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Life History of the Emerald Shiner in Lewis and Clark Lake, South Dakota

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LIFE HISTORY OF THE EMERALD SHINER IN

LEWIS AND CLARK LAKE, SOUTH DAKOTA

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Advisor   Date

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ABSTRACT

The age, rate of growth, reproduction, feeding habits and population dynamics of the emerald shiner (*Notropis atherinoides*) were studied from 10,375 fish collected in Lewis and Clark Lake, South Dakota. The population consisted of four age groups dominated by young-of-the-year during the summer and fall and by age group I during spring and early summer. Age group II was common only in the spring and early summer while age group III was rarely found. Average length at annulus formation was 66 mm for age group I and 84 mm for age group II. Females attained a size advantage over males after the first year. The spawning season extended from June through August. A rapid and precise method was devised for conducting food-habit determinations which could be analyzed statistically. Adult emerald shiners fed selectively on *Daphnia*. A gradual change in young-of-the-year food habits was evident; fish smaller than 40 mm fed primarily on algae whereas larger fish fed chiefly on cladocerans and copepods. Populations of emerald shiners were characterized by a fast turnover. Males had a higher mortality rate than females during their second and third years of life.

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INTRODUCTION

The emerald shiner, Notropis atherinoides (Rafinesque), is widely distributed east of the Rocky Mountains, typically inhabiting large open lakes and rivers (Hubbs and Lagler, 1958). Bailey and Allum (1962) state: "the emerald shiner was probably uncommon originally in the Missouri River, but following impoundment it has increased and will likely become a dominant species in the reservoirs." Walburg (1964) reports the emerald shiner is the dominant minnow in Lewis and Clark Lake (Gavins Point Reservoir).

North Central Reservoir Investigations, U. S. Bureau of Sport Fisheries and Wildlife, Yankton, South Dakota is concerned with fisheries research on the Missouri River main stem reservoirs. One aspect of their studies is the population dynamics of the fish population in Lewis and Clark Lake. The emerald shiner is an important forage species, being utilized by sauger (Stizostedion canadense) and white bass (Roccus chrysops) (Vanicek, 1964; Nelson, unpublished; and Siefert, unpublished). Because of the emerald shiner's importance in the predator-prey relationship, information on its life history is needed for a better understanding of the population dynamics in this reservoir. This study is concerned with the age, rate of growth, reproduction, feeding habits and population dynamics of the emerald shiner.

Although the emerald shiner has a wide distribution and is an important bait and forage fish, life history research has been limited to Lake Erie. The embryology of the emerald shiner was studied by Fish (1932), and Gray (1942), Erwers (1933), and Nanny (1928) studied its food habits. An intensive study on the morphometry and life history of the emerald shiner was conducted by Flittner (1964).

STUDY AREA

Lewis and Clark Lake, located in southeastern South Dakota, is the smallest and southernmost of six Missouri River main stem reservoirs. It has a length of 21 miles, an average width of two miles, and an area of 28,000 acres. The depth varies from a few feet in the upper end to a maximum of 55 feet near the dam. A complete turnover of the lake's volume (450,000 acre feet) occurs every eight to ten days during the navigation season. Changes in discharge rates from Fort Randall Reservoir, 78 miles upstream, cause extreme daily water level fluctuations. The shore line of 50 miles varies from steep rocky cliffs to flat sandy beaches. The Niobrara River enters the lake near its upper end and carries a large silt load which increases the turbidity of the lake. The upstream section of the lake has numerous small islands and extensive areas of flooded timber. The reservoir is described in detail by Shields (1957).

METHODS

North Central Reservoir Investigations divided Lewis and Clark Lake into six sampling areas approximately equal in size and extending from the lower to the upper end (Figure 1). Emerald shiner samples were collected during 1963 in conjunction with a fish population monitoring program. Bi-monthly samples were collected in each area from May through September with an electric boom shocker. Each sampling effort consisted of a run between two predetermined points.

Sampling was restricted to two fixed collecting stations during 1965 to allow more intensive sampling of fish, plankton, and bottom organisms. These two stations were selected to represent sheltered and non-sheltered areas of the lake. Weigand Boat Basin, located in area 2 was chosen to represent sheltered areas whereas non-sheltered areas were represented by a sandy beach with a gently sloping shoal area located in area 3.

Weekly samples were collected in both areas from June through mid-September. Monthly samples were collected from area 2 in October and November and from area 3 in April, May, October and November. Fish were collected along the shore line with a 6- by 100- foot bag seine containing 1/4-inch square mesh in the wings and 1/8-inch square mesh in the bag. The seine was laid out perpendicular to the shore line and the far end was then towed to shore. Each haul covered approximately 7,850 square feet. Collections were made with a 16-foot trawl at depths ranging from 4 to 10 feet whereas a 27-foot trawl was used at depths of 10 and 35 feet. The 16-foot trawl contained 3/4-inch square

