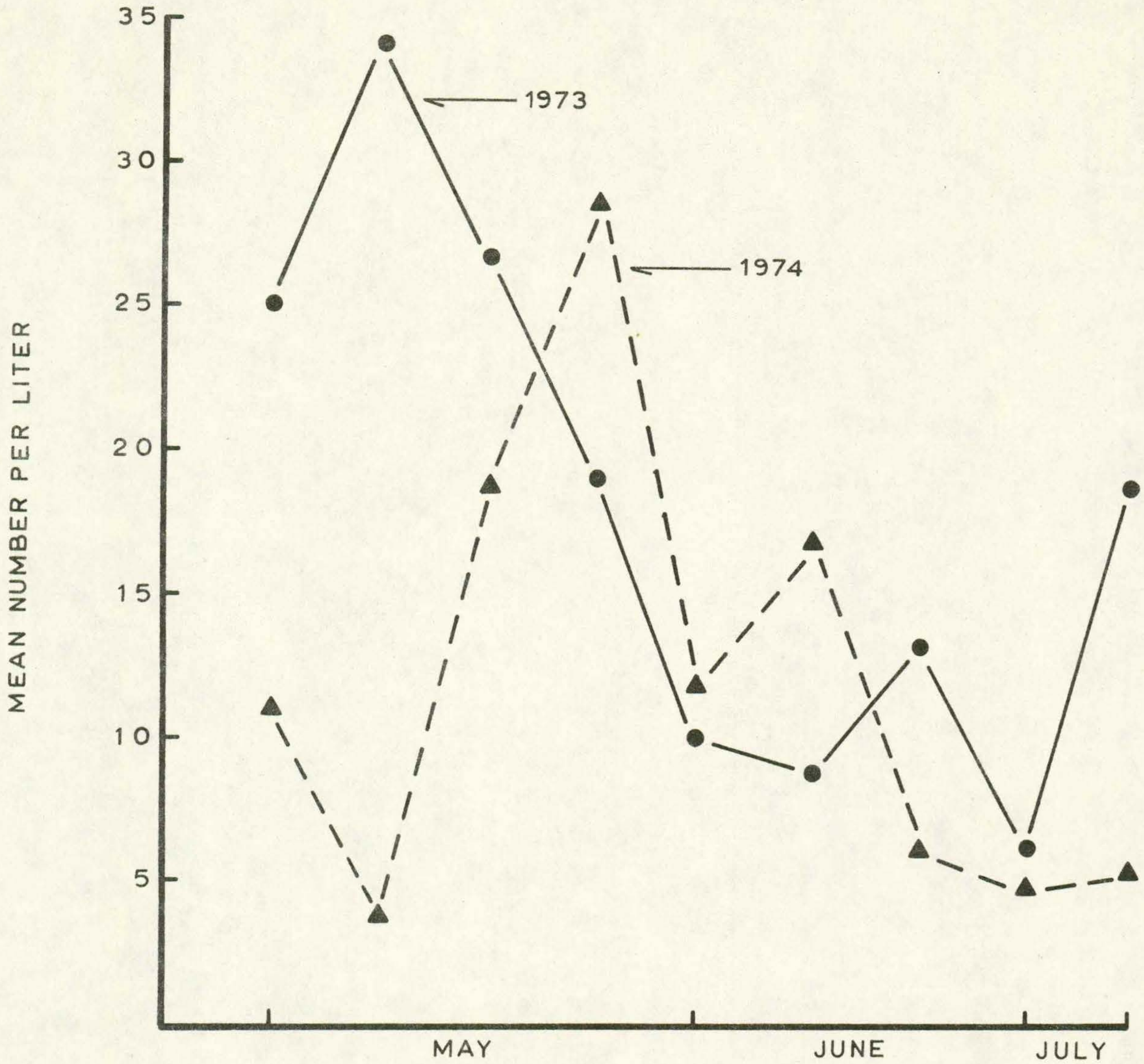


Figure 6. Seasonal distribution of *Daphnia* at Spirit Lake, 1973-74.

Table 17. Catch of *Daphnia* in number per liter in standardized plankton samples at Spirit Lake, 1973.

| 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 |
| 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 |

Table 18. Catch of *Daphnia* in number per liter in standardized plankton samples at Spirit Lake, 1974.

| Sampling station | Sampling interval | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 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 | --- | 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 |

Table 19. Factorial analysis of variance in the numerical catch of *Daphnia* at Spirit Lake, 1973-74.

| Source of variation | df | SS | MS |
|---|---|---|---|
| Year | 1 | 1.545 | 1.545** |
| Station | (9) | (5.689) | ( .632)** |
| Midwater vs shallow water | 1 | 1.564 | 1.564** |
| Among midwater | 3 | 3.995 | 1.332** |
| Among shallow water | 5 | .130 | .026 |
| Year station | 9 | .700 | .078 |
| Interval | 8 | 4.751 | .594** |
| Year x interval | 8 | 5.941 | .743** |
| Residual | 144 | 14.320 | .099 |
| Total (corrected) | 179 | 32.946 | |

**Significant at the 99% level.

## ABUNDANCE AND DISTRIBUTION OF CHYDORUS

The abundance of *Chydorus* decreased significantly ($P < .01$) from 1973 to 1974. Overall catch mean was 1.0 N/l in 1973 and .6 N/l in 1974. Variation in the catch attributable to sampling interval and the year-interval interaction were both highly significant ($P < .01$) indicating numerical catch changed at varying times between years (Figure 7). Peak modes of *Chydorus* in 1973 occurred in late May, and mid- to late June, with means of 1.8 N/l in the late May sampling interval, 2.9 N/l in the mid-June sampling interval and 1.1 N/l in the late June sampling intervals (Table 20). In 1974, the catch curves was unimodal, with peak abundance occurring in early June. Mean catch increased steadily from .3 N/l in the first sampling interval to 1.1 N/l in the early June sampling interval, then decreased steadily to .4 N/l in the last two sampling intervals (Table 21).

*Chydorus* were equally distributed vertically in the midwater samples, but unequally distributed horizontally in shallow water stations. Station catch means for midwater stations were 1.2, 1.4, .76, and 1.2 N/l for Stations 7A, 7B, 8A and 8B, respectively (Table 22). Testing by orthogonal contrasts showed the catch mean of Station 3, .3 N/l, was significantly ($P < .01$) lower than the other five shallow water stations. Catch means were .6, .5, .9, .6, and .8 N/l for other sampling stations.

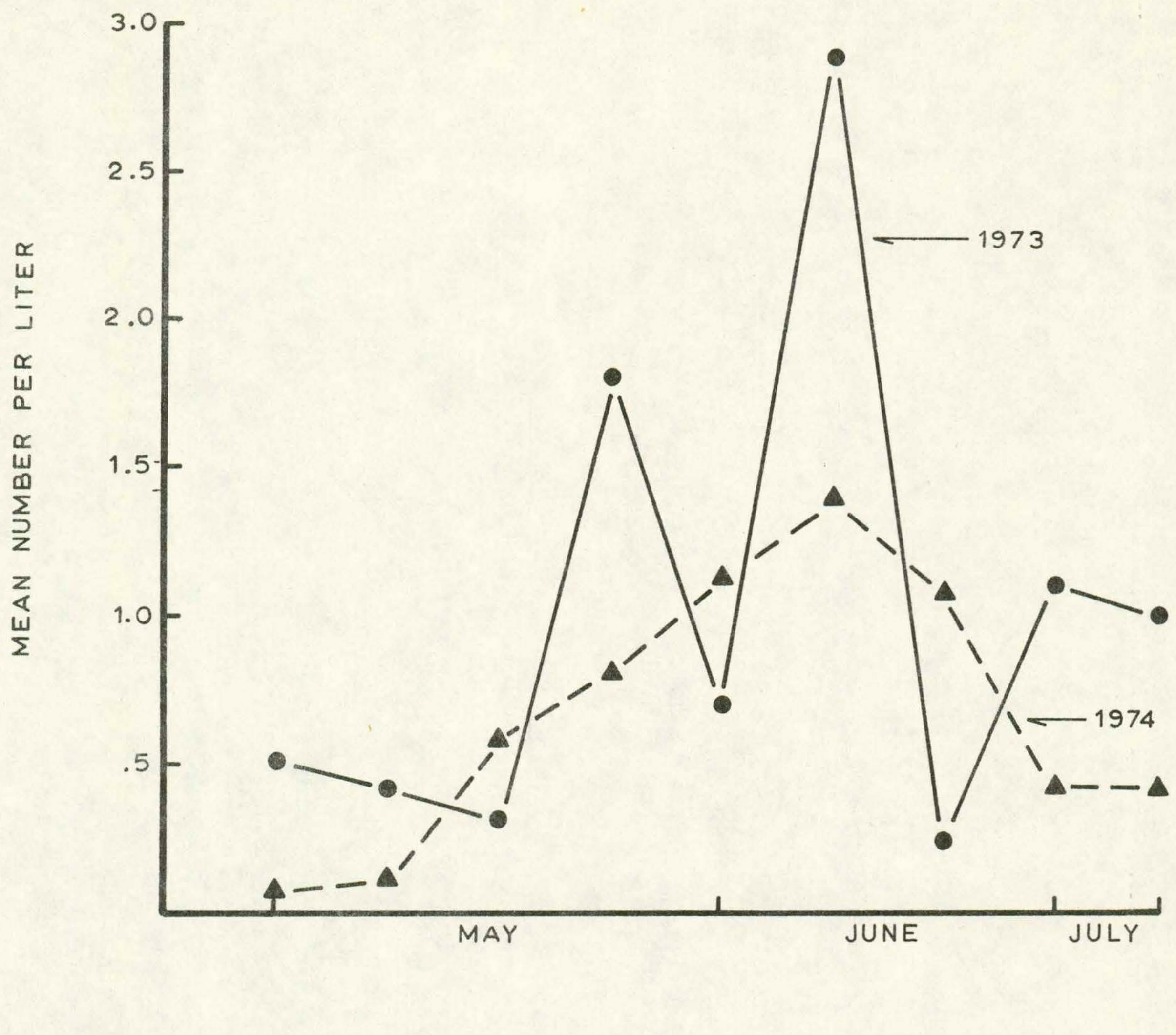


Figure 7. Seasonal distribution of *Chydorus* at Spirit Lake, 1973-74.

Table 20. Catch of *Chydorus* in number per liter in standardized plankton samples at Spirit Lake, 1973.

| 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 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | --- | .8 | --- | .9 | 1.8 | 1.0 | --- | .2 | .2 |
| 2 | --- | --- | --- | 2.8 | 1.5 | .6 | .4 | .4 | .2 |
| 3 | .8 | .5 | .3 | 1.5 | --- | .4 | .9 | .4 | .4 |
| 4 | 1.0 | .5 | .3 | 1.8 | --- | 1.3 | .7 | .7 | .7 |
| 5 | .3 | --- | .5 | .6 | .2 | .9 | .2 | 1.3 | .4 |
| 6 | .6 | --- | --- | 2.4 | .4 | 3.9 | .2 | .6 | 2.2 |
| 7A | .9 | .5 | .2 | 2.0 | .8 | 8.8 | --- | .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 |

Table 21. Catch of *Chydorus* in number per liter in standardized plankton samples at Spirit Lake, 1974.

| Sampling station | Sampling interval 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 | --- | --- | .7 | .3 | 2.0 | 1.3 | .7 | --- | --- |
| 2 | --- | --- | --- | .7 | .3 | .7 | 1.3 | --- | .3 |
| 3 | --- | --- | --- | .3 | --- | --- | --- | .3 | --- |
| 4 | --- | --- | --- | --- | 1.0 | 3.3 | 3.3 | 1.0 | 1.0 |
| 5 | --- | .3 | 1.0 | .7 | 2.0 | 1.3 | .7 | .3 | .3 |
| 6 | --- | --- | --- | --- | .3 | 2.3 | .7 | --- | --- |
| 7A | --- | --- | 1.0 | 2.3 | 1.3 | 1.0 | 1.0 | .3 | .3 |
| 7B | --- | .3 | .7 | 2.3 | 2.0 | 1.3 | 1.3 | 1.7 | --- |
| 8A | --- | --- | 2.0 | 1.0 | 1.0 | 1.0 | | --- | 1.0 |
| 8B | .3 | .7 | .3 | --- | .7 | 1.9 | 2.0 | --- | 1.0 |
| Mean | < .1 | .1 | .6 | .8 | 1.1 | 1.4 | 1.1 | .4 | .4 |

Table 22. Factorial analysis of variance in the numerical catch of *Chydorus* at Spirit Lake, 1973-74.

| Source of variation | df | SS | MS |
|---|---|---|---|
| Year | 1 | .238 | .238** |
| Station | (9) | (.752) | (.084)** |
| Midwater vs shallow water | 1 | .476 | .476** |
| Among midwater | 3 | .088 | .029 |
| Among shallow water | 5 | .188 | .038** |
| Year x station | 9 | .235 | .026 |
| Interval | 8 | 1.809 | .226** |
| Year x interval | 8 | .656 | .082** |
| Residual | 144 | 2.981 | .021 |
| Total (corrected) | 179 | 6.672 | |

**Significant at the 99% level.

## *ABUNDANCE AND DISTRIBUTION OF BOSMINA*

*Bosmina* abundance decreased significantly (P < .01) between 1973 and 1974 with catch means of 1.2 and .7 N/l. Seasonal distribution of *Bosmina* varied significantly (P < .01) with a significant year-interval interaction (P < .01) indicating catch periodicity also varied between years (Figure 8). The catch of *Bosmina* in 1973 was bimodal, with peak abundances recorded in mid-May and in early July. No *Bosmina* were caught during the first sampling interval in 1973 (Table 23). Mean catch decreased from 2.1 N/l in the second sampling interval to .1 N/l in the early June sampling interval, followed by increasing numbers to 4.8 N/l in the last sampling interval. Seasonal catch means in 1974 showed modes in mid-May, early June and the first part of July. Catch means generally increased from .1 N/l in early May to 1.0 N/l in the late May sampling interval. A second mode appeared in mid-June with 2.0 N/l followed by a decrease and a gradual increase to 1.0 N/l in the last sampling interval (Table 24).

