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—Carl W. Prophet
—Claire Schelske

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.

By Carl W. Prophet*
Kansas State Teachers College, Emporia

During March, 1954, the biology department of Emporia State commenced a biological survey of the Fall and Verdigris rivers between Neodesha and Independence, Kansas. The present study utilizes only a small portion of data collected during the period April, 1954 to March, 1955, and may be divided into the following phases:

1. Physical-chemical conditions of the Fall and Verdigris rivers from April 3, 1954 to March 12, 1955.

2. Relative abundance and seasonal variations of the cladocerans and copepods during this same period.

As far as can be ascertained, there are no published data on the cladocerans and copepods or physical-chemical conditions of Kansas rivers and streams. Pennak (1949) implies the need for year-round studies in order to attain a clearer concept of the ecology of aquatic habitats, and Schelske (1957) pointed out the need for limnological data on Kansas rivers. He stated that in recent years numerous federal reservoirs, one of which is the Fall River Reservoir, have been built and more authorized on Kansas rivers and streams. He stated that little is known concerning the effects of these reservoirs on the physical, chemical, and biological aspects of the rivers. Since a federal dam has been proposed for the Verdigris River a few miles above the study area, data collected during this study might be of value as preimpoundment information for future studies.

During the turn of the present century, Kofoid (1903), with an extensive study of the Illinois River, extended the scope of limnology to include lotic as well as lentic waters. Since that time, an increasing number of river and stream investigations have been conducted in the United States (Allen 1920, Galtsoff 1924, Wiebe 1930, Reinhard 1931, Eddy 1932, Dolly 1933, Chandler 1937 and 1939, Stehr and Branson 1938, Hutchison 1939, Brinely 1942 and 1950, Pennak 1943, Berner 1951, Neel 1951 and 1953, Slack 1955, and Schneller 1955).

One of the few published works on Kansas Cladocera and Copepoda is that of Leonard and Ponder (1949) which consisted primarily of a check-list of crustacea collected from various types of aquatic habitats

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near Lawrence, Kansas. Ratzlaff (1952) conducted a limnological study of some roadside ditches and presented seasonal variations of Cladocera and Copepoda that were collected. Andrews and Breukelman (1952), in cooperation with the Forestry, Fish, and Game Commission, made a limnological survey of 19 state lakes. These 3 works constitute the bulk of available published data on Kansas limnology and entomostraca.

During the past 10 years, there have been many unpublished master's theses on the limnology and plankton of certain Kansas lakes (See Literature Cited), and, recently, Brooks (1956) completed an ecological study of the Cladocera of Kansas. Cook (1956), utilizing quantitative planton samples collected during the second year of the biological survey (April, 1955, to March, 1956), compiled an annotated list of the Cladocera and Copepoda of the Fall, Verdigris, and Elk rivers.

DESCRIPTION OF AREA

The Fall and Verdigris rivers are located in the southeastern corner of Kansas and belong to the Arkansas River drainage basin which drains the approximate southern half of the state. The Verdigris River is a relatively sluggish stream with a total length of 351 miles. With no large impoundments along its course, this river frequently overflows during periods of heavy rainfall, and is intermittent during periods of little rain. The Fall River, one of the principal tributaries of the Verdigris River, is about 90 miles long. Because of the presence of the Fall River Reservoir about 54 miles above its mouth, the water level of the Fall River remained fairly constant in the study area in comparison to that of the Verdigris River. Schoewe (1951) gives a physical description of both rivers, while Schelske (1955) presented the precipitation and temperature conditions in Wilson and Montgomery counties during the period 1951 to 1954.

The dominant flora of each river in the study area are similar, composed primarily of *Populus deltoides* Marsh. (cottonwood); *Salix nigra* Marsh. (black willow); *Ulmus* sp. (elm); *Platanus occidentalis* L. (sycamore); *Celtis occidentalis* L. (hackberry); *Rhus radicans* L. (poison ivy); *Ambrosia* sp. (ragweed); and *Polygonum lepathifolium* L. (smartweed). (Fernald 1950).

Although data have been collected from all stations shown in Fig. 1 throughout the survey, only data concerning stations located on the Fall and Verdigris rivers were utilized in this study. As can be seen in Fig. 1, 4 stations were located on the lower approximate 10 miles of the Fall River, and 4 were located along a middle portion, about 20 miles long, of the Verdigris River. Data from Station IV, were not included in this study, since Station IV is a storage lagoon of the Standard Oil Company Refinery at Neodesha. This lagoon with an area of about 13 acres supplied about 90 acre-feet of storage (approximately 29 million gallons of water). Collections from this lagoon revealed that plankton was usually abundant. Water was released periodically throughout this study into the Fall River a short distance above Station V and undoubtedly introduced large numbers of zooplankters into the river at that point. Results from Station X, located on the Elk River a few miles above its confluence with the Verdigris River, also were not included in the present study. A brief description of the stations used during this study follows.