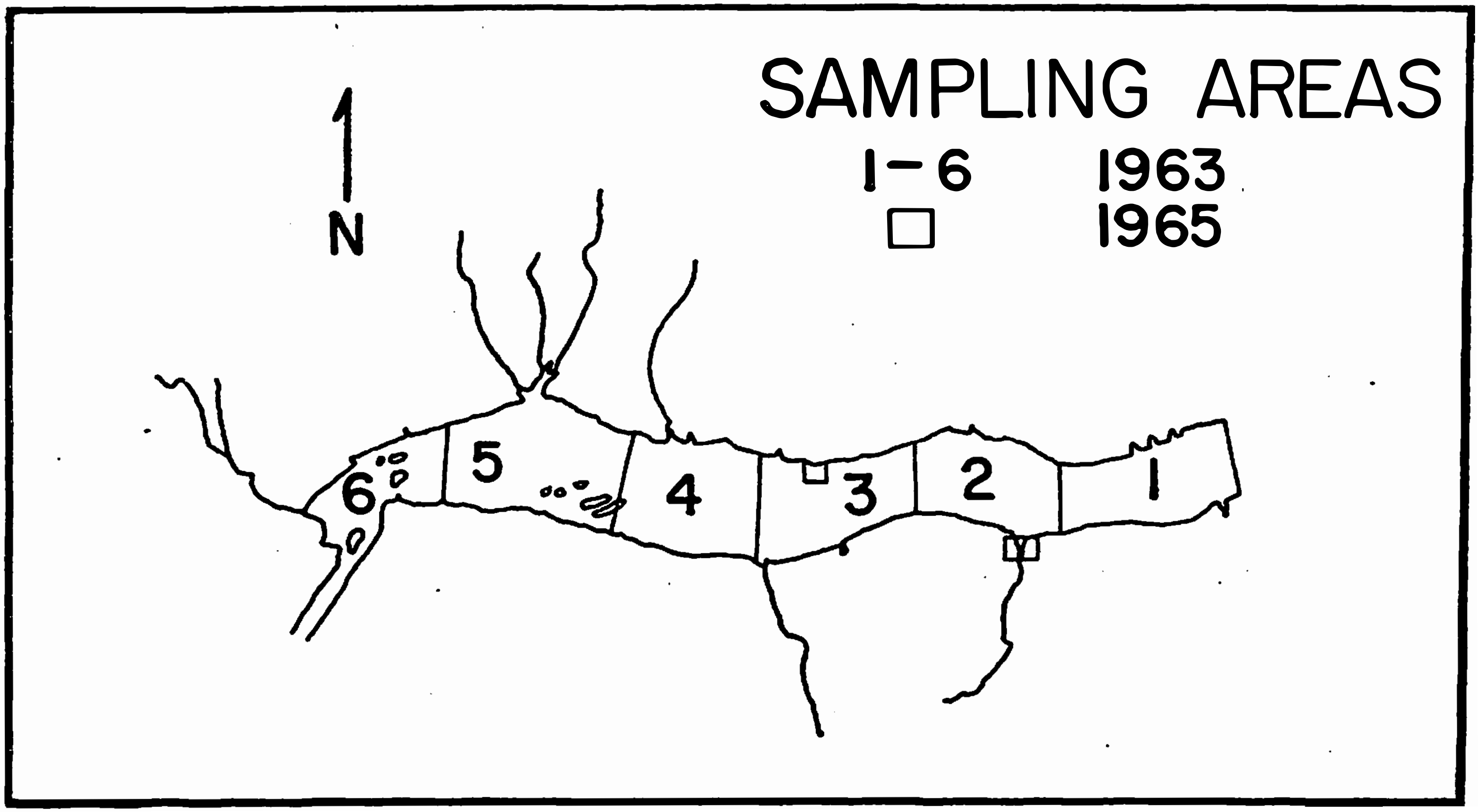

Figure 1. Map of Lewis and Clark Lake showing sampling areas.

mesh in the wings and body, 1/2-inch square mesh in the cod end, and a 1/4-inch liner. The 27-foot trawl contained 3/4-inch square mesh in the wings and body, 1/2-inch square mesh in the cod end, and a bobinet lining. A one-half meter fry net, 2 meters in length with 0.9 mm mesh, was towed at various depths to collect fry.

Sampling gear were selected to collect all sizes of emerald shiners from all depths of the lake. The electric boom shocker and the 100-foot seine were found to be the most effective gear for collecting emerald shiners more than 20 mm in length from relatively shallow shore line areas heavily utilized by the emerald shiner. The seine was more useful for quantitative sampling because of the many biases associated with electric boom shocking. The one-half meter fry net was effective for collecting fry 5-15 mm in length. The 16- and 27-foot trawls proved to be ineffective collecting gear. Only occasional specimens were collected by trawling during the regular sampling periods and these data were not used in this study. Larger numbers were collected with the 27-foot trawl during a special 24-hour sampling period in early September. Five samples collected during daylight averaged one young-of-the-year emerald shiner per sample, which was similar to catches during regular sampling periods. Three samples collected during darkness averaged 42 young-of-the-year per sample, with a maximum of 61 being collected at midnight. The larger number of emerald shiners captured during hours of darkness may suggest a diurnal movement of young-of-the-year away from the shore line areas. Further study would be necessary to determine emerald shiner utilization of deeper areas of the lake.

Plankton was collected with a Miller sampler with number 10 mesh and bottom samples were collected with an orange-peel sampler. Fish and bottom samples were preserved in 10 percent formalin and plankton samples were preserved in Lugol's solution.

Food-habit determinations were conducted on adult emerald shiners collected from area 3 during 1965. Stomach contents were examined from bi-monthly samples collected from June through September and monthly samples collected in April, May and October. Fish were separated into age groups; then each age group was stratified by five millimeter-length increments. A stratified random sample of five fish was subsequently selected from each age group. The first one-third of the S-shaped digestive tract (stomach) was removed and stomach contents of the five fish were combined and diluted to 40 milliliters. Organisms present in three, 3-milliliter subsamples were counted in a zooplankton counter (Ward, 1955). Total counts were made only when the sample contained few organisms. This procedure was repeated on three sets of five fish for each age group and thus gave three separate qualitative and quantitative estimates of food utilization.

Young-of-the-year emerald shiner stomachs were examined to determine changes in food habits associated with increased size. Fish were obtained from seine and fry net collections in area 2 on July 8, August 5 and September 8. Three sets of five fish were analyzed from each length group present in the July sample. Because of food habit similarities among the three sets, stomach analysis was thereafter restricted to one set of five fish for each length group. Stomach contents of the five fish were removed, combined and diluted to 10 milliliters. Microscopic organisms present in three 1-milliliter subsamples were determined from counting ten randomly selected fields at 100x magnification in a Sedgwick-Rafter cell. Total counts were made on all macroscopic organisms present in the combined sample.

Age and growth determinations from scales were conducted on emerald shiners collected from May through August in 1963. Length (mm), weight (grams), and sex were recorded for each fish. Scales were collected from an area located below the front edge of the dorsal fin and immediately above the lateral line. Emerald shiner scales are easily sloughed off, thus were often missing from the scale collecting area. This area often had a high percentage of regenerated scales. The thin translucent scales, which were impossible to read when mounted in a standard mounting medium, were stained with red recording ink. Scale readings were made with the aid of a scale projector at a magnification of 42 diameters. At least two separate readings were made for each scale sample. A third reading was necessary on 20 percent of the scales. Some scales were easily read as the annuli were clearly defined, whereas others had poorly formed annuli.

Age and growth determinations by the length-frequency method were conducted on fish samples collected from April through November, 1963. Sex, length and state of maturity were recorded for each adult emerald shiner. Total counts were made on collections of larger young-of-the-year while a volumetric method was used to estimate total numbers of small young-of-the-year. Total-length measurements were generally made on all young-of-the-year collected; however, when large numbers were collected a subsample of 150-200 fish was used.