*Bosmina* showed significant variation in horizontal distribution at the 99% level among shallow water stations (Table 25). The mean catch at Station 4 was significantly higher than the other stations. Station means for the six stations were .5, 1.1, 1.0, 1.3, .6 and .6 N/l, respectively.

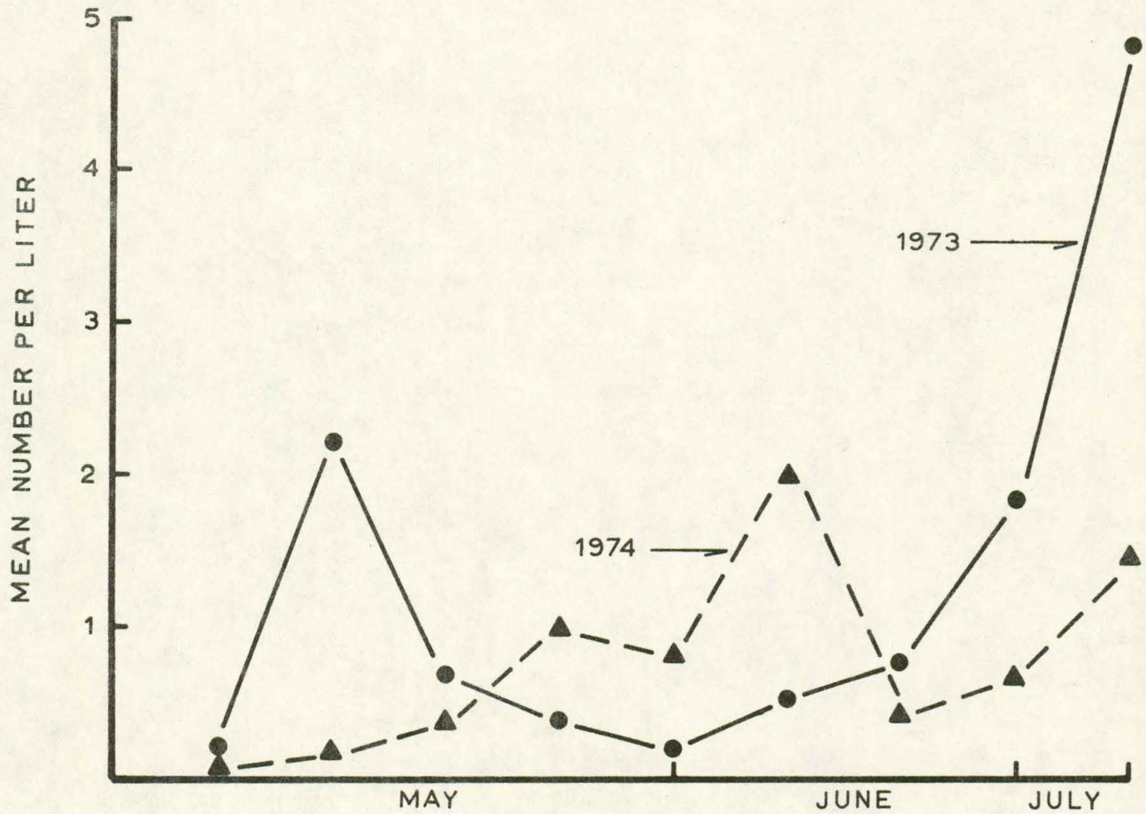


Figure 8. Seasonal distribution of *Bosmina* at Spirit Lake, 1973-74.

Table 23. Catch of *Bosmina* in number per liter in standardized plankton samples in Spirit Lake, 1973.

| Sampling station | 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 |
|---|---|---|---|---|---|---|---|---|---|
| | Sampling interval | | | | | | | | |
| 1 | --- | .3 | --- | .7 | .4 | --- | .8 | .7 | 2.4 |
| 2 | --- | 6.2 | .5 | .6 | --- | --- | --- | 1.1 | 6.4 |
| 3 | --- | 1.8 | 1.3 | .3 | --- | 1.8 | 1.1 | .7 | 5.3 |
| 4 | --- | 3.3 | .8 | .7 | --- | .8 | 2.2 | 3.3 | 6.6 |
| 5 | --- | --- | .3 | --- | --- | --- | .9 | .9 | 2.4 |
| 6 | --- | .5 | --- | .2 | .2 | .2 | .2 | --- | 5.0 |
| 7A | --- | 3.8 | .2 | --- | --- | 1.1 | .2 | 1.5 | 4.2 |
| 7B | --- | 1.5 | 2.0 | .2 | --- | .4 | .4 | 3.0 | 2.3 |
| 8A | --- | 1.3 | .6 | .7 | --- | .4 | --- | 5.3 | 9.2 |
| 8B | --- | 2.3 | .3 | .4 | .2 | .4 | 1.1 | 1.5 | 4.4 |
| Mean | --- | 2.1 | .6 | .4 | .1 | .5 | .7 | 1.8 | 4.8 |

Table 24. Catch of *Bosmina* in number per liter in standardized plankton samples at Spirit Lake, 1974.

| Sampling station | Sampling interval | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 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 | --- | --- | .7 | --- | 1.7 | --- | .3 | .3 |
| 2 | --- | .3 | .3 | 1.0 | --- | 1.0 | .3 | 2.3 | --- |
| 3 | --- | --- | .7 | .7 | .7 | 3.0 | --- | --- | .3 |
| 4 | --- | --- | --- | --- | .3 | 3.3 | .7 | --- | 1.7 |
| 5 | --- | --- | 1.7 | .7 | .3 | 1.0 | .3 | 1.0 | .7 |
| 6 | .3 | --- | .3 | --- | --- | 2.3 | .3 | .3 | .3 |
| 7A | --- | --- | .3 | 3.0 | 1.0 | 4.0 | 1.0 | --- | 1.7 |
| 7B | --- | .3 | --- | 2.3 | 1.0 | 2.7 | .7 | 1.3 | .7 |
| 8A | .3 | --- | .3 | .3 | 1.0 | .3 | --- | .7 | .3 |
| 8B | .5 | --- | .7 | 1.7 | 2.3 | .8 | .3 | --- | 1.0 |
| Mean | .1 | .1 | .4 | 1.0 | .7 | 2.0 | .4 | .6 | 1.0 |

Table 25. Factorial analysis of variance in the numerical catch of *Bosmina* at Spirit Lake, 1973-74.

| Source of variation | df | SS | MS |
|---|---|---|---|
| Year | 1 | .201 | .201** |
| Station | (9) | (.463) | (.051) |
| Midwater vs shallow water | 1 | .147 | .147** |
| Among midwater | 3 | .030 | .010 |
| Among shallow water | 5 | .286 | .057** |
| Year x station | 9 | .340 | .039 |
| Interval | 8 | 2.810 | .351** |
| Year x interval | 8 | 2.726 | .341** |
| Residual | 144 | 3.316 | .023 |
| Total (corrected) | 179 | 9.866 | .055 |

**Significant at the 99% level.

## ZOOPLANKTON UTILIZATION BY 0-AGE WALLEYE

Stomach contents of 0-age walleye were examined to determine utilization of zooplankton for food and to determine food preference. Findings of stomach examinations were grouped by sampling interval.

A total of 46 stomachs were examined in 1973 and 22 in 1974. Mean length of 0-age walleye examined in 1973 were 8.9, 9.3, 11.3 and 15.0 mm TL in the first four sampling intervals (Table 26). Mean lengths in 1974 were 9.9 and 9.8 mm TL in the first two intervals and ranged from 8.9 to 10.5 mm TL.

Walleye larvae with a body length of < 10 mm in 1973 had most or part of the yolk material present, and only 2 fish consumed zooplankton. Larval walleye in 1974 were similar with only 1 of 22 larvae examined containing zooplankton. No other food organisms were found in this size range.

Table 26. Number, mean body length and range of 0-age walleye examined for stomach contents at Spirit Lake, 1973-74.

| Year | Sampling Interval | Number of fish | Mean length (mm) | Range (mm) |
|---|---|---|---|---|
| 1973 | 5/7 -5/11 | 26 | 8.9 | 7.6-10.0 |
| | 5/14-5/18 | 9 | 9.3 | 8.7-10.4 |
| | 5/21-5/25 | 7 | 11.3 | 10.8-12.3 |
| | 5/28-6/1 | 4 | 15.0 | 14.0-15.9 |
| 1974 | 5/6 -5/10 | 21 | 9.9 | 8.9-10.5 |
| | 5/13-5/17 | 1 | 9.8 | --- |

*Diaptomus* was consumed by larval walleye during a single sampling interval each year. In 1973, *Diaptomus* were found in stomach contents during the late May sampling interval, contributing 27.3% of the food consumed for the 10.8-12.3 mm TL range (Table 27). The following year *Diaptomus* was the only food organism found in larvae ranging from 8.9-10.5 mm TL (Table 28).

Electivity indices for *Diaptomus* in 1973 show only a slight preference. The index was +.40 in 1974, but only 1 or 22 larvae examined consumed food organisms.

*Cyclops* was the most important food items during the first two sampling intervals in May, 1973 contributing 50-100% of the total walleye stomach contents in the 7.6-10.4 mm TL range. None were found in 1974. Electivity indices showed *Cyclops* were selected by walleye with values of +.36, +.60 and +.31.

*Diaphnia* was absent in the diet of small larval walleye, but increased in importance as the size increased. In mid-May, *Daphnia* contributed 9.1% of the total food consumed in walleye ranging from 10.8-12.3 mm TL. In late May *Daphnia* contributed 87.5% to the food of walleye ranging from 14.0-15.9 mm TL. Electivity indices show *Daphnia* was not preferred in the 10.8-12.3 mm TL range, but was selected by walleye in the 14.0-15.9 mm TL range with an index of +.50.

*Chydorus* and *Bosmina* were not found in the stomach contents of larval walleye.

Table 27. Number of stomachs examined and percent composition of zooplankton in 0-age walleye at Spirit Lake, 1973-74.

| Sampling interval | Number of stomachs examined | Number of empty stomachs | *Diaptomus* | | *Cyclops* | | *Daphnia* | |
|---|---|---|---|---|---|---|---|---|
| | | | N | % | N | % | N | % |
| 1973 | | | | | | | | |
| 5/7 -5/11 | 26 | 25 | | | 1 | 50.0 | | |
| 5/14-5/18 | 9 | 8 | | | 1 | 100.0 | | |
| 5/21-5/25 | 7 | 1 | 3 | 27.3 | 3 | 27.3 | 1 | 9.1 |
| 5/28-6/1 | 4 | 1 | | | | | 7 | 87.5 |
| 6/4 -7/6 | [a] | | | | | | | |
| 1974 | | | | | | | | |
| 5/6 -5/10 | 21 | 20 | 1 | 100.0 | | | | |
| 5/13-5/17 | 1 | 1 | | | | | | |
| 5/20-7/5 | [a] | | | | | | | |

[a]No larval walleye captured during the sampling interval.