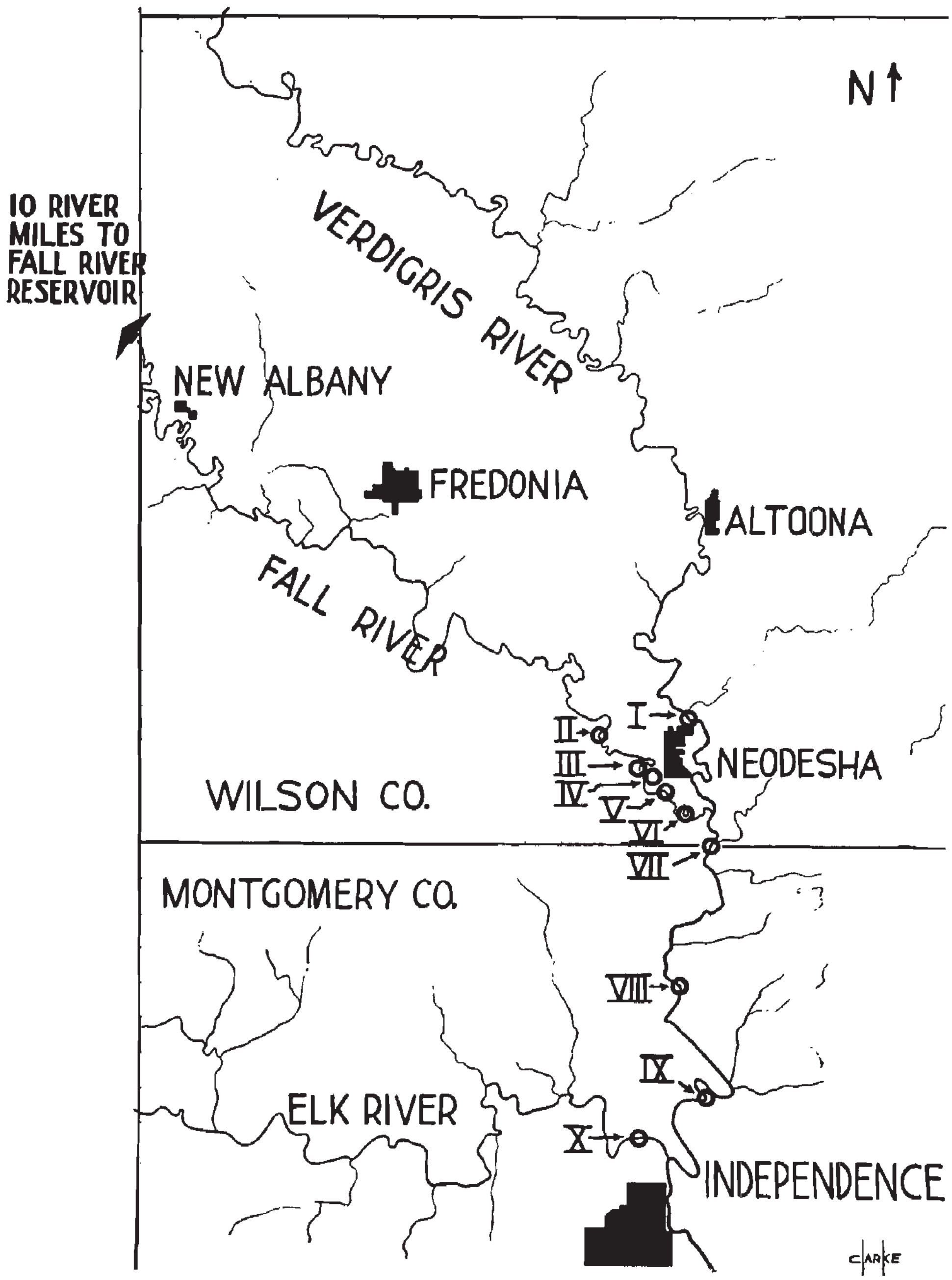

Fig. 1. Map of study area showing locations of collection stations used for the biological survey of the Fall and Verdigris rivers.

Station I

Station I (Fig. 2) was located on the Verdigris River about 0.5 miles northeast of Neodesha, Kansas, at the North Fourth Street Bridge (S.17, T.29E., R.15E.). Army Corps of Engineers (1955) located this station at Virdigris river-mile 221. The collecting area was located in a pool about

Fig. 2. Station I looking downstream from riffles below bridge as quantitative plankton sample is collected in shallow pool.

Fig. 3. Station II looking downstream to pool area, bottom of riffles seen in foreground.

60 feet long and 40 feet wide with an average depth of less than 3 feet. The bottom was composed basically of sand and gravel with a large number of large limestone outcroppings. A short riffles area was located at each end of the pool. The water level fluctuated greatly during this study being out of its banks during the first month of the study and being reduced to a series of small puddles during the latter part of the summer.

Station II

Station II (Fig. 3) was located on the Fall River about one mile northwest of Neodesha at Laverty Ford (S.13, T.29S., R.15E.). This station was 8.8 river-miles above the confluence of the Fall and Verdigris rivers and approximately 45 river-miles below the Fall River Reservoir. Collections were taken in a pool about 25 feet wide and of an undetermined length. Plankton samples were taken at a depth of approximately 3 feet. The bottom was chiefly sand and gravel, and was usually covered with a thick layer of detritus. The water level was fairly constant throughout this study, since there was a continuous flow because of the release of water from the Fall River Reservoir, and clams and *Cladophora* were usually abundant in the riffles.

Station III

Station III (Fig. 4) was located on the Fall River at the city dam about 0.5 miles west of Neodesha (S.19, T.30S., R.15E.), and was 5.6 river-miles above the confluence of the Fall and Verdigris rivers. Collections were taken above the dam from the north bank at a depth of 2 to 3 feet. The river at this point was over 100 feet wide. This station was characterized by high water temperatures and an abundance of algae.

Station V

Station V (Fig. 5) was located on the Fall River near the Missouri Pacific Railroad bridge about 0.5 miles southwest of Neodesha (S.29, T.31S., R. 15E.). This station was 3.6 river-miles above the junction of the Fall and Verdigris rivers. The river at this point was about 20 feet wide and reached a maximum depth of approximately 4 feet. The bottom was very rocky, and *Spirogyra* was abundant during most of this study.

Station VI

Station VI (Fig. 6) was located on the Fall River near the South Fourth Street Bridge about 0.5 miles south of Neodesha (S.32, T.30S., R.15E.), and was 1.9 river-miles above the confluence of the 2 rivers. Plankton samples were taken from a pool about 30 feet wide with a maximum depth of more than 4 feet. The bottom was composed of sand and gravel.

