# DIURNAL AND SEASONAL VARIATION IN ABUNDANCE OF THE CLADOCERA AND COPEPODA OF THE VERDIGRIS AND FALL RIVERS AND THE AFFECTS OF HIGH-WATER LEVELS ON ENTOMOSTRACA POPULATIONS

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## INTRODUCTION

Little information is available concerning the ecology of the entomostraca, Cladocera and Copepoda, in rivers. There is a great deal of literature on river plankton, but the majority of the papers are concerned with the effects of pollution on plankton forms or are papers restricted to a study of the phytoplankton. Many investigators have included a check-list of the entomostraca in rivers, but in most cases, they have placed major emphasis upon the physical-chemical aspects of the river. A few limnologists who have studied the ecology of entomostraca in rivers are Galtsoff (1924), Eddy (1932), Roach (1932), Chandler (1939), and Prophet (1957).

This study was undertaken to add to the information on the ecology of the Cladocera and the Copepoda in rivers. Specifically, this is a study of the diurnal differences in numbers of entomostraca collected, the seasonal differences in numbers of entomostraca collected, and the influences of high-water levels on entomostracan populations.

A great amount of data has been gathered on diurnal variation of numbers of individuals collected in lentic environments. Many review papers, especially those by

Kikuchi (1930), Welsh (1938), and Cushing (1951), are available. This phenomenon refers to a vertical variation in concentration of individuals at any one depth in a lake over a 24-hour period. A common type of diurnal variation, termed diurnal migration, occurs when entomostraca move or migrate away from the surface waters during the daytime and towards the surface waters at night.

Few studies include information about the diurnal variation of abundance of entomostraca in lotic environments. Allen (1920) made hourly collections for 12 hours on the San Joaquin River. Galtsoff (1924) made vertical samples in the Mississippi River to determine if vertical stratification of plankton occurred. These two papers almost exhaust the known literature on this subject.

Prophet (1957) has previously studied the seasonal variation of Cladocera and Copepoda of the Verdigris and Fall rivers. His study was made during a year of below average rainfall while the present study was made during a year of above average rainfall. Differences and comparative points between Prophet's study and the present study concerning seasonal variation of entomostraca will be noted.

Two diurnal collections were made during periods of rising high water. The results of these two collections are presented separately from the data on diurnal variation.

## DESCRIPTION OF AREA

Collections were made at 2 stations: Station I (Fig. 2) on the Verdigris River and Station II (Fig. 4) on the Fall River. A description of these 2 rivers, including the ecology of the area near the rivers, may be found in Prophet's study (1957) on "Seasonal Variations and Abundance of Cladocera and Copepoda and Some Physical-Chemical Conditions of the Fall and Verdigris Rivers in Wilson and Montgomery Counties, Kansas."

### Station I

The Verdigris River (Fig. 1) is a sluggish stream having a gradient of 3 to 4 feet per mile and a variable stream flow throughout the year, Table IX. The river is about 40 feet wide in most areas and usually over 6 feet deep, except in or near riffle zones. At these points the river is 1 to 3 feet deep. There are no major impoundments located on the river; consequently, spring rains often cause high-water levels. During drought seasons, the river becomes intermittent (Prophet, 1957).

Collections on this river were made near the North Fourth Street Bridge, northeast of Neodesha, Kansas. The actual area of collection is located about 50 yards below a riffle zone. The river at this point averages about 3 feet in depth. The stream flow is rather sluggish although

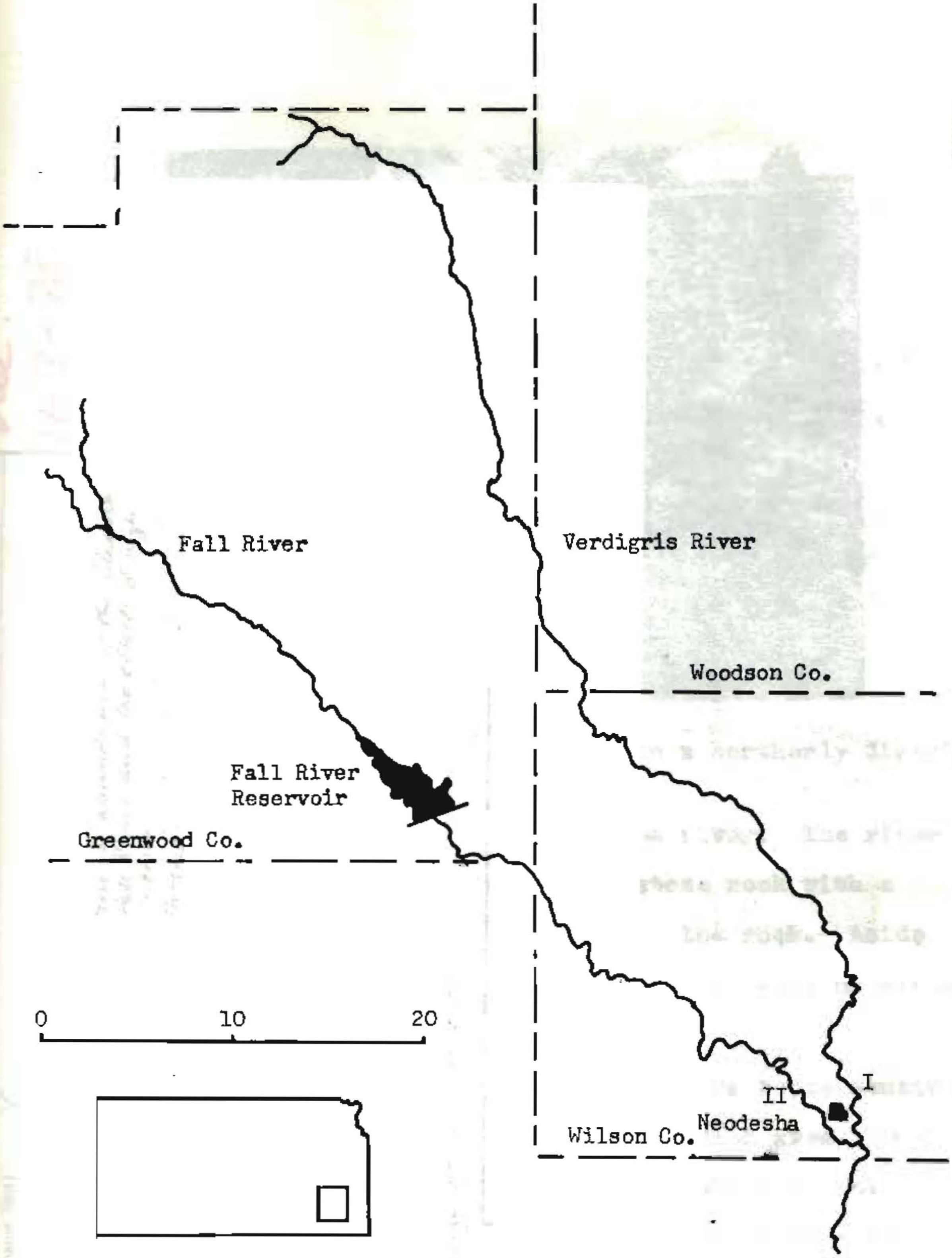

Fig. 1. Map of Verdigris and Fall rivers showing Station I and II, and location of the Fall River Reservoir.

Fig. 2. Station I, looking upstream in a northerly direction towards the collection area.

it varies at different spots across the river. The river bottom is composed of a sheet of limestone rock with a layer of soft mud and detritus covering the rock. Aside from the filamentous algae found near the riffle, no rooted aquatic plants were found in the water.

In January the Army Corps of Engineers began construction of a wier downstream from the collection area. During this period the river was dammed and was about 6 feet deep in the collection area. Collections were made in a pool area below the wier during this time. The river in the new location was very similar to the original collecting area but was about 4 feet in depth. After completion of the wier (Fig. 3) in April, the May collections were made in the original collecting area.

During periods of high-water level, the river rose as much as 20 feet above the normal flow. At these times, the river became very turbid and contained much detritus and large floating logs.

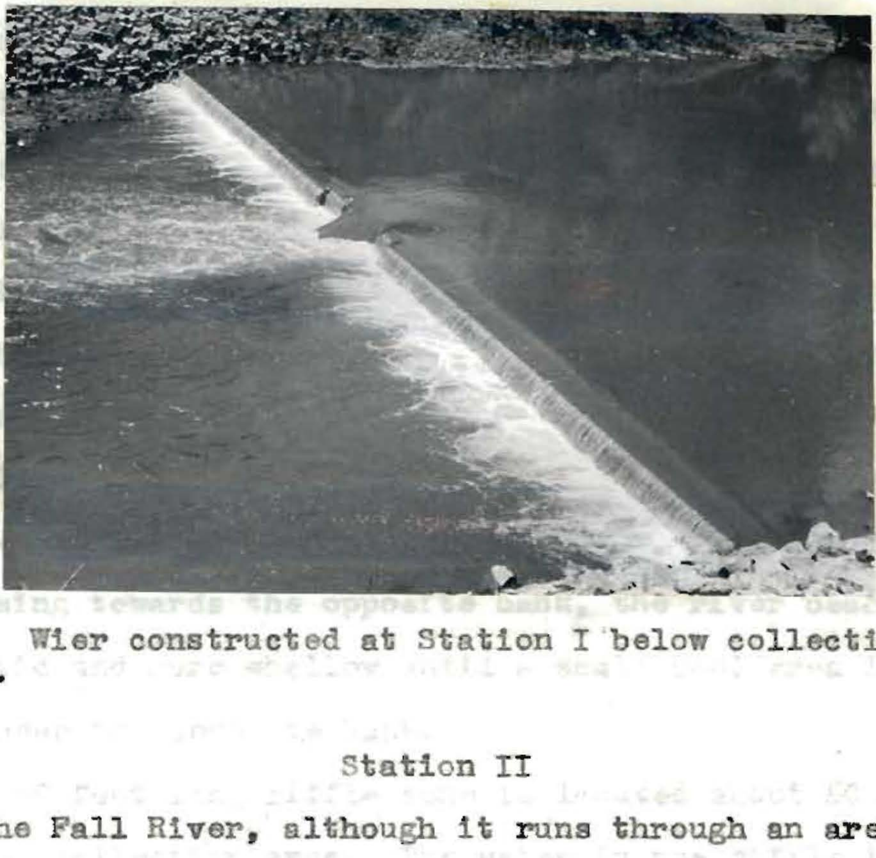

Fig. 3. Wier constructed at Station I below collection area.