Table 29. Number, mean body length and range of 0-age yellow perch examined for stomach contents at Spirit Lake, 1973-74.

| Year | Sampling interval | Number of fish | Mean length (mm) | Range (mm) |
|---|---|---|---|---|
| 1973 | 5/7 -5/11 | 20 | 5.2 | 4.3- 5.7 |
| | 5/14-5/18 | 46 | 6.2 | 5.3- 7.1 |
| | 5/21-5/25 | 50 | 8.4 | 7.3-10.7 |
| | 5/28-6/1 | 83 | 11.7 | 9.5-13.8 |
| | 6/4 -6/8 | 40 | 13.2 | 11.1-16.5 |
| | 6/11-6/15 | 21 | 14.9 | 11.1-21.8 |
| | 6/18-6/22 | 18 | 14.8 | 11.2-29.8 |
| | 6/25-6/29 | -- | | |
| | 7/2 -7/6 | 3 | 39.7 | 37.0-43.0 |
| 1974 | 5/6 -5/10 | 44 | 6.0 | 5.0- 7.7 |
| | 5/13-5/17 | 25 | 9.2 | 6.7-12.0 |
| | 5/20-5/24 | 5 | 9.5 | 8.0-10.7 |
| | 5/27-5/31 | 2 | 16.2 | 15.5-17.0 |
| | 6/3 -6/7 | -- | | |
| | 6/10-6/14 | -- | | |
| | 6/17-6/21 | 1 | 26.2 | |
| | 6/24-6/28 | 1 | 26.3 | |
| | 7/1 -7/5 | -- | | |

Table 30. Number of stomachs examined and percent composition of zooplankton in 0-age yellow perch at Spirit Lake, 1973-74.

| Sampling interval | Number of stomachs examined | Number of empty stomachs | *Diaptomus* N | *Diaptomus* % | *Cyclops* N | *Cyclops* % | *Daphnia* N | *Daphnia* % | *Chydorus* N | *Chydorus* % | *Bosmina* N | *Bosmina* % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1973 | | | | | | | | | | | | |
| 5/7 -5/11 | 20 | 20 | | | | | | | | | | |
| 5/14-5/18 | 46 | 40 | | | 5 | 71.4 | | | | | | |
| 5/21-5/25 | 50 | 12 | 32 | 46.4 | 24 | 34.8 | 1 | 1.4 | | | | |
| 5/28-6/1 | 83 | 7 | 102 | 82.3 | 8 | 6.5 | 9 | 7.3 | | | | |
| 6/4 -6/8 | 40 | 10 | 46 | 39.6 | 8 | 6.9 | 41 | 35.3 | | | 6 | 5.2 |
| 6/11-6/15 | 21 | 1 | 48 | 25.1 | 7 | 3.7 | 55 | 28.8 | 8 | 4.2 | 51 | 26.7 |
| 6/18-6/22 | 18 | 2 | 4 | 8.7 | 7 | 15.2 | 18 | 39.1 | | | 11 | 23.9 |
| 6/25-6/29 | [a] | | | | | | | | | | | |
| 7/2 -7/6 | 3 | 0 | | | 7 | 6.1 | 98 | 86.0 | | | | |
| 1974 | | | | | | | | | | | | |
| 5/6 -5/10 | 44 | 41 | | | | | | | | | | |
| 5/13-5/17 | 25 | 7 | 19 | 73.1 | 4 | 15.4 | 1 | 3.8 | | | | |
| 5/20-5/24 | 5 | 0 | 7 | 77.8 | 1 | 11.1 | | | | | | |
| 5/27-5/31 | 2 | 0 | 3 | 23.1 | 3 | 23.1 | | | 1 | 7.7 | 3 | 23.1 |
| 6/3 -6/7 | [a] | | | | | | | | | | | |
| 6/10-6/14 | [a] | | | | | | | | | | | |
| 6/17-6/21 | 1 | 0 | 2 | 10.0 | | | 10 | 50.0 | | | 5 | 25.0 |
| 6/24-6/28 | 1 | 0 | 4 | 17.4 | 3 | 13.0 | 14 | 60.9 | | | 1 | 4.3 |
| 7/1 -7/5 | [a] | | | | | | | | | | | |

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

The importance of *Daphnia* and *Bosmina* as food increased with greater body size. In 1973, *Daphnia* comprised only 1.4% in fish ranging from 7.3-10.7 mm TL and increased to 86% in perch ranging from 37.0-43.0 mm TL. A similar change in the importance of *Daphnia* was found in 1974, with a 3.8% occurrence in larval yellow perch ranging from 6.7-12 mm TL to 60.9% in yellow perch about 26 mm TL.

*Bosmina* comprised 26.7% of the food organisms in larval perch in the 11.1-21.8 mm TL range and 23.9% in larvae in the 11.1-29.8 mm TL range in 1973. In 1974, 25% occurred in mid-June at a body length of 20.2 mm TL and 23.1% in larval perch ranging from 15.5-17.0 mm TL.

*Chydorus* were found in the stomachs of larval yellow perch during only one sampling interval in 1973, and made up 4.2% of the organisms.

Electivity indices for *Diaptomus* showed larval yellow perch in the 6-10 mm TL range preferred *Diaptomus* with indices of +.31 and +.41 for two sampling intervals in late May, 1973 (Table 31), and +.30 and +.29 for two sampling intervals in late May, 1974. As yellow perch larvae increased in size *Diaptomus* were utilized at a lesser rate with indices of -.01, -.36 and -.63 in 1973 and -.25, -.68 and -.57 in 1974.

No preference for *Daphnia* was shown by yellow perch in 1973, with indices ranging from -.95 for perch in the 7.3-10.7 mm TL range to -.05 for larvae in the 11.2-29.8 mm TL range. In 1974, *Daphnia* was not preferred by smaller yellow perch (6.7-12.0 mm TL range), but selected by larvae captured in late June with indices of +.24 and +.49.

*Chydorus* was found in the stomach contents of yellow perch during a single sampling interval each year. Electivity indices showed *Chydorus* was not selected in 1973 (-.37) but the value was reversed to +.71 in 1974.

*Bosmina* were not found in larval yellow perch stomach contents until they attained 11 mm TL or larger. Electivity indices revealed *Bosmina* was selected by perch and were the most preferred food item. In 1973, indices were +.87, +.89 and +.37 in June with yellow perch ranging from 11.1-29.8 mm TL. In 1974, indices were +.86, +.87 and +.26 for perch ranging from 15.5-26.3 mm TL.

## DISCUSSION OF FINDINGS

There were no significant changes in the abundance of *Copepoda*, *Diaptomus*, or *Cyclops* between 1973 and 1974; however, *Cladocera*, *Daphnia*, *Chydorus* and *Bosmina* decrease significantly. Seasonal catches for all taxa, except *Diaptomus* was highly variable. Furthermore, high catches at one interval in a year did not mean it was abundant in the following year. *Cyclops* and *Daphnia* populations were most abundant in May each year. *Cyclops* gradually declined through the remaining sampling intervals, while *Daphnia* had secondary modes in June each year. *Chydorus* populations were usually low. *Chydorus* was most abundant in mid-June each year with the lowest population density in early and mid-May. The population abundance of *Bosmina* was also low. Modes of *Bosmina* were irregular, peaking in mid-May in 1973 and mid-June in 1974, with increasing populations in both years during the later sampling intervals.

Table 31. Electivity indices for zooplankton of 0-age yellow perch at Spirit Lake, 1973-74.

| Year | Sampling interval | *Diaptomus* | *Cyclops* | *Daphnia* | *Chydorus* | *Bosmina* |
|---|---|---|---|---|---|---|
| 1973 | 5/7 -5/11 | | | | | |
| | 5/14-5/18 | | +.48 | | | |
| | 5/21-5/25 | +.31 | +.41 | -.95 | | |
| | 5/28-6/1 | +.41 | -.32 | -.73 | | |
| | 6/4 -6/8 | -.01 | -.01 | -.12 | | +.87 |
| | 6/11-6/15 | -.36 | -.10 | | -.37 | +.89 |
| | 6/18-6/22 | -.63 | +.61 | -.05 | | +.37 |
| | 6/25-6/29 | | | | | |
| | 7/2 -7/6 | | +.24 | -.33 | | |
| 1974 | 5/6 -5/10 | | | | | |
| | 5/13-5/17 | +.30 | -.32 | -.73 | | |
| | 5/20-5/24 | +.29 | -.25 | | | |
| | 5/27-5/31 | -.25 | +.48 | | +.71 | +.86 |
| | 6/3 -6/7 | | | | | |
| | 6/10-6/14 | | | | | |
| | 6/17-6/21 | -.68 | | +.24 | | +.87 |
| | 6/24-6/28 | -.57 | +.11 | +.49 | | +.28 |
| | 7/1 -7/4 | | | | | |

*Diaptomus* and *Daphnia* showed unequal vertical distribution in midwater stations, with higher populations concentrated at the lower sampling depths. *Cyclops*, *Chydorus* and *Bosmina* were equally distributed vertically. Horizontal distribution was quite variable for all genera, with generally higher populations at midwater.

Walleye larvae 10 mm TL or less did not consume zooplankton with only 3 of 36 larvae examined having discernible food organisms in stomach contents. In all cases, larval walleye in this size range had yolk material remaining. Spykerman (1973) found a similar situation at Clear Lake, Iowa. Tills and Norden (1968) found stocked walleye larvae did not start to feed actively until 5 to 7 days after stocking. During 1973, none of the stocked walleye fry would have reached this transitional period during the first sampling interval, and some, not by the second sampling date. In 1974, stocked walleye fry would have been at the end of the transitional period by the first sampling date. After commencement of feeding, food utilization indicated a strong preference for *Cyclops*. Spykerman (1973), Houde (1967) and Preigel (1970) also found *Cyclops* to a preferred food of walleye larvae. Food preferences for walleye was apparently not related to zooplankton abundance since *Daphnia* and *Diaptomus* were the most abundant zooplankton in early May each year. It is doubtful if walleye larvae exert enough influence on these populations to significantly lower abundance. Larval walleye apparently changed food preferences in late May, selecting *Daphnia*, with a slight preference for *Diaptomus*, although they may have been ingested coincidentally along with *Daphnia*. *Cyclops* was absent from the stomach contents of the fish examined. *Bosmina* and *Chydorus* were never utilized. Paulus (1969) found *Bosmina* utilized by Lake Erie walleye larvae.

Yellow perch larvae approximately 6 mm TL or less did not feed actively, with only 9 larvae of 110 examined in this size range containing food organisms. Yellow perch ranging from 4.3-6.5 mm TL, and including all larvae with no food organisms, contained varying amounts of yolk material.

Active feeding started when larval yellow perch were around 7 mm TL. After feeding commenced, perch between 5.3-13 mm TL showed preferences for *Cyclops* and *Diaptomus*. There was some competition for food between yellow perch and walleye for food, particularly *Cyclops*. *Chydorus* was preferred by yellow perch in the 11.1-25.0 mm TL range, when there was a shift in food preferences to *Cyclops*. *Daphnia* and *Bosmina* were selected periodically, but with no definite trends evident.

*Diaptomus* and *Daphnia* were the most abundant zooplankton in Spirit Lake and were the most important organisms in the food composition of larval perch. *Diaptomus* was a preferred food organism. Although *Daphnia* were generally not a preferred food organism, it appears the abundance of this taxa makes it an important item in the diet of yellow perch larvae.

## RECOMMENDATIONS

Sampling of the plankton populations should be continued using the same procedures in 1975. Computations of the number of zooplankton per liter will be changed to examining 3 ml per sample instead of 4 ml.

## LITERATURE CITED

Eddy, S. and A. Hodson. 1961. Toxonomic keys to the common animals of the North Central states. Burgess Publishing Co., Minneapolis, Minnesota. 162 p.

Houde, E. 1967. Food of pelagic young of the walleye, *Stizostedion vitreum vitreum*, in Oneida Lake, New York. Trans. Am. Fish. Soc. 96(1):17-24.

Ivlev, Y. 1961. Experimental ecology of feeding of fishes. Yale Univ. Press, New Haven, Conn. 302 p.

Marr, J. 1956. The "critical period" in the early life history of marine fishes. J. Cons. Int. Explor. Mer. 21(2):160-170.

Paulus, R. 1969. Walleye food habits in Lake Erie. Ohio Dept. of Nat. Res. Ohio Fish Monogr. No. 2, 45 p.

Pennak, R. 1953. Freshwater invertebrates of the United States. The Ronald Press Co., New York. 769 p.

Priegel, G. 1970. Reproduction and early life history of the walleye in the Lake Winnebago Region. Wisc. Dept. of Nat. Res., Tech. Bull. 45, 105 p.

Spykerman, V. 1973. Food habits, growth, and distribution of larval walleye in Clear Lake, Iowa. M.S. Thesis, Iowa State University.