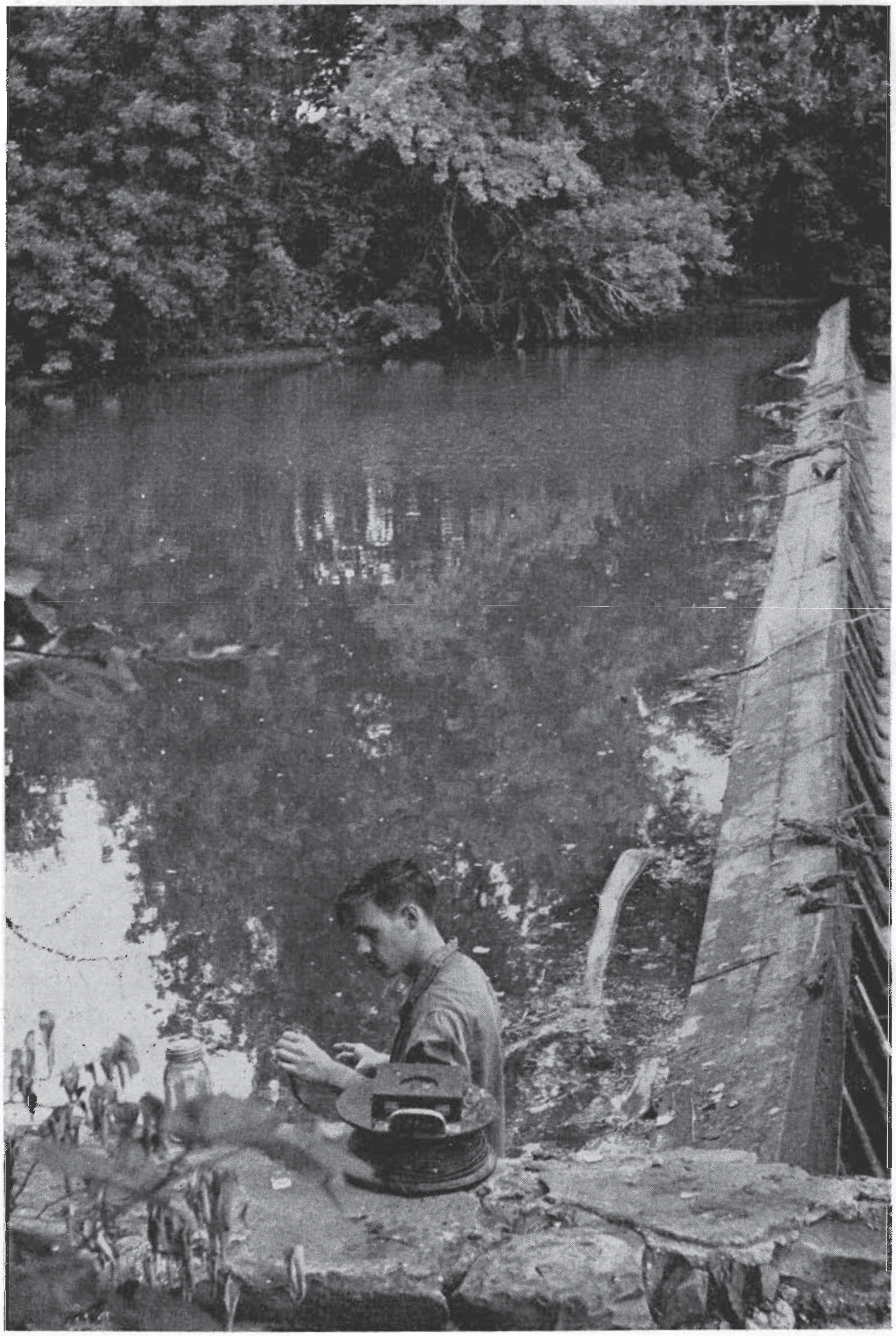

Fig. 4. Station III located above the Neodesha city dam.

Fig. 5. Station V looking east downstream, water from a storage lagoon (Station IV, Fig. 1) enters the river about 50 feet above this point.

Fig. 6. Station VI looking downstream towards pool area, bottom of riffles in foreground.

Station VII

Station VII was located on the Verdigris River (Fig. 7), below its confluence with the Fall River, 1 mile south and about 0.5 miles east of Neodesha at White Hair Ford (S.4, T.30S., R.15E.). Army Corps of Engineers located this station at Verdigris river-mile 213.9. Plankton samples were taken in a large pool over 70 feet wide and about 3 or 4 feet deep. The length of this pool was not known but was thought to extend several hundred feet upstream. The lower end of the pool was marked by riffles extending across the river. The sand and gravel bottom was strewn with limestone outcroppings, and *Cladophora* was consistently present in the riffles.

Fig. 7. Station VII looking downstream in a westerly direction, pool area in the foreground.

Station VIII

Station VIII (Fig. 8), 1.5 miles east of Sycamore on the Verdigris River (S.29, T.31S., R.15E.), was located at Verdigris river-mile 207.4. Collections were taken from a pool about 100 feet above a riffles area. This pool was nearly 150 feet long and about 100 feet wide with a maximum depth of more than 6 feet. Plankton samples were taken at a depth of nearly 4 feet. The silty bottom was littered with numerous limestone outcroppings. This station was usually characterized by its turbidity and abundance of *Cladophora* in the riffles.

Fig. 8. Station VIII looking downstream to the southwest.

Station IX

Station IX (Fig. 9) was located about 1 mile east and 3 miles north of Independence, Kansas, (S.9, T.31S., R.15E.) at Verdigris river-mile 204.2. Collections were taken in a pool about 30 feet below a long

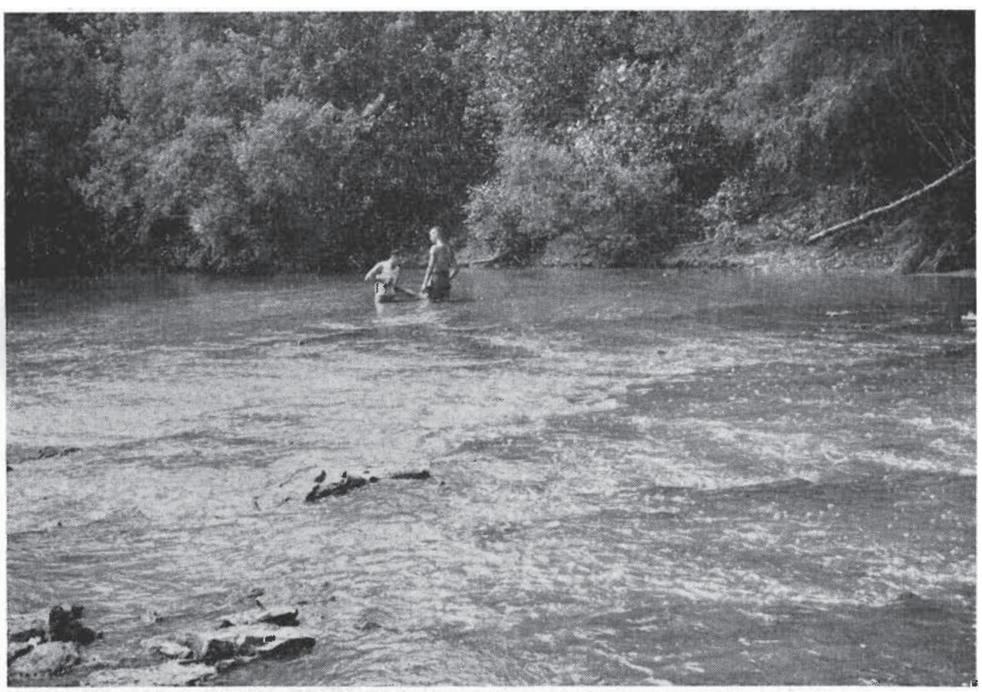

Fig. 9. Station IX showing collecting area below riffles.

