THE EMPORIA STATE RESEARCH STUDIES

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Population Dynamics of *Physa Anatina* Lea in a Natural Spring Community

by

Joyce F. Fleming *

ABSTRACT

A study of the population dynamics of *Physa anatina* Lea inhabiting Ross spring revealed the population density to be related to the amount of watercress present in the spring's pool. Seasonal density of snails ranged from 10 snails per m^2 of plant surface area in the early spring to 145 snails per m^2 in late July. The fluctuations in density and total standing crop of snails were found to be related to the peaks in reproductive activity.

It was found that the Ross population began its reproductive season in late April and continued through July and August with some reproduction year round. Two peaks in natality occurred, the first and greatest in mid-May and the second during July and August. The accumulative effect of these peaks in natality resulted in the July peak in density and standing crop.

Laboratory investigations showed eggs from the Ross population hatched in an average of 18 days from deposition. Hatchability averaged 72.3% while survivability of the young was 24% after the first 60 days. Specific natality ranged from an average of 12.6 young per adult during the winter to 85.1 during the summer.

Investigation of the population age structure further supported two peaks in natality and the effect of natality on the density and total standing crop of snails. Age structure of the Ross population remained stable during the winter and until late April. By May the percentage of young began increasing and reached a maximum in late May.

Reproductive activity was believed related to water temperatures occurring in the spring. Due to the relatively stable temperatures of this aquatic habitat the population showed some natality year round. The age structure investigations supported continuous reproduction since all four age classes were continuously present.

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INTRODUCTION

Physa anatina Lea is a common and widespread snail in Kansas, occurring in a variety of permanent and temporary freshwater habitats. Its probable range extends from Nebraska south to central Texas, and it is known to occur east as far as Illinois and west to New Mexico and Colorado (Leonard, 1959; Brown, 1937).

Leonard (1959) stated that *P. anatina* is found in much the same types of habitats as *P. hawnii* Lea and that there is little difference in life cycles and habits of these two species. The reproductive period of *P. hawnii* usually begins during February and continues into the fall.

There is no previous record of the occurrence of *P. anatina* on Ross Natural History Reservation. Basch, Bainer, and Wilhm (1961) compiled an annotated list of the molluscan fauna of the Ross Natural History Reservation and did not mention collecting *P. anatina*. Although they reported *P. hawnii* to be the most common aquatic gastropod found during their study, only a single specimen was collected from the spring, the study habitat for my research. During the fall, 1973, numerous *Physa* were observed in the small pool at the head of the spring. Specimens were collected and identified as *P. anatina*. Dr. W. J. Clench, Harvard Museum of Comparative Zoology, verified identification of the specimens.

Because of the small size of the habitat and the fact that no other species of gastropods were present, this spring presented an excellent opportunity to observe selected aspects of the population dynamics of *P. anatina*. In November, 1973, a study was initiated to record seasonal variations in population density, reproduction, and population structure of *P. anatina* inhabiting the pool area of the spring.

DESCRIPTION OF STUDY AREA

The Ross Natural History Reservation is operated by the Division of Biological Sciences of Emporia State University. It is located approximately 8.4 km west of Americus and 22.4 km northwest of Emporia. The history, topography, and vegetation of the area have been described by Hartman (1960), Wilson (1963), and Basch et al. (1961).

The study site, hereafter referred to as Ross spring, is located in the southeast corner of grid A39. It consists of an unshaded rectangular pool approximately 1.0 m x 3.5 m bordered by limestone rocks. The pool varies in depth from 8 cm near the spring outflow to 25 cm near the source. Outflow from the pool seeps down a northeast-facing slope, forming a marsh environment. The pool is matted with watercress (*Nasturtium officinale*), which sometimes fills the pool.

Water temperatures in the pool varied from 11 to 16 C during the study. Dissolved oxygen and methyl orange alkalinity also exhibited slight seasonal variations during the period of this study (Table I).

Table I. Seasonal average of physicochemical characteristics of Ross Spring.

	Temperature C	Dissolved Oxygen ppm	M.O. Alkalinity ppm
Spring	11	5.3	413
Summer	16	4.1	348
Fall	15	6.1	367
Winter	11	6.6	*

* not obtained

METHODS AND MATERIALS

Physa anatina was found predominantly among the watercress plants, which necessitated the use of a special device to collect both snails and watercress. A metal cylinder 12.5 cm in diameter and 28.5 cm in height was used. The bottom of the cylinder had a sharp edge that would cut through the watercress mat. Watercress within the cylinder was then removed and placed in plastic bags, labelled, and returned to the laboratory. A small mesh strainer of approximately 0.08 mm mesh was passed through the water within the cylinder to collect loose plant materials and animals, which were added to the samples.

Field samples were collected periodically from November, 1973, through September, 1974. The pool was divided into fifteen 0.25 m^2 quadrats, using nylon twine. Quadrats were numbered and on each sampling date collections were made from two quadrats. The quadrats to be sampled were determined by drawing numbered cards. In general, field samples were collected at intervals of four weeks, with more frequent samples during spring (four day intervals) and summer (8 day intervals) to detect changes in population structure and reproduction. Each plastic bag was marked with the number of the quadrat sampled so that snails and egg masses could be returned to the same general location after the materials had been examined in the laboratory.

In the laboratory, samples were washed through soil sieves; the finest mesh used was 0.04 mm. The snails, egg masses, and watercress were separated. All snails in each sample were counted and examined with the aid of a binocular microscope. Using a vernier caliper, the maximum length of each shell was measured from the spire apex to the outer edge of the aperature. The greatest width of the aperature was also recorded. The product of the shell length and width was used as a size index.

Volume of watercress in each sample was measured by water displacement. After the watercress had been separated from the rest of the sample and washed, it was blotted dry. The plant material was then placed in a graduated cylinder that contained a known volume of water. The increase in volume in the cylinder was recorded as the volume of watercress.

Observation revealed the majority of the snail population occurred within the watercress mat, which occupied from approximately 30% of the basin during the winter to 80% during the summer. Since the watercress represented a substrate on which the snails lived and grazed, feeding on the aufwuchs growing on the plant surface, estimates of standing crops were related to the equivalent plant surface area in samples.

Plant surface area was estimated in the following manner. Volumes of five separate plant samples were measured and dry weights of each obtained. Another five samples were used to measure surface areas; dry weights of these samples were also recorded. The surface area of stems and roots was determined using the method of Harrod and Hall (1962). Several plant roots and five pieces of stems were placed on a glass plate and cut into small cylindrical lengths. The diameter and length of each piece were measured using an ocular micrometer in a binocular microscope. The areas of stems and roots were calculated using the formula, area = π dh, where d is diameter and h is length. A compensating planimeter was used to measure areas of leaves. Leaf areas were doubled to include both sides. The areas for stems, roots, and leaves were then added to estimate the total surface area of each of the five samples of plant material.

The average volume in one milliliter per gram dry weight was then calculated and equated to the average surface area per gram dry weight. One milliliter of watercress averaged 0.06 g dry weight, and one gram dry weight contained 8946.2 cm^2 of surface area. Therefore, one milliliter of plant material was considered the equivalent of 536.8 cm^2 of surface area.

Population density per sampling date was then determined in the following fashion. The average number of snails per milliliter of watercress was multiplied by the area equivalent (1 ml watercress = 536.8 cm^2). The resulting values were then converted to average number of snails per square meter.

A standard procedure was used for culturing snails in the laboratory. Snails were kept in glass containers filled with spring water. All laboratory cultures were maintained in a constant temperature room (15 C) which was equipped with a lighting system that produced a photoperiod that was similar to that occurring at the spring, changing with seasonal change. Watercress taken from the spring was used as the food for laboratory populations.

RESULTS AND DISCUSSION

Population Density and Seasonal Standing Crops of Snails

Variations in population density are summarized in Figure 1. Population density remained relatively stable during the first four months of this study and then declined through the early spring, reaching a minimum density of approximately 10 individuals per m^2 of watercress by mid-April. Although observed values fluctuated throughout the next three months, the general trend was for population density to increase. A maximum density of 145 snails per m^2 was recorded by late July. The density declined throughout the remainder of the study, so that by the first of October, 1974, the density was 26 snails per m^2, a value that was similar to the densities observed the previous fall and winter. The rather marked increases and decreases in densities during the period April through July were probably the result of reproduction and high mortality of young snails, and observed density peaks suggest two periods of maximum reproduction.

When total standing crops of snails inhabiting the spring are estimated, some rather interesting results are obtained. The average total surface area of watercress in the pool was determined for the

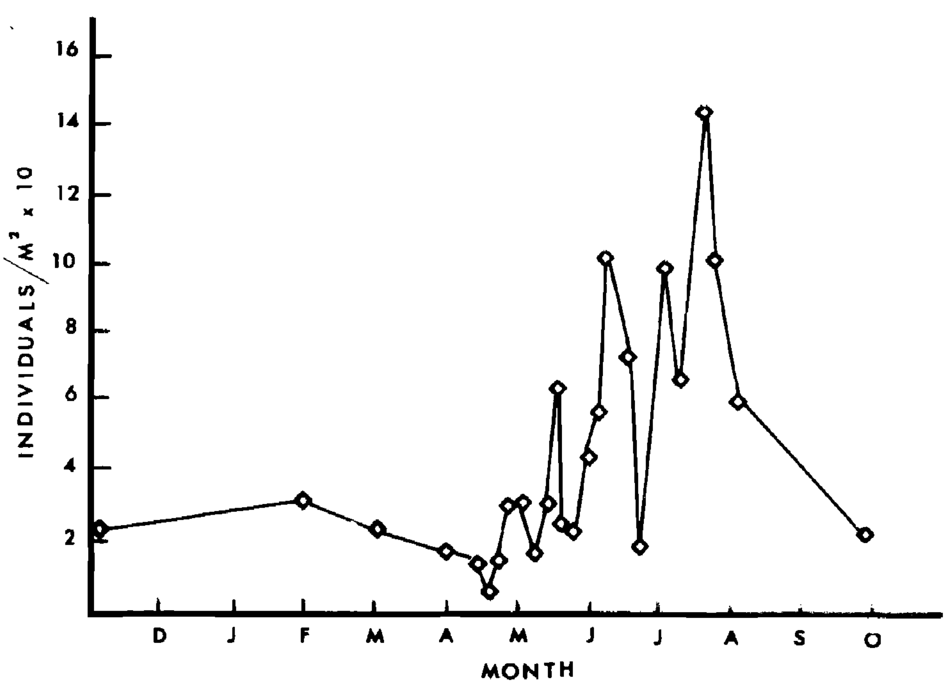

Figure 1. Seasonal variation in population density of *P. anatina*.

winter, spring, summer, and fall periods. This was accomplished by calculating the average surface area of plant material appearing in the cylinder samples for each season and then estimating the total number of cylinder samples of watercress that could be taken from the pool during each period. The product represented the total surface area of watercress present. Values obtained were: winter 104.1 m^2, spring 187.8 m^2, summer 371.8 m^2, and fall 221.4 m^2. Assuming the density estimates representative of abundance, the average density times the total plant surface area yielded standing crop. On this basis the total *P. anatina* population inhabiting the spring in January was 3227 snails, and for mid-April the standing crop was approximately 2567 individuals. For the period of maximum density in July the standing crop was estimated at 53,911 individuals. By the end of September standing crop had declined to approximately 554 snails. Unfortunately, no similar data were found in the available literature to compare with these estimates.

Reproductive Season

Egg masses were observed in the pool throughout the year, but were most abundant during the warmer months. An average of six masses per sample of watercress was found in winter samples compared to an average of 70 egg masses per sample during the late spring. Based on the number of egg masses observed, *P. anatina* begin its reproductive season during late April and exhibited two periods of maximum egg deposition. The first and greatest period occurred in mid-May, and the second less pronounced period during July and August. These observations support the hypothesis that reproduction accounted for the recorded seasonal increases in standing crop. Figure 1 shows a marked increase in population density within three weeks after the onset of increased egg deposition. This three week period may be the hatching period for this population.

Duncan (1959) described the reproductive behavior of *P. fontinalis* in a pond at Stanmore, England. In 1954, he found that the main reproductive period occurred during April and May, although egg masses were found until the last week of August. Some of the snails that hatched during the spring season reached maturity by July and August when a second breeding season occurred. Duncan found that the snails breeding then were all much smaller than those in the April and May season. It was evident that they reached sexual maturity before they reached the same size as the spring breeders. Duncan concluded that the warmer temperatures in the summer produced rapid metabolic activity allowing a more rapid development of the second generation and a subsequent, second breeding season. At Stanmore, reproductive activity ceased in September. During 1955, the Stanmore population did not produce a second generation in the fall (Duncan, 1959). Duncan attributed this to an exceptionally warm summer which caused slowed development. He stated that growth was not solely governed by temperature. A second breeding season was not found in populations at two other locations in the fall of the same year. In the Lake District, 188 km further north of Stanmore, only one generation was the general rule. The reproductive season in that region occurred a little later, continuing until the last week of July. Growth was less rapid and shell length at maturity much shorter.