AGE AND GROWTH

Comments on scale method versus length frequency

Age and growth determinations from scales were conducted on 216 emerald shiners to determine the number of age groups in the population and the relationship between age and growth estimates from scales and those from length frequencies. Validity of the scale method for the emerald shiner was established by Flittner (1964).

Fish used for age determinations were collected from all six areas of the lake. The number per area ranged from 86 in area 3 to only two in area 6. Sixty-seven of the fish were collected during May, 57 during both June and July, and 33 during August. The samples were composed of 93 males, 85 females and 37 immatures. Age groups present were: age group O (young-of-the-year), 29; age group I, 128; age group II, 53; and age group III, 4.

Annulus formation occurred at approximately the same time in both sexes within an age group, although it occurred earlier in age group I than in age group II (Table 1). Annulus formation first took place on May 21 in age group I and on June 11 in age group II. Fifty percent of age group I fish and 14 percent of age group II fish collected in June had formed an annulus. Seventy-nine percent of age group I fish and 67 percent of age group II fish collected in July had formed an annulus. Annulus formation was completed for all adult fish collected in August.

The Dahl-Lea method was used for estimating total length of

Table 1. Progressive seasonal formation of annuli in age group I and II emerald shiners, Lewis and Clark Lake, May through July, 1963

Date	Number collected		Percent with annulus formed	
	I	II	I	II
5/8-5/29	24	39	4	0
5/30-6/12	34	7	47	14
6/13-6/24	16	0	56	--
6/25-7/10	25	3	64	33
7/11-7/25	12	3	100	100

fish at the formation of previous annuli. Average length at annulus formation was 66 mm for age group I and 84 mm for age group II. Age group I females averaged 69 mm at annulus formation whereas males averaged 63 mm. Growth comparisons of age group II were limited by the small sample size; however, it was evident that females retained the growth advantage gained during the first year. Length of females averaged 5 mm longer than males and the maximum difference attained was 17 mm.

Spawning season of the emerald shiner extended from June through August and caused a wide variation in fish length at annulus formation. At annulus formation, age group I fish ranged from 45-92 mm and age group II fish ranged from 75-96 mm. Fish hatching early in the season were considerably larger at annulus formation than those hatching later. Apparently, there was no set or critical time at which the strength of age classes was determined.

Age group III comprised a small percentage of the fish sampled. The four fish, all females, representing this age group apparently hatched late in the spawning season. The average calculated length at the formation of the first annulus was 15 mm smaller than the average calculated length for one-year-old females. Fish hatched late in the spawning season are subject to mortality only during the latter part of the growing season. This may account for their increased longevity.

Comparisons between age determinations by the scale and length-frequency methods during 1963 demonstrated emerald shiner age groups could be separated by their length frequencies, because only a small amount of overlap was found among age groups. In 1965, age groups were separated as peaks in the length-frequency distributions. Fish falling in the small overlapping areas of adjacent age groups were separated by scale examination. Growth estimates made in 1963 by the scale method were similar to those made in 1965 by the length-frequency method. Age and growth determinations from scales involved considerable time and difficulty in collecting, mounting and reading scales.

Seasonal growth and differences between areas

Age and growth determinations by the length-frequency method were made from measurements of 10,159 fish collected from April through November, 1965. Population growth estimates by the length-frequency method were considered more precise than estimates based on the scale method because of the larger sample size.

Flittner (1964) reports that newly hatched prolarvae of the emerald shiner measure approximately 4.0 mm in length. The emerald shiner grows rapidly during the first growing season. They often attain 55 percent of their maximum adult size and may exceed 65 mm in length. This rapid growth is clearly shown by the rapid increase in the maximum size of young-of-the-year throughout the collecting period (Table 2).

Monthly increases in the average calculated length, or a modal group, did not accurately represent seasonal growth of young-of-the-year. The monthly average length of young-of-the-year captured with the 100-foot seine in area 2 (Weigand Basin) was 24 mm in July, 30 mm

Table 2. Minimum and maximum length of young-of-the-year emerald shiners collected from June through November, 1965, areas 2 and 3, Lewis and Clark Lake

	Area 2			Area 3		
	Number meas-	Length in mm		Number meas-	Length in mm	
Date	ured	minimum	maximum	ured	minimum	maximum
6/30	127	8	14			
7/7-7/8	281	6	26	172	13	27
7/13-7/15	258	7	33	188	15	29
7/20-7/22	390	6	40	120	16	39
7/27	284	6	46	412	5	45
8/3-8/5	423	6	60	191	13	52
8/10	384	6	54	281	5	54
8/17-8/19	402	6	52	199	15	52
8/24-8/25	425	7	69	225	6	58
8/31-9/2	242	7	53	397	16	65
9/8	252	14	72	275	16	71
9/15-9/16	112	18	58	45	17	62
10/19-10/21	242	17	77	232	23	71
11/10	233	14	69			

in August, 44 mm in September, 36 mm in October and 31 mm in November. Collections in area 3 gave a somewhat better indication of seasonal growth as young-of-the-year averaged 29 mm in July, 26 mm in August, 37 mm in September and 52 mm in October. These biased growth estimates resulted from the emereld shiner's extended spawning season and high morality of young-of-the-year. Samples were dominated by recently hatched fry and contained relatively few older fry.

A monthly mean length was calculated for age groups I and II, with an adjusted collecting date for those months when more than one sample was collected. Adjusted collecting date =

$$\frac{\text{Number of fish} \times \text{day of month}}{\text{Total number of fish collected in month}}$$

. Monthly means with their adjusted collecting dates were graphed to facilitate growth comparisons between age groups and between sampling areas (Figure 2).

Age group I grew faster than did age group II in both areas. Fish from different sampling stations also showed growth differences within an age group. The estimated mean length of age group I on June 15 was 58 mm in area 3, and only 51 mm in area 2. On September 15, age group I averaged 81 mm in area 3 and 83 mm in area 2. During late September and October the mean length of age group I decreased in area 2. This may have resulted from the limited sampling during these months, mortality, or movement of larger fish out of Weigand Basin.