ANNUAL PERFORMANCE REPORT

RESEARCH PROJECT SEGMENT

STATE: Iowa

STUDY NO.: 101-3

JOB NO.: 3

STUDY TITLE: 0-Age Production and Survival in Spirit Lake

JOB TITLE: Natural reproduction of walleye

Period Covered: May, 1973 through July, 1974

ABSTRACT: *Walleye egg samples were collected at various intervals during the spring each year, with the number of collections dependent upon spawning activity and length of incubation. A total of 17.56 $m^2$ of substrate was sampled on each date. Samples were collected in areas containing good to prime habitat for walleye spawning. Maximum recorded egg density was 116.1 eggs/$m^2$ in 1973 and 4.2 eggs/$m^2$ in 1974, with embryo survival of 2.5% in 1973 and 4.0% in 1974. Estimated number of fry hatched per $m^2$ was 2.9 in 1973 and 1.1 in 1974.*

Author: Dick McWilliams
Fisheries Research Biologist

Date Prepared: 1 July, 1974

Approved by: James Mayhew
Fisheries Research Supervisor

*JOB 3 OBJECTIVE*

*To determine the magnitude and primary cause of embryonic mortality in naturally produced walleye eggs in Spirit Lake.*

## INTRODUCTION AND BACKGROUND

Primary factors in the development of year class abundance of walleye are egg deposition, fertility and survival of the embryo to hatching time. Egg deposition is obviously dependent on the number of mature spawners as well as habitat spawning requirements and the extent of suitable habitat within a lake or stream. Walleye prefer a rock-rubble substrate for spawning activities, in water from 25 to 76 cm (10-30 inches) deep (Harlan and Speaker, 1956; Johnson, 1961; and others).

Johnson (1961), Harlan and Speaker (1956) found walleye utilize many types of substrate for spawning activities, with embryo survival directly related to substrate type. Johnson (1961) found walleye egg survival was best on gravel-rubble substrates, fair on firm, clean sand substrates and poor on soft muck-detritus bottom. Based on these criteria, much of the western shoreline of Spirit Lake was classified as rock-rubble, although plant detritus was present in some areas. Observations of spring gill netting operations indicated the shoreline was preferred by walleye for spawning.

## METHODS AND PROCEDURES

Egg samples were collected using a .9 x .9 m (3 ft x 3 ft) square quadrate, .9 m (3 ft) deep. The frame was constructed of 12 mm (.5 inch) diameter steel rods, covered with screen wire of .001 guage with 36 meshes per $cm^2$.

The quadrate was placed in water from 25-75 cm deep (10-30 inches) and worked carefully into the bottom to prevent eggs from entering or extruded under the frame during collection. A 15.2 cm (6 inches) diameter rubber plunger was used to loosen eggs from the substrate. Current produced by vigorous vertical movements of the plunger brought eggs and debris to the surface where they were skimmed off. The process was repeated until no eggs were collected in two consecutive attempts. The samples were preserved in 10% formalin for sorting and identification.

Seven stations were sampled on each date, with three subsamples collected at each station. Total substrate area sampled was 17.56 $m^2$ along the west shoreline on each date.

The percent of egg survival was derived by the equation

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

where ES was egg survival in percnet, $NE_t$ was the number of viable eggs on the last sampling date, $A_t$ was the total area sampled on the last sampling date, and $D_{max}$ was the maximum density of eggs per unit.

Estimates of the number of walleye fry produced was derived as the

$$\text{Fry/area} = \frac{\text{No. eyed eggs}_t}{\text{total area sampled}_t}$$

product of the number of eyed eggs on the last sampling date and the total area sampled on the last date.

## FINDINGS

Maximum recorded egg density was 116.1 eggs/$m^2$ in 1973 and 27.1 eggs/$m^2$ in 1974 (Table 32). Previous embryonic studies at Spirit Lake showed maximum egg density varied greatly, from 4.2 eggs/$m^2$ in 1969 to 5,040 eggs/$m^2$ in 1966 (Jennings, 1969; and unpublished data),with the maximum density in 1966 about 10 times greater than any other density. In comparison, Johnson (1961) found maximum egg density of 64.6 eggs/$m^2$ on the rock-rubble-gravel substrates at Lake Winnibigoshish, Minn., which compares favorably with the density found in Spirit Lake.

Embryonic survival at Spirit Lake in 1973 was an estimated 2.5% and 4.0% the next year. Jennings (1969) reported walleye embryo survival varied from .1% in 1966 to 34.4% in 1968, averaging nearly 10% annually, considerably higher than 1973 and 1974. Embryonic survival on similar substrate types in Lake Winnibigoshish, Minn. was also considerably higher than Spirit Lake, with estimates of 17.5-17.9% (Johnson, 1961).

The estimated number of fry hatched in 1973 was 2.9 fry/$m^2$, declining to 1.1 fry/$m^2$ in 1974. These compare favorably with previous estimates at Spirit Lake which ranged from .11 fry/$m^2$ to 6.56 fry/$m^2$, averaging 1.67 fry/$m^2$ over an 8-year period. Johnson (1961) estimated fry production ranged from 9.9-49.1 fry/$m^2$ at Lake Winnibigoshish, Minn., with both estimates considerably higher than Spirit Lake.

## DISCUSSION OF FINDINGS

Maximum egg density recorded in 1973-74 were similar to previous years at Spirit Lake. Egg fertility ranged between 2.5-42% and averaged 22.2% (Moen, 1950). Previous findings indicated good potential exists for natural reproduction at Spirit Lake. However, embryo survival of walleye in 1973 and 1974 was from 6-7.5% below the previous 8-year average. The low embryonic survival also reflected the low estimated number of fry hatched per $m^2$.

Table 32. Estimated natural walleye larvae 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| Maximum egg density per $m^2$ quadrate | 305.6 | 24.1 | 6,040.7 | 78.5 | 4.6 | 4.2 | 695.1 | 127.1 | 116.1 | 27.1 |
| Total area in $m^2$ sampled on last sampling date | 13.48 | 6.69 | 5.02 | 5.86 | 10.04 | 14.22 | 17.56 | 17.56 | 17.56 | 17.56 |
| Total number of eggs collected on last sampling date | 55 | 161 | 572 | 18 | 6 | 47 | 1,606 | 16 | 130 | 119 |
| Total number of viable eggs on last sampling date | 2 | 44 | 10 | 2 | 16 | 2 | 40 | 2 | 51 | 19 |
| Estimated number of fry per $m^2$ | .22 | 6.56 | 2.04 | .32 | 1.61 | .14 | 2.37 | .11 | 2.90 | 1.08 |
| Estimated percent egg survival | > .1 | 27.0 | > .1 | .43 | 34.4 | 3.3 | 2.5 | 12.5 | 2.5 | 4.0 |

[a]Jennings, 1969.

Johnson (1961) found water temperatures had a direct influence on embryo survival, with the best survival during years of warmer water and thereby shorter incubation periods. Preigel (1970) found water temperatures did not have noticeable effect on walleye embryo survival. Both studies indicated walleye egg survival was poor when the eggs came into contact with soft detritus materials. Both factors exist in Spirit Lake along the west shoreline and might be influencing embryo survival and natural production of walleye.

## RECOMMENDATIONS

Egg collections should be continued using the same procedures.

## LITERATURE CITED

Harlan, J. and E. Speaker 1951. Iowa fish and fishing. State of Iowa, Des Moines, Iowa. 237 p.

Jennings, T. 1969. Progress report of Spirit Lake walleye studies, natural reproduction. Ia. Cons. Comm., Quart. Biol. Rpts. Vol. XXI(3):10-14.

Johnson, F. 1961. Walleye egg survival during incubation on several types of bottom in Lake Winnibigoshish, Minnesota, and connecting waters. Trans. Am. Fish. Soc. 90(3):312-322.

Moen, T. 1950. Notes on the natural spawning of walleyes in Spirit Lake. Ia. Cons. Comm., Quart. Biol. Rpts. Vol. I(3):70-72.

Priegel, G. 1970. Reproduction and early life history of the walleye in the Lake Winnebago Region. Wisc. Dept. of Nat. Res., Tech. Bull. 45. 105 p.

# ANNUAL PERFORMANCE REPORT

## RESEARCH PROJECT SEGMENT

STATE: Iowa

STUDY TITLE: Dynamics of Predator-Prey Relationship in DeSoto Bend Lake

STUDY NO.: 402-3

JOB NOS: 1-4

Period Covered: 1 April, 1974 through 31 March, 1975

ABSTRACT: *Major fish species were studied in DeSoto Bend Lake, a 310 ha (770 ac) man-made oxbow in western Iowa to determine predator-prey relationships, food habits of predator species and standing crop. Population estimates of largemouth bass and channel catfish were 20,987 ± 2,765 and 10,243 ± 3,520, respectively. Standing crops of each species studied (age 1 and older) were: largemouth bass 38.9 ± 5.1 kg/ha (34.9 ± 4.6 lbs/ac), channel catfish 27.3 ± 9.4 kg/ha (24.4 ± 8.4 lbs/ac), shortnose gar 36.2 ± 9.3 kg/ha (32.3 ± 8.3 lbs/ac), gizzard shad 173.6 ± 70.4 kg/ha (155.0 ± 62.9 lbs/ac), carp 122 ± 49.9 kg/ha (108.9 ± 43.7 lbs/ac), river carpsucker 52.4 ± 11.6 kg/ha (46.6 ± 10.3 lbs/ac), freshwater drum 15.8 ± 6.9 kg/ha (14.1 ± 6.1 lbs/ac), bluegill 21.1 ± 3.5 kg/ha (18.9 ± 3.1 lbs/ac), black crappie 11.5 ± 3.4 kg/ha (10.3 ± 3.0 lbs/ac), and white crappie 10.5 ± 4.6 kg/ha (9.4 ± 4.1 lbs/ac). Largemouth bass fed almost exclusively on young fish with gizzard shad found in a majority of the stomachs, while channel catfish fed mostly on chironomids. Total standing crop estimate of the ten species (age 1 and older) was 509.3 ± 173.1 kg/ha (454.8 ± 154.6 lbs/ac).*

Author: Kay Hill
Fisheries Research Biologist

Date Prepared: 1 May, 1975

Approved by: James Mayhew
Fisheries Research Supervisor

## *STUDY OBJECTIVE*

*To investigate the dynamics of predator-prey relationships in DeSoto Bend by determining population densities and other biological characteristics of major predatory fish populations, the food consumption and selectivity of major predators, the interrelationship and population abundance of predator fish on forage fish populations, and the standing crop of major species.*

## INTRODUCTION

DeSoto Bend Lake is one of the most popular oxbow lakes in western Iowa because of its close proximity to metropolitan areas, public accessibility and highly developed recreation facilities. Fishing is one of the most important type of recreation at DeSoto Bend Lake with approximately 20,000 fisherman hours of use recorded during a fishery survey from April-September in 1973.

Three agencies, Iowa Conservation Commission, Nebraska Game and Parks Commission, and Bureau of Sport Fisheries and Wildlife, mutually agreed to manage the fishery in DeSoto Bend Lake. Most of the management emphasis consisted of population inventories, sport fishery surveys, and fish stockings in an attempt to establish a sport fishery.

Past fishery surveys and inventories disclosed different results ranging from good to poor sport fish populations. In 1961, a Bureau of Sport Fisheries and Wildlife survey revealed the presence of 11 fish species with largemouth bass, channel catfish, and balck crappie most numerous. A survey in 1962 by Iowa revealed 15 fish species with carp, buffalo, gizzard shad, carpsucker, and gar dominating the fish population. An inter-agency inventory in 1963, discosled 23 fish species with bluegill, carp, crappie, largemouth bass, and gizzard shad most numerous. A 1965 survey by Iowa indicated the most numerous fish species were gizzard shad, carp, buffalo, largemouth bass, carpsucker, crappie, and bluegill. The Fisheries Division of Nebraska Game and Parks Commission in 1966 stated carp and crappie were the only species of fish caught by fishermen and recommended chemical complete renovation because rough fish population would probably increase. A 1968 survey revealed large populations of carp and gizzard shad and small numbers of channel catfish and largemouth bass. By 1970, the three conservation agencies confirmed the density of undesirable fishes exceeded an acceptable level for a sport fishery and agree to total chemical renovation for October, 1971. Channel catfish was the only game fish species in significant number, but they were not important in the sport fishery. Lack of coordination among agencies and lack of funds caused postponement of the renovation project. To date no additional consideration of renovation has been proposed by any inter-agency member of the management group.

Several supplemental fish stockings occurred in DeSoto Bend Lake since 1961 to improve sport fish populations. Twenty thousand largemouth bass fingerlings were stocked in 1961, while in the following year, 160,000 largemouth bass fingerlings were planted (Table 1). No additional largemouth bass were stocked until 1965 when 34,500 fingerlings were added.