Station II

The Fall River, although it runs through an area of vegetation and soil similar to the Verdigris River, is completely different from this river. The river is swift flowing, has an average width of about 30 feet, and rarely gets deep. The river bottom, as opposed to the soft bottom

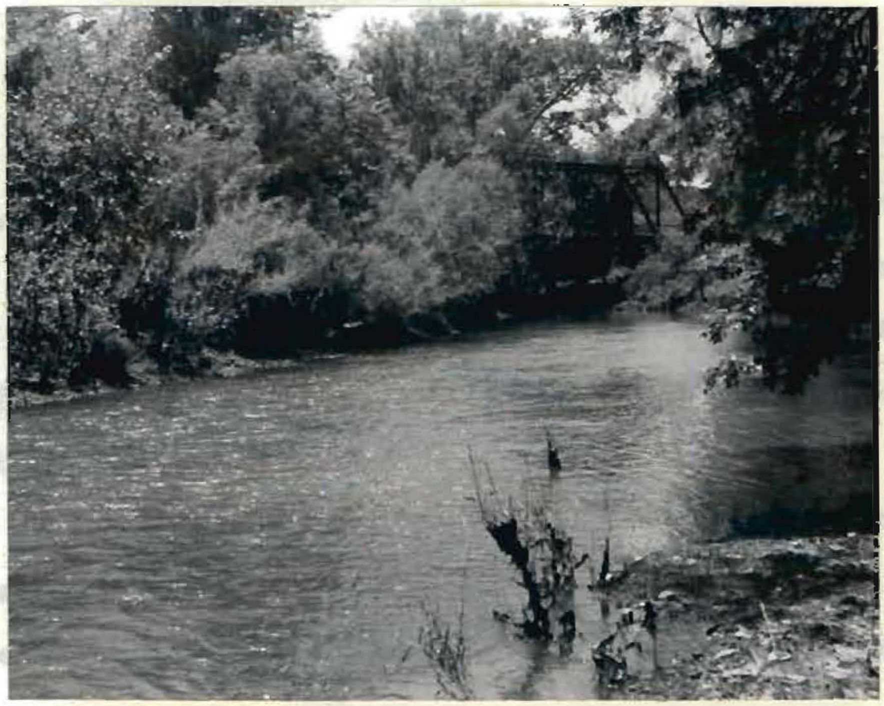

Fig. 4. Station II looking downstream towards collection area.

while Station I is characterized by slowly moving water or pools with a soft unstable bottom.

During periods of high-water level, the Fall River is about 10 feet above normal flow and always very swift. Floating logs are seldom seen in this river, and the turbidity is never as great as the turbidity recorded at Station I.

## METHODS AND MATERIALS

Eleven monthly collections were made from July, 1958, to May, 1959; all were diurnal studies, or 24-hour studies, except the January 1959 collection. During each diurnal study, collections were made every 4 hours at 0400, 0800, 1200, 1600, 2000, and 2400. In May 1959 collections were made every 4 hours throughout a 72-hour period.

Both qualitative and quantitative entomostraca samples were taken, and the following physical-chemical data were recorded: temperature, turbidity, carbon dioxide, and oxygen.

### Plankton Collections

The qualitative samples were taken by holding a dip net (Fig. 5, B), made of number 20 bolting silk, in the current to filter out the entomostraca. The entomostraca were gathered in a 2-ounce bottle attached to the apex of the net.

Ten liter samples, using a 2-liter Kemmerer Water Bottle, were taken during the July and August 1958 collections. The number of individuals collected in the 10-liter samples was so small that it was thought necessary to make larger samples. A 10-liter bucket (Fig. 5, C) was substituted, and a 100-liter sample was thereafter collected. The 10 samples composing the 100-liters were taken at different

Fig. 5. Field equipment. (A) Whitney underwater electrical resistance thermometer; (B) number 20 plankton net; (C) 10-liter water bucket; (D) oxygen and carbon dioxide sampling jars.

places across the river to reduce error due to an uneven horizontal distribution of the entomostraca.

After each sample was collected, a small tag indicating the type of collection (dip net, or 100-liter), time of collection, date, and station number was placed in each bottle, and 40 percent formalin was added to each bottle to kill and preserve the entomostraca.

The entomostraca were later identified in the laboratory using identification keys in Ward and Whipple (1945) and Pennak (1953).

## Physical-Chemical Data

The temperature on the river bottom and near the surface of the water was measured using a Whitney underwater electrical resistance thermometer (Fig. 5, A). Turbidity was measured with a United States Geological Survey Turbidity Rod. Oxygen content was determined using the unmodified Winkler method, and the carbon dioxide content was determined using the standard titration method described in Welch (1948, page 213).

# RESULTS

## Diurnal Variation in Abundance of Entomostraca

Figures 6 and 7 show the results of the diurnal collections. All monthly collections except those made in January, April, July, and August are included in these results and are grouped according to seasons. The spring collections included 2 diurnal monthly collections made during March and May; the fall collections included 3 diurnal collections made during September, October, and November; the winter collections included 2 diurnal collections made during December and February.

Numbers given below which refer to entomostraca from 100 liter collections were obtained by averaging the number of individuals collected at any specific hour during each season. For example, 14 cladocerans were collected at 2000 in December and 2 were collected at 2000 in February in the 100 liter collections. The total of these 2 collections, 16, was divided by the number of collections to give an average number of 8 per 100 liters at 2000 during the winter.

Station I. There appears to be a diurnal variation in numbers of Copepoda collected in the samples at this station, Fig. 6. The Cladocera were collected in such small numbers that no variation is apparent, Fig. 6. The variation of the Copepoda, however, is based on larger numbers of individuals collected. In the spring, the Cladocera averaged

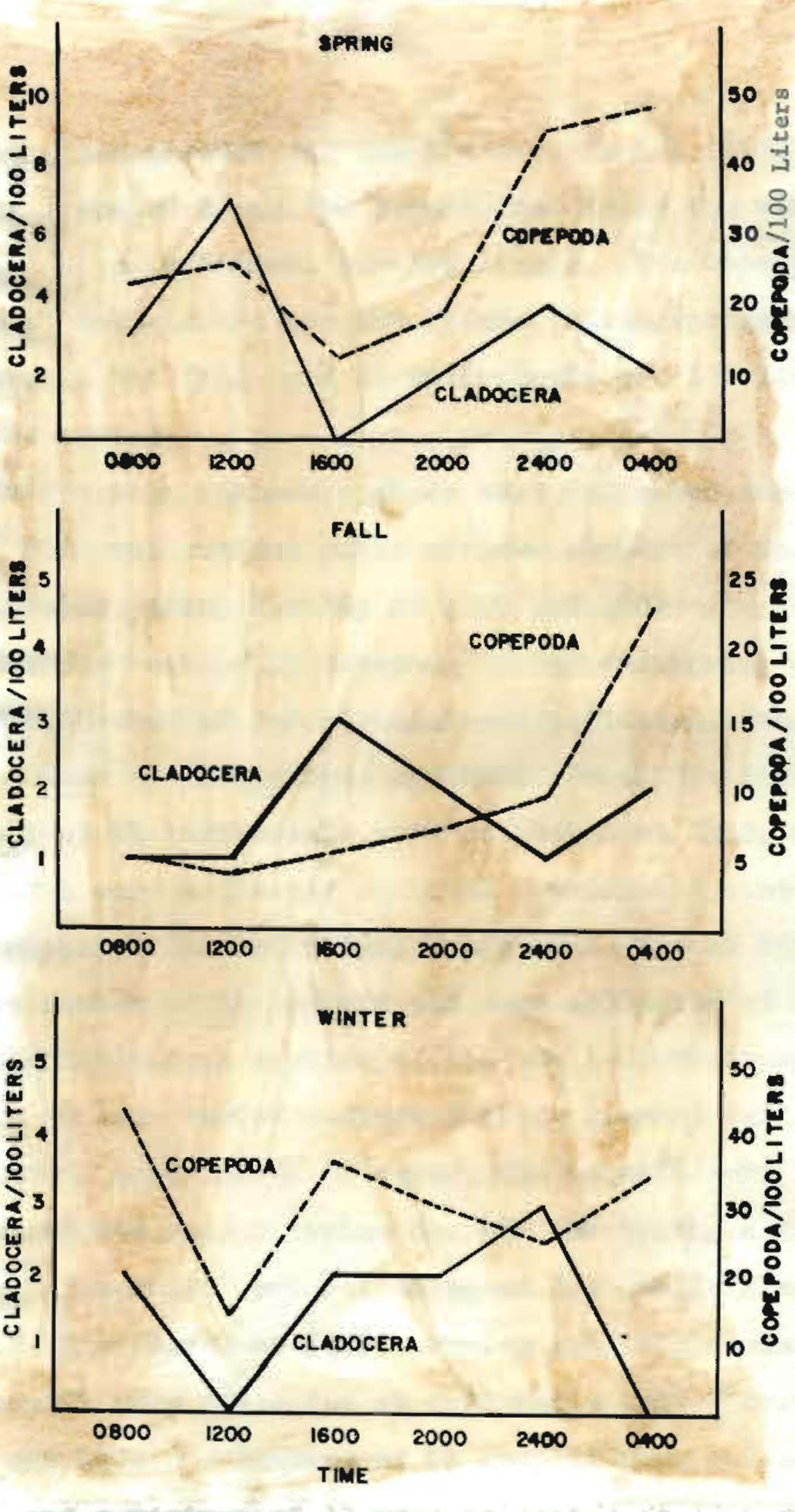

Fig. 6. Diurnal variation of numbers of entomostraca collected from near surface water at Station I, during spring, fall, and winter months. Each point on the graph represents an average number of individuals collected at each specific hour from 2 collections in the spring, 3 collections in the fall, and 2 collections in the winter.

3 individuals collected per 100 liters. In the fall, the Cladocera averaged 2 per 100 liters and during the winter they averaged 1 individual per 100 liters. The Copepoda averaged 29 individuals per 100 liters in the spring, 9 per 100 liters in the fall, and 31 individuals per 100 liters during the winter.

In general, maximum numbers were collected during the 0400 and 0800 collections while minimum numbers of individuals were collected during the day at 1200 and 1600.

Maximum numbers of Copepoda during the spring were found at 0400 when 48 individuals were collected. The minimum number of 12 appeared at 1600. In the fall a maximum number of 23 individuals were collected at 0400, and a minimum of 4 were collected at 1200. During the winter, a maximum number of 44 individuals were collected at 0800 while a minimum number of 14 individuals were collected at 1200.

The individual species of the adult Copepoda were collected in such varied numbers that no diurnal variation may be noted, Appendix B. However, the nauplii were abundant and did show a variation. In the spring a maximum number of 43 nauplii were collected at 0400 while a minimum number of 12 appeared at 1600. During the fall a maximum of 16 nauplii were collected at 0400 while only 3 occurred at 0800 and 1200. A maximum of 41 nauplii were collected at 0800, and a minimum of 13 were collected at 1200 during the winter. In general, the nauplii appeared to be most abundant at Station I between 0400 and 0800 while a minimum abundance occurred between 1200 and 1600.

Station II. Both the Cladocera and the Copepoda showed a diurnal variation in abundance at Station II, Fig. 7. Greatest numbers occurred at 2000 and 0400 while minimum numbers appeared at 1200.

The variation at this station is based on larger numbers of individuals collected per 100 liters than the numbers at Station I. The Cladocera averaged 17 individuals per 100 liters in the spring collections, 3 individuals per 100 liters in the fall collections, and 136 individuals per 100 liters in the winter collections. The Copepoda averaged 86 individuals per 100 liters in the spring collections, 10 individuals in the fall collections, and 131 individuals in the winter collections.

During the spring, maximum numbers of Cladocera collected appeared at 0800 when 21 individuals appeared. A minimum of 14 individuals were collected at 1200. In the fall a maximum number of 5 cladocerans were collected at 1600, 2000, and 0400, while a minimum of 1 was collected at 1200 and 2400. The winter maximum number of 244 was collected at 2000 while a minimum of 65 occurred at 1200. The Cladocera then appear to be most abundant at 2000 and 0800 and least abundant at 1200 during the day.

The maximum number of copepods collected during the spring was 118 at the 0400 collections. The minimum number of 50 individuals appeared at 1200. In the fall collections, a maximum number of 23 individuals were collected at 2000 while a minimum number of 4 occurred at 1200. During the winter, the copepods were at maximum numbers at 2000 when 193 individuals were collected and at a minimum at 1200 when 52 individuals were recorded.

The Copepoda, in general, were most abundant at 2000 and at 0400 and least abundant at 1200.

The individual species variation is given in Appendix C. Bosmina longirsotris (O.F.M.) occurred in abundance only during the winter season when it was at a maximum number of 238 individuals per 100 liters at 2000 and at a minimum number of 62 individuals per 100 liters at 1200.