Percent of total growth in length completed during each year of life was estimated from data collected in area 3. An average of 55

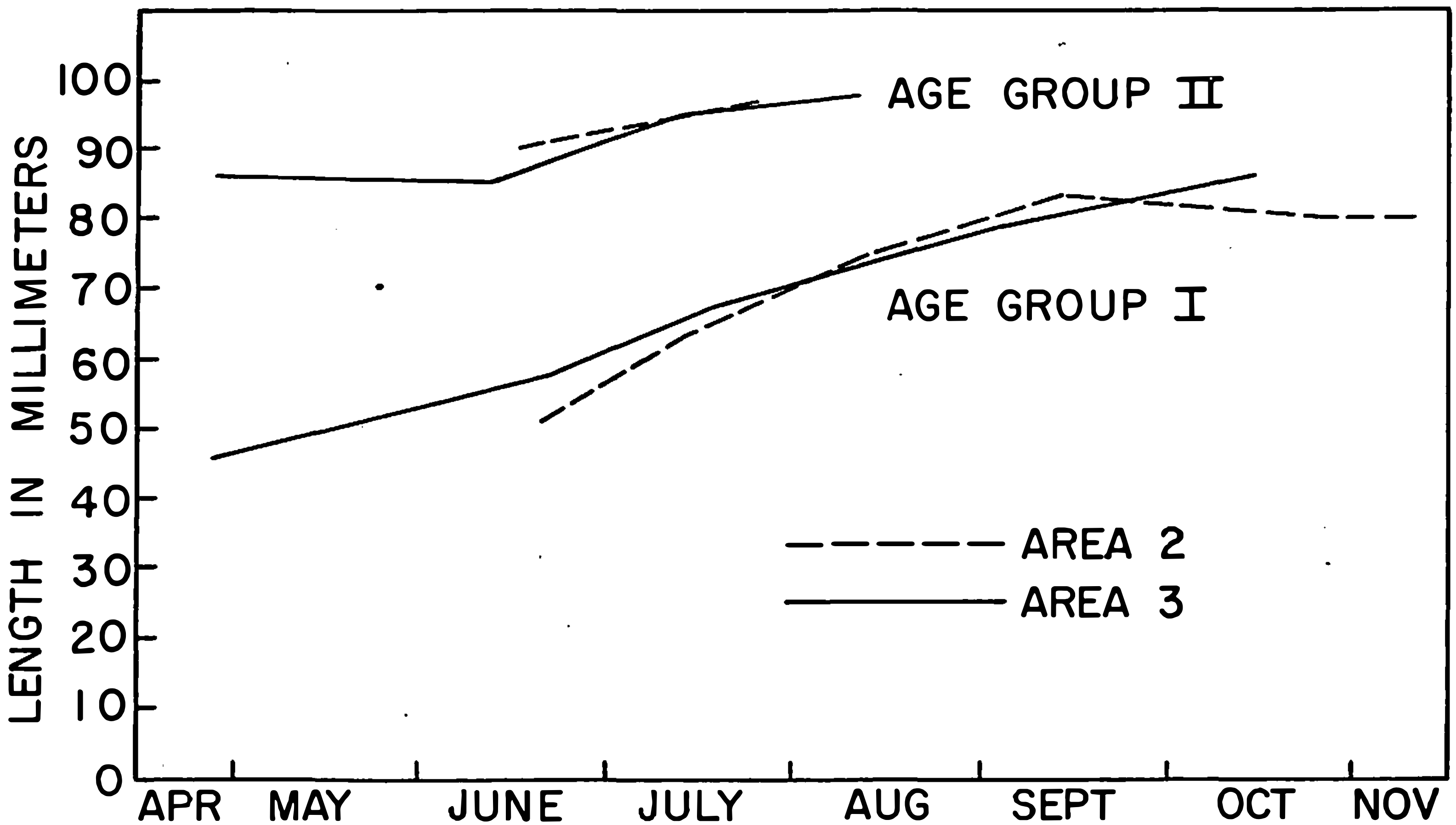

Figure 2. Seasonal growth of age group I and II emerald shiners collected in areas 2 and 3 from April through November, 1965, Lewis and Clark Lake.

percent of the total growth was completed during the first year, 33 percent during the second, and 12 percent during the third. These estimates only represent general trends because they are influenced by the extended spawning season, yearly fluctuations in growth, differential growth rates between sexes and higher mortality of males.

Growth differences between sexes

In area 3, age group I males and females grew at the same rate during May and early June but females exhibited a faster growth rate during late June, July and August (Figure 3). They averaged 3 mm longer than the males on July 15 and 8 mm longer on August 15. Both sexes grew at approximately the same rate through September and October as females retained their 8 mm size advantage. Age group II males grew slightly faster than the females. The growth advantage gained by the females during the previous year was retained through May and June but was reduced to 6 mm by July 15 and 3 mm by August 15.

In area 2, age group I males and females grew at the same rate during June (Figure 4). Females grew faster during July--they averaged 6 mm longer than the males on July 15. Both sexes grew at approximately the same rate during August. Data collected after August were insufficient for making precise growth estimates but females maintained their size advantage. Growth comparisons between sexes in age group II were impossible because only females were captured.