DeWitt (1954a) studied an April population of *P. gyrina* in Michigan consisting entirely of sexually mature individuals which had begun to oviposit. By May the adults were replaced by juveniles, and egg masses were scarce from June through October. In August a high percentage of this population consisted of individuals within the same size range as that which had oviposited in the spring. As at Stanmore in 1954 a second generation occurred. DeWitt observed, as Duncan had in *P. fontinalis*, snails which hatched in the spring developed at a rate that enabled them to reach sexual maturity in the fall and some of these snails oviposited. Snails from the second generation did not reach maturity until the following spring.

Hunter (1961) reported the reproduction of *P. fontinalis* in Loch Lomond began from late May to late June. There was no replacement of one generation with another, as DeWitt found with *P. gyrina*.

Brown (1937) reported March as the main period of reproduction for an Illinois population of *P. anatina*. She found reproduction declined during the summer months and a second season occurred in September, which reached a maximum activity in November when 80% of a laboratory population produced egg masses. In Kansas, the reproductive season of *P. anatina* begins in February and continues into the fall (Leonard, 1959). The relatively stable water temperatures in Ross spring may have influenced the reproductive behavior of the resident population. Many researchers agree that temperature affects the reproductive behavior of *Physa*. Duncan (1959) and DeWitt (1954b) related observed reproductive behavior to temperature, but Hunter (1961) disputed any direct effect of temperature. He found no evidence that the incidence or extent of a subsidiary breeding season was in any way related to summer temperatures occurring at the time. He contended that the variations found in sizes attained by snails could be correlated with conditions prevailing the preceding year. However, DeWitt (1955) stated reproduction in *P. gyrina*, under natural conditions, is directly related to temperature. He observed oviposition began when temperatures in the pond he studied reached 10 C-12 C. Duncan (1959) found temperature the basic, though indirect, factor governing oviposition through its control of the rate of development. In both years of his investigations at Stanmore, his observations showed temperatures between 7 C and 11 C critical in the initiation of oviposition. He found 7 C the temperature at which growth was initiated again after the winter lag. Since water temperature was never below 11 C in the Ross spring and snails of all sizes were found throughout the year, it is possible that there was less lag in reproduction of overwintering animals. The Ross spring temperatures of 11 C to 16 C fall within the range given by Duncan (1959) and DeWitt (1954b) as the range in which reproduction and development of *Physa* could occur. This would account for the presence of egg masses during the winter in Ross spring.

Natality

It was hypothesized that observed variations in the estimated density of the Ross spring *Physa* population were due primarily to reproductive and survival behavior. Observations reported in the previous section supported this hypothesis, since maximum reproduction, in terms of egg masses deposited, coincided with the period of maximum population density. Additional observations and data analysis were designed and executed to provide additional evidence in the form of seasonal natality and survival rates.

Average seasonal egg production of the study population was estimated from field data in the following manner. During certain months the total number of eggs in five separate egg masses, selected at random from samples, were used to calculate the average number of eggs per egg mass for that month. A seasonal average was then determined from the averages. Averages from March, April, and May's samples were used to determine the average for the spring period. Summer averages were determined from the cases selected in June, July, and August. The fall average was determined in September, while the winter average was determined in January. Fall and winter are periods of decreased reproductive activity and results based on a single month were believed representative. Total eggs present in a given sample were equal to the number of egg masses per sample times the appropriate seasonal value for the average number of eggs per mass.

It was reasoned that if the approximate number of eggs present was known and if development time and percentage of eggs hatching were known, then the number of young snails entering the population per unit of time could be estimated. Hence, it would be possible to predict the population density at a future time given an initial population density plus a natality value. Of course, to be realistic the predicted population density should be corrected for mortality.

The initial task was to derive a value to represent the expected proportion of an egg mass to hatch, or the percentage hatchability. This value was determined in the laboratory.

Fourteen egg masses, collected from isolated snails, were transferred to culture vessels of spring water and maintained at 16 C. Cultures were examined several times daily and a record was kept of how long it took for hatching to begin as well as the number of eggs that hatched. Brown's (1937) study of *P. anatina* showed hatching required four to 17 days, at 19 C to 22 C, and she estimated 33% hatchability. Duncan

(1959) found *P. fontinalis* usually hatched in about 17 days at 19 C. At 16 C the Ross spring eggs began hatching 10 to 29 days after deposition, with the average hatching time being 18 days. Hatchability of individual egg masses ranged from 6% to 100% and averaged 72.3%.

The number of young produced per mature snail (specific natality) of the study population was calculated by multiplying the seasonal average number of eggs per mass by percentage hatchability times the average number of cases, divided by the number of mature snails found in each sample. Snails were considered mature if they measured 4.5 mm in length, the length at which oviposition was observed to begin in laboratory populations.

Figure 2 summarizes the estimated specific natality for the Ross spring population throughout the study period. Actually, values were advanced 18 days to account for developmental time. For example, the specific natality value shown in the figure for the first of May was based on the number of eggs present in samples taken during the second week of April. Natality was lowest during winter, when an average of 12.6 young was produced per mature snail. During spring estimated specific natality increased to an average of 65.5 young per mature individual. The first natality peak, 214.0 young per mature snail, was reached in the spring. Summer specific natality averaged

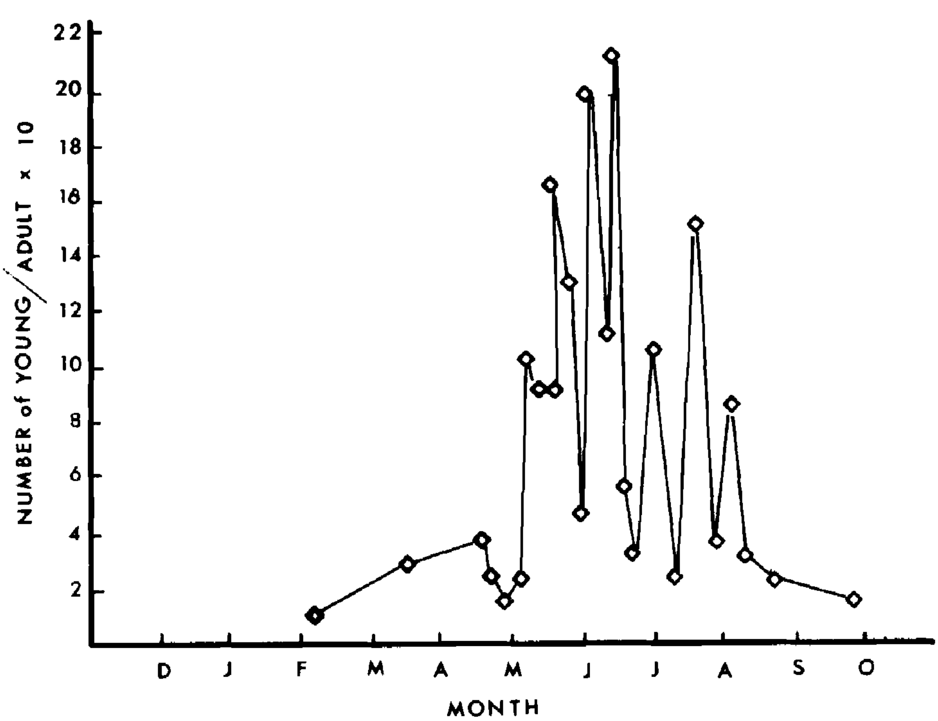

Figure 2. Seasonal variation in specific natality of *P. anatina* inhabiting Ross spring.

85.1. The second peak in natality, reached during the summer, was 148.0 young per mature snail. By September values dropped to 61.2 young per mature snail.

Duncan (1959) observed that the number of eggs in a mass was not proportional to the size of *P. fontinalis* in the laboratory, but depended on where the animal was in its oviposition cycle. DeWitt (1954b) found, under natural conditions, a significant positive correlation between the number of eggs per mass and the size of *P. gyrina.* Duncan's observations were made through recording the number of eggs per case in relation to the development of the genital systems which he determined through dissection. DeWitt's observations were made from collecting egg masses from isolated snails for an entire year. DeWitt found that the snails which began oviposition in the spring were smaller and laid fewer eggs per case. He found (DeWitt, 1954b) *P. gyrina* initially laid masses that tended to contain the maximum number of eggs. The number of eggs per mass and the number of masses he found progressively declined.

Cultures of *P. anatina* were set up in the laboratory to determine the relationship between size and egg production. Two groups of *P. anatina* of differing sizes were cultured. Each snail was isolated, and all were sexually mature. The younger group containing ten snails of average size index 7.6, produced only 0.4 young per snail per day. The older group also containing ten snails, with an average size index of 39, produced 1.7 young per snail per day. Thus the younger snails tended to produce fewer eggs than older, larger snails.

DeWitt (1954b) indicated that in *P. gyrina* there was a definite relationship between population density, the size attained by the snail before sexual maturity, and egg production. As the number of snails reared together was increased the size at commencement of oviposition decreased and the mean number of eggs per snail decreased. An experiment was conducted in the laboratory to investigate the relationship of population density to egg production in the study population of *P. anatina.* Four snails of an average size index of 6.0 were cultured at 16 C. Ten snails of an average size index of 7.6 were isolated individually. The four smaller snails produced 2.4 young per snail per day. The ten isolated snails produced 0.4 young per snail per day. The denser population yielded a higher natality. This is the opposite relationship DeWitt found. Additional experiments of this type are needed.

Survivability

Data on survivability of young snails for the Ross population were recorded in the laboratory. Snails hatched from 14 isolated egg cases were placed into separate cultures with spring water and watercress. Each group was observed over a 60 day period and the number of snails surviving from each egg case was recorded. Figure 3 shows the average number of snails surviving from the 14 groups for each ten

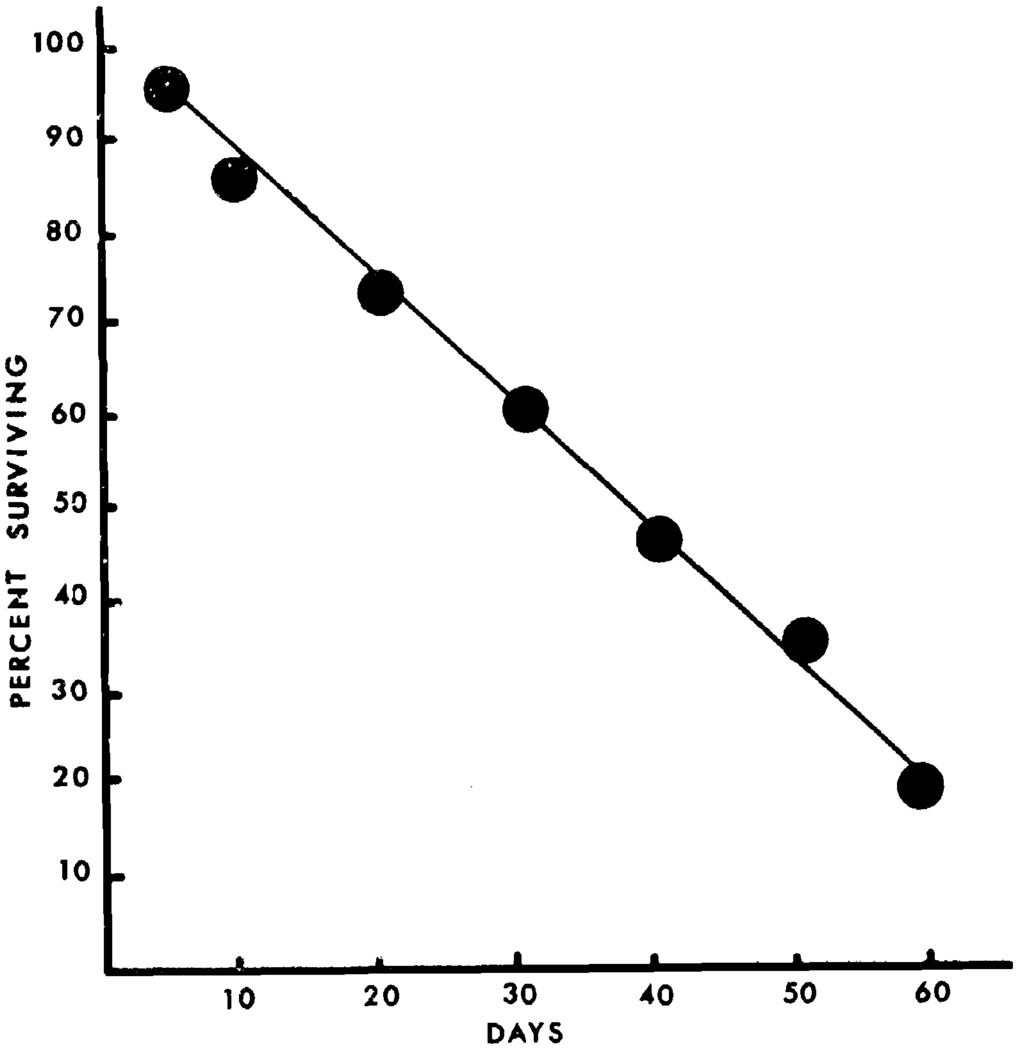

Figure 3. Percentage of newly hatched snails surviving.

day interval of the 60 days. Mortality appeared constant and averaged 12.6% per ten days, ranging from 10% to 16%. After the 60 days, only 24% of the original numbers of young survived, indicating a mortality of 76%. The periodic decreases in population density recorded in Figure 2 is believed to be largely due to the high mortality occurring in the first 60 days after hatching.