Table 1. Fish stockings at DeSoto Bend Lake from 1961-1971.

| Species | Size | Number |
|---|---|---|
| 1961 | | |
| Lm bass | Fingerling | 20,000 |
| 1962 | | |
| Lm bass | Fingerling | 160,000 |
| Walleye | Fry | 2,000,000 |
| Walleye | Fingerling | 44,000 |
| W bass | Adult | 1,700 |
| C catfish | Fingerling | 80,000 |
| 1963 | | |
| Lm bass | Fingerling | 139,000 |
| C catfish | Fingerling | 53,000 |
| N pike | Fry | 50,000 |
| Walleye | Fry | 3,000,000 |
| Walleye | Fingerling | 140,000 |
| 1964 | | |
| Walleye | Fry | 4,000,000 |
| 1965 | | |
| Lm bass | Fingerling | 34,000 |
| 1966 | | |
| Walleye | Fry | 750,000 |
| Walleye | Fingerling | 50,000 |
| 1969 | | |
| Bullhead | Adult | 9,000 |
| 1970 | | |
| Bullhead | Adult | 3,500 |
| Y perch | Fingerling | 20,000 |
| 1971 | | |
| Bullhead | Adult | 3,500 |
| 1972 | | |
| N pike | Fry | 100,000 |
| N pike | Fingerling | 10,000 |

More effort was expended attempting to build a walleye fishery. During 1962, 2 million walleye fry and 44,000 walleye fingerlings were added to DeSoto Bend Lake. Three million walleye fry were stocked in 1963 and 4 million in 1964. An additional 140,000 walleye fingerling were introduced in 1963. Again during 1966, 750,000 walleye fry and 50,000 walleye fingerling were stocked.

Five additional fish species were added to DeSoto Bend Lake. In 1962, 80,000 channel catfish fingerlings and 1,700 adult white bass were stocked. An additional 53,000 channel catfish fingerling were placed in the lake during 1963. Northern pike were stocked in 1963 and 1972, with 50,000 fry being added in 1963 and 100,000 fry and 10,000 fingerling stocked in 1972. Nine thousand adult bullheads were introduced in 1969 and 3,500 adult bullheads stocked in 1970 and 1971. One stocking of 20,000 yellow perch fingerling was made in 1970.

All of the available historical data on the fishery at DeSoto Bend Lake indicated channel catfish and largemouth bass were the most prevalent predatory species. The primary objective of this study was to make an intensive survey of the dynamics of the predator-prey relationship in DeSoto Bend Lake. Supportive objectives were to estimate population densities and other biological characteristics of major predators, to determine food habits and selectivity of these predators and to estimate the standing crop of other species including carp, smallmouth and bigmouth buffalo, carpsucker, freshwater drum, and centrarchids.

## DESCRIPTION OF DESOTO BEND LAKE

DeSoto Bend Lake is a 310 ha (770 ac) man-made oxbow located 9.7 km (6 miles) west of Missouri Valley, Iowa. It is located in DeSoto Bend National Wildlife Refuge which is managed for migratory waterfowl as a feeding and nesting area. The lake was formed in 1959 when a bend of the Missouri River was separated from the main river channel by two earth and rock levees. Inlet and outlet structures connecting the lake with the Missouri River allow partial control of the lake water level.

DeSoto Bend Lake is a long, 12.1 km (7.5 miles) narrow horseshoe shaped lake. It has a mean width of 247 m (752 ft) with a 411 m (1,252 ft) maximum width. Maximum depth at 301.6 m MSL is 10.6 m (39 ft) and mean depth of 3.6 m (10 ft). Bottom slope is quite steep ranging from 3.8% to 48.5% with a mean slope of 4.1%. Thermal stratification usually occurs at a depth of 1-2 m (3-6 ft) intermittantly throughout the summer (Huggins, 1968).

The lake receives limited surface runoff water from Rand's Ditch, Young's Ditch and Coulthard's Ditch (Figure 1). Surface runoff is mostly from tillable land. Sedimentary turbidity was low except for a belt up to 15 m (49 ft) adjacent to shore. This area of increased turbidity is caused from wave action from wind and boating. Increased turbidity occurred periodically from plankton blooms and after periods of extreme runoff. Rooted aquatic vegetation was abundant from May through June forming a continuous aquatic macrophyte community around the entire shoreline extending 10-20 m (33-66 ft) outward. After June this vegetation belt was partially destroyed from the shear forces of wave action and from the increased turbidity of wave action.

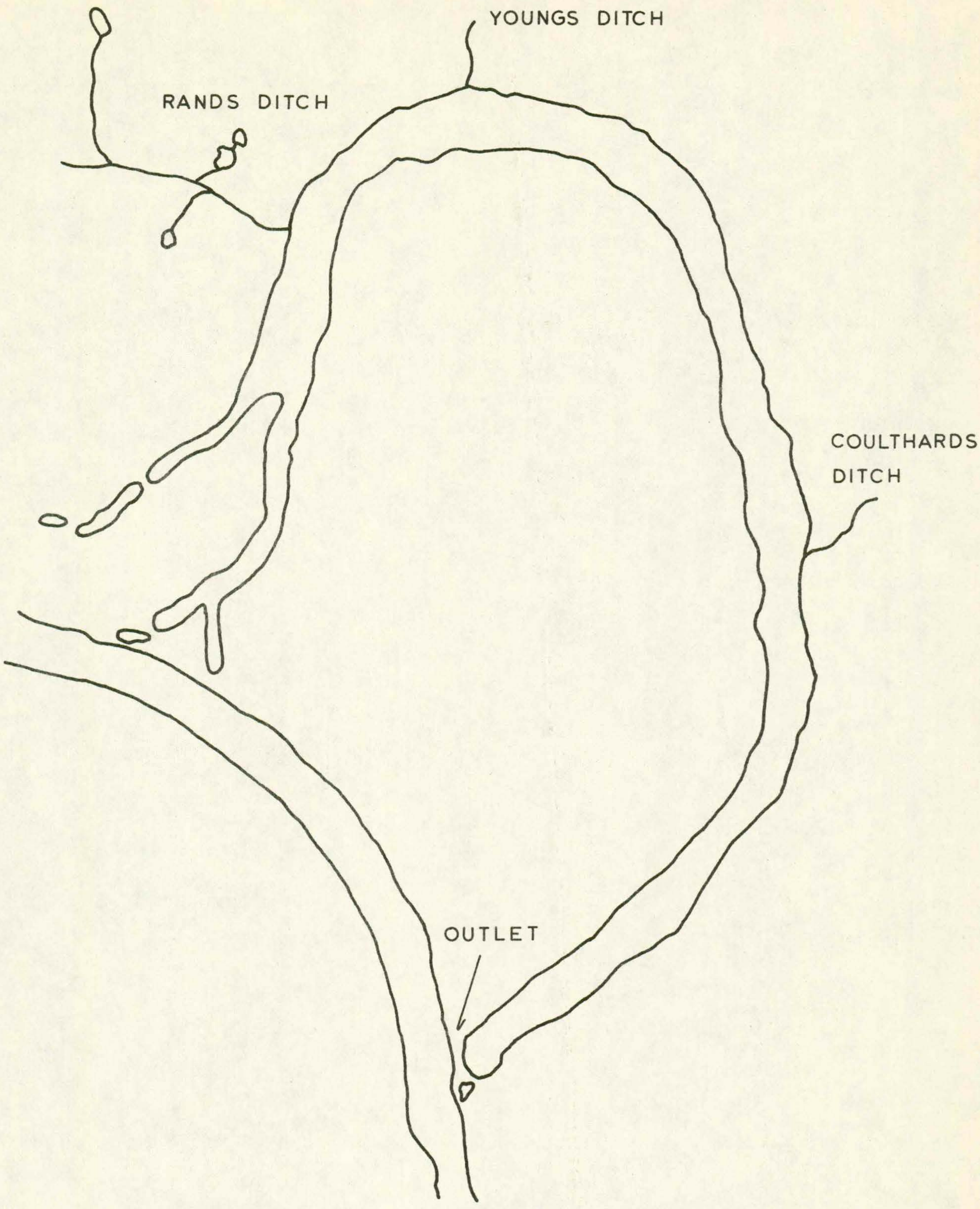


Figure 1. Outline map of DeSoto Bend showing 3 water ditches and outlet channel.

Lake water levels fluctuated greatly through the years causing surface area and volume of the lake to change accordingly. In 1973, during May through September the mean surface area was 315 ha (778 ac) while in 1974, during the same period mean surface area was 303 ha (748 ac) at 301.3 m MSL. This decrease in volume can be attributed to the lack of precipitation in surrounding areas and abnormally low Missouri River water level during 1974.

Thirty-one fish species inhabit DeSoto Bend Lake comprised mostly of species indigenous to the Missouri River. Carp, carpsucker, gizzard shad, freshwater drum and gar comprise the major part of fish standing stock in the lake. Channel catfish, bigmouth and smallmouth buffalo populations were quite low. The most abundant sport fish species are largemouth bass, bluegill, black crappie and white crappie.

## METHODS AND PROCEDURES

Fish sampling was conducted for one entire week, at biweekly intervals from 15 April to 30 October each year. Subsequent periods were denoted by month and week. Sampling gear consisted of frame-trap nets, electroshocker, seine, and gill nets. The frame nets had 15.24 m (50 ft) leads with .61 x 1.22 m (2 x 4 ft) frames ahead of a hooped net .61 m (2 ft) diameter and 2.44 m (8 ft) long. A winged throat was formed by the frames and two additional throats were located in the hoop net section. Webbing of 19 mm (3/4 in) bar measure covered the entire net. Frame nets were set with leads perpendicular to shore in water depth sufficient to cover the entire net. The electroshocker consisted of a boat outfitted with a 240 volt alternating current generator with the cylindrical electrodes suspended 2.44 m (8 ft) in front of the boat. Each electrode, 13 mm (1/2 in) in diameter and 1.83 m (6 ft) in length, was located in a row at 1.60 m (5.5 ft) intervals. The boat was slowly driven parallel to the shoreline with one person attempting to retrieve all stunned fish sufficiently large to stay in a dip net with 19 mm (3/4 in) bar measure webbing. A seine with 6.3 mm (1/4 in) bar measure web and measuring 15.24 m (50 ft) long by 1.22 m (4 ft) deep was used for all seine hauls. Each seine haul consisted of pulling the seine parallel to shoreline for 15.24 m (50 ft) and then pulling the deep end up to shore. Gill nets were used each spring until warm water temperatures caused excessive mortality to fish in the nets. Each gill net measuring 45.72 m (150 ft) long and 1.83 m (6 ft) deep consisted of five 9.14 m (30 ft) panels each with mesh sizes of 13 mm (1/2 in), 19 mm (3/4 in), 25 mm (1 in), 32 mm (1 1/4 in), and 38 mm (1 1/2 in) bar measure.

Population estimates were conducted simultaneously with other study portions using the Peterson equation $\hat{N} = \frac{MC}{R}$ where,

$\hat{N}$ = estimated number in the population
M = total number of fish marked in the sampling period
C = total number of fish captured in the sampling period
R = total number of fish recaptured in the sampling period.

Confidence intervals for the 95% level were determined from the sample standard error:

$$\left(\hat{N}\sqrt{\frac{(\hat{N}-M)(\hat{N}-C)}{MC(\hat{N}-1)}}\right)$$

where the equation components were the same as before.

Largemouth bass, channel catfish, freshwater drum, and shortnose gar were collected for stomach content analysis from randomly chosen samples during all periods of the year. Only fish collected with the electroshocker were used for stomach analysis to minimize regurgitation of contents. All fish collected for stomach content analysis were immediately refrigerated for later laboratory examination. Volumetric measurements of stomach contents were made immediately upon removal and individual diet items were identified. If the contents contained fish remains, body length measurements were made.

Food preference was determined by the Ivlev procedure:

$$E = \frac{r_i - p_i}{r_i + p_i}$$

where,

$r_i$ = percent occurrence of the ith food item in the stomach
$p_i$ = percent occurrence of the same food item in the seine sample
$E$ = electivity index.

Values of food electivity ranged from -1.0 to +1.0 where +1.0 indicated absolute selection for the food item and a -1.0 indicated the food item was ingested, but not selected. One seine haul was taken daily from four individual permanent sampling stations each sampling period. All contents were preserved in 10% formaldehyde for later laboratory analysis.

Relative abundance data was collected simultaneously with other aspects of the study and estimated directly from catch effort data using fyke net, electroshocker and seine catches.

## FINDINGS

### *RELATIVE ABUNDANCE OF MAJOR FISH SPECIES*

Relative abundance of largemouth bass, channel catfish, freshwater drum and shortnose gar was determined directly from catch effort statistics collected biweekly from 22 April to 12 October, 1974. Catch rates were determined from permanent sampling stations for electroshocker and fyke net. Catch success increased from period 3 through period 11 for all species (Table 2). Electroshocker success F/HR (fish/stocking hour) was higher than netting succes F/ND (fish/net day). Catches of largemouth bass/hour ranged from 1.0 in period 5 to 106.1 in the last period with a mean of 28.2 F/HR. Largemouth bass were less vulnerable to fyke netting than any other species.