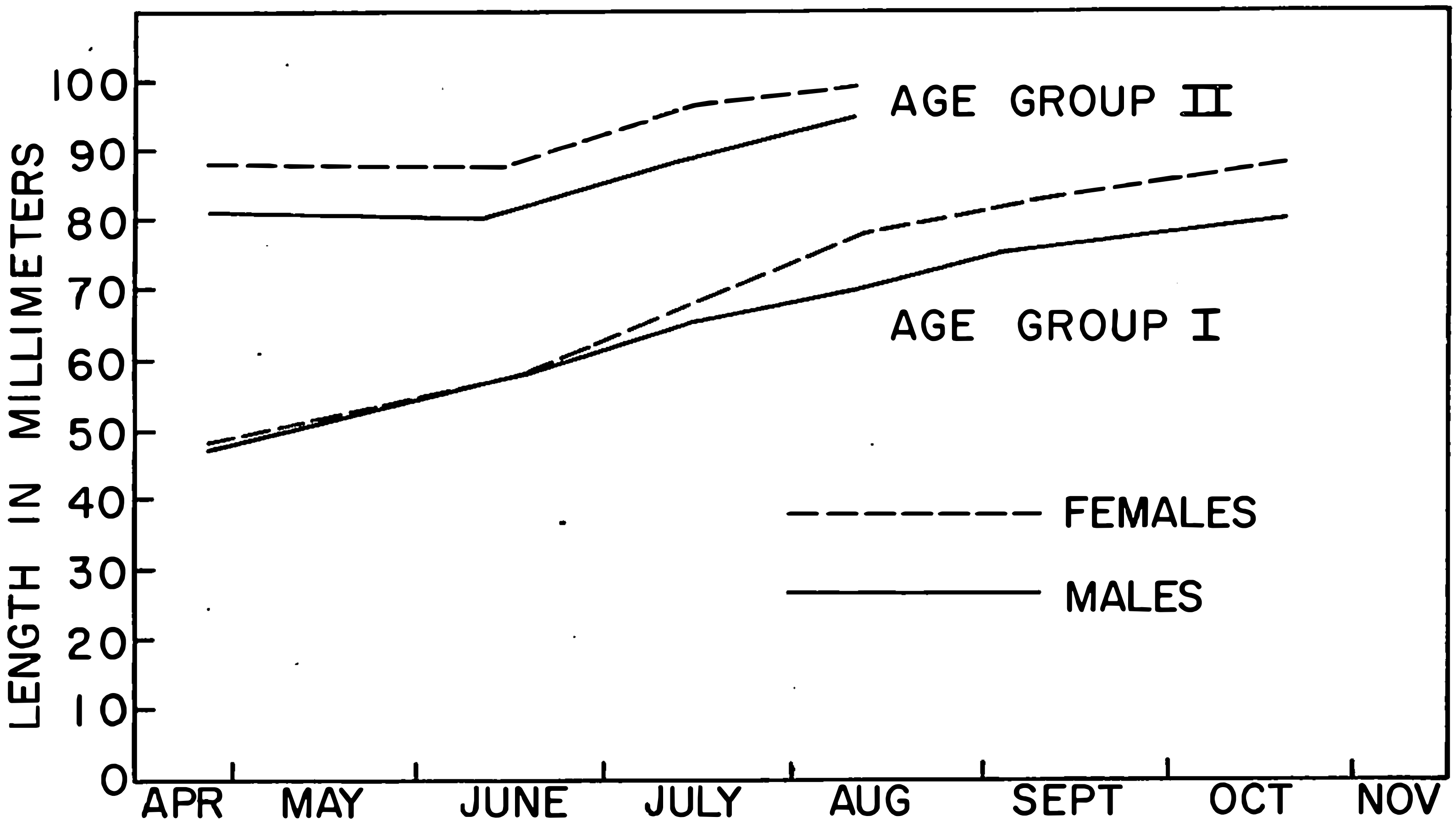

Figure 3. Growth differences between male and female emerald shiners collected in area 3 from April through October, 1965, Lewis and Clark Lake.

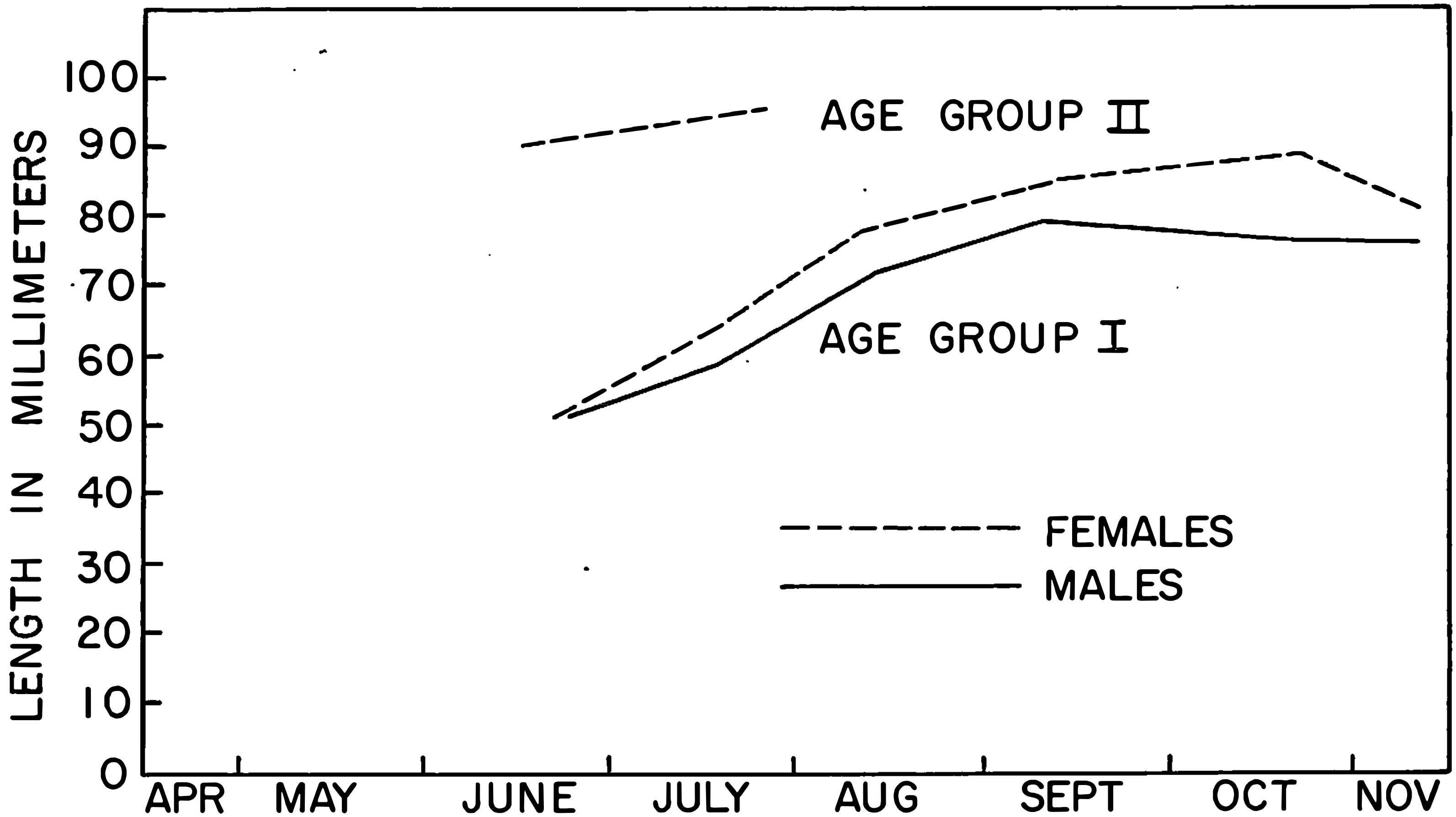

Figure 4. Growth differences between male and female emerald shiners collected in area 2 from June through November, 1965, Lewis and Clark Lake.