Growth and Maturity

The variations found in the size of ***Physa*** at sexual maturity supports the plasticity of this genus. Duncan (1959) found the size attained at sexual maturity varied in the same population at Stanmore.

He found that snails breeding in the spring season measured an average of 10 mm in length while the second generation reached 7.1 mm by fall and were spawning by this time. Brown (1937) found *P. anatina* began ovipositing between 5.3 mm to 9.3 mm in length. The Ross population of *P. anatina* began ovipositing in the laboratory at an average length of 4.5 mm when cultured at 16 C. Determination of growth rate for *P. anatina* was made in the laboratory. Ten newly hatched snails were isolated individually in cultures. Each snail was measured and its size index determined daily for the first ten days. After the first ten days they were measured at five day intervals. These ten snails exhibited an average growth rate of 0.01 index units per day for the first 30 days. During the second 30 days their growth rate increased to 0.02 units per day. Hunter (1961) found that newly hatched *P. fontinalis* could gain 1.1 mm in length the first 20 days. The shell increase corresponding to the newly hatched Ross snails' index was 1.2 mm the first 20 days.

Growth rates of two older groups of snails were recorded. A mid-sized group with an average size index of 22.0 increased an average of 0.11 units per day. The size index of the older group averaged 45.0. These snails grew an average of 0.58 index units per day. This indicated the older snails were growing at a more rapid rate.

Population Structure

In order to study population age structure a method was needed for grouping snails into age classes. An egg mass was selected which had over 20 developing embryos to insure at least ten would be available for the determination. When hatching occurred, ten of the newly hatched snails were measured and each isolated in a shallow, covered dish of spring water with food. For the first ten days the snails were measured daily and the size index of each recorded. After the initial ten days they were measured at ten day intervals for 50 more days. A second group of snails was obtained and measured in the same manner, to determine if their growth rates would be the same. No significant difference ($p=0.05$) was found between the two groups when their average indexes were analyzed statistically.

Figure 4 shows the range of measurements of the ten snails on each of the days measured. There was overlap in the range of size indexes from one interval to the next, so four age intervals were selected to represent population age structure. The first interval contained snails which were younger than 20 days and exhibited an index of 0.35 or less. The second interval represented snails considered to be 20 to 40 days old and consisted of snails with indexes of 0.36 to 0.70. The third interval represented snails between 40 and 60 days old. These snails had indexes of 0.71 to 1.0. The last interval contained the oldest snails, all over 60 days old and exhibiting indexes greater than 1.0.

Population structure was studied in the spring over an entire year. Size indexes for all snails collected during the study were recorded.

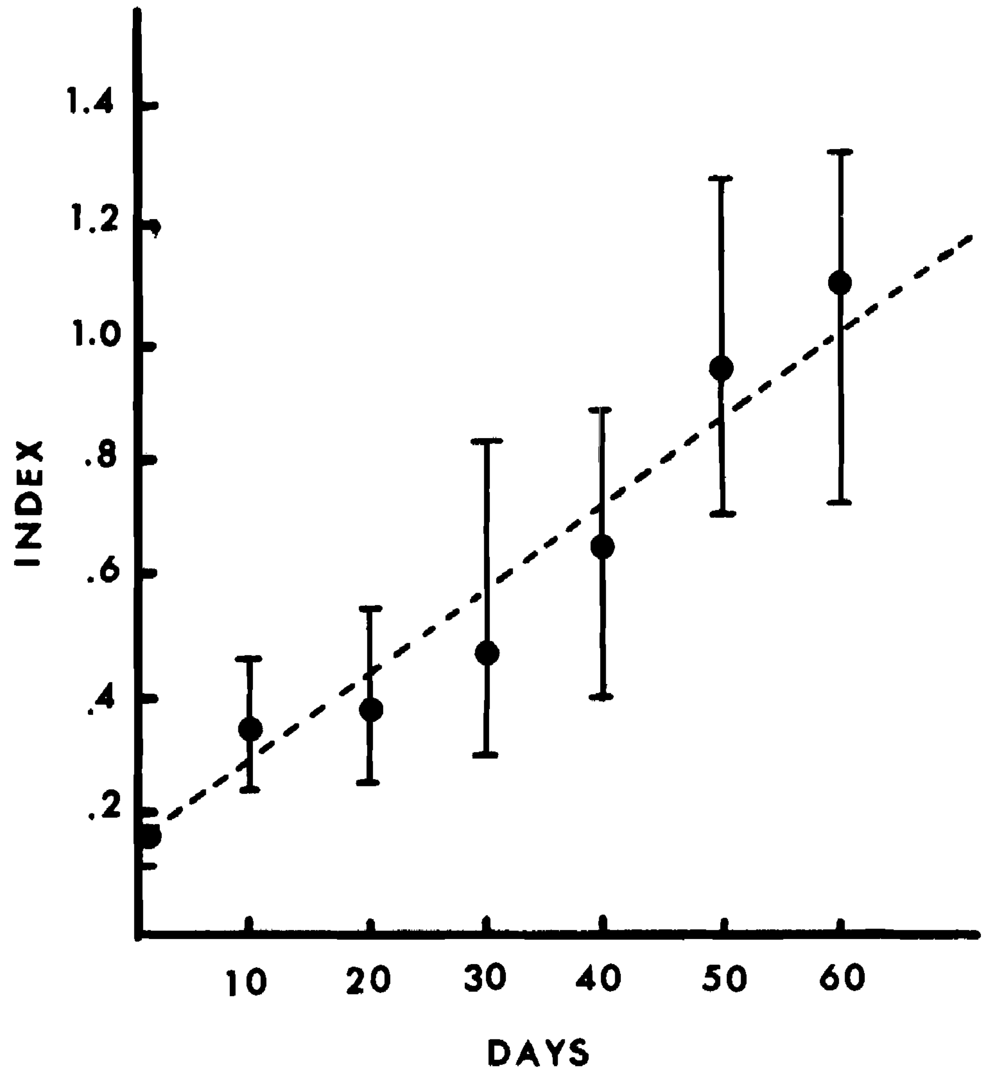

Figure 4. Range and average age index for ten snails from hatching to 60 days.

Each snail's index number was then placed into the appropriate age class interval. The percentage of each age class present in the population was then estimated by determining the percentage of each age class on each sampling date, (Figures 5-8).

For the first three sampling periods the population age structure remained relatively stable (Figure 5,A,B,C). The proportion of older snails (age greater than 60 days) increased during the early spring. By April 28 the percentage of young snails in the population was increasing (Figure 6). This trend continued throughout the next three months. The periods of maximum population density and maximum

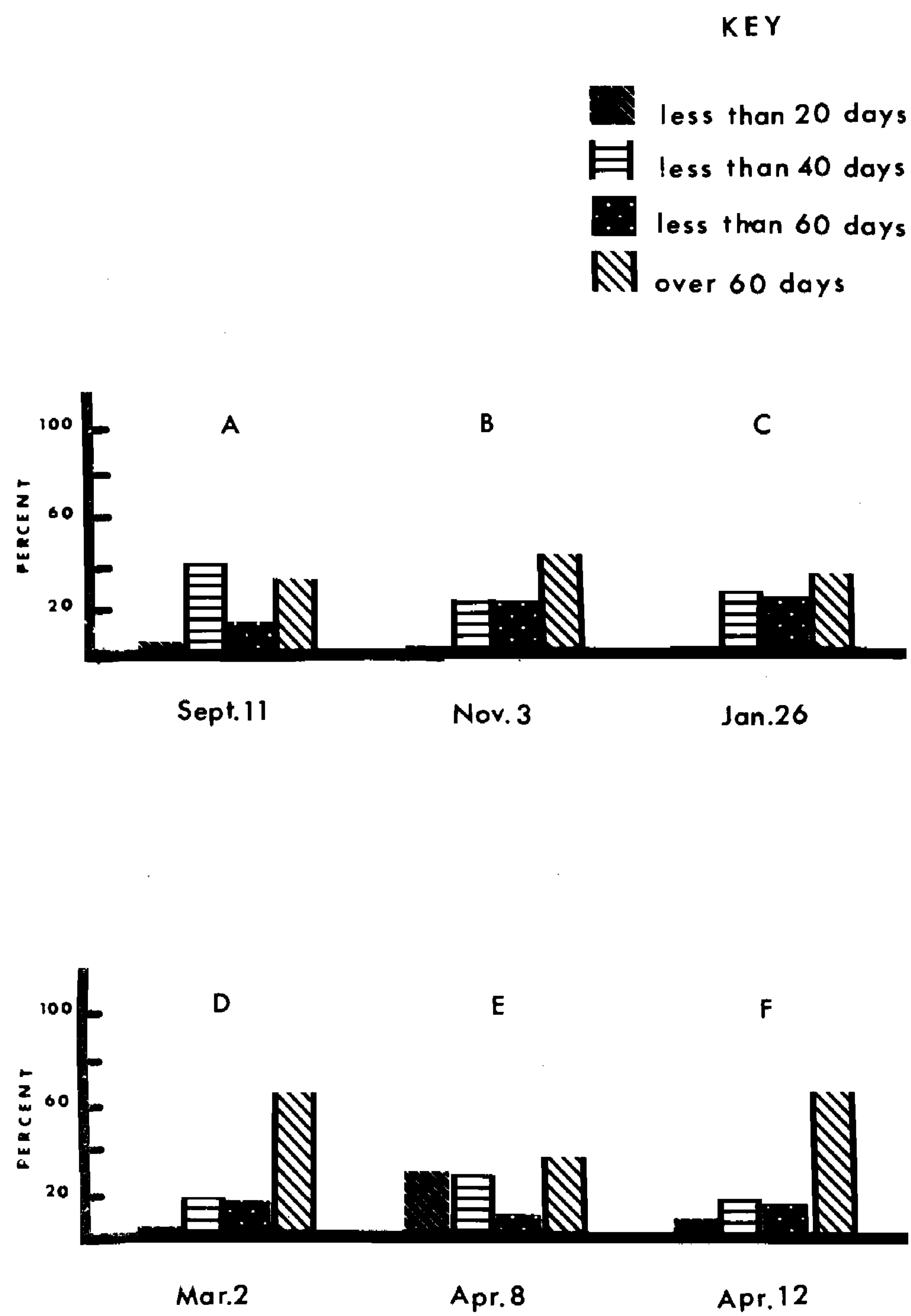

Figure 5, A-F. Percentage of snails occurring in each age class from September 11 through April 12.