riffles area. The river at that point was nearly 40 feet wide and over 4 feet deep. An exposed fossiliferous limestone layer formed the lower end of the riffles and entire south bank of the river. The bottom was chiefly sand and gravel, and *Cladophora* was abundant in the riffles.

METHODS AND MATERIALS

Planton Collection and Identification

During the first 5 months when stream conditions were rapidly changing because of the drought, collections were made on a weekly basis, whenever possible. Collections, in general, were made on a bi-monthly basis during the remainder of this study. Each plankton sample consisted of 4-liters of water collected with a Kemmerer Water Sampler, as described by Welch (1948), and strained through a net made of bolting silk (173 meshes/inch) into a collecting bottle attached to the bottom of the net. Formalin was added as preservative, with the resulting concentration being about 10 per cent.

In the laboratory, contents of each bottle were examined using a binocular microscope with magnifications of 20X and 60X. Specimens more difficult to identify were studied under a monocular microscope with magnifications of 26X, 100X, and 440X. Transfer of the concentrated plankton to a Sedgwick-Rafter counting cell and the use of a mechanical stage attached to the binocular microscope greatly facilitated the counting of the entomostracans. Species were identified from keys in *Freshwater Invertebrates of the United States* (Pennak 1953) and *Freshwater Biology* (Ward and Whipple 1945).

Physical-Chemical Conditions

Seston was determined by the method employed by Ratzlaff (1952), which consisted of centrifuging a 500 ml. sample of water, drying the residue, and finally oxidizing it in order to calculate the inorganic and organic sestons by weight. Turbidity was determined with a U.S. Geological Survey Turbidimeter, as described by Welch (1948), while water temperatures were measured with a Whitney underwater electrical resistance thermometer. Water flow data were supplied by the Army Corps of Engineers district office in Tulsa, Oklahoma. All chemical analyses of water samples were made by chemists of the Standard Oil Company Research Laboratory at Neodesha, Kansas, according to methods described in *Standard Methods for Examination of Water and Sewage* (American Public Health Association 1946 and 1955).

RESULTS AND DISCUSSION

Physical Conditions

The monthly means of each physical condition studied are given in Tables I to IV. In general, surface-bottom temperature differences were seldom greater than 1°C. because of the shallow depth of the rivers; therefore, only the monthly mean surface temperatures were used. In the Fall River, surface temperatures varied from 1.5° at Station II on January 29, and February 12, 1955, to 39.2°C. at Station V on July 23, 1954. Surface temperatures in the Verdigris River ranged from 0.7° at Station I on February 12, 1955, to 37.2°C. at Station IX on July 17, 1954. As can be seen in Table I, the mean temperatures were similar for both rivers in most cases. Almost without exception, water temperatures were greater at Station III than at any of the other stations, caused by the entrance of heated water into the Fall River from the Standard Oil Refinery about 400 yards above the collecting area at Station III. The refinery uses water from the Fall River as a coolant and releases this heated water into the river. Thin ice covers were formed at all stations, except Stations III, V, and VI, during January and February.

Maximum water flow in the study area occurred during April. The water level and rate of discharge fluctuated greatly in the Verdigris River but remained fairly constant in the Fall River throughout this study. From the latter part of July through September, there was no flow in the Verdigris River above the junction of the Fall River (Fig. 1), and only a slight amount of flow was detected during November and December. Water flow in the Verdigris River above the confluence of the Fall River can be attributed to the release of water from the Fall River Reservoir and from Station IV (Lagoon No. 4). The mean monthly discharge for the Fall River ranged from 3.5 to 306.5 cfs., while that of the Verdigris River above the confluence of the two rivers varied from zero to 1221.8 cfs.

TABLE I. Monthly mean surface water temperatures in degrees Centigrade.

	Stations	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Verd. R.	I	15.4	19.9	18.1	29.2	24.7	21.0	15.5	10.4	5.8	3.1	3.1	12.1
	VII	14.0	21.5	25.5	31.2	28.6	24.0	21.9	11.4	5.8	4.8	4.7	14.5
	VIII	17.8	21.6	26.5	32.2	32.7	26.4	19.1	13.8	7.5	6.7	6.6	15.2
	IX	19.6	22.0	26.4	32.5	32.3	27.8	18.7	13.9	6.5	5.7	5.6	15.2
Fall R.	II	16.1	21.0	26.3	29.9	26.4	21.9	18.4	11.4	5.3	5.5	4.5	14.1
	III	19.6	27.0	30.7	35.5	25.5	29.5	23.7	18.1	10.0	9.0	10.2	19.3
	V	18.0	23.6	27.2	33.1	30.5	25.5	15.8	11.4	7.7	4.8	6.9	15.2
	VI	17.6	22.3	26.2	31.1	28.3	23.7	17.8	12.2	6.2	3.5	6.0	14.2

Of the two rivers, the Fall River appeared to be the least turbid. The mean monthly turbidity of the Fall River ranged from less than 10 to 97 ppm., while that of the Verdigris River varied from less than 10 to 538 ppm. (Table II). In each case the turbidities were less than those reported for some larger rivers. Platner (1946) reported a mean turbidity of 300 ppm. for the Mississippi River above the mouth of the Missouri, and Berner (1951) stated that the turbidity of the Missouri River was never less than 1000 ppm. During the summers of 1950 and 1951, Wallen (1954) collected data from several streams in Oklahoma. Based on 10 observations, the average turbidity of the Arkansas River at Webbers Falls was 960 ppm. Although most Oklahoma streams in low water stages are relatively transparent, during periods of rainfall soil erosion produces turbidities of 18,000 ppm. or more. Wallen attributes this to tillage of soil which is composed of extremely fine particles.