Length-weight relationship

A general length-weight relationship was calculated for a combined sample of 497 fish collected from area 3 on June 10, 1965 and 262 fish collected October 19, 1965. Fish ranged from 30-106 mm and were grouped by 5 mm intervals. The length-weight equation for the 759 fish was: $\text{Log } W = -3.9417 + 2.9218 \text{ Log } L$. Differences between empirical and calculated weights were generally small.

REPRODUCTION

Spawning activity was determined from weekly observed changes in ovarian conditions of adult females and weekly collections of young fry (5-10 mm). Ovaries were classified into one of three categories: green, ovaries containing eggs incompletely filled with yolk; mature, ovaries containing eggs fully developed; spent, ovaries whose eggs had been deposited. The onset, peak and completion of spawning activity were determined from changes in percent composition of these three conditions of ovarian development. Estimates of hatching time of fry less than 10 mm in length were based on early life-history data determined under controlled conditions by Flittner (1964). He found emerald shiners hatch 24-32 hours after spawning at a size of approximately 4 mm; at 4.9 mm their estimated age was 30 hours; at 6.1 mm it was 90-96 hours; and at 8.9 mm it was about 11 days.

The number of fry collected in a sample was affected by spawning activity several days prior to sampling and by dispersion of fry after hatching. Young fry are weak swimmers and subject to considerable drift from wave and current action. Because of this dispersion, fry net catches could be misleading. Interpretation of this data was more meaningful when considered with information on changes in ovarian condition.

Young fry (5-10 mm) were collected in area 3 from June 2 through August 25. Very few fry and no spent females were captured in June. On July 7, 172 fry 13-27 mm in length were captured with the 100-foot seine. Their size indicated they hatched during June although it is unknown whether this occurred in area 3. Large fry net catches were first made July 20 and spent females were also captured for the first time on this date. The peak fry net catch occurred July 27 and the last large collection was made August 25. The majority of spawning occurred in late July and August as the percent of spent females in the catch steadily increased over this period (Table 3). Four percent of age group I females in the catch were spent on July 27, 13 percent on August 3, 40 percent on August 10, 61 percent on August 17, and 90 percent on August 25. All age group I females captured after September 1 were spent. Forty age group II females collected in area 3 from June 10 through August 10 were mature. No spent females belonging to age group II were found.

Larger numbers of fry were collected with the one-half meter fry net in area 2 than in area 3. The protected nature of Weigand Basin, which prevents widespread dispersal of fry, may account for this increased catch. Young fry (5-10 mm) were collected from June 24 through August 31 and large numbers were collected from June 30 through July 22. Inspection of ovaries showed the majority of spawning occurred throughout July and in early August. Forty-nine percent of the age group I females captured in July were spent, as were 90 percent of those captured on August 10 and 100 percent of those captured after this date. Although the majority of spawning occurred earlier in area 2 than in area 3, progression of spawning followed the same pattern in both areas.

Table 3. Percent of green, mature, and spent age group I females collected from April through September, 1965, in areas 2 and 3, Lewis and Clark Lake

	Area 2				Area 3			
	Number	Ovarian classification			Number	Ovarian classification		
Month	collected	green	mature	spent	collected	green	mature	spent
April	---	--	--	--	28	100	--	--
June	426	80	20	--	564	42	58	--
July	109	15	36	49	438	2	96	2
Aug	223	--	10	90	96	--	57	43
Sept	6	--	--	100	37	--	--	100

There was a wide variation in time of maturation among age group I females. Age group I females above 60 mm in length showed egg development in early June whereas age group I females below 50 mm failed to show this development. As these smaller fish grew during June, the percent of females bearing developing eggs also increased. In early July the majority of females either contained fully developed or developing eggs. These small age group I fish constituted a large percent of the emerald shiners which spawned later in the season.

Observations indicated each fish may spawn more than once during the summer because mature females contained eggs in two stages of development. The majority of fish spawn during their second summer of life. Almost all fish above 60 mm in length showed gonad development, and most age group I fish attained this size by mid-July.

FEEDING HABITS

Quantitative food-habit determinations were conducted on adult emerald shiners collected from area 3 during 1965 to compare food availability with food utilization and to study seasonal changes in food habits. Statistical analysis of organism counts was performed for age groups I and II using analysis of variance with a hierarchal classification. Precision was good within samples, as indicated by the relatively small subsample mean square in both cases (Table 4). Differences between samples were highly significant (0.01) for both age groups, and differences between dates were significant (0.01) for age group I. This was both a rapid and precise method for conducting food-habit determinations.

Adult emerald shiners fed primarily on zooplankton, with insects being of secondary importance (Table 5). The adults were not random feeders, but fed selectively on certain organisms. Daphnia usually made up less than 20 percent of the plankton by number but often constituted more than 90 percent of the stomach contents. Age group II fish were more selective for Daphnia than age group I fish. Emerald shiners apparently selected Daphnia because of its large size. Gray (1942) also noted this selectivity of larger organisms while studying food habits of the emerald shiner in Lake Erie. He further observed that when emerald shiners in an aquarium were fed zooplankton they tended to select the larger individuals first, regardless of species.

Diaptomus was of secondary importance as a food item but on

Table 4. Analysis of variance of food organism counts by age group

Source of variation	df	MS	EMS
		Age group I	
Dates	8	3726.055**	$\sigma_\epsilon^2 + 3.106\sigma_S^2 + 8.596\sigma_D^2$
Samples/dates	16	365.480**	$\sigma_\epsilon^2 + 3.125\sigma_S^2$
Subsamples	53	30.922	σ_ϵ^2
		Age group II	
Dates	4	4067.720	$\sigma_\epsilon^2 + 3.214\sigma_S^2 + 5.250\sigma_D^2$
Samples/dates	4	740.500**	$\sigma_\epsilon^2 + 3.000\sigma_S^2$
Subsamples	19	64.420	σ_ϵ^2

**significant at the 1-percent level.

Table 5. Comparison of food availability, determined from plankton samples, and food utilization, determined from stomach samples, for age group I and II emerald shiners, April through October, 1965, Lewis and Clark Lake. (Plankton data expressed as organisms per liter and percentage composition by genera. Food items expressed as average number of organisms per fish stomach and percentage composition by genera.)