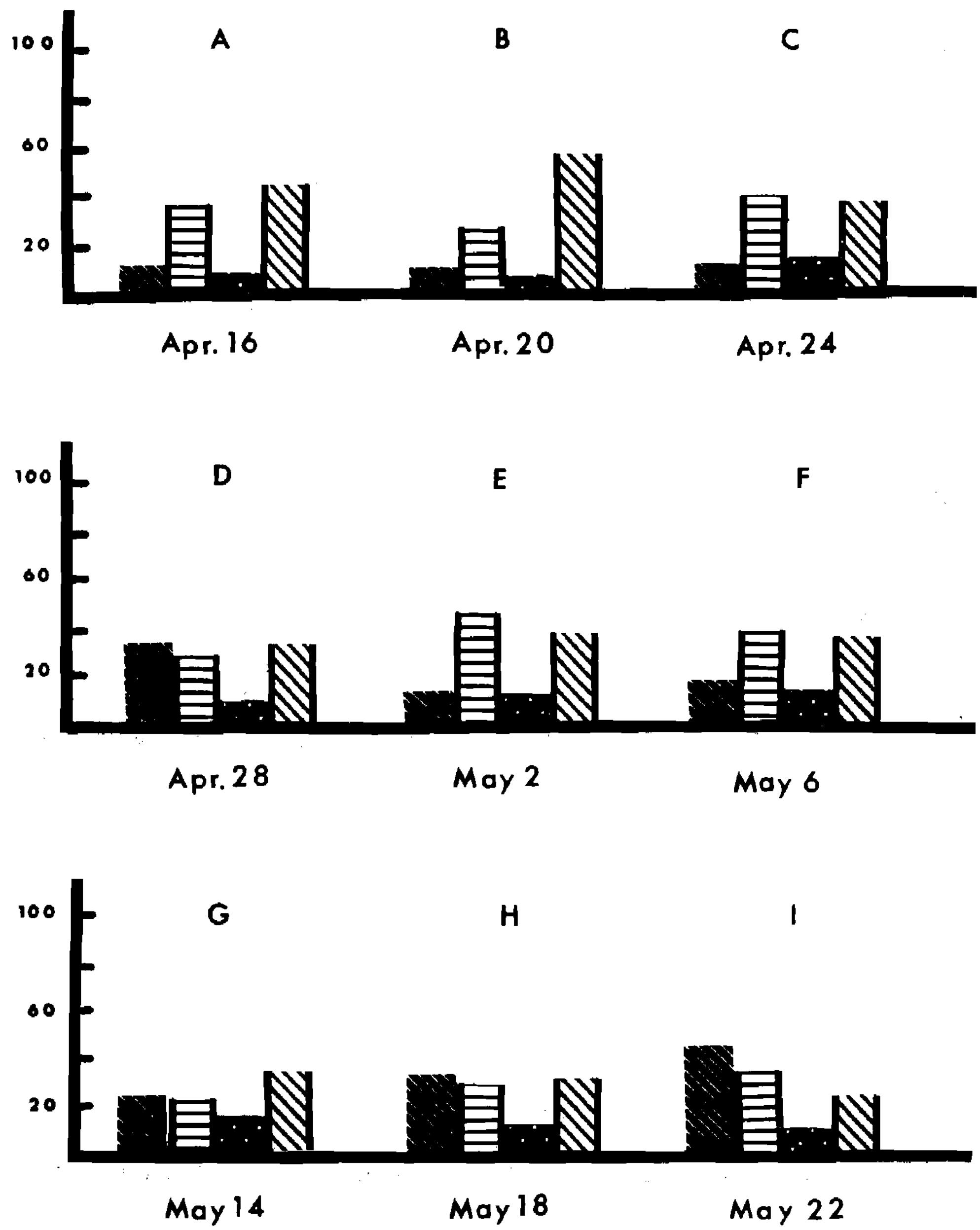

Figure 6, A-I. Percentage of snails occurring in each age class from April 16 through May 22.

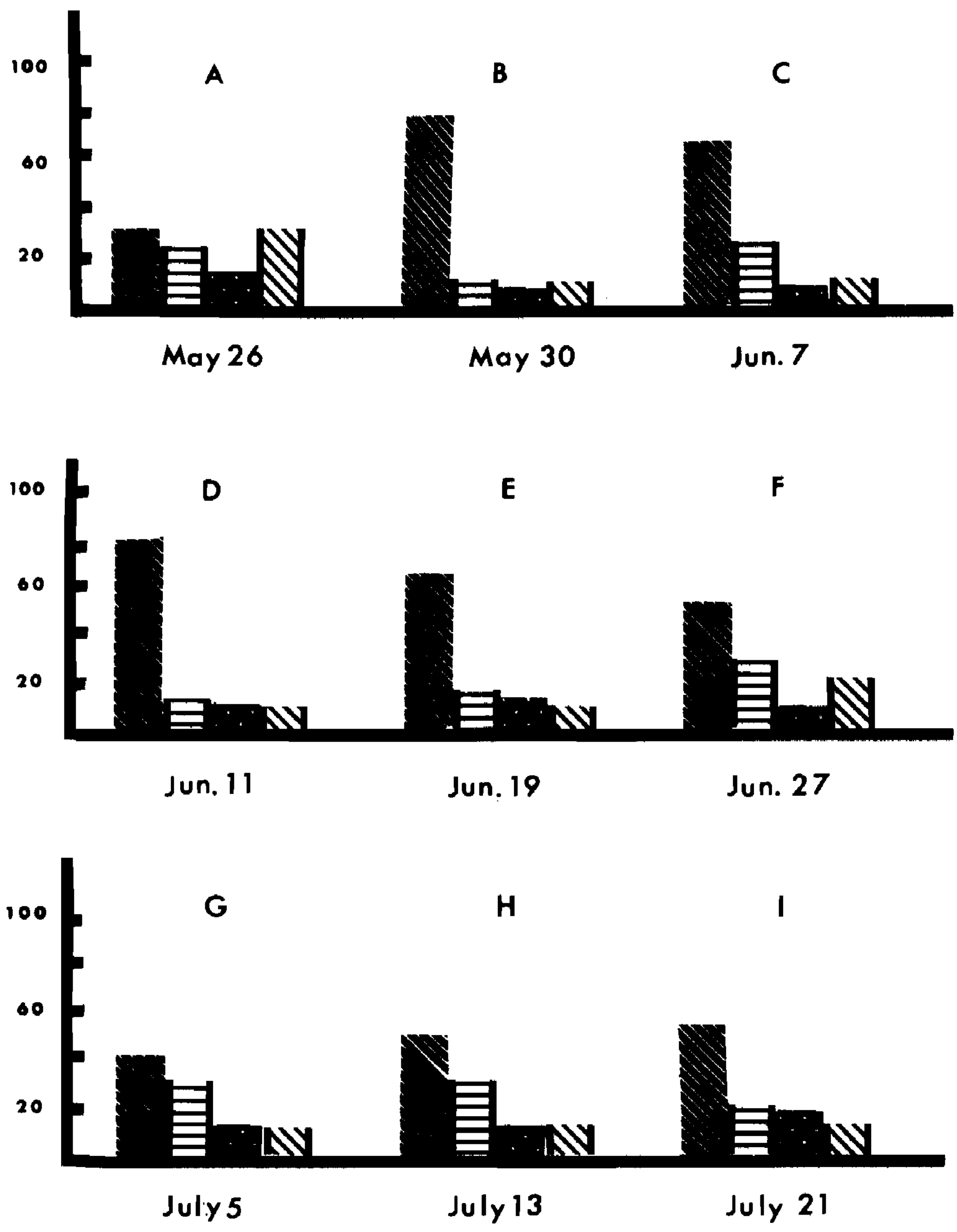

Figure 7, A-I. Percentage of snails occurring in each age class from May 26 through July 21.

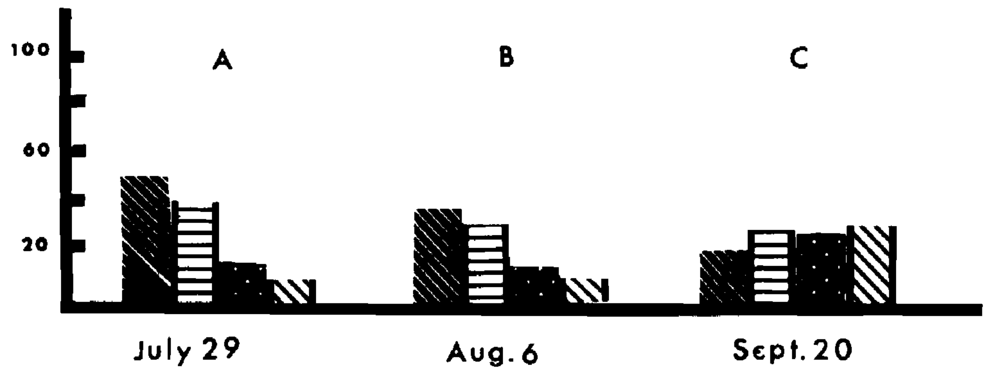

Figure 8, A-C. Percentage of snails occurring in each age class from July 29 through September 20.

egg production are reflected by the population age structure. By the end of May nearly 80% of the population consisted of individuals less than 20 days old (Figure 7). The percentage of young snails then gradually decreased through the remainder of the summer, and by September 20 the relative proportion of young had decreased to levels approximating that recorded the previous September (Figure 8).

Some relationships are apparent among data obtained on population structure, density of snails, and hatching. Figures 1 and 2 highlight these relationships. The peaks for estimated specific natality closely coincide with those of peak density. This not only supports the hypothesis that the peaks in standing crop and density were due to natality, but supports the proposed 18 day developmental period. While the first peak in density was probably due to the great upsurge in natality, the second and maximum peak was reached when the first increase was added to by a second period of natality. Note from the population structure figures that after the first period of natality in May and June the percentages of the age classes began to level off. The second age class began to increase as the snails grew out of the first age class. Young produced from the second period of natality added to those surviving from the first period. This accumulative effect caused the peak in density and total standing crop of the population. Mortality and growth of individuals then caused the age structure to level off.

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Benthic Species Diversity and Related Physicochemical Features of John Redmond Reservoir, 1971-72

by

Francis L. Funk and John D. Ransom *

ABSTRACT

Benthic fauna and water quality analyses were made on monthly samples from John Redmond Reservior, Kansas, from September, 1971, through August, 1972. Species diversity indices were calculated on benthic community structure. Relationships between species diversity and physicochemical estimates were established.

A total of 6,259 individuals representing 23 taxa of benthic macroinvertebrates was collected during the year. The aquatic oligochaete, *Limnodrilus* sp., was the most abundant organism collected. Members of the family Chironomidae (Insecta: Diptera) represented 45% of the total number of macroinvertebrates collected. Generally, numbers of individuals increased with depth and individuals were not abundant during the winter and early spring. Emergence accounted for large, seasonal fluctuations in numbers of insect larvae.

Chemical concentrations were generally uniform from top to bottom. Nutrient levels were high at times, but did not appear to be critical. Little evidence of thermal stratification was noted and dissolved oxygen was not a limiting factor.

Turbidity was extremely high throughout the year. Following periods of high rainfall, Secchi disc transparency averaged less than 30 cm. This compared to readings of more than 100 Jackson Turbidity Units.

Results of species diversity analyses indicated there was moderate stress on organisms in the Reservior. Monthly variations in $\bar{d}$ ranged from 2.39 to 1.18. The t-test at p = .05 revealed no significant differences of $\bar{d}$ values by depth or by month. It appeared that turbidity may have been the single most critical factor limiting diversity of benthic macroinvertebrates in John Redmond Reservoir.

INTRODUCTION

Rationale for the Study

The main stimulus for choosing this study was a report prior to 1970 that the Kansas Gas and Electric Company together with the Kansas City Power and Light Company were considering the feasibility

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of constructing a nuclear generating station on John Redmond Reservoir, Kansas, and using water from the Reservoir as a coolant. A question arose about whether or not the heated water could become a source of thermal pollution when released back into the Reservoir. A baseline study on benthic fauna diversity and related physicochemical features in the Reservoir was needed to provide data on these conditions as they existed before the nuclear station was to go into operation. Those data could then be compared to data collected after the nuclear station became operational.

In May, 1972, when this study was almost completed, the Kansas Gas and Electric Co. with the Kansas City Power and Light Co. announced they would purchase land east of John Redmond Reservoir and would build their own storage and heated-water reservoirs, if preliminary environmental impact research and geological research, as well as other research, would indicate it to be feasible to locate there. Therefore, the data of this 1971-72 study will be useful only as environmental inventory data and as baseline data for future aquatic research in the area.

Background for Benthic Community Analyses

Investigators have attempted to classify bottom organisms according to pollution tolerances; but Gaufin and Tarzwell (1956) found the presence or absence of a given species is less reliable than population associations in determining water quality in streams. Wilhm and Dorris (1966) drew attention to the use of species diversity indices to characterize water quality of streams. Ransom and Dorris (1972) first demonstrated the application of diversity indices to characterize water quality conditions in a lake.

Several water quality surveys using species diversity indices ($\bar{d}$) have been made in the vicinity of John Redmond Reservoir. Edwards (1970) used $\bar{d}$ values to characterize the effects of cattle feedlot runoff into the Cottonwood River above John Redmond Reservoir. Prather (1969) applied $\bar{d}$ values to zooplankton within John Redmond Reservoir and within two other reservoirs above it.

The objectives of this study were to characterize John Redmond Reservoir by using species diversity indices of benthic macroinvertebrates collected at various depths along selected transects and to relate those indices to the physicochemical features of the Reservoir.

DESCRIPTION OF THE RESERVOIR

John Redmond Reservoir was formed by impounding the Grand (Neosho) River at a point approximately 48 kilometers below the confluence of the Cottonwood and the Neosho rivers east of Emporia, Kansas. The dam was built by the United States Army Corps of Engineers and completed in 1965. The Reservoir forms a shallow pool having a surface area of 3,157 hectares and approximately 75% of the basin is less than 3 m in depth (Prophet, 1966).