Table 2. Catch rates from electroshocker (F/HR) and fyke net (F/ND) samples for largemouth bass, channel catfish, freshwater drum, and shortnose gar in DeSoto Bend Lake during 1974.

| | Largemouth bass | | Channel catfish | | Freshwater drum | | Shortnose gar | |
|---|---|---|---|---|---|---|---|---|
| | Shocker | Net | Shocker | Net | Shocker | Net | Shocker | Net |
| April | | > .1 | | .7 | | > .1 | | |
| | | | | | | | | .1 |
| May | 12.5 | | 4.7 | .4 | 2.2 | > .1 | 7.5 | 2.5 |
| | 5.2 | | 2.8 | .9 | 2.0 | .1 | 1.3 | .8 |
| June | 1.0 | > .1 | | .3 | 1.5 | > .1 | .5 | .4 |
| | 2.0 | | .8 | > .1 | 2.5 | .3 | 2.3 | .9 |
| July | 8.5 | .3 | 1.5 | .2 | 5.5 | 1.0 | 3.3 | .9 |
| | 31.7 | > .1 | 1.1 | .1 | 10.5 | .3 | .3 | 1.3 |
| August | 47.2 | > .1 | 2.0 | .4 | 9.5 | .3 | 4.3 | 1.1 |
| | 42.5 | .7 | 3.8 | .2 | 6.5 | | 1.0 | 2.7 |
| September | 54.5 | > .1 | 9.2 | .2 | 1.5 | .7 | 1.3 | .3 |
| | 106.1 | | 2.0 | | 1.5 | | | |
| Mean | 28.6 | .2 | 3.1 | .3 | 4.3 | .3 | 2.4 | 1.1 |

Channel catfish were captured with both devices, but higher catch success was obtained with the electroshocker. Catch rates of channel catfish collected with an electroshocker ranged from no fish in the second period to 9.2 F/HR during the last period with a mean of 2.5 F/HR. Freshwater drum were more vulnerable to shocking than channel catfish with an average of 3.9 F/HR.

Shortnose gar were most easily collected with electroshocking (1.98 F/HR) than fyke netting (1.0 F/ND). Highest catch success occurred from periods 8-10.

According to the sample index, largemouth bass were the most abundant species followed by shortnose gar, freshwater drum, and channel catfish. This is the exact order found in the population estimates.

Seine haul data were used to determine relative abundance of forage fish species. Eighteen fish species were collected in total seine samples of 35,570 fish (Table 3). Few fish were caught during early and late periods with most

Table 3. Seining success in number per seine haul (F/SH) in DeSoto Bend Lake during 1974.

| | May | | June | | July | | August | | September | | October |
|---|---|---|---|---|---|---|---|---|---|---|---|
| B minnow | .8 | .6 | .8 | .5 | | | | | | | |
| R shiner | 8.2 | 6.4 | 8.2 | 4.7 | .3 | .2 | 1.4 | 2.6 | 1.3 | .6 | |
| B shiner | | .5 | .8 | .3 | | | | | | | |
| S shiner | .8 | 2.0 | 1.0 | .5 | .6 | 1.2 | 2.1 | 1.8 | 4.1 | .4 | .4 |
| F minnow | 10.4 | | | | 1.3 | .1 | .4 | .1 | | | |
| B buffalo | 10.4 | 49.8 | 156.4 | 145.7 | 70.2 | .9 | 5.3 | .6 | | | |
| B crappie | | | | | .1 | .2 | | | | | |
| W crappie | | | | | .1 | .3 | 2.6 | .2 | | | |
| Bluegill | | | | | 9.1 | 203.9 | 13.2 | 1.4 | .8 | .7 | .4 |
| Carp | | | 2.8 | 13.6 | 29.1 | 2.7 | 9.2 | .4 | | | |
| Carpsucker | | 1.2 | 10.2 | 17.7 | 21.7 | 8.5 | 12.1 | 3.8 | 2.9 | .7 | .4 |
| C catfish | | | | | | | 1.0 | | | | |
| F drum | | | | | 1.5 | .2 | 3.9 | .1 | | | |
| G shad | | | | .1 | 99.8 | 166.2 | 302.7 | 96.4 | 7.9 | 43.3 | 35.6 |
| G sunfish | | | | | .7 | 1.2 | .5 | .3 | .1 | .1 | |
| Lm bass | | | | | 2.7 | 2.3 | 4.9 | 1.9 | 2.0 | 1.0 | 1.2 |
| S buffalo | | | | | | .5 | 9.4 | 11.9 | .7 | 1.5 | .4 |
| Y perch | | | | .9 | .7 | 2.2 | .4 | | | | |
| Total/haul | 20.1 | 60.5 | 180.1 | 183.4 | 237.9 | 390.6 | 369.5 | 130.4 | 19.5 | 48.1 | 38.4 |
| Total/fish | 402 | 1,210 | 3,602 | 3,668 | 4,758 | 7,812 | 7,390 | 2,608 | 390 | 962 | 768 |

caught in early June through late July. Catches ranged from 19.5 fish/seine haul (F/SH) during the second to last period to 390.6 F/SH during mid-July with a mean of 152.5 F/SH. Red shiner, *Notropis lutrensis*, was the most abundant minnow (excluding carp) and was taken in 10 sample periods. The second most abundant minnow was the sand shiner, *Notropis stramineus*, and was captured during 11 consecutive periods. Other minnows collected were: brassy minnow, *Hybognathus hankinsoni*; fathead minnow, *Pimephales promelas*; bigmouth shiner, *Notropis dorsalis*; and carp.

The most numerous species captured in seine hauls was young-of-the-year gizzard shad. They were found during eight sampling periods ranging from .1 F/SH in mid-June, to 302.7 F/SH during late July. Bigmouth buffalo young-of-the-year were the second most abundant species being collected in eight periods. They were most abundant in June and ranged from 156.4 F/SH in early June to .6 F/SH in mid-August. Third most numerous species was bluegill ranging from .4 F/SH to 203.9 F/SH with a mean of 32.7 F/SH for the seven periods in which they were collected. The only other fish species taken in significant numbers was river carpsucker, occurring in samples from ten periods and ranging from .4 F/SH during the last periods to 21.7 F/SH in early July with a mean of 7.9 F/SH.

Largemouth bass young reached maximum numbers during the same period as young gizzard shad. They appeared in seine samples on 1 July, increased to a peak of 4.9 F/SH on 29 July, and slowly declined to 1.0 F/SH in mid-September.

Maximum abundance of young fish occurs on different dates for each species. Gizzard shad numbers did not peak until late July, while bigmouth buffalo numbers were highest in early June (Figure 2). Gizzard shad occurred in seine hauls from mid-June until early October, reaching 99.8 F/SH in early July, 166.2 F/SH in mid-July, and peaking at 302.7 F/SH by late July. Numbers of age 0 gizzard shad declined to a low of 7.90 F/SH in late September, and increased to 35-40 F/SH for the remaining two periods.

Bigmouth buffalo young-of-the-year first appeared in seine hauls in early May, and reached a maximum of 156.4 F/SH in early June. In the next sampling period their numbers declined to 145.6 F/SH followed by a sharp decline to .9 F/SH in mid-July. No young bigmouth buffalo were seined after mid-August. Young bigmouth buffalo collected by seining were present in high numbers for two sampling periods, unlike other species which exhibited a single sharp peak in a single sampling period.

Bluegill young-of-the-year were the third most abundant fish in seine hauls and were collected from early July through early October. They were collected in low numbers at first and peaked at 203.9 F/SH during mid-July, and declined to 13.2 F/SH during the next period. From late August through early October they were present in low numbers, ranging from .4-1.4 F/SH.

Young river carpsucker were not numerous in seine hauls but were collected from late May through the last sampling period. Their numbers were highest (21.7 F/SH) in early July samples and declined slowly to .4 F/SH in early October.

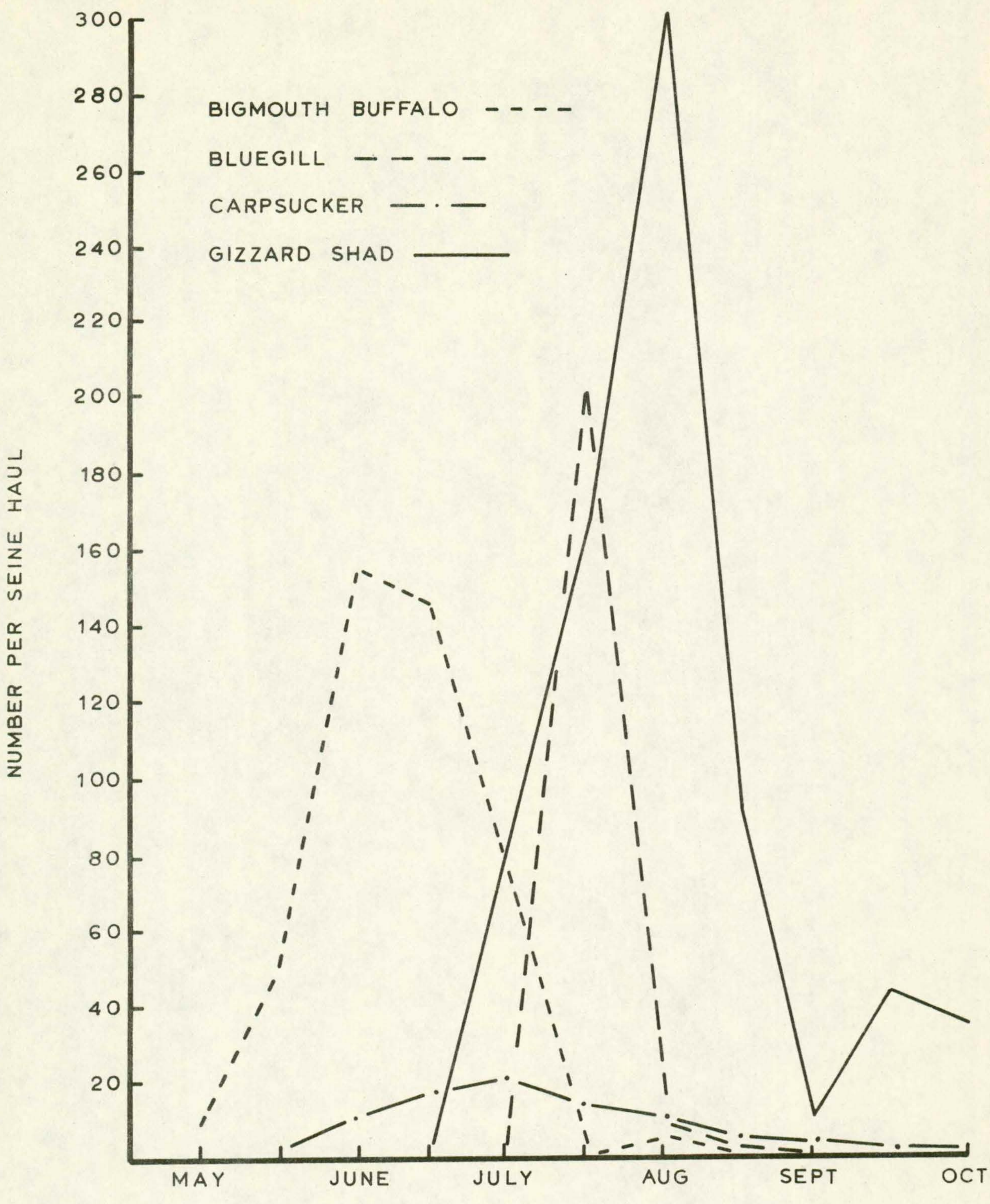


Figure 2. Abundance of bigmouth buffalo, bluegill, carpsucker, and gizzard shad in seine hauls from DeSoto Bend during 1974.

*PREDATOR FISH POPULATION DENSITY*

Population estimates were conducted simultaneously with food habit, age and growth and relative abundance studies. Estimates were started on 23 April and continued through 9 October.

Validity of fish population estimates rely upon certain assumptions of which Ricker (1958) lists six. All criteria were met in this study except the assumption dealing with recruitment. Recruitment was minimized by fin clipping only fish age 1 and older. Marked fish did not appear to suffer increased mortality compared with unmarked fish. All fish captured were immediately placed in a live tank, body measurements taken, fin clipped and released.