Cyclops bicuspidatus Claus varied in the winter collections from a maximum of 87 individuals collected at 2000 to only 13 individuals collected at 1200. This species was common during the spring, but the lack of data for the 2000 collections during this season prohibits valid conclusions.

Diaptomus siciloides Lillj. showed a variation during the spring of a maximum of 48 individuals collected at 0400 and a minimum of 6 individuals at 1200. Although this species

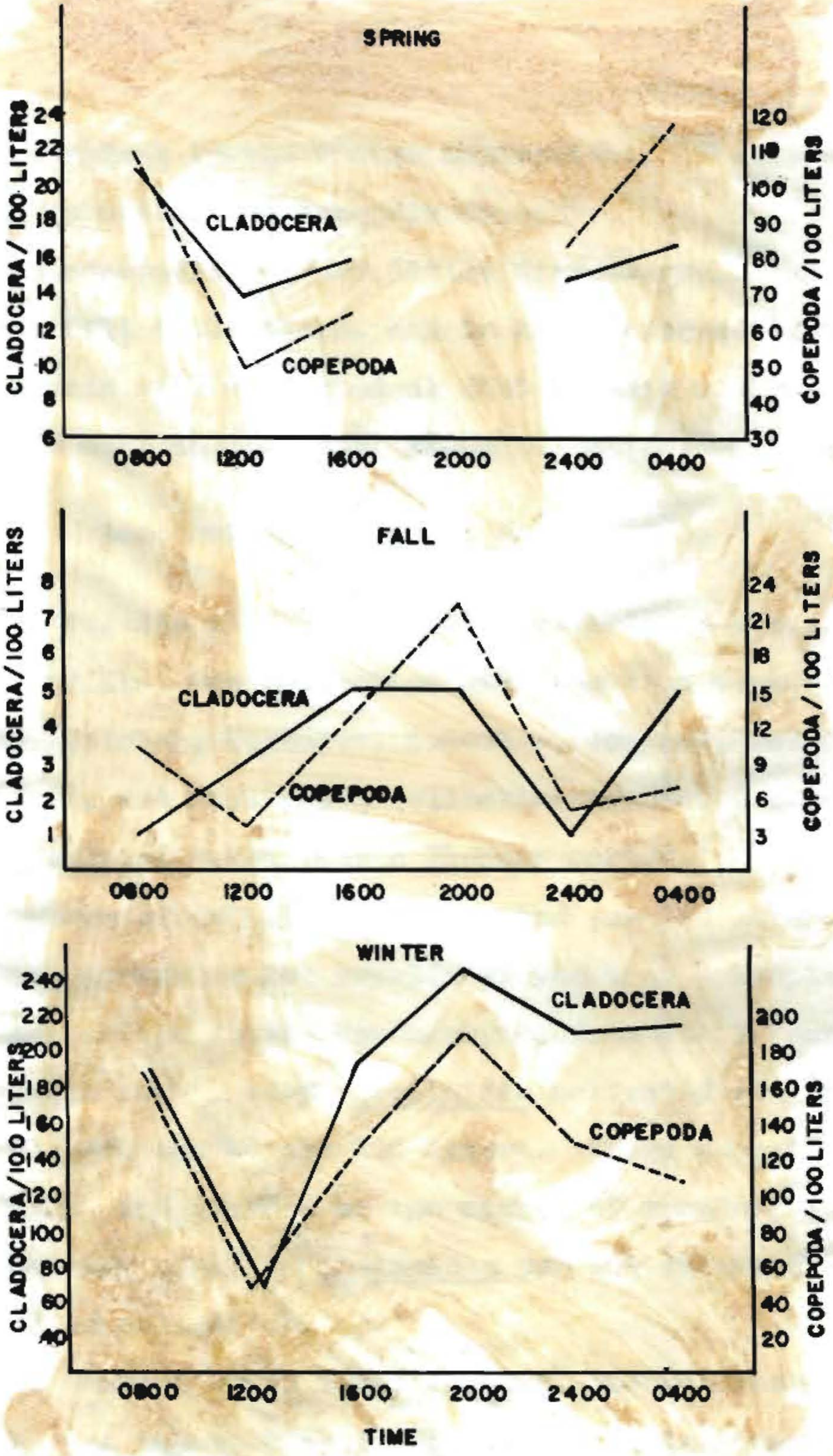

Fig. 7. Diurnal variation of numbers of entomostraca collected from near surface water at Station II during spring, fall, and winter months. Each point on the graph represents an average number of individuals collected at each specific hour from 2 collections in the spring, 3 collections in the fall, and 2 collections in the winter.

was most abundant in the winter collections, no diurnal variation is noted, see Appendix C.

The copepodids showed little diurnal variation in the spring and fall collections, but in the winter collections, 42 individuals were collected at 2000 while a minimum of 12 individuals were collected at 1200.

## Seasonal Variation of Entomostraca

The results of the 9 monthly collections are given in Tables I and II. One collection was made each month during September, October, November, December, January, February, March, April, and May. Each collection consisted of a series of 6 or 7 samples taken over a 24-hour period.

Numbers of individuals collected per 100 liters were obtained by averaging the results of the 6 or 7 samples on any one collection date. For example, from the 7 samples in February, the number of D. siciloides collected was 69, 24, 37, 61, 61, 36, and 40 per 100 liters. These numbers were totaled, 328, and divided by the number of samples, 7, to give an average of 47 D. siciloides per 100 liters during that month of collection.

The numbers which refer to total entomostraca, Cladocera and Copepoda were obtained by adding the above averages for all species collected during any one month.

*Station I*. The entomostracan population at Station I showed a period of greatest abundance from February to May and least abundance from September to January. From September to January, the number of individuals collected varied from a total of 17 to 5. In December only 5 individuals were collected. The entomostraca increased from a total of 10 individuals collected in January to 63 individuals in February. In March a total of 54 individuals were collected, 111 in April, and 41 during May. The greatest abundance of 111 in April was collected during a period of high-water.

The cladocera were most numerous during the high-water period in April. A total of 69 individuals were collected during this month. During the other months of the year, the total number of individuals collected varied from 0 to 12. No cladocerans were found in the January collections. The numbers in November and December were also small; only 1 individual was collected during November, and 2 were collected in December. Slightly larger numbers occurred in February when a total of 4 individuals were collected and in May when a total of 12 individuals were collected.

Only 2 species of Cladocera were common at this station, *Bosmina longirostris* (O.F.M.) and *Chydorus sphaericus* (O.F.M.). *B. longirostris,* although never abundant occurred during 5 of the 9 months. This species was most abundant in May when an average of 6 individuals per 100 liters were

| Species | Sept. 58 | Oct. 58 | Nov. 58 | Dec. 58 | Jan. 59 | Feb. 59 | Mar. 59 | Apr. 59 | May 59 |
|---|---|---|---|---|---|---|---|---|---|
| D. pulex | 1 | | | 2 | | | | 2 | |
| S. vetulus | 1 | | 1 | | | | | 2 | 1 |
| B. longirostris | | 1 | | | | 3 | 1 | 4 | 6 |
| I. sordidus | | | | | | | | 1 | 1 |
| I. spinifer | | 1 | | | | | | | |
| M. laticornis | | 2 | | | | | | | |
| K. latissima | | | | | | | | 1 | |
| L. quadrangularis | | | | | | | | 1 | |
| A. costata | 1 | | | | | | | | |
| A. rectangula | | | | | | 2 | | 2 | 1 |
| P. denticulatus | | | | | | | 1 | 3 | |
| C. sphaericus | | | | | | 2 | 2 | 53 | 3 |
| M. ater | 3 | | | | | | | | |
| E. agilis | 2 | 1 | 1 | | 3 | 2 | 3 | 6 | 3 |
| M. albidus | | | | | | | | 1 | |
| M. leuckarti | | | | | | | | 1 | |
| C. vernalis | | | 1 | | 1 | 1 | | 2 | 1 |
| C. bicuspidatus | | | | | | 1 | 1 | 3 | 9 |
| D. siciloides | | | | | | | | 1 | |
| C. robertcokeri | | | | | | | | 2 | |
| *Nauplii | 4 | 1 | 11 | 2 | 3 | 51 | 43 | TN | 10 |
| Copepodid | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 26 | 6 |
| Total Cladocera | 3 | 4 | 1 | 2 | 0 | 7 | 4 | 69 | 12 |
| Total Copepoda | 12 | 3 | 16 | 3 | 10 | 56 | 50 | 42 | 29 |
| Total Entomostraca | 15 | 7 | 17 | 5 | 10 | 63 | 54 | 111 | 41 |

Table I. Average number of individuals (per 100 liters) and total numbers of Cladocera and Copepoda collected each month at Station I.

*TN - Too numerous to count.

collected. During February, March, April, and October, it averaged between 1 and 4 individuals per 100 liters.

C. sphaericus (O.F.M.), the most abundant cladoceran at Station II, was collected from February to May. It was most numerous during the high-water period in April when an average of 53 individuals were collected. During February, March, and May there were only 2 or 3 individuals per 100 liters.

The Copepoda were more abundant than the Cladocera at Station I. A total of 218 individuals were collected during the 9 months of collections while 102 cladocerans were collected. The Copepoda were most numerous from February to May. In February, a total of 56 individuals were collected, 50 in March, 42 in April, and 29 in May. From September to January the total number of individuals collected varied from 3 to 16, the least abundant number occurring in October and December.

Of the more commonly collected copepods at Station I, Eucyclops agilis (Koch) was probably the most characteristic species. This species was never abundant, averaging between 2 and 3 individuals per 100 liters, but it was collected during all months except December. It was most numerous during April when it averaged 6 individuals per 100 liters. E. agilis appeared to be able to recover much faster after periods of high water than the other copepods as is evidenced by the March, April, and May collections. An average of 3 individuals per 100 liters were collected in March; 6 individuals were collected in April during the high water. In May the numbers were again 3 individuals per 100 liters.

| Species | Sept. 58 | Oct. 58 | Nov. 58 | Dec. 58 | Jan. 59 | Feb. 59 | Mar. 59 | Apr. 59 | May 59 |
|---|---|---|---|---|---|---|---|---|---|
| D. brachyurum | 1 | | | 1 | | | 1 | | |
| D. pulex | 1 | | | 2 | 2 | 3 | 1 | 15 | |
| S. vetulus | 1 | | | 2 | | | | 1 | |
| S. serrulatus | | | 1 | | | | | | |
| C. lacustris | | 1 | | | | | | | |
| B. longirostris | | | 2 | | 69 | 190 | 11 | 344 | |
| I. sordidus | | | | | | | | 1 | 1 |
| I. spinifer | | 1 | | | | | | | |
| M. laticornis | 1 | | | | | | | | |
| L. quadrangularis | | | | | | | | 1 | |
| L. acanthocercoides | | | | | | | 1 | | |
| A. costata | 1 | | | | | | | | |
| A. rectangula | 1 | | 1 | | 1 | 1 | 4 | 1 | |
| P. hamulatus | | | | | | 1 | | | |
| P. denticulatus | | | | | | | 3 | 1 | |
| C. sphaericus | | | | 2 | 2 | 2 | 8 | 40 | 1 |
| E. agilis | 1 | | 2 | 1 | | | 2 | 2 | 2 |
| T. prasinus | 3 | | | | 1 | 1 | 1 | | |
| M. albidus | | | | | | | | 1 | |
| M. edax | 1 | | | | | | | 2 | |
| C. vernalis | | | | 1 | | 3 | | 1 | |
| C. bicuspidatus | | | | | 29 | 55 | 50 | 390 | |
| D. siciloides | | | | | 87 | 47 | 23 | 46 | |
| C. robertcokeri | | | 1 | 2 | 1 | 2 | 6 | 22 | 1 |
| *Nauplii | 3 | 2 | 12 | 6 | TN | TN | TN | TN | 1 |
| Copepodite | 3 | | 2 | 2 | 16 | 44 | 17 | 431 | 1 |
| Total Cladocera | 6 | 2 | 4 | 7 | 74 | 197 | 29 | 404 | 2 |
| Total Copepoda | 11 | 2 | 17 | 12 | 134 | 152 | 99 | 895 | 5 |
| Total Entomostraca | 17 | 4 | 21 | 19 | 208 | 349 | 128 | 1299 | 7 |

Table II. Average number of individuals (per 100 liters) of Cladocera and Copepoda collected each month at Station II.