TABLE II. Monthly mean turbidity in ppm.

River	Stations	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Verd. R.	I	230	100	207	*64	*10	40	538	350	22	*28	38	55
	VII	16	152	153	25	27	19	353	250	*18	*16	23	30
	VIII	*12	68	92	33	36	25	198	350	20	18	28	30
	IX	84	62	105	36	23	24	223	55	22	23	25	*10
Fall R.	II	*14	73	38	*32	33	24	30	22	*10	*10	*10	*10
	III	*12	*10	*11	*15	*10	*10	*10	*10	*10	*10	*10	*10
	V	16	81	44	*19	*10	*10	*10	*10	*10	*14	*10	35
	VI	27	97	97	*24	*10	*10	*10	*10	*10	*10	*10	*10

*Mean turbidity was less than measurement shown.

In general, the total sestons of the Verdigris River stations were greater than those of the Fall River stations (Tables III and IV). Monthly mean total sestons for the Verdigris River stations varied from 4.5 to 294.7 mg./liter, while the mean total sestons for the Fall River stations ranged from 4.4 to 32.1 mg./liter. Organic seston ranged from 0.4 to 88.8 mg./liter in the Verdigris and from 1.3 to 18 mg./liter in the Fall River. In general, the organic seston comprised a larger percentage of the total seston in the Fall River than in the Verdigris. The organic seston varied from 22.4 to 72 per cent in the Fall River and from 2.0 to 87.1 per cent in the Verdigris River (Tables III and IV).

TABLE III. Monthly mean total seston and organic seston in mg./liter and per cent of organic seston for Fall River stations.

	Station II			Station III			Station V			Station VI		
Month	Tot.	Org.	Per cent	Tot.	Org.	Per cent	Tot.	Org.	Per cent	Tot.	Org.	Per cent
Apr.	11.5	4.7	43.1	20.4	7.0	40.7	8.9	4.9	58.2	14.0	6.6	51.3
May	29.5	7.5	28.9	21.5	5.9	44.1	26.0	8.0	44.6	32.1	8.0	41.5
June	17.3	4.8	31.4	7.9	4.3	54.7	24.5	17.6	65.6	26.1	18.0	70.0
July	20.8	6.8	32.6	16.0	5.4	38.5	12.6	9.2	72.0	9.8	5.4	54.3
Aug.	15.2	3.4	22.4	28.1	6.5	29.9	5.2	4.8	61.4	4.9	2.4	63.1
Sept.	11.5	2.8	26.1	4.8	2.9	67.6	7.2	2.9	41.1	9.1	3.6	39.9
Oct.	15.9	4.2	28.3	7.2	3.8	56.5	6.1	2.9	51.2	13.5	5.3	52.8
Nov.	8.6	3.0	34.9	14.2	3.8	26.8	6.8	3.6	52.9	5.6	2.4	42.2
Dec.	8.5	4.0	48.2	11.4	5.0	50.6	8.2	3.5	31.2	6.8	3.3	39.0
Jan.	26.4	2.8	34.0	7.6	2.7	36.5	8.0	3.2	40.0	4.9	1.3	26.9
Feb.	7.6	3.1	40.9	10.3	4.6	44.6	13.8	2.8	32.2	11.9	3.0	36.7
Mar.	4.4	2.6	59.2	8.4	4.4	52.3	5.2	3.0	57.7	4.4	2.0	45.4

TABLE IV. Monthly mean total seston and organic seston in mg./liter and per cent of organic seston for the Verdigris River stations.

	Station I			Station VII			Station VIII			Station IX		
Month	Tot.	Org.	Per cent	Tot.	Org.	Per cent	Tot.	Org.	Per cent	Tot.	Org.	Per cent
Apr.	117.8	16.4	32.8	47.9	9.3	42.1	26.3	7.1	42.4	47.8	9.2	30.2
May	44.1	9.1	23.0	56.5	10.3	22.9	49.7	8.7	31.6	40.5	7.6	22.3
June	90.7	15.9	19.5	77.6	11.3	15.9	53.8	10.9	21.1	85.3	15.1	18.9
July	13.4	3.8	35.1	13.1	6.4	50.5	17.7	5.8	33.6	16.9	6.5	39.7
Aug	7.3	1.9	28.8	10.9	5.2	48.7	18.4	6.2	34.2	11.7	3.5	29.8
Sept.	9.1	2.1	21.5	13.5	6.0	44.5	16.5	4.5	21.5	12.3	3.7	30.2
Oct.	294.7	88.8	27.3	136.5	24.8	18.6	56.8	10.2	18.5	82.9	36.6	33.1
Nov.	78.4	12.2	17.0	54.8	8.4	16.9	71.4	11.0	15.4	22.6	.4	2.0
Dec.	8.8	3.9	41.5	10.4	4.1	39.7	9.7	5.6	53.3	11.5	4.4	40.9
Jan.	14.9	4.1	35.1	9.1	5.9	63.7	7.6	3.5	45.5	9.3	3.8	46.2
Feb.	12.9	2.5	22.2	6.1	1.9	32.3	8.4	2.8	35.4	4.5	2.8	63.8
Mar.	22.8	3.6	15.8	14.0	12.2	87.1	*	*	*	6.0	1.6	26.7

*Bottle broken

Chemical Conditions

Free carbon dioxide was present in small quantities during most months (Table V). Increases in amounts of free carbon dioxide during the fall and winter months were probably caused, in part, by the decomposition of organic matter. The monthly mean carbon dioxide varied from zero to 6.6 ppm. in the Fall River and from zero to 12.9 ppm. in the Verdigris River. The absence of large quantities of free carbon dioxide during

Table V. Monthly mean free carbon dioxide in ppm.