	Date of Collection									
	4/28	5/20	6/10	6/22	7/7	7/20	8/3	8/17	9/3	10/19
Number of fish										
Age group I	15	5	15	15	15	15	15	15	15	15
Age group II	15	-	4	1	15	7	1	--	--	--
Average length of fish										
Age group I	48	38	61	56	64	66	70	78	78	86
Age group II	85	--	81	100	94	95	101	--	--	--
Average number organisms/stomach										
Age group I	15	13	37	16	53	60	143	125	121	87
Age group II	105	--	53	38	212	145	271	--	--	--
Organisms/liter in plankton samples	3.4	15.7	4.0	10.8	9.1	9.5	3.3	1.1	1.4	4.3
Food items										
<u>Cyclops</u>										
Plankton	94	76	55	94	54	52	34	10	19	60
Age group I	--	--	--	2	3	--	1	--	--	--
Age group II	--	--	--	--	--	--	--	--	--	--

Table 5 (continued)

	Date of Collection									
	4/28	5/20	6/10	6/22	7/7	7/20	8/3	8/17	9/3	10/19
<u>Daphnia</u>										
Plankton	2	17	20	.4	26	11	21	19	14	11
Age group I	98	86	94	48	45	89	96	100	99	99.6
Age group II	100	--	100	82	99	93	100	--	--	--
<u>Diaptomus</u>										
Plankton	3	5	9	2	17	15	31	54	51	23
Age group I	2	-	-	3	51	11	1	--	--	--
Age group II	-	-	-	-	--	1	--	--	--	--
<u>Leptodora</u>										
Plankton	-	-	-	-	.3	.5	-	-	-	-
Age group I	-	-	-	1	-	-	2	-	.5	-
Age group II	-	-	-	-	-	6	-	-	-	-
Insects										
Age group I	-	14	5	46	1	-	-	-	.5	.4
Age group II	-	--	-	18	1	-	-	-	-	-

July 7 composed 51 percent of the stomach contents of age group I emerald shiners, whereas *Daphnia* dropped to 45 percent. This increase in *Diaptomus* utilization apparently resulted from the presence of two large species, *Diaptomus forbesi* and *D. clavipes*, both of which are considerably larger than other species of *Diaptomus* present in the lake. These larger species, which have a short seasonal appearance in Lewis and Clark Lake, were selected by age group I fish. *Diaptomus* was not a major food item for age group II fish collected on July 7. They continued to select *Daphnia* which composed 99 percent of their stomach contents.

Leptodora, a large zooplankton, was occasionally found in stomach contents even when it did not appear in the plankton samples. Although *Leptodora* was very rare, it was apparently utilized by emerald shiners whenever encountered. *Cyclops* often made up a large percent of the available plankton, but was found in the stomach contents on only three collecting dates. This was apparently due to its small size. *Bosmina* composed a small percent of the available plankton and was found in the stomach contents on only one collecting date.

Insects were important food items on June 22, composing 46 percent of the stomach contents of age group I fish and 18 percent of age group II. This heavy utilization coincided with the season's low for *Daphnia* availability and utilization. Insects possibly were selected as food organisms because of the scarcity of *Daphnia*. All immature and adult insects found in the stomach contents belonged to the order

Diptera. The majority of insects eaten were adults and Ceratopogonids were the most numerous.

The number of organisms eaten by adult emerald shiners generally increased throughout the sampling period, as a result of increasing fish size. The total number of organisms per fish ranged from 13.3 to 142.6 for age group I and from 38.0 to 271.0 for age group II.

Food-habit changes in young-of-the-year fish were primarily associated with an increase in fish size. Food-habit differences occurred among the six length groups on all collecting dates, whereas few differences occurred within a length group. Blue-green algae was the major food item of the 6-10 mm and 21-25 mm length groups, although rotifers (<u>Branchionus</u>) were found in small numbers. Ciliated protozoa also occurred in the 6-10 mm length group, and green algae (<u>Pediastrum</u>) was found in the 21-25 mm group. Rotifers and protozoa are digested faster than algae and therefore may be more important than indicated. <u>Leptodora</u> was first utilized by the 31-35 mm group, although blue-green algae was the major food item. <u>Leptodora</u> and <u>Daphnia</u>, in order of abundance, became the most important food items in the 41-45 mm group, and blue-green algae assumed secondary importance. <u>Daphnia</u> was the most abundant organism found in the 51-55 mm length group. <u>Leptodora</u> and <u>Diaptomus</u> were secondarily important, and blue-green algae and diatoms were found in small numbers. <u>Daphnia</u> became the dominant item in the 61-65 mm group, whereas <u>Leptodora</u> and <u>Diaptomus</u> were of minor importance. At this size, young-of-the-year were similar to adults, selectively feeding on the larger zooplankton.

POPULATION DYNAMICS

Population turnover of the emerald shiner was determined from samples collected at both stations during 1965. Monthly age group composition and length frequency were determined by summation of weekly collections.

Population turnover in area 3

The population from April through June consisted of age groups I and II (Figure 5). Age group I dominated the population, composing 74.8 percent of the catch in April and 98.8 percent in June. Age group O was taken for the first time in July and composed 32.7 percent of the catch. The catch was dominated by age group I (65.6 percent) whereas age group II constituted 1.7 percent. The composition of the August catch was 94.8 percent age group O fish, 4.8 percent age group I fish, and 0.4 percent age group II fish. The catch in September was composed of 97.2 percent age group O and 2.8 percent age group I fish. No age group II fish were taken. In October, age group O remained dominant (84.7 percent) and age group I increased to 15.3 percent. This increase in age group I may be an actual increase resulting from greater mortality among age group O during late September and October, or it may represent only an apparent increase resulting from the limited sampling in October.