*TN - Too numerous to count.

December and in May, the number of individuals collected varied from 4 to 21. The period of least abundance occurred in October when only 4 individuals were collected.

The Cladocera were most numerous from January to April. Seventy-four individuals were collected in January. During February a total of 197 cladocerans were collected. A decline in numbers was recorded for March when a total of 29 individuals were collected; however in April a total of 404 individuals were collected.

Three species of Cladocera were commonly collected at Station II: B. longirostris, Daphnia pulex (de Geer), and C. sphaericus. B. longirostris, the most common cladoceran at this station, was abundant in January and February. No individuals were found in the December collections, but 69 individuals were collected in January and 190 in February. This species was very common in the April collections when it averaged 344 individuals per 100 liters. D. pulex appeared during the winter months averaging between 2 and 3 individuals per 100 liters in December, January, and February but was most abundant in April when 15 individuals were collected. C. sphaericus showed a slight increase from 2 individuals in February to 8 individuals in March. This species was common in April when an average of 40 individuals were collected. It appeared over a longer period of months (December to May) at this station than at Station I (February to May).

The Copepoda were, again, more numerous than the Cladocera; a total of 1,327 copepods were collected as compared to 725 cladocerans. The Copepoda were numerous from January to April. They increased from a total of 12 individuals collected during December to 134 collected in January. They remained abundant during February when 152 individuals were collected but decreased in March to a total of 99 individuals. The maximum number of 895 occurred during the high-water in April.

During September, October, November, and December, the number of individuals collected varied from a total of 2 to 17. They were least abundant during October when only 2 copepods were collected. Few individuals appeared during May after the April maximum. A total of 5 individuals were collected during this month.

Three species of copepods were commonly collected at this station. Cyclops bicuspidatus and Diaptomus siciloides were common from January to April. An average of 87 D. siciloides per 100 liters were collected in January when they were most abundant. This is rather surprising since no individuals were collected in December. After January, the numbers decreased to 47 per 100 liters during February and 23 in March, but increased to 46 individuals in April. No specimens were found in May.

C. bicuspidatus was least abundant in January, averaging 29 individuals per 100 liters. After which it increased in number in February to 55 and in March to 50 individuals per 100 liters to reach a maximum number of 390 individuals during the April high water. Apparently the population had been completely removed during April, for none appeared during May.

Canthocamptus robertcokeri appeared in all collections except September and October. It increased in number in March from 2 individuals collected in February to 6 individuals in March and was fairly abundant in April, averaging 22 individuals per 100 liters.

The immature copepods, the nauplii and the copepodids, were numerous at this station. During the months of January, February, March, and April, the nauplii were too numerous to count. In September, October, November, December, and May, they varied from 1 to 12 individuals per 100 liters, the fewest number occurring in May after the April high water.

The copepodids were most abundant in February when they averaged 44 individuals per 100 liters and in April when an average of 431 individuals were present. During the other months of collections, they varied from 1 to 17 individuals per 100 liters and were not collected in October.

### Collections Made During High Water

Two diurnal collections, July 11, 1958, and April 9, 1959, were made during periods of high-water level at both the Verdigris and Fall rivers. In both cases, collections began after the water was well above normal but was still rising. At Station I (Fig. 8), the Verdigris River was about 15 feet above normal when collections began; then the river rose from 3 to 4 more feet, crested, and began falling by the time the last collections were made 24 hours later.

The Fall River was about 10 feet above normal when collections began, rose about 3 more feet, crested, and began falling by the time the last collections were made.

Both rivers were very turbid. Station I had a turbidity reading of 3000 p.p.m., and Station II had a turbidity reading of 700 p.p.m. during the April high water. During the July high water, both rivers had turbidity readings of greater than 800 p.p.m.

During both periods of high-water level, large entomostracan populations were collected, and a greater

Fig. 8. Station I, Verdigris River, looking downstream towards collection area. During period of normal flow and during period of high-water.

number of species were recorded than during periods of normal water level.

The collections in July 1958 (see Appendix D and E) showed a large population of immature Cladocera and Copepoda (nauplii and copepodids). The Copepoda outnumbered the Cladocera at both stations, but more species of Cladocera were found in the samples.

The occurrence of benthic forms of entomostraca were noticeable at this time. Some of these forms, such as *Scapholeberis mucronata*, (O.F.M.) were collected only during floods.

The total increase in the entomostraca population during the July 1958 high-water level is not known since the number of individuals per 100 liters during June was not known.

In April 1959 the plankton population increased more than 2-fold over the March population at Station I (Table III) and almost 10-fold at Station II (Table IV). These increases would have been much greater if the nauplian stages had been counted.

*Chydorus sphaericus*, which increased from an average of 2 individuals per 100 liters in March to 53 in April showed the biggest increase at Station I. Copepodids showed an increase of from 3 to 26 per 100 liters, and *Eucyclops agilis* increased from 3 to 6 individuals.

| Species | 0800 | 1200 | 1600 | 2000 | 2400 | 0400 | 0800 |
|---|---|---|---|---|---|---|---|
| Daphnia pulex | 1 | 0 | 2 | 0 | 2 | 0 | 0 |
| Simocephalus vetulus | 5 | 1 | 0 | 0 | 1 | 2 | 0 |
| Bosmina longirostris | 5 | 3 | 1 | 3 | 6 | 10 | 1 |
| Ilyocryptus sordidus | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| Kurzia latissima | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| Leydigia quadrangularis | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Alona rectangula | 4 | 1 | 0 | 0 | 2 | 1 | 0 |
| Pleuroxus denticulatus | 2 | 5 | 3 | 3 | 1 | 0 | 2 |
| Chydorus sphaericus | 83 | 81 | 35 | 41 | 67 | 56 | 10 |
| Copepodite | 36 | 22 | 18 | 19 | 44 | 37 | 4 |
| Eucyclops agilis | 10 | 12 | 5 | 0 | 4 | 8 | 2 |
| Macrocyclops albidus | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| Mesocyclops leuckarti | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cyclops vernalis | 4 | 0 | 2 | 1 | 1 | 1 | 0 |
| Cyclops bicuspidatus | 5 | 4 | 0 | 2 | 4 | 0 | 1 |
| Diaptomus siciloides | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| Canthocamptus robertcokeri | 6 | 3 | 2 | 1 | 4 | 2 | 1 |
| Total Cladocera | 101 | 92 | 41 | 47 | 80 | 71 | 13 |
| Total Copepoda | 62 | 42 | 28 | 23 | 58 | 49 | 8 |
| Total | 163 | 134 | 69 | 70 | 138 | 120 | 21 |

Table III. Station I, Verdigris River. Affects of high water on number of individuals per 100 liters collected at 4 hour intervals throughout a 24-hour period during high water at Station I, Verdigris River in April 1959.

| Species | 0800 | 1200 | 1600 | 2000 | 2400 | 0400 | 0800 |
|---|---|---|---|---|---|---|---|
| Daphnia pulex | 0 | 2 | 0 | 13 | 14 | 18 | 26 |
| Simocephalus vetulus | 1 | 0 | 3 | 0 | 1 | 1 | 1 |
| Bosmina longirostris | 8 | 1 | 22 | 194 | 376 | 741 | 1069 |
| Ilyocryptus sordidus | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Leydigia quadrangularis | 0 | 0 | 1 | 1 | 1 | 3 | 2 |
| Alona rectangula | 1 | 1 | 1 | 6 | 7 | 5 | 4 |
| Pleuroxus denticulatus | 2 | 1 | 4 | 3 | 2 | 3 | 4 |
| Chydorus sphaericus | 24 | 15 | 46 | 59 | 47 | 55 | 37 |
| Copepodite | 14 | 8 | 26 | 228 | 447 | 885 | 1406 |
| Eucyclops agilis | 2 | 1 | 0 | 3 | 0 | 0 | 1 |
| Cyclops vernalis | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| Cyclops bicuspidatus | 1 | 1 | 25 | 272 | 510 | 688 | 1235 |
| Macrocyclops albidus | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Mesocyclops edax | 0 | 0 | 0 | 0 | 0 | 2 | 3 |
| Diaptomus siciloides | 0 | 0 | 0 | 30. | 51 | 51 | 50 |
| Canthocamptus robertcokeri | 8 | 7 | 15 | 50 | 17 | 31 | 28 |
| Total Cladocera | 36 | 20 | 77 | 277 | 448 | 826 | 1143 |
| Total Copepoda | 25 | 17 | 67 | 584 | 1025 | 1658 | 2723 |
| Total | 61 | 37 | 144 | 861 | 1473 | 2484 | 3866 |

Table IV. Station II, Fall River. Affects of high water on number of individuals per 100 liters collected at 4 hour intervals throughout a 24-hour period during high water at Station II, Fall River in April 1959.

The number of species present jumped from 5 species recorded in March to 16 species in April.

At Station II the greatest increase in numbers was noted for copepodids, which increased from an average of 17 during March to 431 in April. *Bosmina longirostris* increased from 11 specimens in March to 344 in April. *Cyclops bicuspidatus* increased from 50 to 390 individuals.

Although the greatest increases occurred in the true plankton forms such as *Bosmina* and *Cyclops*, significant increases occurred from the microbenthic forms. *Chydorus sphaericus* increased from 8 in March to 40 in April. *Canthocamptus robertcokeri* increased from an average of 6 to 22 specimens.

The total entomostraca population increased from an average of 128 individuals in March to 1,299 organisms, exclusive of the nauplii, in April.

The diurnal collections at Station I showed a decrease from a high point at 0800, April 9, of 163 individuals to 69 entomostracans at 1600. The 2400 collection increased to 138 entomostracans; after which the population decreased to 120 individuals at 0400 and to only 21 individuals by 0800, April 10.

The 7 samples taken over the 24-hour period at Station II showed a surprising increase, as seen in Table IV. The population increased from 61 organisms collected at

0800, April 9 to 3,866 entomostracans collected at 0800 on April 10. The increase in numbers began between 1200, 1600, and 2000 collections. Only 37 entomostracans occurred at 1200, 144 at 1600, and 861 at 2000, and continued to increase throughout the night.

Most species showed a gradual increase in numbers during the 7 collections. D. siciloides did not appear in the 0800, 1200, and 1600 collections. At 2000 there were 30 individuals of this species, an increase which must be due to some other factor than high water.

## Physical-Chemical Data

Oxygen. The oxygen readings throughout the study exhibited the expected seasonal trends of high readings during the winter and spring months, December to May, and low readings during the warm months, July to November (Table V and VI). Highest readings were recorded in February at both stations when a reading of 15.6 p.p.m. occurred at Station I and 15.0 p.p.m. at Station II. The lowest readings occurred in July when a reading of 4.2 p.p.m. occurred at Station I and 5.2 p.p.m. at Station II.