*Largemouth Bass - Population Estimate and Standing Crop* One thousand and eighty-seven largemouth bass were captured during 1974, of which 1,004 were marked and 52 recaptured (Table 4). Most of the fish were captured after 1 July, with the greatest number captured in August. Individual month estimates ranged from 675 ± 649 in June to 7,082 ± 1,361 in August. No estimates were made in April and May because no fin clipped fish were recaptured. Estimates for June are biased downward by about 37% since the hypothesis stated by Robson and Regier (1964) that MC ≃ N would result in a bias of this magnitude. To eliminate meaningful bias in the population estimate MC must ≃ 4N or more.

Table 4. Numerical population estimate of largemouth bass in DeSoto Bend Lake during 1974.

| | Number caught | Number marked | Number recaptured | Population estimate | 95% confidence interval |
|---|---|---|---|---|---|
| April | 15 | 10 | | | |
| May | 50 | 44 | | | |
| June | 27 | 25 | 1 | 675[a] | ± 649 |
| July | 138 | 123 | 2 | 8,487[a] | ± 5,908 |
| August | 426 | 399 | 24 | 7,082 | ± 1,361 |
| September | 219 | 199 | 17 | 2,563 | ± 570 |
| October | 212 | 204 | 8 | 5,406 | ± 1,837 |
| Combined | 1,087 | 1,004 | 52 | 20,987 | ± 2,765 |

[a]Population estimate biased due to small number of recaptures.

The numbers of fish captured, fin clipped and recaptured plus the time involved, made the combined population estimate a more reliable estimate. The 1974 largemouth bass combined estimate was 20,987, which at the 95% sampling level would vary between 23,752 and 18,222. Estimated population density at normal water level was 66 per ha (60 per ac) and would vary no more than 9 per ha (8 per ac).

Standing crop was determined as the product of mean weight of bass and the population estimate. Mean weight of marked largemouth bass was 563 g (1.24 lbs). Using this value and the combined population estimate, standing crop of largemouth bass in DeSoto Bend was estimated at 37.1 ± 5.1 kg/ha (33.1 ± 4.6 lbs/ac). Standing crop of largemouth bass in farm ponds and other impoundments in Iowa are higher than DeSoto Bend, but usually species diversity is greatly reduced in these lakes.

*Channel Catfish - Population Estimate and Standing Crop* Two hundred ninety-eight channel catfish were collected, of which 275 were fin clipped and 8 recaptured (Table 5). No recaptures were collected until May, and the largest number collected was 3 in any month. Total number captured ranged from 4 in October to 71 in April. Individual month estimates ranged from 136 ± 66 in July to 3,416 ± 3,357 in May. Monthly channel catfish estimates are biased downward from 2 to 37% because of few recaptures. Combined population estimates for 1974 was 10,243 ± 3,520. This appeared to be the most reliable estimate because the number of fish caught, marked, and recaptured are greater than monthly findings. Estimated population density was 33.8 per ha (30.2 per ac) and would fluctuate no more than 11.6 (10.4) at the 95% level.

Table 5. Numerical population estimate of channel catfish in DeSoto Bend Lake during 1974.

| | Number caught | Number marked | Number recaptured | Population estimate | 95% confidence interval |
|---|---|---|---|---|---|
| April | 71 | 70 | | | |
| May | 61 | 56 | 1 | 3,416 | ± 3,357 |
| June | 49 | 47 | 1 | 2,303 | [a] |
| July | 24 | 17 | 3 | 136 | [a] |
| August | 45 | 39 | 2 | 877 | ± 590 |
| September | 44 | 42 | 1 | 1,848 | ± 1,805 |
| October | 4 | 4 | | | |
| Combined | 298 | 275 | 8 | 10,243 | ± 3,520 |

[a] 95% confidence intervals were not computed.

Standing crop of channel catfish was determined using the identical procedures for largemouth bass. Mean weight of channel catfish captured was 810 g (1.78 lbs) and ranged from 100-1,843 g (.22-4.06 lbs). Assuming the combined estimate of 10,243 ± 3,520 was reliable, standing crop of channel catfish in DeSoto Bend during 1974 was estimated at 27.4 ± 9.4 kg/ha (24.5 ± 8.4 lbs/ac).

## *ESTIMATED STANDING CROP OF MAJOR FISH SPECIES*

Numerical estimates of carp, smallmouth and bigmouth buffalo, river carpsucker, freshwater drum, shortnose gar, black and white crappie, and bluegill were conducted simultaneously with estimates for major predatory species. Estimates were initiated in late April and continued through early October.

Similar procedures to estimate standing crops were used in this study portion and the previous study segment. Recruitment was minimized by marking only fish age 1 and older. Marked fish did not appear to incur increased mortality over unmarked fish through observations of dead fish by personnel from state-federal agencies. All fish captured were immediately placed in a live tank, body measurements taken, fin clipped and released.

*Carp - Population Estimate and Standing Crop* Five hundred ninety-seven carp were captured during 1974, of which 590 were fin clipped and six recaptured (Table 6). A majority of the carp were collected during July and August with no recaptures collected until July. Because of the few recaptures, monthly estimates were biased. Estimates for August and September was based on 2 or fewer recaptures. The combined population estimate, which was considered the most accurate, was 58,706 ± 23,482 yielding a carp population density of 189 ± 75 per ha (169 ± 70 per ac). Mean body weight of carp collected during 1974 was 631 g (1.39 lbs). Using the estimated numerical population densities and mean weight, the standing crop of carp in DeSoto Bend Lake was 119 ± 47 kg/ha (106 ± 42 lbs/ac) during 1974.

Table 6. Numerical population estimates of carp in DeSoto Bend Lake during 1974.

| | Number caught | Number marked | Number recaptured | Population estimate | 95% confidence interval |
|---|---|---|---|---|---|
| April | 15 | 15 | | | |
| May | 94 | 94 | | | |
| June | 47 | 47 | | | |
| July | 235 | 231 | 3 | 18,095 | ± 10,314 |
| August | 168 | 766 | 2 | 13,944 | ± 9,760 |
| September | 33 | 32 | 1 | 1,056 | ± 1,024 |
| October | 5 | 5 | | | |
| Combined | 597 | 590 | 6 | 58,705 | ± 23,482 |

*Buffalo - Population Estimate and Standing Crop* Numerical population estimates of smallmouth and bigmouth buffalo were attempted during 1974, but no marked fish were recaptured for either species. A total of 33 smallmouth buffalo and 19 bigmouth buffalo were collected and fin clipped. Fourteen smallmouth buffalo were captured during August, 6 in October, and during the other months of sampling the number captured ranged from 1 to 4. A majority of the bigmouth buffalo were collected in July (7 fish) and in October (9 fish).

*Carpsucker - Population Estimate and Standing Crop* River carpsucker were collected and fin clipped to determine the numerical population. Six hundred fifty-nine river carpsuckers were captured, 581 marked and 19 recaptured during 1974 (Table 7). Individual monthly population estimates ranged from 1,120 ± 613 in September to 19,880 ± 19,739 in April. Nine of the 19 recaptures were collected in June, with fewer recaptures taken in other months. The combined population estimate was 20,152 ± 4,481 river carpsuckers. Mean weight of river carpsucker was 788 g (1.74 lbs). Standing crop of river carpsucker was estimated at 52.4 kg/ha (46.8 lbs/ac) and would vary no more than ± 11.6 kg/ha (10.4 lbs/ac) at the .05 sampling probability level.

Table 7. Numerical population estimates of river carpsucker in DeSoto Bend Lake during 1974.

| | Number caught | Number marked | Number recaptured | Population estimate | 95% confidence interval |
|---|---|---|---|---|---|
| April | 142 | 140 | 1 | 19,880 | ± 19,739 |
| May | 104 | 46 | 2 | 2,392 | ± 1,639 |
| June | 58 | 57 | 1 | 3,306 | ± 3,249 |
| July | 111 | 102 | 9 | 1,258 | ± 384 |
| August | 177 | 173 | 3 | 10,207 | ± 5,792 |
| September | 60 | 56 | 3 | 1,120 | ± 613 |
| October | 7 | 7 | | | |
| Combined | 659 | 581 | 19 | 20,152 | ± 4,481 |

*Freshwater Drum - Population Estimate and Standing Crop* Freshwater drum population estimates were made simultaneously with other species. Number of fish captured each month ranged from three in October to 121 during July (Table 8). Five recaptures were collected from 249 marked fish from a sample of 266 freshwater drum captured. Two of the recaptures were collected in September while the remaining three were collected the previous month. An estimate of 13,247 ± 5,809 freshwater drum was made for the lake during 1974. Mean weight of drum collected was 363 g (.80 lbs). Total weight of freshwater drum age 1 and older was 4,808 kg (1,059 lbs) and would vary no more than ± 2,108 kg (± 464 lbs). Estimated standing crop was 15.8 ± 6.9 kg/ha (14.1 ± 6.2 lbs/ac during 1974.

Table 8. Numerical population estimates of freshwater drum in DeSoto Bend Lake during 1974.

| | Number caught | Number marked | Number recaptured | Population estimate | 95% confidence interval |
|---|---|---|---|---|---|
| April | 5 | 5 | | | |
| May | 12 | 11 | | | |
| June | 17 | 17 | | | |
| July | 121 | 110 | | | |
| August | 80 | 77 | 3 | 2,053 | ± 1,140 |
| September | 28 | 26 | 2 | 364 | ± 239 |
| October | 3 | 3 | | | |
| Combined | 266 | 249 | 5 | 13,247 | ± 5,809 |

*Bluegill - Population Estimate and Standing Crop* More bluegill were collected to determine population estimates than any other species. Marked fish were recaptured in all sampling periods except April (Table 9). Bluegills captured monthly ranged from 78 in October to 572 during August. Individual sampling period population estimates ranged from 5,212 ± 1,499 for September to 43,430 ± 43,222 in May. The total number of bluegill collected was 1,859, of which 1,771 were fin clipped and 34 recaptured. The combined numerical estimate of bluegill in DeSoto Bend Lake was 96,832 and would fluctuate no more than ± 16,295 at the 95% level. Mean weight of bluegill in the lake during 1974 was 66 g (.15 lbs). Total weight and numbers was 6,390 ± 1,075 kg (1,407 ± 237 lbs) of bluegill in the lake. Standing crop was estimated at 21.1 kg/ha varying no more than ± 3.5 kg/ha (3.1 lbs/ac).

*Black Crappie - Population Estimate and Standing Crop* Five hundred thirty-seven black crappie were captured, of which 504 were marked and 11 recaptured (Table 10). A majority of the black crappie, 64%, were collected in July and August; while all recaptures were collected in July, August, and September. Individual period numerical population estimates ranged from 1,026 ± 561 to 10,614 ± 4,644. The combined population estimate was 24,604 and would vary no more than ± 7,262 at the .05 sampling probability level. Mean weight of black crappie collected during 1974 was 142 g (.31 lbs). Using these statistics, standing crop of black crappie in DeSoto Bend Lake was estimated at 11.5 ± 3.4 kg/ha (10.3 ± 3.0 lbs/ac).

Table 9. Numerical population estimates of bluegill in DeSoto Bend Lake during 1974.

| | Number caught | Number marked | Number recaptured | Population estimate | 95% confidence interval |
|---|---|---|---|---|---|
| April | 123 | 113 | | | |
| May | 215 | 202 | 1 | 43,430 | ± 43,222 |
| June | 198 | 186 | 2 | 18,414 | ± 12,885 |
| July | 428 | 411 | 7 | 25,129 | ± 9,339 |
| August | 572 | 558 | 12 | 26,598 | ± 7,514 |
| September | 245 | 234 | 11 | 5,212 | ± 1,499 |
| October | 78 | 67 | 1 | 5,226 | ± 5,154 |
| Combined | 1,859 | 1,771 | 34 | 96,832 | ± 16,295 |

Table 10. Numerical population estimate of black crappie in DeSoto Bend Lake during 1974.

| | Number caught | Number marked | Number recaptured | Population estimate | 95% confidence interval |
|---|---|---|---|---|---|
| April | 65 | 65 | | | |
| May | 53 | 43 | | | |
| June | 13 | 13 | | | |
| July | 108 | 103 | 3 | 3,708 | ± 2,080 |
| August | 238 | 223 | 5 | 10,614 | ± 4,644 |
| September | 57 | 54 | 3 | 1,026 | ± 561 |
| October | 3 | 3 | | | |
| Combined | 537 | 504 | 11 | 24,604 | ± 7,262 |

*White Crappie - Population Estimate and Standing Crop* White crappie were nearly as numerous as black crappie; 337 were collected, 301 marked and 5 recaptured (Table 11). Numbers of white crappie collected each month, excluding October, ranged from 22 in June to 91 during August, the only period in which recaptures appeared in the sample. The combined numerical population estimate for white crappie in DeSoto Bend Lake was 20,287 ± 8,930. Mean weight was 157 g (.35 lbs). Using the mean weight and the numerical population estimate, standing crop of white crappie, age 1 and older, was 10.5 kg/ha (9.4 lbs/ac) and would vary no more than ± 4.6 kg/ha (4.1 lbs/ac).