Unlike most multipurpose reservoirs in eastern Kansas which have many bays and small tributaries causing an irregular shoreline, John Redmond has a relatively smooth shoreline, few tributaries and a generally round shape at conservation pool, elevation 1036 msl (Fig. 1). Winds blowing across the Reservoir have a long fetch from any direction. This feature, coupled with the extremely shallow depth, causes the Reservoir water to be mixed from top to bottom on most days.

MATERIALS AND METHODS

Bottom fauna samples and water samples were taken once each month, except in January when ice covered the Reservior, during a twelve month period beginning in September, 1971, and ending in August, 1972. Sampling was started approximately two hours after sunrise on each collecting date. Samples were taken at each meter drop in depth from top and bottom along a transect extending from shore to the deepest area of the Reservoir (Fig. 1). Samples were not taken from depths greater than 4 m because the maximum depth was in the old river channel and represented an atypical portion of the

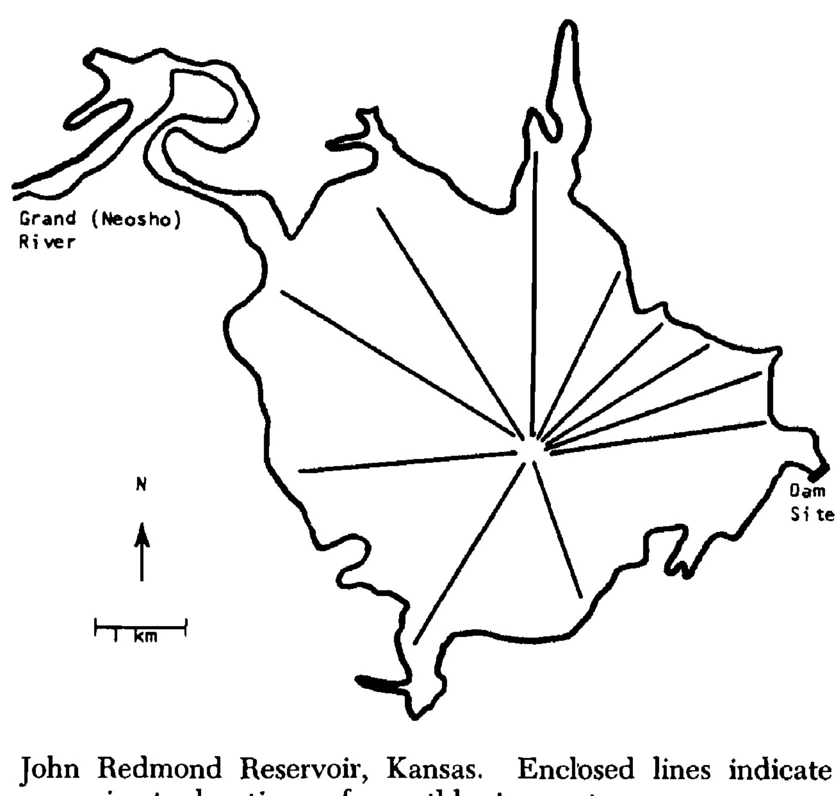

Figure 1. John Redmond Reservoir, Kansas. Enclosed lines indicate approximate locations of monthly transects.

Reservoir. All samples were taken when the water level was near conservation pool (1036 msl), except during the month of May when the pool was approximately one meter deeper than conservation pool.

Four benthic samples were taken with a 15 cm Ekman dredge at each sampling depth and combined into a pair of double samples. Samples were washed free of mud and silt in field screens of 60 to 80 mesh. Organisms and remaining debris were preserved in 10% formalin and the organisms were picked and sorted by hand in the laboratory and were preserved in 80% isopropyl alcohol. Identifications and density determinations were made at later dates.

Estimates of diversity per individual ($\bar{d}$) were determined by using the Shannon-Weaver (1949) equation

$$\bar{d} = -\sum_{i=1}^{s} \left[\frac{n_i}{n} \log_2 \frac{n_i}{n} \right]$$

where n is the total number of individuals and n_i is the number of individuals of species i. Species diversity ($\bar{d}$) values were subject to a t-test at the $p = .05$ level of significance.

Water temperatures were taken at the top and at the bottom. Specific conductance was determined by measuring the electrical resistance converted to micromhos/cm at 25 C. Transparency was determined with a 20 cm Secchi disc and was correlated and converted to Jackson Turbidity Units on a Bausch and Lomb Spectronic 20.

Chemical analyses of water samples were conducted according to procedures outlined in Standard Methods (A.P.H.A., 1960). Water samples were taken with a Kemmerer water bottle. Except for dissolved oxygen, a composite water sample consisting of 2 liters from the top and 2 liters from the bottom at each sampling site was used for laboratory chemical analyses. Dissolved oxygen was determined on duplicate top and bottom samples by the Alsterberg modification of the Winkler Method titrated with .025 N phenylarsene oxide. The stannous chloride method was used to measure phosphates and the direct Nesslerization was used to measure ammonia nitrogen. A colorimetric method was used to measure pH. All chemical estimates, except dissolved oxygen, were made on a Bausch and Lomb Spectronic 20.

RESULTS AND DISCUSSION

BIOLOGICAL

Taxa Collected

A total of 6,259 individuals representing 23 taxa of benthic macroinvertebrates was collected (Table I). Eleven of the 23 taxa were midges of the Family Chironomidae. The members of this family are an important link in the food chain between algae and macroinverte-

TABLE I

ANNUAL NUMBERS OF BENTHIC MACROINVERTEBRATES

DEPTH (Meters)	1	2	3	4
	Individuals/m^2			
NEMATODA	0	4	0	0
ANNELIDA				
OLIGOCHAETA				
Branchiura sowerbyi Bedd.	0	6	4	11
Tubifex tubifex (O.F.M.)	1	13	55	60
Limnodrilus sp.	52	239	592	742
MOLLUSCA				
PELCYPODA				
Sphaerium sp.	3	1	1	4
ARTHROPODA				
EPHEMEROPTERA				
Caenis sp.	1	0	0	0
Hexagenia sp.	13	53	11	1
TRICOPTERA				
Polycentropus sp.	1	10	0	1
Neothremma sp.	1	1	0	0
COLEOPTERA				
Dubiraphia sp.	1	0	0	0
Narpus sp.	1	0	0	0
DIPTERA				
CULICIDAE				
Chaoborus punctipennis Say	78	34	88	124
CHIRONOMIDAE				
Anatopynia (*Psectrotanypus*) sp.	7	0	0	0
Tanypus sp.	39	392	213	154
Procladius sp.	20	263	527	423
Coelotanypus sp.	106	351	454	598
Pentaneura sp.	1	1	1	0
Chironomus (*Xenochironomus*) sp.	0	10	3	0
Pseudochironomus sp.	14	7	1	0
Chironomus (*Cryptochironomus*) sp.	14	8	2	3
Chironomus (*Chironomus*) sp.	17	138	213	163
Chironomus (*Dicrotendipes*) sp.	7	6	0	2
Polypedilium sp.	8	1	0	2

brates, and the larger macroinvertebrates and fishes (Mason, 1968). They exhibit a wide range of tolerance to environmental factors, but work by Paine and Gaufin (1956) questioned the use of chironomid larvae as indicator organisms. However, certain genera within the family have adapted well to living in water where concentrations of dissolved oxygen are low and where lake bottoms are composed of fine silt (Pennak, 1953). The distribution of chironomids and other macroinvertebrates collected in this study seemed to bear this out. Specimens taken from the one meter depth where little or no silt occurred were few in number. As depth of water and bottom silt increased, generally greater numbers of chironomids and oligochaetes were found. This situation was somewhat different than that found by Ransom and Dorris (1972) who collected from a much larger and deeper reservoir which stratified throughout the summer. John Redmond Reservoir rarely, if ever, stratifies. *Tanypus* sp., *Procladius* sp., *Coelotanypus* sp., and *Chironomus* (*Chironomus*) sp. were the most abundant and represented 98% of the total chironomids collected.

Three species of oligochaetes, *Branchiura sowerbyi* Bedd., *Tubifex tubifex* (O.F.M.), and *Limnodrilus* sp. were collected. *Limnodrilus* sp. was the most abundant and represented 26% of the total macroinvertebrates collected. One nematode, one pelecypod, two ephemeropterans, two tricopterans, two coleopterans, and one dipteran, in addition to the chironomids, were collected.

Distribution and Seasonal Changes in Numbers of Benthic Organisms

Six benthic species were collected in sufficient numbers to establish trends in distribution or to identify seasonal changes in numbers of organisms. Generally, density of individuals increased as depth increased (Table I). *Limnodrilus* sp., *Chaoborus punctipennis* Say and *Coelotanypus* sp. increased in number at each meter increase in depth. *Procladius* sp. and *Chironomus* (*Chironomus*) sp. increased as depth increased, but were less abundant at the 4 m depth than at the 3 m depth. *Tanypus* sp. was most abundant at the 2 m depth and their number decreased as depth increased. Perhaps this is additional evidence that most bottom species do not distribute themselves evenly over the bottom. They are adapted to live at certain depths and on different bottom types.

Only 317 individuals were collected from the one meter depth. The reason for such a small number at this depth was probably due to the lack of suitable substrate on which benthic organisms could thrive. Hard clay was encountered often near the shore making collections with the Ekman dredge difficult. *Coelotanypus* sp. was by far the most abundant organism at that depth. Fluctuating water levels could also account for reduced density of benthic invertebrates near shore.

Seasonal changes in some instances were dramatic. *Tanypus* sp. was not collected during the winter, then suddenly in the month of

June the total for this species was 931 individuals per m^2 and continued high throughout the summer. A possible answer may be that *Tanypus* sp. have strict temperature requirements necessary to initiate hatching. Assuming this is true, and since no individuals of *Tanypus* sp. were collected where water temperature was less than 18 C, then hatching and rapid larval growth must occur somewhere between 18 and 25 C. With the exception of *Tanypus* sp., all species of Chironomidae were most abundant during the winter months. Their numbers built up to a peak in February and declined as air and water temperatures increased throughout the spring and summer. Numbers of the aquatic annelid, *Limnodrilus sp.,* were highest in March and remained high throughout the summer months. *Chaoborus punctipennis* Say did not exhibit a sharp rise or fall in number but was slightly more abundant in the winter. Generally, the benthic macroinvertebrates were least abundant in September, October, and November.

Seasonal fluctuations of insect larvae apparently were due to growth and emergence. Many larvae were probably too small to be noticed or passed through the screens in collections made during the fall. As growth occurred more larvae were collected until the times they emerged from the water as adults. Aquatic annelids reproduce during the winter months and do not exhibit emergence as do some insects. Therefore, their continued abundance throughout spring and summer was not unexpected.

Species Diversity

Species diversity indices ($\bar{d}$) reflect the manner in which individuals are distributed among species in a community. As the probability of collecting a species increases $\bar{d}$ decreases, and as the probability decreases, $\bar{d}$ increases. If an aquatic environment is polluted, some degree of stress will be exerted upon those communities involved and after a period of time only the more tolerant species will remain. This is not to say all individuals of the less tolerant species will be eliminated; but their abundance will remain low while the abundance of individuals of the more tolerant species will remain high. Hence, the probability is high that an individual in a sample will belong to a species already collected, causing $\bar{d}$ to be low. The opposite is true in clean water environments.

Diversity per individual ($\bar{d}$) values generally range from 0 – 4, or more, in aquatic environments. Values of less than one represent aquatic areas of high stress, values of 1 – 3 represent areas of moderate stress, and values greater than 3 are found in clean water environments (Wilhm and Dorris, 1968).

A diversity index (d) was calculated for each depth each month. The results indicated the Reservoir was moderately stressed and at times it tended to be more severely stressed. Mean annual diversity per individual ($\bar{d}$) by depth was never more than 2 (Fig. 2). A t-test at the $p = .05$ level of significance revealed no significant differences among

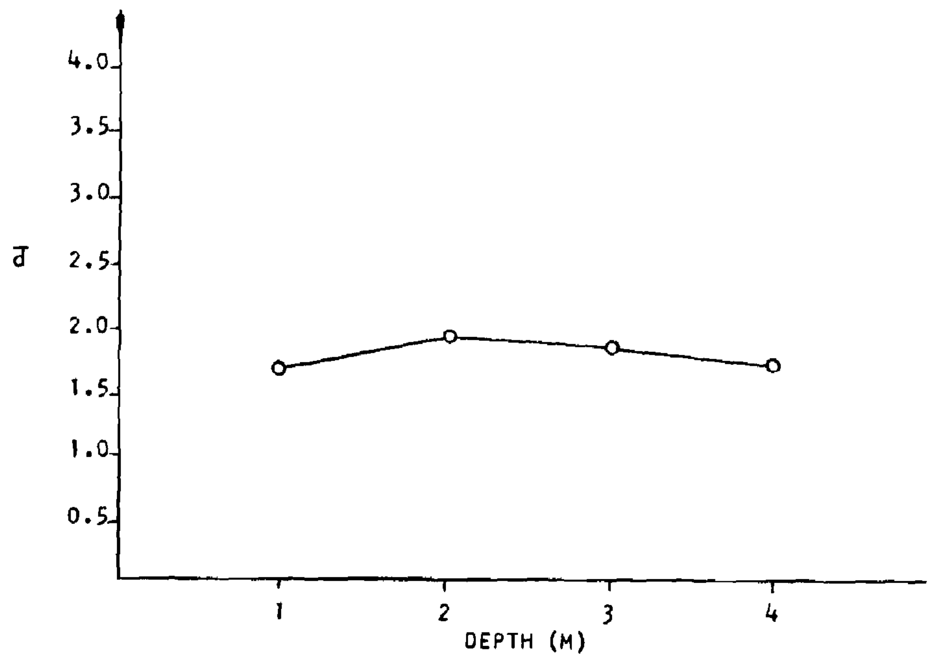

Figure 2. Mean annual variation in diversity per individual ($\bar{d}$) by depth.