During several monthly collections, the oxygen readings displayed a variation over the 24-hour period of high readings in the day and low readings at night. The October readings at Station I showed a high of 9.6 p.p.m. at 1200 and a low of 8.8 p.p.m. at 2400. In December a high reading of 14.0

| Date | 0800 | 1200 | 1600 | 2000 | 2400 | 0400 |
|---|---|---|---|---|---|---|
| July 11, 1958 | 5.2 | 4.2 | 7.2 | 5.7 | 6.0 | 5.8 |
| August 2, 1958 | 7.0 | 6.4 | 6.8 | 6.6 | 6.4 | 6.8 |
| September 6, 1958 | 7.2 | 6.6 | 7.4 | 6.0 | 6.8 | 7.0 |
| October 3, 1958 | 8.8 | 9.6 | 9.0 | 8.0 | 8.8 | 9.0 |
| November 14, 1958 | 7.2 | 7.0 | 7.8 | 7.2 | 6.9 | 6.5 |
| December 20, 1958 | 13.1 | 13.4 | 14.0 | 12.8 | 12.6 | 13.4 |
| February 21, 1959 | 13.4 | 13.4 | 14.2 | 15.0 | 14.6 | 14.2 |
| March 6, 1959 | 12.2 | 11.8 | 12.3 | 12.3 | 14.2 | 13.2 |
| April 9, 1959 | 9.6 | 9.8 | 11.6 | 11.0 | 10.8 | 10.8 |
| May 14, 1959 | 8.4 | 9.8 | 11.4 | 12.8 | 12.0 | 11.0 |
| May 15, 1959 | 10.4 | 11.2 | 11.4 | 11.3 | 11.5 | 10.0 |
| May 16, 1959 | 10.4 | --- | 11.8 | 10.6 | 10.4 | 10.8 |

Table V. Seasonal and diurnal variation of oxygen in p.p.m., at Station I. Numbers represent values recorded every 4 hours over a 24-hour period on each collection date.

| Date | 0800 | 1200 | 1600 | 2000 | 2400 | 0400 |
|---|---|---|---|---|---|---|
| July 11, 1958 | 5.2 | 7.2 | 6.8 | 7.2 | 6.6 | 6.4 |
| August 2, 1958 | 7.2 | 7.2 | 6.6 | 7.0 | 7.2 | 7.0 |
| September 6, 1958 | 7.6 | 8.0 | 8.2 | 6.1 | 6.4 | 6.2 |
| October 3, 1958 | 8.4 | 8.8 | 9.2 | 8.3 | 9.2 | 8.8 |
| November 14, 1958 | 7.0 | 7.3 | 6.6 | 6.3 | 7.1 | 7.0 |
| December 20, 1958 | 13.2 | 13.6 | 14.5 | 13.2 | 13.0 | 13.0 |
| February 21, 1959 | 14.8 | 15.6 | 15.6 | 14.0 | 14.2 | 14.0 |
| March 6, 1959 | 12.5 | 13.0 | 12.8 | 14.0 | 12.6 | 12.4 |
| April 9, 1959 | 9.2 | 10.6 | 10.6 | 11.0 | 11.0 | 13.0 |
| May 14, 1959 | --- | 11.6 | 13.4 | 10.0 | 10.2 | 10.0 |
| May 15, 1959 | 11.0 | 12.3 | 12.2 | 11.0 | 9.4 | 9.2 |
| May 16, 1959 | 10.6 | --- | 11.4 | 9.8 | 10.0 | 10.2 |

Table VI. Seasonal and diurnal variation of oxygen in p.p.m. at Station II. Numbers represent values recorded every 4 hours over a 24-hour period on each collection date.

| Date | 0800 | 1200 | 1600 | 2000 | 2400 | 0400 |
|---|---|---|---|---|---|---|
| July 11, 1958 | 5.0 | 7.0 | 6.5 | 5.0 | 10.0 | 6.4 |
| August 2, 1958 | 4.5 | 3.5 | 3.5 | 5.0 | 4.5 | 4.5 |
| September 6, 1958 | 2.5 | 0.0 | 0.0 | 3.0 | 3.0 | 3.5 |
| October 3, 1958 | 2.0 | 1.0 | 1.0 | 2.0 | 2.0 | 2.0 |
| November 14, 1958 | 3.0 | 3.0 | 3.0 | 4.5 | 5.5 | 5.5 |
| December 20, 1958 | 5.0 | 2.0 | 3.0 | 4.5 | 5.5 | 5.0 |
| February 21, 1959 | 3.0 | 2.5 | 3.0 | 1.0 | 3.5 | 3.0 |
| March 6, 1959 | 1.0 | 0.0 | 0.0 | 2.0 | 0.5 | 1.0 |
| April 9, 1959 | 11.0 | 7.8 | 5.4 | 6.2 | 9.5 | 6.9 |
| May 14, 1959 | 2.0 | 1.0 | 1.5 | 2.0 | 2.5 | 3.5 |
| May 15, 1959 | 2.0 | 1.2 | 0.0 | 2.0 | 2.5 | 2.0 |
| May 16, 1959 | 1.5 | --- | 0.0 | 2.5 | 2.5 | 3.0 |

Table VII. Seasonal and diurnal variation of carbon dioxide, in p.p.m. at Station I. Numbers represent values recorded every 4 hours over a 24-hour period on each collection date.

| Date | 0800 | 1200 | 1600 | 2000 | 2400 | 0400 |
|---|---|---|---|---|---|---|
| July 11, 1958 | 6.0 | 4.0 | 3.5 | 4.0 | 5.0 | 4.5 |
| August 2, 1958 | 2.5 | 3.0 | 2.0 | 3.5 | 3.5 | 3.5 |
| September 6, 1958 | 2.0 | 1.0 | 0.0 | 2.5 | 3.5 | 3.0 |
| October 3, 1958 | 1.5 | 1.0 | 1.0 | 2.0 | 2.0 | 2.5 |
| November 14, 1958 | 3.0 | 3.5 | 2.5 | 4.0 | 4.0 | 4.0 |
| December 20, 1958 | 3.0 | 1.0 | 2.0 | 3.0 | 3.5 | 4.0 |
| February 21, 1959 | 1.0 | 0.0 | 0.0 | 0.5 | 1.0 | 1.0 |
| March 6, 1959 | 0.0 | 0.0 | 0.0 | 0.5 | 0.5 | 1.0 |
| April 9, 1959 | 6.2 | 3.6 | 4.5 | 3.5 | 4.8 | 3.2 |
| May 14, 1959 | --- | 1.0 | 0.6 | 1.5 | 2.0 | 3.0 |
| May 15, 1959 | 3.3 | 0.0 | 0.0 | 1.5 | 2.8 | 2.5 |
| May 16, 1959 | 1.3 | --- | 0.0 | 2.0 | 2.2 | 2.5 |

Table VIII. Seasonal and diurnal variation of carbon dioxide in p.p.m. at Station II. Numbers represent values recorded every 4 hours over a 24-hour period on each collection date.

High readings at Station II of 6.0 and 6.2 p.p.m. were recorded during the July and April high water. Excluding these 2 months, a high reading of 4.0 p.p.m. occurred in November and December, and a low reading of 0.0 p.p.m. was found in September, February, March, and May.

During the diurnal sampling, low carbon dioxide readings were recorded in the daytime and high readings were found at night. At Station I in September, a low reading of 0.0 p.p.m. occurred at 1200 and 1600 while a high reading of 3.5 p.p.m. occurred at 0400. In November a low reading of 2.0 p.p.m. was found at 1200, and a high of 5.5 p.p.m. was found at 2400. In May a low of 0.0 p.p.m. was recorded at 1600, and a high of 2.5 p.p.m. was recorded at 2400.

Station II readings followed the same trend as those at Station I. In September a reading of 0.0 p.p.m. occurred at 1600, and a high of 3.5 p.p.m. occurred at 2400. In December a low of 1.0 p.p.m. was found at 1200, and a high of 4.0 p.p.m. was found at 0400. In May a low reading of 0.0 p.p.m. occurred at 1200 and 1600, and a high of 2.8 p.p.m. occurred at 2400.

Temperature. Temperature, turbidity, and stream flow data are given in Tables IX and X.

The highest temperature recorded at Station I was 27.2° C. in August, and the lowest was .7° C. in January.

The highest temperature at Station II was 28.1° C. in August, and the lowest was .6° C. in January.

The temperature varied but slightly over the 24-hour period; because of this, the diurnal temperature recordings are not given.

Turbidity. In general, the turbidity at Station I was between 20 and 50 p.p.m. suspended material while that of Station II was usually less than 10 p.p.m. The highest turbidity reading at both stations occurred during the two periods of high water. In July both stations had a reading of greater than 800 p.p.m. In April Station I had a reading of 3000 p.p.m. while Station II had a reading of 700 p.p.m.

Excluding April and July, the highest reading at Station I was 200 p.p.m. in August, and the lowest was less than 10 p.p.m. in December. Station II had a high reading of 700 p.p.m. in August and a low reading of less than 10 p.p.m. in September, November, December, January, and February.

Stream flow. Stream flow measurements were taken at Altoona, Kansas, on the Verdigris River and Fredonia, Kansas, on the Fall River by the Army Corps of Engineers. These data, Table IX and X, were acquired from the district office at Tulsa, Oklahoma (1959).

The stream flow varied considerably throughout the period of this study. Stream flow readings above 1000 c.f.s.

| | | July | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature | | 22.5 | 27.2 | 27.0 | 17.2 | 15.3 | 1.9 | .7 | 3.2 | 5.7 | 9.8 | 20.9 |
| Turbidity | | 800 | 200 | 65 | 50 | 21 | 10 | 15 | 35 | 20 | 3000 | 73 |
| Stream | Max. | 15,800 | 76 | 4,500 | | 3,850 | 88 | 133 | 579 | 316 | 4,500 | 6,110 |
| Flow | Min. | 390 | 53 | 38 | 22 | 16 | 54 | 77 | 100 | 89 | 180 | 117 |
| | Mean | 4,365 | 65 | 1,591 | 46 | 1,933 | 71 | 133 | 277 | 202 | 1,711 | 3,632 |

Table IX. Average monthly temperature in degrees centigrade and turbidity in p.p.m. at Station I; maximum, minimum, and mean stream flow in c.f.s.

| | | July | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature | | 24.4 | 28.1 | 26.5 | 17.0 | 14.5 | 2.8 | .6 | 3.5 | 5.4 | 10.2 | 20.8 |
| Turbidity | | 800 | 70 | 10 | 30 | 10 | 10 | 10 | 10 | 30 | 700 | 25 |
| Stream | Max. | 1,090 | 70 | 196 | 19 | 1,980 | 84 | 142 | 255 | 285 | 2,180 | 6,100 |
| Flow | Min. | 88 | 27 | 32 | 13 | 9 | 54 | 79 | 116 | 86 | 105 | 834 |
| | Mean | 490 | 49 | 133 | 17 | 994 | 69 | 110 | 185 | 185 | 752 | 4,171 |

Table X. Average monthly temperature in degrees centigrade and turbidity in p.p.m. at Station II; maximum, minimum, and mean stream flow in c.f.s.

(cubic feet per second) are considered high-water levels while those less than 1000 c.f.s. are considered low-water levels.

High-water levels were reported in July, September, November, April, and May on the Verdigris River. The maximum readings occurred in July, a reading of 15,800 c.f.s., while other high-water readings were between 6,110 and 3,850 c.f.s.

Low-water levels existed during August, October, December, January, February, and March. Low-water levels varied from 16 c.f.s. in November and 579 c.f.s. in February.

High-water levels on the Fall River were reported during July, November, April, and May. The highest reading was 6,100 c.f.s. in May while the other readings were between 1.090 and 2,180 c.f.s.