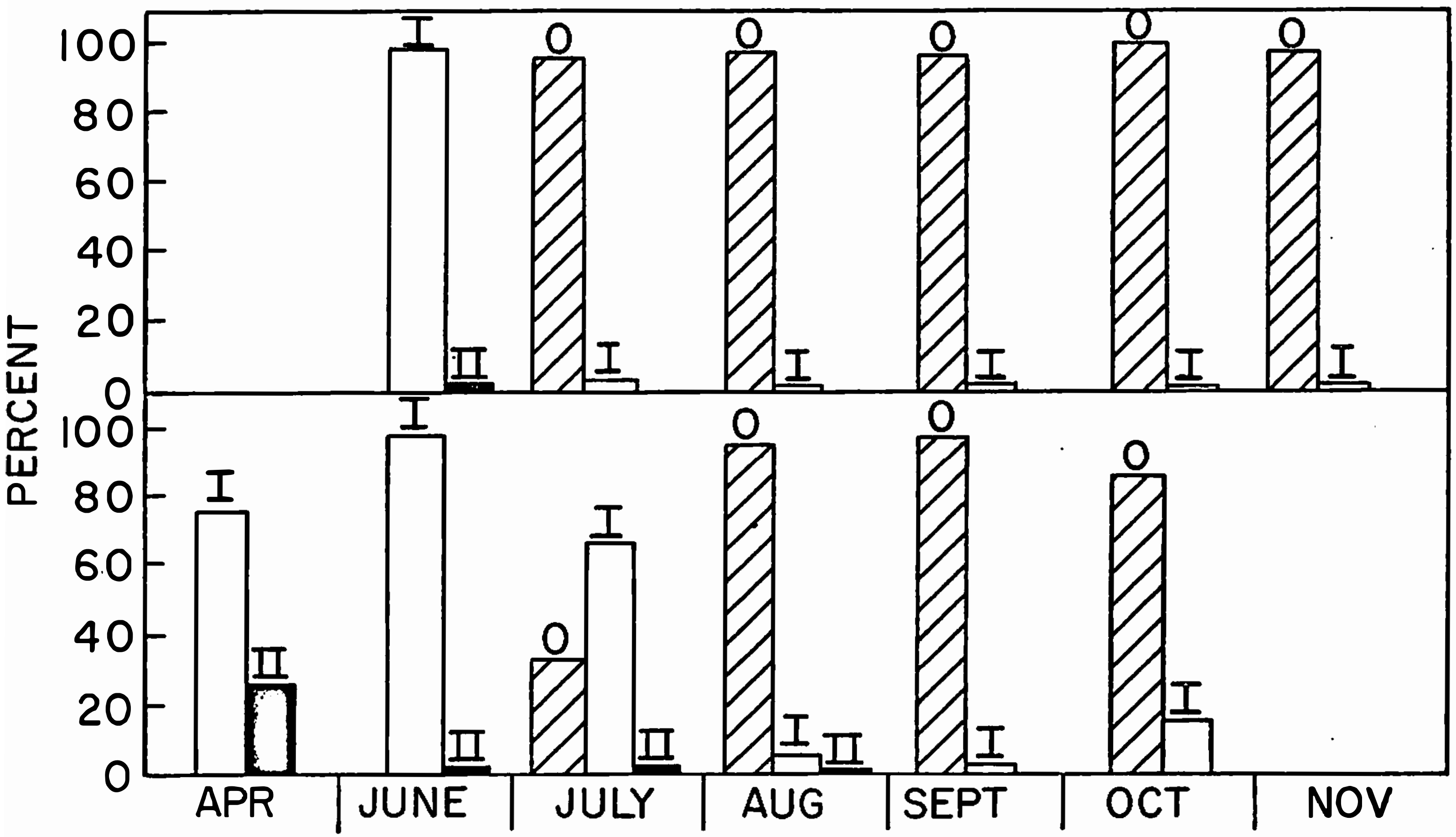

Figure 5. Percentage age composition of monthly seine catches in areas 2 (top) and 3 (bottom) from April through November, 1965, Lewis and Clark Lake.

Population turnover in area 2

The population in June consisted of age groups I and II, the former amounting to 98.4 percent of the catch. In July, a very rapid and sudden change occurred in the age composition of the catch. Age group I was reduced to 3.8 percent and age group II almost disappeared from the catch. Age group O appeared for the first time and made up 96.2 percent of the catch. It continued to dominate the population from August through November, composing more than 97 percent of each month's catch.

Estimates of the population turnover were made at both sampling stations. A faster turnover occurred in area 2 (Weigand Basin). Possible causes were: (1) failure of young-of-the-year to randomly disperse out of Weigand Basin; (2) differences in mortality rates between area 3 (unprotected area) and area 2 (protected area); and (3) movement of adult emerald shiners into and out of Weigand Basin. Regardless of the differences between stations, populations of emerald shiners were characterized by high rates of reproduction and mortality, rapid growth and a fast population turnover.

Mortality trends

Mortality trends of young-of-the-year and adult emerald shiners were obtained from monthly changes in the seine catch-per-unit-effort. Catch-per-unit-effort was influenced by wind conditions, fluctu ting water levels and underwater obstructions. Despite the difficulties involved, definite trends in the monthly average catch-per-unit-effort were evident (Table 6).

Young-of-the-year catch-per-unit-effort increased in area 3 during July and August, peaked in September, and decreased during October and November. Catch-per-unit-effort in area 2 markedly increased during July and August, then dropped sharply in September. These increases resulted from continuous spawning of the emerald shiner throughout July and August. Mortality of young-of-the-year probably accounted for the rapid drop in catch-per-unit-effort at both sampling stations.

Adult emerald shiners were captured in greatest numbers during June, after which their numbers generally decreased. In area 3, the average adult catch-per-unit-effort dropped sharply from 123 fish in July to only 17 fish in August. This drop may represent mortality or movement of adults to deeper water. However, the number of adults captured by trawling in the deeper waters did not increase at this time. In area 2 there was a drop from June to July, a small rise in August and a decrease again in September. The fluctuations were smaller than those which occurred in area 3, however the same general trends existed.

Differences in mortality between sexes were determined from changes in the sex ratio of adult emerald shiners. Sex ratios for age group I males and females in area 3 were approximately equal in May, June and July. Age group I females were more abundant in the latter part of the sampling period. They composed 53 percent of the catch in

Table 6. Monthly catch-per-seine haul of young-of-the-year and adult emerald shiners from April through November, 1965, areas 2 and 3, Lewis and Clark Lake

	Area 2			Area 3		
Month	Hauls	Y.-of-y.	Adult	Hauls	Y.-of-y.	Adult
April	--	--	--	4	0	18
May	--	--	--	3	0	2
June	13	0	69	9	0	131
July	11	457	15	13	68	128
Aug	11	887	24	12	280	17
Sept	4	155	2	8	367	8
Oct	3	81	1	2	116	21
Nov	2	117	3	2	1	0

August, 58 percent in September and 69 percent in October. This trend continued among age group II females. They composed 71 percent of the catch in April, 60 percent in June, 90 percent in July and 93 percent in August.

Age group I females in area 2 dominated the catch over the entire sampling period. They composed 61 percent of the catch in June, 71 percent in July and 80 percent in August. All age group II fish collected in area 2 were females.

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