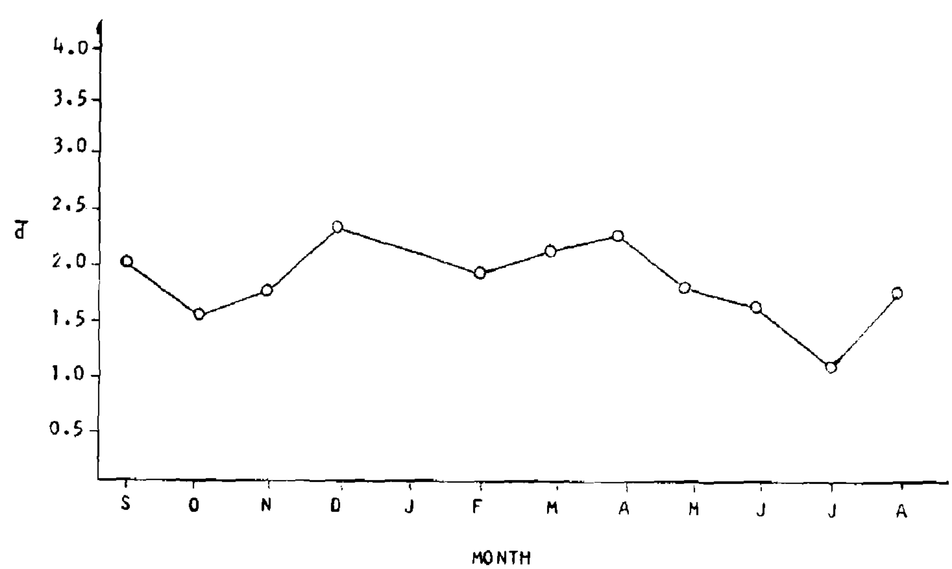

Figure 3. Monthly variations in diversity per individual ($\bar{d}$). All depths combined.

mean annual $\bar{d}$'s by depth. Monthly $\bar{d}$ values with all depths combined were slightly higher in the winter than in the summer (Fig. 3). No significant differences were found among monthly diversity indices.

Applying species diversity indices to zooplankton in John Redmond Reservoir, Prather and Prophet (1968) found $\bar{d}$ values ranging from 1.83 to 2.70. Ransom and Dorris (1972) found $\bar{d}$ values generally ranged between 1.5 and 2.5 in Keystone Reservoir, Oklahoma. They also found that $\bar{d}$ values decreased with depth. This was not the case in the much shallower John Redmond Reservoir and a good comparison was not possible. Edwards (1970) applying species diversity indices to benthic macroinvertebrates in the Cottonwood River above John Redmond Reservoir found $\bar{d}$'s ranged from near 3 at stations above sources of pollution to a value of 1.29 below those sources.

PHYSICOCHEMICAL

pH and Temperature

Little difference was observed in pH among depths or months except in August when values ranged from 6.9 at the 1 m depth to 5.1 at the 4 m depth. This may be evidence that weak stratification occurred during the month of August causing a build up of CO_2 which resulted in lower pH values. Dissolved oxygen at the 4 m depth was low.

Water temperatures were not abnormal and were nearly uniform from top to bottom.

Transparency

Secchi disc transparency was highest in March and lowest in July. Transparency was uniform across the lake except in June and August when turbidity was considerably higher near the shore. At no time could the Secchi disc be observed below 0.45 m.

A comparison was made on summer water samples between Secchi disc transparency and transparency determined on the Bausch and Lomb Spectronic 20 and converted to Jackson Turbidity Units. In July when Secchi disc transparency was less than 0.25 m, measurements of 131 to 156 J. T. U.'s were recorded.

High turbidity in the Reservoir was due to a combination of shallowness, constant mixing by the wind, and inflow of sediment. High turbidity corresponded to periods of high rainfall and inflow. During July 21.6 cm of rainfall was recorded at Emporia and resulted in the highest turbidity readings during the study period.

Dissolved Oxygen and Conductivity

Of all chemical parameters of waters, oxygen is one of the most significant (Reid, 1961). It is significant because oxygen is a product of photosynthesis; it is taken up by plants and animals during respiratory activities; it enters into oxidation reactions of inorganic material; and its solubility varies inversely with temperature.

The most remarkable feature concerning dissolved oxygen in John Redmond Reservoir was its uniformity from top to bottom which indicated that the water was well mixed throughout the year (Fig. 4). Thermal stratification was not evident on any of the sampling dates. Dissolved oxygen did not appear to be a limiting factor to the benthic macroinvertebrates. Dissolved oxygen values were never below 9 mg/liter until May and the following summer months. This four month period coincided with the period of highest rainfall. Therefore, the lower O_2 values, although not limiting, were probably due to the oxygen requirements of bacteria necessary to break down new organic debris brought into the Reservoir and to rises in water temperature. Edwards (1970) found organic debris from feedlots and the resulting decomposition was a limiting factor in the Cottonwood River above John Redmond Reservoir. Probably the dilution by reservoir water prevents complete anoxia during these times.

Specific conductance varied greatly from month to month, but was uniform from top to bottom. Generally, specific conductance was low in the winter and high in the summer; however, the highest measurement occurred in April when it was nearly 480 micromhos, but that was not unusually high for fresh waters.

Phosphate and Nitrate

Both phosphate and nitrate values were relatively high when compared with other Eastern Kansas reserviors. Slight differences were noted among sampling dates and among depths, but no trends were established. Prophet et al. (1970) reported phosphate means in Council Grove and Marion reservoirs in the same watershed above John Redmond to be 0.09 mg/liter and 0.18 mg/liter, respectively. Nitrate means in the two reservoirs were 0.95 mg/liter and 0.37 mg/liter, respectively. The yearly phosphate mean in John Redmond was 0.28 mg/liter and the yearly nitrate mean was 1.28 mg/liter. Possible sources of these two nutrients include effluents from treatment plants, effluents from slaughter houses, runoff from fertilized cropland, and runoff from feedlots. Feedlots may constitute the single most important source of nutrients for John Redmond Reservoir. It is important to note that phosphate and nitrate levels during the study period were nearly the same as those recorded by Prophet (1966) during the early years of impoundment.

Ammonia Nitrogen

Little difference was noted among depths in concentration of ammonia. Some differences did occur among sampling dates. During the spring and summer high ammonia concentrations generally followed periods of high rainfall. The highest amount recorded was in July following the period of highest rainfall.

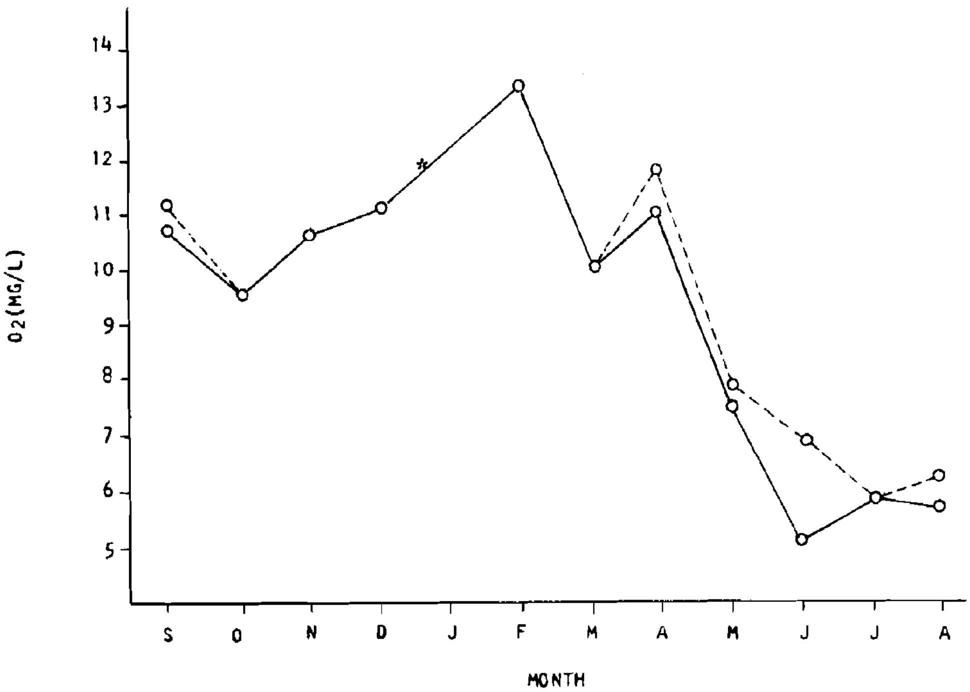

Figure 4. Mean monthly top (----) and bottom (——) dissolved oxygen.

*No samples taken due to ice cover.

Sulfates

Sulfates were generally lowest in the fall and highest in the spring. Sulfates were over 100 mg/liter at all depths in March and April. Apparently sulfates in the Reservoir came from sedimentary geologic formations existing in the watershed. Other reservoirs in the Flint Hills Region have high concentrations of sulfates. Tuttle Creek Reservoir, which is similar to John Redmond in turbidity and which is also located in the Flint Hills, had sulfate concentrations over 120 mg/liter in April, 1969 (Corps of Engineers Data, 1970). Reid (1961) suggested that seasonal pulses in sulfate concentration are due to reductions of sulfide taken up in the bottom mud.

PHYSICOCHEMICAL EFFECTS ON SPECIES DIVERSITY

Even though other studies have shown that productivity is good, turbidity may be the single most critical factor limiting species diversity in John Redmond Reservoir. Of those physical and chemical parameters estimated in this study, turbidity departed most from the range of average values reported for freshwater lakes (Tarzwell et al., 1965).

Nutrient levels may also have contributed to the low diversity of benthic invertebrates. Nitrate nitrogen and phosphate values were much higher than world averages (Reid, 1961). Ammonia nitrogen was high enough to be limiting to most forms of bottom fauna. Ammonia was probably derived mostly from organic breakdown. This is further evidenced by the high coliform bacteria counts found in the Reservoir. The Kansas State Health Department at one time closed the Reservoir to contact recreation (Grey, 1973).

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Winter Fauna of Cladocera and Copepoda in Ponds and Ditches, Lyon County, Kansas

by

David J. Palavanchuk *

ABSTRACT

Twenty-five species of Cladocera and 11 species of Copepoda were identified in 180 qualitative townet samples collected from 14 roadside ditches and 16 small farm ponds within a radius of 35 km of Emporia, Kansas, during the months of November, 1973, and February and May, 1974. Ditch habitats exhibited a greater diversity of species than pond habitats. In both habitat types the number of cladoceran species collected was approximately twice as great as the number of species of Copepoda. Those entomostracans from pond and ditch habitats that were considered of widespread occurrence were *Daphnia parvula, Daphnia ambigua, Scapholeberis kingi, Bosmina longirostris, Bosmina coregoni, Chydorus sphaericus, Diaptomus pallidus, Diaptomus siciloides, Eucyclops agilis, Tropocyclops prasinus,* and *Cyclops vernalis.* Only four species were of widespread occurrence in both habitat types: *Bosmina longirostris, Chydorus sphaericus, Diaptomus siciloides,* and *Cyclops vernalis.* The six species considered abundant during this study were *Bosmina longirostris, Bosmina coregoni, Chydorus sphaericus, Eucyclops agilis, Tropocyclops prasinus, and Cyclops vernalis.* The only species found abundant in both habitat types was *Cyclops vernalis. Camptocercus oklahomensis* was reported for the first time in Lyon County. A cyclopoid, *Eucyclops speratus* constitutes a new species record for the state. A species list of Cladocera and Copepoda for Lyon County was compiled from the results of the present study and from other available records for the county.