Low-water levels were reported during August, September, October, December, January, February, and March. They varied from 9 c.f.s. in November to 285 c.f.s. in May.

## DISCUSSION

### Diurnal Variation of Entomostraca

Galtsoff (1924) stated that, "Plankton organisms are passively carried by running water; therefore their vertical distribution in the rivers depend entirely on the current." Welch (1952) said, "...vertical distribution of plankton in running waters is very variable not only in different systems but also in different portions of the same system."

An attempt to find a diurnal pattern for the abundance of plankton in the surface waters of rivers is very difficult. Many variables enter into such a study, variables which do not occur when studying the diurnal variation of numbers of entomostraca in the surface waters of lakes. It would seem logical, however, that the factors causing this variation in lakes would also be present in lotic environments, and hence a diurnal variation in numbers of individuals collected should be found.

The results of 12 samples taken during an hourly series on the San Joaquin River led Allen (1920) to state:

> As to the Entomostraca, the catches of Cladocera were too variable to give any information, and those of Copedoda were also rather indefinite. There was not much difference between the forenoon and afternoon catches either of Cladocera or of Copedoda or of both together.

Galtsoff (1924) found that:

> ...the volume of plankton taken from different strata show that sometimes the amount of plankton in the

> deeper strata is greater than that in the surface waters while sometimes the vertical distribution is the same as that usually found in the lakes during the warm season; that is, the surface layers are richer in plankton than the deeper layers.

Roach (1932) found "practically no vertical distribution or stratification of plankton" in the Hocking River.

Cushing (1951) states that, "Migrations of *Calanus finmarchicus* have been demonstrated in the St. Lawrence River." This statement cannot be taken at face value. Cushing's remarks refer to collections made by Willey (1919) in the Gulf of St. Lawrence. His collections were made in an area where the "river" depth was between 300 and 400 meters.

All of these remarks appear to be rather ambiguous, and no definite conclusions can be drawn from them.

The results of this study show a definite variation in numbers of entomostraca collected at 1200 and at 2400. This variation, although based on a small number of individuals collected, in most cases, is nevertheless a variation which is consistent.

At Station I, the Verdigris River, the number of individuals collected appeared to be at a minimum number at 1200 in the daytime and at a maximum at 2400 and 0400. Entomostraca populations at Station II, the Fall River, tended to be at a minimum number at 1200 in the daytime and at a maximum at 2000 in the evening. The difference between the two rivers can be explained by Welch's above statement

(1952) that the vertical distribution of plankton is variable in different systems. This appears to be due to differences in turbidity and particularly in stream flow in the two rivers investigated.

The cause of this variation in numbers collected, if it is a true variation, is not well understood. The principle factor controlling the time of appearance of largest numbers of entomostraca in the surface waters is apparently light, but this is not the only factor. Other environmental factors, controlled by a variation in light intensity, must also influence the variation of entomostraca.

After more work has been done on rivers, it may be found that indigenous river plankters are benthic forms. This is suggested by the results of the plankton collections during high water at Station I and II (see discussion on affects of high water). If this is the case, the variation in numbers could be due to a diurnal variation in activity, i. e., the entomostraca may be on or in the bottom sediments and on vegetation during the day. As the light intensity decreased, they would increase their activity, possibly controlled by the same factor causing entomostracans to migrate in lentic environments. As they increased their activity by swimming, they would be swept into the main channel by the current and thus would add numbers to the true plankton forms which were brought into the river from pools or sloughs near the river.

This may or may not be the answer, but no one will know the answer until more studies have been done on the ecology of entomostraca in lotic environments.

B. longirostris showed a variation in numbers during the winter collections at Station II. Pennak (1944) found B. longirostris to show a slight variation in Silver Lake in Colorado. Yeatman (1956) showed this species to migrate in Woods Reservoir. C. bicuspidatus showed a diurnal variation in the winter collections. Andrews (1947) found C. bicuspidatus to exhibit a definite diurnal variation under snow-covered ice in Lake Erie. Pennak (1944) found a moderate variation for C. bicuspidatus males, but found no variation of the females in Silver Lake. Plew and Pennak (1949) found a diurnal variation for this species. D. siciloides exhibited a diurnal variation in individuals collected in the spring collections. No previous literature concerning diurnal variation has been found for this species.

The copepodids exhibited a slight variation in the winter collections. Pennak (1944) found no variation for the copepodid stages of C. bicuspidatus. Maloney and Tressler (1942) found a slight variation for the copepodids below the thermocline.

The nauplii apparently showed a diurnal variation in numbers collected at Station I. Few investigators have studied the diurnal variation of anuplii in lakes. Maloney and Tressler (1942) found that the nauplii showed no definite variation in Caroga Lake. Plew and Pennak (1949) found the nauplii to show a diurnal variation during all seasons in an Indiana lake, and Langford (1938) found the nauplii to show a diurnal pattern in Lake Nippissing.

The results of this study show that a diurnal variation in numbers of entomostraca collected from near the surface water of the Fall and Verdigris rivers, does occur. In the Verdigris River this variation shows a minimum population number at 1200 and a maximum population number at 2400 and 0400. In the Fall River the minimum numbers appear at 1200, and the maximum numbers occur at 2000.

This variation appears to be constant during the spring, fall, and winter seasons. It must, however, be emphasized that the variation in numbers is to an extent dependent upon the current of the river and is subject to variation at different locations in the same river and in different rivers.

## Seasonal Variation of Entomostraca

In general the number of entomostraca collected during this study was small. An average of .4 individuals per liter were collected at Station I and 2.3 individuals per liter at Station II. Prophet (1957) collected an average of 7.1 individuals per liter at Station I and 5.4 individuals per liter at Station II during his study. Apparently this difference is due to the fluctuating water level during the present study.

As is shown in the above paragraph, a greater number of individuals were collected at Station II, 2.3 individuals, than at Station I, .4 individuals. Prophet (1957) found the number of individuals collected at Station I to be greater than the number collected at Station II, 7.1 individuals at Station I as opposed to 5.4 individuals at Station II. The increased number of entomostraca collected at Station II as compared to those collected at Station I of the present study appears due to a discharge of water from the Fall River Reservoir adding lake plankton to the Fall River.

Station I, Verdigris River. The Copepoda were twice as abundant as the Cladocera at Station I. A total of 221 copepods were collected and 102 cladocerans. Prophet (1957) found a similar ratio of Copepoda to Cladocera in his collections.

C. Sphaericus was the most abundant cladoceran at Station I. It was most abundant in April during the high water and appeared during February, March, April, and May. Prophet (1957) found it to be most numerous in December and March.

B. longirostris, the most abundant cladoceran in Prophet's Station I collections (1957), was collected in February, April, and May. Prophet found this species to be most numerous in April, May, and June.

The most numerous copepod in Prophet's collections was Cyclops vernalis, a species which was never abundant in this study. Apparently this species could not adapt to the high-water conditions which occurred. He found this species to be most abundant in September and December. During the present study, it is possible that high water during July washed away the potential September populations.

The abundance of the nauplii and copepodid stages in this study is no doubt due to the unstable conditions of the river caused by fluctuating water levels.

Station II, Fall River. The Copepoda were twice as abundant as the Cladocera at Station II as was true at Station I. A total of 1,327 copepods and 725 cladocerans were collected. Both of these numbers were much greater than the total number of individuals collected at Station I. Prophet (1957) found the Cladocera to be 3 times as abundant as the Copepoda at this station.

B. longirostris was the most abundant cladoceran at Station II. It was most numerous from January to April. Prophet (1957) found it to be most abundant in April and May.

C. sphaericus was most numerous in March and April. Prophet (1957) found it most common in April, May, and June. This species was recorded as his most abundant cladoceran at Station II. B. longirostris was probably more abundant than C. sphaericus in the present study because of the discharge of water from the Fall River Reservoir. B. longirostris, a pelagic plankton form, would have been more numerous in the reservoir waters than C. sphaericus, a microbenthis corm, and hence, would thus show an increased number in the river water.

The most abundant copepod at Station II was Cyclops bicuspidatus, which was abundant from January to April. Prophet (1957) found this species in small numbers in April and May. This increase again appeared to be due to the addition of lake plankters to the river. The second most abundant copepod was Diaptomus siciloides, a species which Prophet (1957) did not collect at Station II.

Canthocamptus robertcokeri, which was collected at both Station I and II, was not reported previously from these 2 rivers. It was probably formerly identified as Attheyella illinoisensis (Forbes) by previous Kansas investigators.

The abundance of the nauplii and copepodid stages again reflect the fluctuating water-level which occurred during the period of this study. Prophet (1957) did not report on the nauplii or the copepodid stages in his study.

The greatest abundance of entomostracans occurred from January to April. Prophet (1957) found the greatest abundance in April and May, the time when most blooms are expected.

The question arises as to whether the increased entomostraca numbers at Station II is due to a seasonal variation in abundance or to the discharge of entomostracans in water from the Fall River Reservoir. If Chandler's results (1937, 1939), on the fate of lake plankton in streams is valid for entomostracans, it would seem that any entomostraca discharged from the reservoir would be destroyed before it could travel the 46 river-miles to the collection area.

This would be especially true during the spring months because this river usually has a large amount of bottom vegetation, which according to Chandler's results (1937) greatly decreases the lake plankton in rivers.

If more were known about the ecology of the species common during the time of the most abundance at Station II, it might be found that these species are able to survive the action of the current. B. longirostris, C. bicuspidatus, and D. siciloides make up the majority of the entomostraca population at Station II. Prophet (1957) found B. longirostris to be common at Station II, and C. bicuspidatus present but not common. Prophet, et al., (1959) found these 3 species in lentic environments more frequently than lotic environments. Eddy (1932) found these 3 species common in the Sangamon River. It could be said, then, that these entomostracans might occur in abundance in rivers.

Before a valid answer can be given to this question, a study similar to Chandler's (1937, 1939) should be on this river. It may be that the entomostraca of the reservoir were able to survive the stream conditions and become a part of the plankton of the stream.

### Affects of High-Water Level

It would be natural to expect an increased water level to dilute a plankton population, resulting in a decrease in entomostraca numbers in quantitative samples. Pennak (1946) stated:

> ...high turbidity of rivers and streams, especially at times of high water, may decrease plankton populations by 'silting out' the organisms and greatly decrease photosynthesis by cutting down on light penetration.

Kofoid (1903) explains the "silting out" effect by stating:

> Hydographic changes affect the Cladocera by increasing the amount of silt and flocculent debris in suspension, which, by adherence to the swimming antennae and flotation processes of the animal, tend to impede its movement and sink it to the bottom, where it is removed from its normal feeding area and readily becomes the prey of the larger organisms of the bottom fauna.

Turbidity readings at both stations were above normal during the periods of high-water. Station I had a turbidity of greater than 800 p.p.m. in the July 1958 collections and a reading of 3000 p.p.m. during the April 1959 collections. Station II had a turbidity reading of greater than 800 p.p.m. in July 1958 and a reading of 700 p.p.m. in April 1959. In both instances, the "silting out" factor should have been in evidence; however, as is given in the results, numbers of entomostraca collected increased during these periods. Apparently other factors were operating to offset the decrease in population by silting, causing an increase in the population numbers.

The Verdigris River has no major impoundments along its course; however, there are a few small dams near upstream cities which hold back a water supply for each city. These dammed area produce lake-like conditions, perhaps allowing greater numbers of plankton to develop. During periods of high water, it is probable that these small reservoirs would be flushed out and their plankton populations would be added to the river plankton population. Besides the small reservoir areas, there are many sloughs which were formed along the river during previous high-water levels. Between high-water stages, the sloughs would also store a plankton that would later add to the river population.