	Stations	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Verd. R.	I	.44	.73	.59	.2	.00	.94	2.6	2.6	7.1	5.3	.00	.00
	VII	.4	.6	.6	.3	.7	.00	2.2	12.9	12.3	3.5	.00	.00
	VIII	.5	.7	.6	.4	.3	.00	2.5	10.6	6.2	2.7	.00	.00
	IX	.7	.6	.00	.2	.00	.00	3.4	3.5	4.0	.00	.00	.00
Fall R.	II	.66	.29	.00	.2	.00	.9	1.7	.9	1.8	1.8	.00	.00
	III	.7	.6	.00	.00	.00	.4	1.7	4.4	4.0	4.4	.00	.00
	V	1.3	.6	1.4	2.0	1.1	1.6	1.6	3.5	3.1	6.6	.00	.00
	VI	1.9	.3	2.9	.5	.00	.9	.7	6.2	.00	.00	.00	.00

most of the year is characteristic of most rivers and streams. Welch (1952) stated that decomposition gases tend to be minimal in lotic waters because of the circulating effect of the current. Coopey (1953) found that free carbon dioxide was never present in the Columbia River during a 13 month period, while Slack (1955) and Schneller (1955) found that some free carbon dioxide was always present in certain Indiana creeks.

The pH of both rivers remained fairly constant, ranging from 7.0 to 8.4 in the Verdigris and from 6.9 to 8.4 in the Fall River. This condition appears to be common in lotic waters. Welch (1952) stated that the pH of lotic waters tends to be uniform over considerable distances. Brinely (1942), Slack (1955), and Schneller (1955) found that the pH fluctuated only slightly in certain rivers and streams in Indiana. Wallen (1954) found the pH of certain Oklahoma streams to fluctuate little during the summers of 1950 and 1951. The monthly median pH of each station is shown in Table VI.

TABLE VI. Monthly median hydrogen-ion concentration.

	Stations	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Verd. R.	I	7.95	7.6	7.5	7.4	7.6	7.25	7.5	7.3	7.4	7.7	7.9	7.7
	VII	8.0	7.4	7.3	7.9	7.7	7.8	7.5	7.2	7.35	7.65	7.9	8.2
	VIII	8.25	7.5	7.5	7.7	7.6	7.6	7.4	7.4	7.55	7.7	7.85	8.1
	IX	8.05	7.6	7.6	7.6	7.7	7.8	7.5	7.7	7.65	7.95	7.87	8.2
Fall R.	II	7.95	7.6	7.5	7.5	7.6	7.5	7.6	7.5	7.55	7.75	7.9	8.0
	III	7.75	7.6	7.8	7.5	7.7	7.6	7.6	7.4	7.45	7.6	7.85	7.9
	V	7.65	7.5	8.0	7.5	7.5	7.55	7.5	7.6	7.5	7.6	7.9	7.8
	VI	7.8	7.2	7.2	7.5	7.5	7.5	7.6	7.6	7.45	7.75	8.05	7.9

Since there were so few carbonates present, the methyl orange alkalinity was representative of the total alkalinity in both rivers. The monthly mean methyl orange alkalinity of the Verdigris River varied from 53 to 202 ppm. and from 106 to 184 ppm. in the Fall River (Table VII).

TABLE VII. Monthly mean methyl orange alkalinity in ppm.

	Stations	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Verd. R.	I	200.5	137.3	111.3	113	119.6	53	69.3	70	117	147	158	152
	VII	163	136	112.7	130	123	129	93	76	151	148	161	156
	VIII	140	135	115	132	124	131	100	76	202	151	153	156
	IX	143	139	113	130	139	128	103	98	102	155	156	160
Fall R.	II	163.5	120.6	137	120.8	126	129	114.7	106	119	143	157	136
	III	163	123	141	124	123	132	117	118	128	133	155	156
	V	175.5	125.3	116.7	128.8	120.7	129	121.3	158	146	154	168	184
	VI	166	125	125	128	123	127	123.3	160	156	170	164	182

Dissolved oxygen fluctuated considerably in both rivers. The mean monthly dissolved oxygen ranged from 4.1 to 13.9 ppm. in the Verdigris River and from 3.4 to 14.2 ppm. in the Fall River (Table VIII). As would be expected, there appeared to be an inverse relationship between water temperatures and amounts of dissolved oxygen. In general, there appeared to be sufficient oxygen to maintain aquatic life at all stations for most of

TABLE VIII. Monthly mean dissolved oxygen in ppm.

	Stations	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Verd. R.	I	7.6	6.2	6.3	4.7	4.6	4.1	7.5	8.1	8.5	11.8	12.8	10.0
	VII	7.9	7.4	5.1	6.9	6.8	7.9	6.9	4.7	6.9	13.6	12.1	12.6
	VIII	9.4	7.9	6.6	6.2	7.0	7.1	6.8	6.8	10.3	13.1	13.1	12.2
	IX	7.9	8.2	8.1	6.8	6.5	8.1	7.6	10.0	11.6	13.9	12.9	13.0
Fall R.	II	8.4	7.4	6.1	5.6	5.3	6.5	8.0	10.5	10.5	12.1	13.1	10.8
	III	6.3	6.3	6.8	6.8	3.9	4.6	4.7	3.4	5.7	6.6	8.9	6.6
	V	6.9	8.1	6.6	4.7	4.8	5.9	6.1	7.9	8.0	10.5	13.0	13.0
	VI	8.4	8.2	4.2	6.6	6.2	6.9	7.0	9.9	9.3	11.5	14.2	10.6

the time. The amounts of dissolved oxygen found to occur in both rivers were similar to those reported in other stream studies (Berner 1951, Coopey 1953, and Neel 1953).

Total hardness in the Verdigris River varied from 98 to 438 ppm. and from 109 to 336 ppm. in the Fall River (Table IX).

TABLE IX. Monthly mean total hardness in ppm.

	Stations	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Verd. R.	I	236.5	222	215	233	249	438	116	98	154	217	271	224
	VII	243	220	235	180	163	230	160	118	255	176	189	248
	VIII	200	217	245	194	143	194	176	110	173	171	175	240
	IX	210	219	275	198	187	162	172	154	145	185	185	252
Fall R.	II	242	167	187	150	197	251	229	180	109	237	289	276
	III	249	167	188	154	175	243	239	238	224	153	282	292
	V	260	174	217	189	171	240	247	296	244	168	292	316
	VI	255	179	239	196	169	241	246	284	258	174	220	336

Entomostraca

Almost without exception, Cladocera were the predominant entomostracans collected at each station (Table X). Copepods outnumbered cladocerans only at Station I. As can be seen, Station II, VII, and VIII yielded the most species of entomstracans. Entomostracans were the most abundant at Station V and the least abundant at Station III.