INTRODUCTION

Many studies of species composition and relative abundance of microcrustaceans in aquatic habitats in Lyon County have been conducted. However, most of these studies dealt with only one kind of habitat. The present study was concerned with winter species composition and relative abundance of Cladocera and Copepoda in selected ponds and ditches within the vicinity of Emporia, Kansas.

One of the early studies of species composition and seasonal variation of zooplankters in temporary and permanent lentic communities in Kansas was conducted by Leonard and Ponder (1949). Their investigation took place within a 4 km radius of Lawrence in Douglas

* Mr. Palavanchuk is a pharmaceutical representative of Hoyt Laboratories, Needham, Massachusetts. This study originated as a master's thesis in the Division of Biological Sciences at Emporia State University under the direction of Dr. Carl Prophet.

County, Kansas. The results of their study provided an annotated list of 29 species of microcrustacea, 12 of which were Cladocera and 7 were Copepoda. A comprehensive study on the ecology of the cladocerans of Kansas was conducted by Brooks (1956) from April, 1949, to April, 1952. During his study qualitative net samples were collected from at least three bodies of water in each county of the state, except for a few far western counties. The collecting sites included 113 roadside ditches, 95 pounds, 42 creeks, 26 sloughs, 16 lakes, 5 backwaters, 2 salt marshes and 2 strip-pits. Thus, the majority of the 301 townet samples collected were from lentic communities. He reported a total of 41 species of cladocerans, of which 23 were new records for the state. Ratzlaff (1952) studied the limnological features, including the entomostraca, of six separate ditch habitats between Emporia and Strong City along U. S. highway 50 in Lyon and Chase Counties for one year beginning March, 1950. He identified 16 species of Cladocera and five species of Copepoda and noted that definite fluctuations in plankton abundance occurred at different times during the investigation.

Numerous studies of the zooplankton have been conducted on Lake Wooster, a small artificial pond located on the campus of Emporia State University (Carter, 1954; Wilhm, 1955; Spencer, 1955; McKinley, 1960; and Gehrs, 1967). The data concerning species composition, relative abundance, and physicochemical conditions accumulated from all of these studies provide an exiguous but valuable insight as to what might be expected to occur in other pond habitats in Lyon County.

Davis (1958) conducted an eight month study of winter plankton in a Kansas slough. Compared to the previously mentioned studies, his study was unique because it concerned the plankton of a recently reflooded aquatic habitat. Although the slough had a history of intermediate dry periods, its nature was not characteristic of other ephemeral habitats which completely dry up and refill several times during a year. The results of his study indicated a more diverse composition of species than that in Lake Wooster.

The present study may be considered a follow-up of the work of Prophet, Andrews, and Goulden (1959). They obtained plankton samples from numerous lentic and lotic habitats throughout Lyon County, Kansas, during the period September, 1958, to April, 1959, and compiled a species check list of the Cladocera and Copepoda of Lyon County, with annotations of their relative abundance and seasonal occurrence. It is hoped that the current study will provide a more complete and up-to-date check list of the winter microcrustacea of pond and ditch habitats in the Emporia area, and that this information will be useful in the continuing efforts to develop a state-wide list of those organisms.

The primary objectives of this study were: (1) to determine the variations in the winter species composition and relative abundance of microcrustaceans in lentic communities in the vicinity of Emporia, Kansas, and (2) to compile a species list of Cladocera and Copepoda for Lyon County, Kansas.

METHODS AND MATERIALS

A total of 180 qualitative plankton samples were collected from 16 ponds and 14 ditches during the winter season of 1973-74 in the vicinity of Emporia, Kansas. Sampling occurred during November, 1973, and February and May, 1974. All samples were collected within ten consecutive days from the beginning of each sampling period.

Two qualitative townet samples, taken from near the surface, were collected from each site during each collecting period. Each sample consisted of two or three longitudinal hauls of approximately 2 meters using a townet constructed of no. 20 bolting silk, with a mouth diameter of 21 cm and a sleeve length of 35 cm. Each plankton sample was transferred to a 50 ml screwcap bottle and relaxed by addition of nicotine before being preserved in 10% formalin. Samples were later processed in a 5 cm x 2.5 cm plastic counting chamber. The bottom of the counting chamber was divided into 16 quadrats, each enclosing an area of 12.7 cm^2.

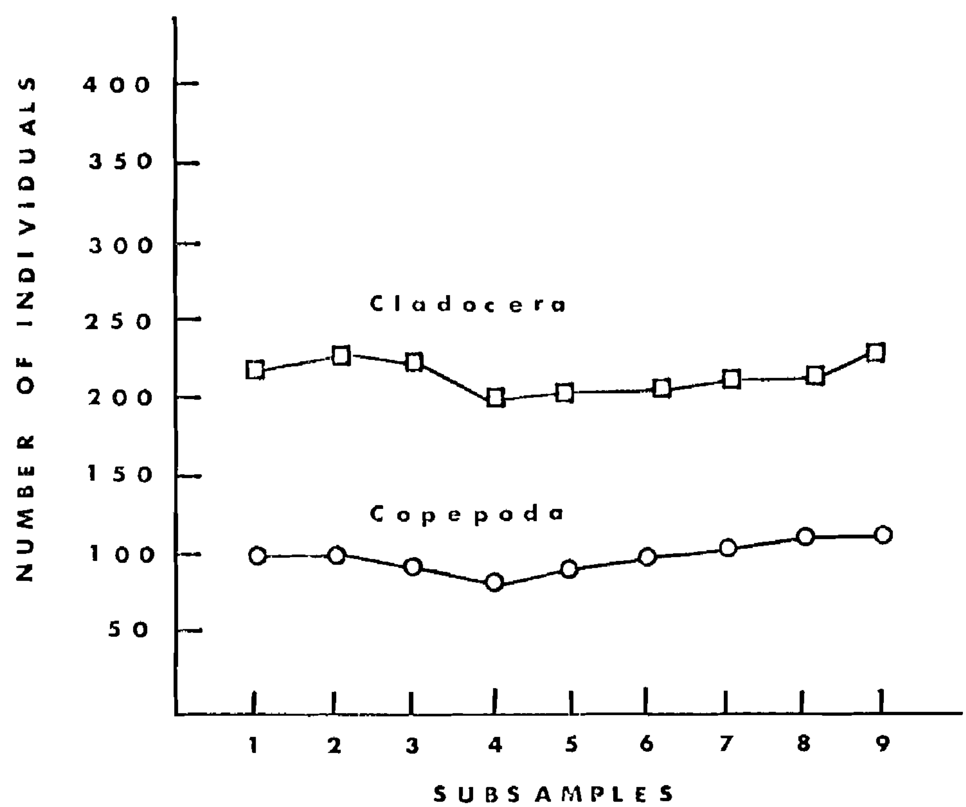

Figure 1. Variation in average numbers of Cladocera and Copepoda in pooled subsamples.

Because of the qualitative nature of the samples, it was necessary to devise a method to obtain comparable representations of species abundance from each habitat. One sample from each habitat sample set was chosen at random and subjected to the following procedure. The sample was emptied into the counting chamber and the total number of all Cladocera and Copepoda in each of the 16 quadrats was recorded. The accumulative average number of Cladocera and Copepoda per quadrat for the sample was determined and plotted as in Figures 1 and 2. From these results it was determined that six squares would give a good representation of the density of species in each sample bottle.

A random sampling procedure was used to determine which six quadrats within the counting chamber would be examined during the processing of each sample. The mean number of cladocerans and Copepoda occurring within the six randomly selected quadrats were used to estimate the relative abundance and species composition of zooplankters in each habitat. The remaining organisms in each sample bottle were later scanned under a binocular scope to see if there were

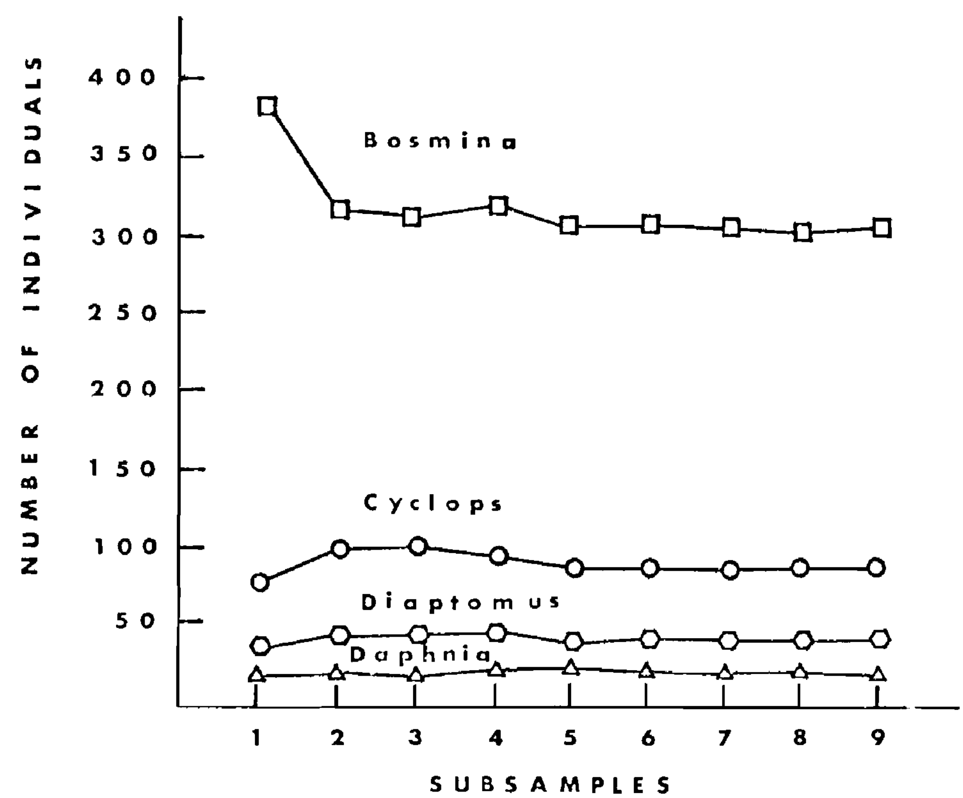

Figure 2. Variation in average numbers of two genera of Cladocera and two genera of Copepoda in pooled subsamples.

any species present that did not occur in the quadrats previously examined. A new set of randomly selected quadrats was employed for each habitat during the three sampling periods.

All Cladocera and Copepoda were identified to species. The taxonomic keys used for their identification were Brooks, 1959; Wilson and Yeatman, 1959; Pennak, 1953; Brooks, 1957; and Goulden, 1968.

RESULTS AND DISCUSSION

The Cladocera and Copepoda Faunas of Lyon County, Kansas

A total of 25 species of Cladocera and 11 species of Copepoda were identified in townet samples collected from 14 roadside ditch habitats and 16 small farm ponds within a radius of 35 km of Emporia, Kansas (Table I).

Comparisons of present-day species lists with lists published by previous researchers are often confusing due to nomenclatural changes and misidentification of organisms. The most frequent cases of misidentification and use of invalid names in publications pertaining to the Cladocera and Copepoda of Kansas were discussed by Prophet and Waite (1974) and will not be repeated here. However, their interpretations influenced conclusions concerning similarities between the observations of this researcher and those of earlier investigators.

One of the earlier published investigations reporting species composition and relative abundance of Cladocera and Copepoda in ditch habitats in Kansas was that of Ratzlaff (1952). He reported 16 species of Cladocera and five species of Copepoda from six roadside ditch habitats in Chase and Lyon Counties. All of the species identified by Ratzlaff were found in the present study, with the exception of *Kurzia latissima, Macrocyclops ater,* and *Diaptomus clavipies.*

One of the more extensive studies on the occurrence of Cladocera and Copepoda in Lyon County, Kansas was that of Prophet, et al. (1959). They identified 35 species of Cladocera and 18 species of Copepoda in samples taken from 33 cattle ponds, 21 streams, 6 sloughs, and 9 roadside ditches from September, 1958, to April, 1959. Twenty-nine of the species observed in their study were also found during the present study. The larger number of species they reported could be attributed to the greater variety of habitats sampled; and since their study began in September, two months earlier than mine, there is a chance that they collected some summer species. Species collected in this study but which were not reported by Prophet, et al. (1959) were *Daphnia parvula, Daphnia ambigua, Moina affinis, Alonella excisa, Ectocyclops phaleratus,* and *Eucyclops speratus. Daphnia pulex* was collected by Prophet et al. (1959); but Prophet and Waite (1974) pointed out that some cladocerans identified as *Daphnia pulex* in earlier studies were probably either *Daphnia parvula* or *Daphnia schødleri.*

Table I. Species list of Cladocera and Copepoda found in 16 pond habitats and 14 ditch habitats in Lyon County, Kansas.