The entomostraca population at Station I, during the April 1959 collections, was primarily composed of <u>Chydorus sphaericus</u>, a microbenthich form (Cole, 1955). The increased current, caused by the high water would sweep a great number of the benthic entomostracans off the river bottom and off bottom vegetation. It may be that the overall increase is due to the increase in the benthic forms while the true plankton entomostraca showed little increase in number.

It is surprising that <u>C. sphaericus</u> should appear in such increased numbers during the high water. In March, only 2 individuals per 100 liters were collected while in April this species increased to 53 individuals per 100 liters. Because of this marked increase, it seems plausible to assume that this species, being a benthic form, is able to survive in great numbers in its benthic environment adding to the plankton when accidentally swept off the bottom by the current or during a period of rising water.

Welch (1952) in a discussion of the origin of stream plankton (page 427) resolved the issue in a statement that, "...it appears that the plankton of many streams is a composite of plankters from several sources, some of which may be the limnetic and benthic zones as well as contributing lentic environments." <u>C. sphaericus</u> then, may be an indigenous form, produced in streams, not added to the stream from lentic environments.

Station II showed a much greater increase in the entomostracan population than Station I. It does not seem possible that this increase would be due to the above factors. This increase may be due to an overflow of water from the Fall River Reservoir. If this is true, then the scarcity of the true plankton entomostraca (D. siciloides, B. longirostris, and C. bicuspidatus) in the 0800 and 1200 collections probably means that these forms had already been washed downstream before collections were begun. Since C. sphaericus and C. robertcokeri are microbentic forms, they would not have been washed downstream as quickly as the true plankton forms, but would follow these forms in abundance as the current became rapid enough to sweep them from their benthic environment.

Water flow data received from the Army Corps of Engineers, Tulsa Office, showed an increase discharge of from 70 c.f.s. on April 8, 1959, to 1,460 c.f.s. of water on April 9, and 2,080 c.f.s. on April 10. The discharge of water, in order to add lake plankters to the collections, would need to reach Station I by 2000, 12 hours after collections began. The Fall River Reservoir is located 46 river miles above Station II. The mean velocity of the Fall River Reservoir as measured at Fredonia, Kansas, on April 11 was 3.13 feet per second. Assuming the river to have moved at this speed on April 9, it would have taken the reservoir water about 22 hours to reach the area of collection.

With these data, it then appears that the increase in numbers of entomostraca during the 1600, 2000, and 2400 collections could not have been due to the addition of the reservoir plankton, but must have been due to a flooding of sloughs and ponds near the river banks.

It may be that the 0400 and 0800 collection numbers were due to the discharge of water from the reservoir. Reif (1939) in a study similar to Chandler's work (1937, 1939) on lake plankters in streams found that the plankton of the lake decreased downstream in all cases, but not so marked in the spring plankton when the velocity of the current was doubled by high water.

Flood recovery. It is generally accepted that low plankton numbers follow periods of high water. This is the case in the Verdigris and the Fall rivers although the time of flood recovery differs from that of other studies. Moffett (1936) stated that the, "Rate of recovery will vary in different waters since few streams present identical physical, chemical, and biological characteristics which have direct effect upon the cycle of their aquatic life."

Stehr and Branson (1938) found that the "rebuilding process begins as soon as the stream returns to normal." Roach (1932) found that, "the small planktonts are present, although in small numbers, within five days after heavy floods, while for the larger plankton, the entomostraca and rotifers, it was 15 days before fairly normal association had been formed."

Results are not given for the August 1958 collections because numbers were too negligible in the 10-liter samples to be converted into a 100-liter samples for purposes of comparison. It would appear then that the time of recovery was very slow. The entomostracan numbers in September was also very small, but it would seem doubtful that the July flood would still have its affect 2 months later. Periods of high water apparently occurred during August which again greatly diminished the entomostraca numbers.

The May 1959 collections showed that the entomostraca population had not fully recovered from the April high-water. The population at Station I appeared to have almost recovered, but a small number of entomostraca were collected at Station II.

Apparently the entomostracan population recovered within 1 months time in the Verdigris River; whereas in the Fall River, recovery required at least 2 months. Of course, recovery at Station II would be much faster if water were released from the Fall River Reservoir adding new plankters to the river water.

## Physical-Chemical Data

Oxygen. The seasonal variation of oxygen found in this study was similar to that found by Prophet (1957); however, his lowest oxygen content was recorded in August at Station I and September at Station II. The low readings of this study were found in July at both stations. This difference is probably due to the fact that the low readings of this study were recorded during a period of high-water level. High-water levels are not conducive to high oxygen readings. Denham (1938) stated, "The effects of increased water level are noticeable in that an increase accompanied by turbidity causes a sudden decrease in total oxygen..."

The seasonal highs occurred in February at both stations in this study; Prophet (1957) found the same results although oxygen recordings were lower than those recorded in this study (i.e., 12.8 p.p.m. at Station I and 13.1 p.p.m. at Station II). This variation is due to the fact that Prophet's readings were usually made early in the day while the readings of this study were made throughout the day.

It appears that the oxygen values obtained over the 24-hour period follow a trend of low values at night and high values during the day. This trend is more apparent at Station II than at Station I probably because of the low turbidity readings found at Station II.

Butcher et al. (1927, 1930) found a diurnal variation in oxygen readings from several rivers in England. Their data showed that "...the oxygen content rises shortly after sunrise, to a maximum soon after midday and then falls to a minimum, which lasts throughout the hours of darkness." Denham (1938) found "The greatest amount of oxygen occurred in the late afternoon and the least in the early morning."

Carbon dioxide. Prophet (1957) had a high carbon dioxide reading of 7.1 p.p.m. in December at Station I, which compares with the high reading of 5.5 p.p.m. in November and December during the time of this study. The reason for this difference is not known.

The low of 0.0 occurring in August, March, and May compare well with the low during Prophet's study (1957).

The high reading at Station II of 4.0 p.p.m. which occurred in November and December was much higher than that found by Prophet of 1.8 p.p.m. in December and January. Since the turbidity readings were similar at both times during the two studies, this factor could not account for the difference. The cause of this difference may have been an increased amount of detritus in the water during the present study that was not detected by the turbidity measurements. This increase in detritus would raise the carbon dioxide level because of an increase in the decay rate.

In general, the diurnal carbon-dioxide values are inverse to the oxygen values. Low carbon dioxide readings were recorded during the day and high readings were found at night. Denham (1938) found that carbon dioxide displayed a variation in content over the 24-hour period in the White River. His readings are similar to the readings of this study.

Temperature. The surface water temperatures of this study are lower than those found by Prophet (1957). His high readings of 29.2°C. at Station II are higher than the high readings of 27.2°C. and 28.1°C. recorded in August during the present study. His low readings of 3.1° C. at Station I in January and February and 4.5°C. at Station II in February are higher than the .7°C. at Station I and .6°C. at Station II recorded in January during this study. The only apparent answer for this difference in temperatures would be that the climatic temperature during the present study was lower than the climatic temperature in 1954-55.

Turbidity. Turbidity readings varied considerably throughout the time of this study. There was a variation of from less than 10 p.p.m. to 3000 p.p.m. at Station I and 800 p.p.m. at Station II. This extreme variation is due to the fluctuating water level.

The higher turbidity recorded at Station I appears to reflect the difference between the Verdigris and the Fall rivers. Since the Fall River Reservoir controls the stream flow of the Fall River, less erosion occurs along its banks. Contrary to this, the Verdigris River because of its frequent high water has a greater amount of erosion occuring along the river banks which adds suspended clay to the river water.

Stream flow. The effects of the Fall River Reservoir may be seen in the variation in stream flow between the 2 rivers. Although the 2 rivers drain areas close to one another, variation in stream flow occurred much more frequently on the Verdigris River than on the Fall River. The upper reaches of the Fall River drain into the reservoir. During heavy rains, much of this water is held in the reservoir and thus does not contribute to the high-water conditions.

The high-water level of July, September, November, April, and May on the Verdigris River is a factor in considering the numbers of entomostraca collected during this study. Prophet (1957) found high-water only in April on the Verdigris. Other periods had a steady flow except August and September when the river became intermittent. This steady flow is conducive to larger plankton populations.

The results of the Fall River are very similar to those on the Verdigris River. High-water levels were found during July, November, April, and May. Prophet found high water only in April when the stream flow amounted to 833 c.f.s. This is much less than the 6,100 c.f.s. which was the high recording in the present study.

His season low of 4.1 c.f.s. in June compares with the low of 9 c.f.s. in November of the present study.

# SUMMARY

1. Monthly diurnal (a collection every 4 hours throughout a 24-hour period) collections of entomostraca were made on the Verdigris (Station I) and Fall (Station II) rivers near Neodesha, Kansas, from July 1958 to May 1959.

2. During the diurnal collections, water temperature in degrees centigrade, turbidity, oxygen, and carbon dioxide in p.p.m. were determined.

3. Diurnal collections of entomostraca showed a variation in numbers of individuals collected. Greatest numbers were collected at 2400 and 0400 and smallest numbers at 1200 and 1600 at Station I. At Station II greatest numbers occurred at 2000 and smallest numbers at 1200.

4. The organisms which exhibited an obvious diurnal variation in numbers collected were the nauplii at Station I; *Bosmina longirostris*, *Cyclops bicuspidatus*, *Diaptomus siciloides*, and copepodids at Station II.

5. Cladocera at Station I showed greatest seasonal variations in abundance during April; the Copepoda were most abundant during February, March, April, and May. The Cladocera and the Copepoda at Station II showed greatest seasonal variations in abundance during January, February, March, and April.

6. B. longriostris, Chydorus sphaericus, Cyclops bicuspidatus, and D. siciloides were the most common entomostracans at Station I and II and were most abundant during January, February, March, and April.

7. Greatest number of entomostraca at both stations were collected during the late winter and early spring months: January, February, March, and April.

8. The entomostraca were most abundant in April during a high-water stage. Collections made during the periods of high water at Station I showed that the number of entomostraca collected increased quantitatively during the early period of rising water and later decreased in numbers until a great majority of the plankton population had been washed downstream. An increase in the microbenthic entomostracan C. sphaericus was noted.

9. Collections during periods of high water at Station II showed a continued increase in numbers of entomostraca collected at 0800, April 9, to 0800, July 10. This increase is probably due to the addition of individuals from flooded sloughs and ponds above the collection area. This increase may also in part be due to the discharge of water from the Fall River Reservoir adding additional plankters.

10. Seasonal oxygen content showed highest readings during the winter and lowest readings during the summer. The carbon dioxide content was greatest during the winter

while lowest readings were recorded during the summer months. During periods of high water, the oxygen content of the water was low while the carbon dioxide content was high.

11. Diurnal records of oxygen content showed highest readings during the day and lowest readings during the night at both stations. Diurnal carbon dioxide readings were highest at night and lowest during the day at both stations.

12. Stream flow readings during the period of this study varied from 15,800 c.f.s. to 16 c.f.s. on the Verdigris River and from 6,100 c.f.s. to 9 c.f.s. on the Fall River. High-water levels were reported on the Verdigris River during July, September, November, April, and May. High-water levels on the Fall River were reported during July, November, April, and May.