Table 11. Numerical population estimates of white crappie in DeSoto Bend Lake during 1974.

| | Number caught | Number marked | Number recaptured | Population estimate | 95% confidence interval |
|---|---|---|---|---|---|
| April | 70 | 60 | | | |
| May | 42 | 35 | | | |
| June | 22 | 20 | | | |
| July | 66 | 60 | | | |
| August | 91 | 86 | 5 | 1,565 | ± 660 |
| September | 46 | 40 | | | |
| October | | | | | |
| Combined | 337 | 301 | 5 | 20,287 | ± 8,930 |

## FOOD CONSUMPTION AND SELECTIVITY BY MAJOR PREDATOR FISH SPECIES

*Largemouth Bass* First food of largemouth bass are small zooplankton and as body size increases insects become most important in the diet and later in life bass consume small fishes. Fish are important in the diet of adult largemouth bass and constitute as much as 60% or more of the total stomach content volume (Couey, 1935). Crayfish are important food and make up a substantial part of the diet. A wide variety of foods are consumed by bass and in some areas gizzard shad is an important food source (Dendy, 1946).

Stomach examination of 62 largemouth bass in DeSoto Bend Lake showed 47 contained measurable contents. Early season examinations in May indicated 30% of the fish collected had ingested food items (Table 12). About 90% of the fish collected during July, August, and September contained stomachs with measurable contents. Mean stomach volume was 7.4 ml, ranging from 2.0 ml in May to 24.8 ml in August. The large value in August was the result of 3 large stomach samples, one containing a volume of 100 ml. Mean content volume increased throughout the summer with volumes of 2.0 ml in May to 7.6 ml in October.

Table 12. Number and mean volume of stomachs collected from largemouth bass in DeSoto Bend Lake during 1974.

| | Number of fish collected | Number of stomachs collected | Mean volume (ml) |
|---|---|---|---|
| May | 10 | 3 | 2.0 |
| June | 10 | 7 | 2.9 |
| July | 11 | 10 | 3.7 |
| August | 10 | 10 | 24.8 |
| September | 11 | 10 | 3.9 |
| October | 10 | 7 | 7.6 |

Seven species of fish were identified in largemouth bass stomachs (Table 13). Gizzard shad was the most commonly eaten species followed by bluegill, silvery minnow, red shiner, green sunfish and freshwater drum. Minnows were found in largemouth bass stomachs only during May and June with gizzard shad becoming common in July and continuing through October. Gizzard shad were found in 63% of the stomachs collected during August and 83% of stomachs collected during September. Green sunfish, largemouth bass and freshwater drum were not commonly ingested, being found in about 4% of the stomachs. Prey availability was the main reason minnows were found only in early season stomach samples. Seine haul data showed only minnows and an occasional centrarchid during May and June, but young-of-the-year gizzard shad were first collected in July and remained the most abundant species in all following seine hauls.

Food preference based on Ivlev's electivity index showed freshwater drum was the most preferred food species, with a value of +1.0. All other food species had indices of +.004 to +.65. The electivity index for gizzard shad was +.28 in July, +.19 in August, +.005 in September and +.004 in October. Although gizzard shad were the most abundant species ingested by largemouth bass, they were preferred less as food items as summer progressed.

*Channel Catfish* Channel catfish were mainly omnivorous eating both plant and animal products. A large part of the natural diet of channel catfish is insects and larvae (Bailey and Harrison, 1948). This species is not a selective feeder, but takes advantage of available food.

Fifty-three channel catfish were collected for stomach analysis and 14 (25%) contained food (Table 14). Catfish collected in May and June had lower stomach contents than those collected later in the summer. One stomach with measurable contents was collected from 20 catfish during May and June. Thirty-nine percent of the catfish collected from July through October contained food items. Catfish collected in September appeared to eat more frequently because measurable contents were found in 50% of the fish.

Table 13. Food items found in the stomach contents of largemouth bass in DeSoto Bend Lake during 1974.

| | Food item | Number | Frequency of occurrence (%) |
|---|---|---|---|
| May | Silvery minnow | 1 | 10 |
| | Red shiner | 2 | 20 |
| June | Silvery minnow | 2 | 20 |
| | Crappie | 1 | 10 |
| | Red shiner | 1 | 10 |
| | Unknown | 3 | 30 |
| July | Gizzard shad | 16 | 71.4 |
| | Green sunfish | 1 | 4.8 |
| | Largemouth bass | 1 | 4.8 |
| | Unknown | 3 | 14.3 |
| August | Gizzard shad | 15 | 62.5 |
| | Bluegill | 4 | 16.7 |
| | Freshwater drum | 1 | 4.2 |
| | Unknown | 4 | 16.7 |
| September | Gizzard shad | 10 | 83.3 |
| | Unknown | 1 | 8.3 |
| October | Gizzard shad | 8 | 66.7 |
| | Unknown | 1 | 8.3 |

Table 14. Number, mean volume, and contents of stomachs collected from channel catfish in DeSoto Bend Lake during 1974.

| | Number of fish collected | Number of stomachs collected | Mean volume (ml) | Food item | Frequency of occurrence (%) |
|---|---|---|---|---|---|
| May | 10 | 0 | | | |
| June | 10 | 1 | 10 | Chironomids | 10 |
| July | 10 | 3 | 15 | Bluegill | 10 |
| | | | | Gizzard shad | 10 |
| | | | | Chironomids | 8 |
| | | | | Diptera larvae | 2 |
| August | 7 | 3 | 64.2 | Bluegill | 14.3 |
| | | | | Largemouth bass | 14.3 |
| | | | | Chironomids | 14.3 |
| September | 8 | 4 | 47.5 | Chironomids | 34.6 |
| | | | | Crayfish | 10.1 |
| October | 8 | 3 | 8.2 | Chironomids | 37.1 |
| | | | | Gizzard shad | 12.2 |

Mean stomach volume of catfish collected during all periods was 28.8 ml, ranging from 8.2 ml in September to 64.2 ml in August. Mean content volume was low the first three months, increased in late summer and decreased the last period. Chironomids were the most numerous item in stomachs, being found in eight of 14 stomachs containing food. Bluegill and gizzard shad were each found in two stomachs. Other contents found were Diptera larvae and crayfish.

Food preferences of catfish based on the electivity index showed bluegill preferred over gizzard shad with values of +.33 compared to values of -.34 for shad during July.

*Shortnose Gar* Forty-eight shortnose gar were collected during 1974 for stomach analysis, but all stomachs were empty upon examination. This species apparently has a very rapid digestion rate, and refrigeration does not sufficiently slow body functions, which results in the stomach contents completely digested by examination.

## DISCUSSION OF FINDINGS

The most numerous fish species in DeSoto Bend Lake in 1974 was gizzard shad followed by bluegill, carp, black crappie, largemouth bass, white crappie, river carpsucker, shortnose gar, freshwater drum, and channel catfish (Table 15). Gizzard shad had the greatest standing crop, 173.6 ± 70.4 kg/ha (155 ± 63 lbs/ac). Bluegill standing crop was only 21.1 ± 3.5 kg/ha (18.8 ± 43.7 lbs/ac) despite being second in abundance. Second most dominant species by standing crop was carp with 122 ± 48.9 kg/ha (108.9 ± 43.7 lbs/ac). The two major predators, largemouth bass and channel catfish, had standing crops ranging from 37.1 ± 5.1 kg/ha (33.1 ± 4.6 lbs/ac) and 27.3 ± 9.4 kg/ha (24.4 ± 8.4 lbs/ac), respectively. River carpsucker and freshwater drum contributed 52.4 ± 11.6 kg/ha (46.8 ± 10.4 lbs/ac)and 15.8 ± 6.9 kg/ha (14.1 ± 6.2 lbs/ac) to the standing crop, respectively. The three major centrarchids standing crop combined was 43.1 ± 11.5 kg/ha (38.4 ± 10.2 lbs/ac). Bluegill standing crop was about twice as great as black crappie although they were nearly 4 times as numerous. Black crappie and white crappie have nearly the same number of individuals and differ only slightly in standing crop. The ten species contribute a combined total of 507.5 ± 173.1 kg/ha (453.2 ± 154.6 lbs/ac).

Table 15. Population estimate, mean weight, and standing crop of major fish fish species in DeSoto Bend Lake in 1974.

| Species | Population estimate | 95% confidence interval | Mean weight (g) | Standing crop kg/ha | 95% confidence interval |
|---|---|---|---|---|---|
| Lm bass | 20,987 | ± 2,765 | 563 | 37.1 | ± 5.1 |
| C catfish | 10,243 | ± 3,520 | 810 | 27.3 | ± 9.4 |
| S gar | 17,200 | ± 4,463 | 638 | 36.2 | ± 9.3 |
| G shad | 175,350 | ± 4,463 | 300 | 173.6 | ± 70.4 |
| Carp | 58,705 | ± 23,482 | 631 | 122.0 | ± 48.9 |
| R carpsucker | 20,152 | ± 4,481 | 788 | 52.4 | ± 11.6 |
| F drum | 13,247 | ± 5,809 | 363 | 15.8 | ± 6.9 |
| Bluegill | 96,832 | ± 16,292 | 66 | 21.1 | ± 3.5 |
| B crappie | 24,604 | ± 7,262 | 142 | 11.5 | ± 3.4 |
| W crappie | 20,287 | ± 8,930 | 157 | 10.5 | ± 4.6 |
| Total | | | | 507.5 | ±173.1 |

Results of standing crop estimates showed the most dominant species was gizzard shad followed by carp, river carpsucker, largemouth bass, shortnose gar, channel catfish, bluegill, freshwater drum, black crappie, and white crappie. Carp have a higher estimated crop than the combined three major predators, largemouth bass, channel catfish, and shortnose gar. The five species that comprise the bulk of the sport fishery, bass, catfish, bluegill, black crappie, and white crappie have a combined standing crop of 109 kg/ha (97.3 lbs/ac), while the other five major species made up nearly 400 kg/ha (357 lbs/ac) of the standing crop. Removal of carp might increase the standing crop of more desirable species, but it would be difficult to crop enough to cause major shifts in the population structure. It is highly doubtful a commercial fishery would attract fishermen because of the small, non-marketable size of food fish.

Channel catfish were considered a major fish predator, but the findings showed 25% contained stomachs with measurable contents, while 75% of largemouth bass contained food items. Minnows and small fish were found in 74% of largemouth bass stomachs, while fish were found in 28% of channel catfish stomachs. Catfish fed more heavily on chironomids than fish.

Shortnose gar were thought to be a major predator, but all stomachs examined were empty from 48 specimens. The lack of measurable stomach contents may be caused by extremely rapid digestion by shortnose gar or refrigeration may not slow metabolic processes enough to halt digestion. They could perhaps be regurgitating stomach contents when captured by electroshocking, but this was not observed. If they feed heavily at night, contents would probably remain to some extent until the following day, and all shortnose gar were collected during daylight. If they fed in late afternoon and had rapid digestion rates, perhaps the stomachs could be empty when the fish were captured.

Most of the forage after July was young gizzard shad. Minnows were most numerous in earlier seine hauls. Young gizzard shad are less preferred by largeouth bass as the season progressed, but they are the most numerous species ingested by this predator. Bluegill were preferred over gizzard shad during July, but this could be misleading because of the high numbers of young gizzard shad present in July seine hauls.

## RECOMMENDATIONS

The study should be continued for one additional season to further define the problems of predator-prey dynamics in DeSoto Bend Lake before a comprehensive experimental program for fishery management can be initiated.

# LITERATURE CITED


Bailey, R. and H. Harrison. 1948. Food habits of the southern channel catfish *Ictalurus lacustric punctatus* in the Des Moines River, Iowa. Trans. Amer. Fish. Soc., Vol. 75, p. 133.

Couey, F. 1935. Fish food studies of a number of northeastern Wisconsin lakes. Trans. Wisc. Acad. Sci. Arts. and Lett., Vol. 29, p. 131-172.

Dendy, J. 1946. Food of several species of fish, Norris Reservoir, Tennessee. J. Tenn. Acad. Sci., Vol. 21, No. 1, p. 105-127.

Huggins, D. 1968. Limnology of DeSoto Bend Lake. Master of Science Thesis, Iowa State Univ. Press. Ames. 96 pp.

Ricker, W. 1968. Handbook of computations for biological statistics of fish populations. Fish. Res. Bd. Canada, Bull. No. 119, 300 pp.

Robson, D. and H. Regier. 1964. Sample size in Peterson mark-recapture experiments. Trans. Amer. Fish. Soc., Vol. 93, p. 216.