Species	Ponds	Ditches
CLADOCERA		
Diaphanosoma brachyurum	X	X
Daphnia ambigua	X	X
Daphnia parvula	X	X
Daphnia pulex	X	X
**Simocephalus exspinosus*		X
Simocephalus vetulus	X	X
Scapholeberis kingi	X	X
Ceriodaphnia reticulata		X
Ceriodaphnia lacustris	X	X
**Ceriodaphnia quadrangula*	X	X
**Ceriodaphnia laticaudata*		X
**Moina affinis*		X
Bosmina longirostris	X	X
Bosmina coregoni	X	X
Macrothrix laticornis		X
**Camptocercus oklahomensis*		X
Leydigia quadrangularis		X
Alona guttata	X	
Alona quadrangularis		X
Alona costata		X
Alona rectangula	X	X
Pleuroxus denticulatus	X	X
**Pleuroxus hamulatus*	X	
Chydorus sphaericus	X	X
**Alonella excisa*	X	
COPEPODA		
Diaptomus siciloides	X	X
Diaptomus pallidus	X	X
Ectocyclops phaleratus	X	X
**Macrocyclops albidus*	X	X
***Eucyclops speratus*	X	
Eucyclops agilis	X	X
Tropocyclops prasinus	X	X
Cyclops vernalis	X	X
Cyclops bicuspidatus thomasi	X	X
Mesocyclops leukarti	X	
Canthocamptus robertcokeri	X	X

* Not listed as common to east central Kansas (Prophet and Waite, 1974)
** Indicates new species record for the state

Thus, species of *Daphnia* common in east central Kansas are *D. parvula, D. pulex,* and *D. ambigua* (Prophet and Waite, 1974).

To date, a total of 59 species of Cladocera and 23 species of Copepoda have been verified as occurring in Kansas (Prophet and Waite, 1974). They listed 24 species of Cladocera and 13 species of Copepoda as being common in Lyon, Chase, Coffey, Marion and Morris Counties, of which 18 of the cladocerans and 13 species of the Copepoda were found during this study (Table I).

Only one species observed during this study, *Eucyclops speratus,* had not been previously reported for the state and constitutes a new species record. This species was found during November in a farm pond which was approximately 40 acres in area. There was no obvious aquatic vegetation in the pond, and only one specimen was found in the two townet samples collected from that habitat. *Eucyclops speratus* was not observed at any other time during this study.

A combined species list of the Cladocera and Copepoda in Lyon County was compiled from the present results and from other available records. (Brock, 1965; Brooks, 1947; Griffith, 1961; Prophet et al., 1959; Prophet, 1965; Prophet, 1970). To date, 43 species of Cladocera and 21 species of Copepoda have been reported for Lyon County (Table II). Species found during the current study representing a new record for the county were *Camptocercus oklahomensis* and *Eucyclops speratus. Eucyclops speratus* was mentioned in an unpublished thesis but there was no indication that this species had been verified.

Comparison of Ditch and Pond Species Composition

Although the majority of the species observed during this study were found in both pond and ditch habitats, ditches appeared to support greater diversity of species. Thirty-one species were found in ditches and 27 species were found in ponds. Of course, not all species reported in either habitat type were ever present in any single sample. Those species found in ditches but not ponds, and *vice versa,* are listed in Table I.

Throughout this study, in both types of habitats, the number of cladoceran species collected was approximately twice as great as the number of species of Copepoda. Similar trends have been observed in other studies (Ratzlaff, 1952; Wilhm, 1955; Prophet et al., 1959). Ditches supported a greater number of species of Cladocera than ponds. Pennak (1957) stated that a limnetic population, according to ordinary sampling methods, usually consists of two to four species, each species being a different genus. Essentially, results from both ponds and ditches during the current study exhibited these same trends. Generally, single samples from ditch habitats yielded three to five species of Cladocera and one to three species of Copepoda, while single samples from pond habitats yielded two to three species of Cladocera and one

Table II. Species list of Cladocera and Copepoda for Lyon County, Kansas.

CLADOCERA

Family Sididae

Sida crystallina (O. F. Muller) 1785
Latona setifera (O. F. Muller) 1785
Diaphanosoma brachyurum (Lieven) 1848

Family Daphnidae

Daphnia ambigua Scourfield 1947
Daphnia parvula Fordyce 1901
Daphnia pulex Leydig, 1860 emend. Richard 1896
Daphnia catawba Coker 1926
Simocephalus exspinosus (Koch) 1841)
Simocephalus vetulus Schødler 1858
Simocephalus serrulatus (Koch) 1841
Scapholeberis kingi Sars 1903
Scapholeberis aurita (Fischer) 1849
Ceriodaphnia rigaudi Richard 1894
Ceriodaphnia reticulata (Jurine) 1820
Ceriodaphnia lacustris Birge 1893
Ceriodaphnia quadrangula (O. F. Muller) 1785
Ceriodaphnia laticaudata P. E. Muller 1867
Moina micrura Kurz 1874
Moina macrocopa Straus 1820
Moina rectirostris (Leydig) 1860
Moina affinis Birge 1893

Family Bosminidae

Bosmina longirostris (O. F. Muller) 1785
Bosmina coregoni Baird 1857

Family Macrothricidae

Ilyocryptus spinifer Herrick 1884
Macrothrix laticornis (Jurine) 1820

Family Chydoridae

Eurycercus lamellatus (O. F. Muller) 1785
Camptocercus oklahomensis Mackin 1930
Camptocercus rectirostris Schødler 1862
Kurzia latissima (Kurz) 1874
Leydigia quadrangularis (Leydig) 1860
Alona guttata Sars 1862
Alona affinis (Leydig) 1860
Alona quadrangularis (O. F. Muller) 1785
Alona costata Sars 1862
Alona rectangula Sars 1861

Table II. (Continued)

Pleuroxus striatus Schødler 1863
Pleuroxus denticulatus Birge 1878
Pleuroxus hamulatus Birge 1910
Chydorus globosus Baird 1850
Chydorus gibbus Lilljeborg 1880
Chydorus sphaericus (O. F. Muller) 1785
Alonella acutirostris (Birge) 1878
Alonella excisa (Fischer) 1854

COPEPODA

CALANOIDA

Family Diaptomidae

Diaptomus clavipes Schacht 1897
Diaptomus saltillinus Brewer 1898
Diaptomus siciloides Lilljeborg 1889
Diaptomus sanguineus S. A. Forbes 1876
Diaptomus pallidus Herrick 1879
Diaptomus oregonensis Lilljeborg 1889

CYCLOPOIDA

Family Cyclopidae

Ectocyclops phaleratus (Koch) 1838
Orthocyclops modestus (Herrick) 1883
Macrocyclops alter (Herrick) 1882
Macrocyclops albidus (Jurine) 1820
Paracyclops fimbriatus poppei (Rehberg) 1880
Eucyclops speratus (Lilljeborg) 1901
Eucyclops agilis (Koch) 1838
Tropocyclops prasinus (Ficher) 1860
Cyclops vernalis Fischer 1853
Cyclops bicuspidatus thomasi S. A. Forbes 1882
Cyclops varicans rebellus Lilljeborg 1901
Cyclops bicolor Sars 1863
Mesocyclops edax (S. A. Forbes) 1891
Mesocyclops leukarti (Claus) 1875

HARPACTICOIDA

Family Canthocamptidae

Canthocamptus robertcokeri M. S. Wilson 1958

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to three species of Copepoda. However, in some pond habitats single samples contained two species from the same genus. *Bosmina longi-*

rostris and *Bosmina coregoni* were found to occur simultaneously in 13 of 16 pond habitats. They did not coexist in any of the study ditches. In most instances, when these species coexisted in ponds, *Bosmina longirostris* was found in larger numbers. Two cyclopoids, *Cyclops vernalis* and *Cyclops bicuspidatus thomasi,* coexisted in some of the study pond's and ditches. Coexistence of these species has been reported in numerous other studies and therefore is not considered an uncommon occurrence.

Comparison of Habitat Occurrence

The frequency at which each species of Cladocera and Copepoda was observed in the study habitats was catagorized as being either widespread or scattered. Widespread species were those that occurred in nine or more sites in either habitat type. Species that occurred in less than nine sites of either habitat type were considered scattered.

Nine species were found widespread in pond habitats and only six species were found widespread in ditches (Table III). Four species were widespread in both habitat types: *Bosmina longirostris, Chydorus sphaericus, Diaptomus siciloides, and Cyclops vernalis.*

On the basis of this study *Daphnia parvula, Daphnia ambigua, Scapholeberis kingi, Bosmina longirostris, Bosmina coregoni,* and *Chydorus sphaericus* are the species of Cladocera most likely to occur in pond and ditch habitats in Lyon County during the winter season. Those species of Copepoda most likely to occur in both habitat types in Lyon County during the winter months are *Diaptomus pallidus, Diaptomus siciloides, Eucyclops agilis, Tropocyclops prasinus* and *Cyclops vernalis.*

Relative Abundance

The relative abundance of species was determined from the total number of individuals of each species present in each of the 180 samples collected during the study. The relative abundance for a species was designated arbitrarily as either abundant, common or rare (Table IV). Abundant species were those found regularly in samples and were obviously present in large numbers. Species were designated as common when found sporadically in relatively modest numbers, and rare species were found infrequently and in limited numbers.

The cladocerans *Bosmina longirostris, Bosmina coregoni,* and *Chydorus sphaericus,* and three species of Copepoda, *Eucyclops agilis, Tropocyclops prasinus,* and *Cyclops vernalis,* were considered abundant during this study. *Cyclops vernalis* was the only species found abundant in both habitat types. These species are frequently mentioned as being abundant in plankton samples taken from a variety of habitat types in Lyon County (Gehrs, 1967; Endicott, 1965; Davies, 1958; Davis, 1958; Ratzlaff, 1952; Prophet et al., 1959).

Table III. Frequency of occurrence of entomostraca in pond and ditch habitats in Lyon County, Kansas.

Species	Ponds	Ditches
CLADOCERA		
Diaphanosoma brachyurum	S	S
Daphnia ambigua	W	S
Daphnia parvula	W	S
Daphnia pulex	S	S
Simocephalus exspinosus		S
Simocephalus vetulus	S	S
Scapholeberis kingi	S	W
Ceriodaphnia reticulata		S
Ceriodaphnia lacustris	S	S
Ceriodaphnia quadrangula	S	S
Ceriodaphnia laticaudata		S
Moina affinis		S
Bosmina longirostris	W	W
Bosmina coregoni	W	S
Macrothrix laticornis		S
Camptocercus oklahomensis		S
Leydigia quadrangularis		S
Alona guttata	S	
Alona quadrangularis		S
Alona costata		S
Alona rectangula	S	S
Pleuroxus denticulatus	S	S
Pleuroxus hamulatus	S	
Chydorus sphaericus	W	W
Alonella excisa	S	
COPEPODA		
Diaptomus siciloides	W	W
Diaptomus pallidus	W	S
Ectocyclops phaleratus	S	S
Macrocyclops albidus	S	S
Eucyclops speratus	S	
Eucyclops agilis	S	W
Tropocyclops prasinus	W	S
Cyclops vernalis	W	W
Cyclops bicuspidatus thomasi	S	S
Mesocyclops leukarti	S	
Canthocamptus robertcokeri	S	S

W – widespread S – scattered

Table IV. Relative abundance of Cladocera and Copepoda in 16 pond and 14 ditch habitats in Lyon County, Kansas during the winter season.

Species	Ponds	Ditches
CLADOCERA		
Diaphanosoma brachyurum	C	C
Daphnia ambigua	C	C
Daphnia parvula	C	C
Daphnia pulex	C	C
Simocephalus exspinosus		R
Simocephalus vetulus	C	C
Scapholeberis kingi	C	C
Ceriodaphnia reticulata		R
Ceriodaphnia lacustris	C	R
Ceriodaphnia quadrangula	R	R
Ceriodaphnia laticaudata		C
Moina affinis		C
Bosmina longirostris	A	C
Bosmina coregoni	A	C
Macrothrix laticornis		C
Camptocercus oklahomensis		R
Leydigia quadrangularis		C
Alona guttata	R	
Alona quadrangularis		R
Alona costata		R
Alona rectangula	R	C
Pleuroxus denticulatus	C	C
Pleuroxus hamulatus	C	
Chydorus sphaericus	A	C
Alonella excisa	R	
COPEPODA		
Diaptomus siciloides	C	C
Diaptomus pallidus	C	C
Ectocyclops phaleratus	R	R
Macrocyclops albidus	R	C
Eucyclops speratus	R	
Eucyclops agilis	C	A
Tropocyclops prasinus	A	C
Cyclops vernalis	A	A
Cyclops bicuspidatus thomasi	C	C
Mesocyclops leukarti	R	
Canthocamptus robertcokeri	C	R

A – abundant C – common R – rare

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