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## LITERATURE CITED

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# APPENDIX

# APPENDIX A

## Checklist of Entomostraca Collected

### Cladocera

Sididae
- *Diaphanosoma brachyurum* (Lievin)

Daphnidae
- *Daphnia pulex* (de Geer)
- *Simocephalus exspinosus* (Koch)
- *Simocephalus vetulus* (O.F.M.)
- *Simocephalus serrulatus* (Koch)
- *Scapholeberis mucronata* (O.F.M.)
- *Ceriodaphnia rigaudi* Richard
- *Ceriodaphnia reticulata* (Jurine)
- *Ceriodaphnia lacustris* Birge
- Ceriodaphnia laticaudata P. E. Müller
- *Moina micrura* Kurz
- *Moina brachiata* (Jurine)

Bosminidae
- *Bosmina longirostris* (O.F.M.)

Macrothricidae
- *Macrothrix laticornis* (Jurine)
- *Ilyocryptus sordidus* (Lieven)

Chydoridae
- *Kurzia latissima* (Kurz)
- *Camptocercus rectirostris* Schödler
- *Leydigia quadrangularis* (Leydig)
- *Leydigia acanthocercoides* (Fischer)
- *Alona* costata Sars
- *Alona rectangula* Sars
- *Pleuroxus hamulatus* Birge
- *Pleuroxus denticulatus* Birge
- *Chydorus sphaericus* (O.F.M.)

## Eucopepoda

Cyclopidae
- Paracyclops fimbriatus (Fischer)
- Eucyclops agilis (Koch)
- Tropocyclops prasinus (Fischer)
- Macrocyclops ater (Herrick)
- Macrocyclops albidus (Jurine)
- Mesocyclops leuckarti (Claus)
- Mesocyclops edax (Forbes)
- Cyclops vernalis Fischer
- Cyclops bicuspidatus Claus

Diaptomidae
- Diaptomus clavipes Schacht
- Diaptomus siciloides Lillj.

Canthocamptidae
- Canthocamptus robertcokeri M. S. Wilson

| Species | | 0400 | 0800 | 1200 | 1600 | 2000 | 2400 |
|---|---|---|---|---|---|---|---|
| Daphnia pulex | F | 0 | 0 | 1 | 0 | 0 | 0 |
| | W | 0 | 0 | 0 | 0 | 2 | 0 |
| Simocephalus vetulus | F | 1 | 0 | 0 | 0 | 0 | 1 |
| Bosmina longirostris | S | 1 | 1 | 5 | 0 | 0 | 0 |
| | F | 0 | 0 | 0 | 1 | 0 | 0 |
| | W | 0 | 0 | 0 | 0 | 0 | 2 |
| Ilyocryptus sordidus | S | 0 | 1 | 0 | 0 | 0 | 1 |
| Ilyocryptus spinifer | F | 0 | 0 | 0 | 1 | 0 | 0 |
| Macrothrix laticornis | F | 0 | 0 | 0 | 1 | 2 | 0 |
| Alona costata | F | 1 | 0 | 0 | 0 | 0 | 0 |
| Alona rectangula | S | 0 | 0 | 0 | 0 | 1 | 0 |
| | F | 0 | 1 | 0 | 0 | 0 | 0 |
| | W | 0 | 2 | 0 | 0 | 0 | 1 |
| Pleuroxus denticulatus | S | 0 | 0 | 0 | 0 | 0 | 1 |
| Chydorus sphaericus | S | 1 | 1 | 2 | 0 | 1 | 2 |
| | W | 0 | 0 | 0 | 2 | 0 | 0 |
| Macrocyclops ater | F | 1 | 1 | 0 | 0 | 0 | 1 |
| Eucyclops agilis | S | 4 | 1 | 1 | 0 | 2 | 1 |
| | F | 1 | 0 | 0 | 0 | 1 | 1 |
| | W | 6 | 1 | 0 | 1 | 1 | 1 |
| Cyclops vernalis | F | 1 | 0 | 0 | 0 | 0 | 0 |
| | W | 0 | 0 | 0 | 1 | 0 | 1 |
| Cyclops bicuspidatus | S | 0 | 0 | 9 | 0 | 0 | 1 |
| | W | 1 | 1 | 0 | 0 | 0 | 0 |
| Nauplii | S | 43 | 19 | 13 | 12 | 16 | 39 |
| | F | 16 | 3 | 3 | 4 | 5 | 6 |
| | W | 26 | 41 | 13 | 36 | 28 | 22 |
| Copepodite | S | 1 | 2 | 4 | 0 | 1 | 4 |
| | F | 4 | 1 | 1 | 2 | 1 | 1 |
| | W | 1 | 1 | 0 | 0 | 1 | 1 |
| Total Cladocera | F | 2 | 1 | 1 | 3 | 2 | 1 |
| Total Cladocera | W | 0 | 2 | 0 | 2 | 2 | 3 |
| | S | 2 | 3 | 7 | 0 | 2 | 4 |
| Total Copepoda | S | 48 | 22 | 27 | 12 | 19 | 45 |
| | F | 23 | 5 | 4 | 6 | 7 | 9 |
| | W | 34 | 44 | 13 | 38 | 30 | 25 |

Appendix B. Diurnal variation in numbers of entomostraca collected at Station I (F = Fall, S = Spring, W = Winter).

| Species | | 0400 | 0800 | 1200 | 1600 | 2000 | 2400 |
|---|---|---|---|---|---|---|---|
| Diaphanosoma brachyurum | S | 0 | 0 | 0 | 0 | 0 | 1 |
| | W | 0 | 0 | 0 | 1 | 0 | 0 |
| Daphnia pulex | S | 0 | 0 | 1 | 0 | 0 | 0 |
| | F | 0 | 0 | 1 | 2 | 1 | 1 |
| | W | 0 | 3 | 2 | 2 | 4 | 2 |
| Simocephalus vetulus | F | 1 | 0 | 0 | 0 | 0 | 0 |
| | W | 0 | 2 | 0 | 0 | 0 | 0 |
| Simocephalus serrulatus | F | 0 | 0 | 0 | 0 | 1 | 0 |
| Ceriodaphnia lacustris | F | 0 | 1 | 0 | 0 | 0 | 0 |
| Bosmina longirostris | S | 13 | 9 | 8 | 13 | - | 10 |
| | F | 2 | 0 | 0 | 2 | 3 | 0 |
| | W | 218 | 182 | 62 | 196 | 238 | 208 |
| Ilyocryptus sordidus | S | 0 | 1 | 1 | 1 | 0 | 0 |
| Ilyocryptus spinifer | F | 0 | 0 | 1 | 0 | 0 | 0 |
| Macrothrix laticornis | F | 1 | 0 | 0 | 1 | 0 | 0 |
| Leydigia acanthocercoides | S | 0 | 0 | 0 | 0 | 0 | 1 |
| Alona rectangula | S | 1 | 1 | 1 | 0 | 0 | 1 |
| | F | 1 | 0 | 1 | 0 | 0 | 0 |
| | W | 1 | 0 | 1 | 0 | 1 | 0 |
| Pleuroxus hamulatus | S | 0 | 1 | 0 | 0 | 0 | 0 |
| Chydorus sphaericus | S | 3 | 9 | 3 | 2 | 0 | 3 |
| | W | 0 | 1 | 0 | 0 | 1 | 1 |
| Eucyclops agilis | S | 1 | 0 | 0 | 0 | - | 1 |
| | F | 0 | 0 | 0 | 1 | 2 | 0 |
| | W | 0 | 0 | 0 | 0 | 0 | 1 |
| Tropocyclops prasinus | S | 0 | 0 | 0 | 1 | 0 | 0 |
| | F | 0 | 3 | 2 | 2 | 4 | 0 |
| | W | 1 | 1 | 0 | 0 | 0 | 1 |
| Mesocyclops edax | F | 0 | 0 | 0 | 0 | 0 | 1 |
| Cyclops vernalis | F | 1 | 0 | 0 | 0 | 0 | 0 |
| | W | 0 | 0 | 0 | 1 | 0 | 4 |
| Cyclops bicuspidatus | S | 61 | 63 | 36 | 47 | - | 45 |
| | W | 60 | 70 | 13 | 66 | 87 | 46 |
| Diaptomus siciloides | S | 48 | 28 | 6 | 8 | - | 27 |
| | W | 36 | 69 | 24 | 37 | 61 | 61 |
| Canthocamptus robertcokeri | S | 1 | 5 | 0 | 4 | 1 | 3 |
| | F | 0 | 1 | 0 | 0 | 1 | 1 |
| | W | 1 | 0 | 1 | 0 | 3 | 0 |
| Nauplii* | F | 4 | 5 | 2 | 7 | 14 | 2 |
| Copepodite | S | 7 | 14 | 8 | 7 | - | 7 |
| | F | 2 | 2 | 0 | 3 | 2 | 1 |
| | W | 13 | 22 | 12 | 24 | 42 | 19 |
| Total Cladocera | S | 17 | 21 | 14 | 16 | - | 15 |
| | F | 5 | 1 | 3 | 5 | 5 | 1 |
| | W | 219 | 188 | 65 | 199 | 244 | 211 |
| Total Copepoda | S | 118 | 110 | 50 | 67 | - | 83 |
| | F | 7 | 11 | 4 | 13 | 23 | 5 |
| | W | 111 | 172 | 52 | 128 | 193 | 132 |

Appendix C. Diurnal variation in numbers of entomostraca collected at Station II (F = Fall, S = Spring, W = Winter).
*Too numerous to count during spring and winter months.

| Species | 1600 | 2000 | 2400 | 0400 | 0800 | 1200 | 1600 |
|---|---|---|---|---|---|---|---|
| Diaphanosoma brachyurum | 0 | 0 | 0 | 0 | 1 | 0 | 2 |
| Daphnia pulex | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Scapholeberis mucronata | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Moina brachiata | 2 | 2 | 0 | 0 | 0 | 2 | 1 |
| Ceriodaphnia lacustris | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| Bosmina longirostris | 8 | 2 | 7 | 2 | 4 | 11 | 7 |
| Macrothrix laticornis | 2 | 0 | 0 | 0 | 0 | 0 | 1 |
| Leydigia quadrangularis | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Alona rectangula | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| Chydorus sphaericus | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| Immature Cladocera | 7 | 1 | 0 | 2 | 1 | 0 | 2 |
| Nauplii | 55 | 19 | 17 | 17 | 31 | 28 | 41 |
| Copepodite | 9 | 16 | 8 | 1 | 4 | 5 | 6 |
| Total Cladocera | 23 | 5 | 7 | 6 | 8 | 15 | 15 |
| Total Copepoda | 64 | 35 | 25 | 18 | 35 | 33 | 47 |
| Total Entomostraca | 87 | 40 | 32 | 24 | 43 | 48 | 62 |

Appendix D. Diurnal variation in numbers of entomostraca (per 10 liters) collected during the July 1958 high water at Station I.

| Species | 1600 | 2000 | 2400 | 0400 | 0800 | 1200 | 1600 |
|---|---|---|---|---|---|---|---|
| Diaphanosoma brachyurum | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Ceriodaphnia rigaudi | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| Ceriodaphnia lacustris | 0 | 0 | 0 | 1 | 1 | 2 | 0 |
| Bosmina longirostris | 0 | 8 | 0 | 2 | 8 | 4 | 1 |
| Alona rectangula | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Eucyclops agilis | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Nauplii | 7 | 16 | 6 | 6 | 5 | 5 | 5 |
| Copepodite | 1 | 0 | 1 | 1 | 2 | 0 | 1 |
| Total Cladocera | 0 | 8 | 0 | 3 | 13 | 6 | 1 |
| Total Copepoda | 8 | 17 | 7 | 7 | 7 | 5 | 7 |
| Total Entomostraca | 8 | 25 | 7 | 10 | 20 | 11 | 8 |

Appendix E. Diurnal variation in numbers of entomostraca (per 10 liters) collected during the July 1958 high water at Station I.

## APPENDIX F

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