TABLE X. Number of species and individuals per species of Cladocera and Copepoda collected at each station.

Stations		CLADOCERA		COPEPODA		TOTALS	
		No. Species	No. Indiv.	No. Species	No. Indiv.	No. Species	No. Indiv.
I	Verd. R.	11	71	8	136	19	207
II	Fall R.	16	123	5	46	21	169
III	Fall R.	8	43	5	35	13	78
V	Fall R.	14	3395	3	314	17	3709
VI	Fall R.	10	456	4	119	14	575
VII	Verd. R.	15	474	7	210	22	684
VIII	Verd. R.	17	325	5	135	22	460
IX	Verd. R.	13	429	6	159	19	588

The general composition of entomostraca collected from both rivers is shown in Table XI. Thirty-two species of entomostraca were collected

TABLE XI. A comparison of the composition of entomostraca collected from the Fall and Verdigris rivers.

River	Order	No. Species	Total No. Indiv.	Per Cent of Total Entomostraca
Fall	Cladocera	24	4018	88.7
Fall	Copepoda	8	514	11.3
Verdigris	Cladocera	22	1299	67.0
Verdigris	Copepoda	11	640	33.0

from the Fall River stations from a sampling of 480 liters. These 32 species totaled 4,532 individuals, over twice the number collected from the Verdigris River. Thirty-three species totaling 1,939 individuals were collected from the Verdigris River stations from a total sample of 484 liters.

Cladocera of the Fall River

Twenty-four species of Cladocera were collected from a total sample of 480 liters, and comprised over 88 per cent of all entomostracans collected from the Fall River (Table XI).

Relative Abundance. Monia brachiata was the most abundant cladoceran, as well as the most abundant entomostracan, collected from either river (Table XII). It comprised over 66 per cent of the entomostracans collected from the Fall River, but rarely occurred during any month except June and July. This species was apparently introduced into the Fall River at Station V in the drainage from Lagoon No. 4 (Station IV, Fig. 1). Samples taken from this lagoon revealed that it was numerous prior to its appearance at Station V. Many male *M. brachiata* were also present in the June collections at Station V. Occurrence of the males was probably caused by adverse conditions due to overcrowding of individuals (Andrews 1948, and Pennak 1953).

Apparently *Moina brachiata* is not too common in Kansas. Although at least 3 collections were made in each of the 105 Kansas counties, Brooks (1956) found it but once, in a slough in the northwest corner of the state. He had previously collected this species from the Lyon County State Lake (Brooks 1947). Cook (1956) reported that it also occurred in some samples taken from the Fall, Verdigris, and Elk rivers during the second year of the biological survey.

The second most abuandant species was *Simocephalus serrulatus*, which composed about 15 per cent of the total entomostraca collected from this river (Table XII). Although it occurred at all Fall River stations, it was most abundant at Station V.

As can be seen from Table XII, two species, *Moina brachiata* and *Simocephalus serrulatus*, accounted for over 80 per cent of all cladocerans and copepods collected from the Fall River. This predominance of just a few species is not uncommon. Successive studies on Lake Wooster, located on the campus of the Kansas State Teachers College in Emporia, by Dowell (1952), Carter (1954), and Wilhm (1955) showed that a relatively few species composed a large percentage of the entomostracans collected. Brooks (1956) stated that of the 41 species of Cladocera he collected throughout Kansas, only 4 species were predominant.

Seasonal Trends. The following seasonal trends were based on the monthly abundance of species, and should not be used for the prediction of occurence of any species in any body of water. It is possible that future studies on these same rivers would show different seasonal trends for the same species, since the specific time of maximum populations for a single species may vary considerably from one year to the next (Pennak 1953).

TABLE XII. Total number of each species collected and the percentage each species represented of the total entomostraca collected from the Fall and Verdigris rivers.

Species	Fall River		Verdigris River	
	Total	Per cent	Total	Per cent
CLADOCERA				
Diaphanosoma brachyurum	7	.1	51	2.5
Daphnia pulex	23	.5	20	1.0
Daphnia longispina	11	.2	14	.6
Simocephalus vetulus	12	.3	142	7.3
Simocephalus serrulatus	680	15.0	32	1.6
Scapholeberis mucronata	2	*	1	*
Ceriodaphnia reticulata	1	*		
Moina macrocopa	12	.3		
Moina brachiata	3002	66.8	29	1.4
Moina affinis			6	.3
Bosminia longirostris	41	.9	103	5.0
Macrothrix laticornis	1	*	25	1.2
Kurzia latissima	2	*	1	*
Leydigia quadrangularis	4	.1	23	1.1
Alona guttata	32	.7	39	2.0
Alona affinis	63	1.4		
Alona quadrangularis	6	.1	1	*
Alona costata	14	.3	13	.6
Alona rectangula	2	*		
Pleuroxus striatus	3	.1	4	.2
Pleuroxus hamulatus	3	.1	6	.3
Pleuroxus denticulatus	4	.1	4	.2
Pleuroxus aduncus			1	*
Alonella diaphana			1	*
Alonella rostrata	13	.3	1	*
Anchistropus minor	1	*		
Chydorus sphaericus	79	1.7	782	40.3
COPEPODA				
Macrocyclops ater			3	.2
Paracyclops fimbriatus			1	*
Eucyclops agilis	156	3.4	88	4.5
Eucyclops prasinus	2	*	23	1.1
Mesocyclops leuckarti	56	1.2	4	.2
Mesocyclops edax	1	*	2	.1
Cyclops varicans			6	.3
Cyclops vernalis	286	6.3	461	23.7
Cyclops bicuspidatus	8	.2	37	1.8
Diaptomus oregonensis	1	*	2	.1
Diaptomus pallidus	4	.1	13	.6
	Grand Total 4532		Grand Total 1939	

*Comprised less than 0.1 per cent of total entomostraca.

Although never abundant, *Diaphanosoma brachyurum* was collected only during July and August in the Fall River. Numerous other investigators have found this species to be a summer form. Pennak (1953) stated that this species exhibits a single pulse during the warm months in lakes, and Eddy (1932) found it to increase in abundance during July in the Sangamon River. Ratzlaff (1952) reported that this species was abundant in some roadside ditches in Kansas during the summer. Cook (1956) found that it was present only during the warm months from these same rivers during the second year of the biological survey.

Simocephalus serrulatus increased in abundance during August, September, and December at Station V, but was never collected in large numbers at other Fall River stations. This species is a common inhabitant of temporary pools in eastern Kansas during the spring and fall (Leonard and Ponder 1949). *Moina brachiata* was present in large numbers at Station V during June, and for a brief period during July at Station VI. The appearance of this species at Station VI was probably due to the stream current carrying part of the population downstream from Station V.

Bosmina longirostris appeared to be most abundant during April and May. Ratzlaff (1952) found it to be the most numerous cladoceran in some roadside ditches, occurring during practically all months of the year, and Eddy (1932) stated that *B. longirostris* was one of the more conspicuous cladocerans of the Sangamon River. *Chydorus sphaericus* also appeared to be a spring form during the present study, and has previously been found to reach its maximum pulse during the spring and summer in other studies (Ratzlaff 1952 and Pennak 1953).

Cladocera of the Verdigris River

Although 22 species of cladocerans were collected, they were considerably less abundant than in the Fall River. Once again, Cladocera were the predominant forms accounting for 67 per cent of all entomostracans collected from the Verdigris River (Table XII).

Relative Abundance. As was true in the Fall River, a relatively few species constituted the majority of the individuals collected from the Verdigris River. The most abundant cladoceran, *Chydorus sphaericus*, comprised over 40 per cent of the total entomostraca collected from the Verdigris River (Table XII). As can be seen, this species was second only to *Moina brachiata* in total numbers of individuals collected during this study. *Chydorus sphaericus* is apparently widespread throughout Kansas. Brooks (1956) collected this species in a variety of habitats throughout Kansas but stated that it was more frequently found in roadside ditches, ponds, creeks, and lakes.

Simocephalus vetulus was the second most abundant Verdigris River cladoceran but composed only about 7 per cent of the total entomostraca from that river (Table XII). This species is apparently a common inhabitant of lotic waters in Kansas. Brooks (1956) collected this species most frequently from creeks and roadside ditches. The third most abundant cladoceran, *Bosmina longirostris,* accounted for only 5 per cent of the Verdigris River entomostraca (Table XII).

Seasonal Trends. Diaphanosoma brachyurum and *Bosmina longirostris* exhibited trends similar to those that occurred in the Fall River. Perhaps the most clearly defined seasonal trend in the Verdigris River was exhibited by *Chydorus sphaericus*, which was collected simultaneously in large numbers during April at Stations VII, VIII, and IX. Another pulse, although smaller, was noted at Station IX during September.

Simocephalus vetulus exhibited what was considered to be the only winter pulse, as over 85 per cent of the individuals of this species were collected during December.

Copepoda of the Fall River

A total of 8 species of copepods were collected from the Fall River stations; however, these 8 species constituted less than 12 per cent of the total entomostraca. (Table XI).

Relative Abundance. Cyclops vernalis, a common inhabitant of freshwater habitats (Pennak 1953), was the most abundant copepod but comprised less than 7 per cent of the total entomostraca collected from the Fall River stations (Table XII). *Eucyclops agilis,* comprising less than 4 per cent of the entomostraca, was the second most abundant copepod collected (Table XII). Carter (1954) reported the occurrence of this species in Lake Wooster, and Leonard and Ponder (1949) collected it from pools and roadside ditches in eastern Kansas. Pennak (1955) stated that *E. agilis* was often associated with rooted aquatics, being a bottom dweller, and that its occurrence was fortuitous.

Seasonal Trends. Practically all species of copepods were sporadic in their appearances. *Cyclops vernalis* appeared to be a year-round form, but, in general, was most abuandant during the spring and summer months. Andrews (1953) found this species to be a spring, summer, and fall form in Western Lake Erie, reaching its maximum during late June or early July.

Copepoda of the Verdigris River.

Eleven species of copepods were collected from the Verdigris River, representing 33 per cent of the total entomostraca of that river (Table XI). Copepods were slightly more abundant in the Verdigris River than in the Fall River.

Relative Abundance. As was the case in the Fall River, the most abundant copepod was *Cyclops vernalis.* It comprised over 23 per cent of the entomostraca (Table XII) and was nearly twice as abundant in the Verdigris River as it was in the Fall. *Eucyclops agilis* was the next most abundant copepod, representing less than 5 per cent of the entomostraca. It was interesting to note that the 2 most abundant copepods were the same in both rivers; this was not true of cladocerans. Apparently this condition is common in freshwater habitats. Pennak (1953) pointed out that the limnetic copepod plankton is rather monotonous in lakes, usually being composed of a relatively few species.

Seasonal Trends. As was the case in the Fall River, the copepods did not exhibit many obvious seasonal trends. *Cyclops vernalis* again appeared to be a year-round form, being collected during each month of this study. It was collected in greatest numbers during April, September, and December. *Cyclops bicuspidatus,* though never abundant, appeared mainly during the spring and winter months. Andrews (1953) found this species to be a winter form in Western Lake Erie.

Relationships of Entomostraca to Physical-Chemical Conditions

There were no apparent relationships between any of the chemical conditions studied and the abundance of entomostracans. However, it should again be pointed out that, in general, data were collected at intervals of 1 to 2 weeks, and had the interval between collections been much shorter, relationships might have been evident. It is also probable that conditions other than those studied might have influenced seasonal variations and abundance of the cladocerans and copepods present in both rivers.

Although most cladocerans are eurythermal (Pennak 1953), Brooks (1956) found that the optimum temperature range for cladocerans in Kansas was from 22° to 32°C. So far as known, there are no data available concerning optimum temperature ranges for copepods in Kansas. In general, cladocerans and copepods were most abundant during this study from April to July when the mean water temperature varied from 14° to 32.5°C. and water flow was continuous. Of the conditions studied, water flow was perhaps a major limiting factor since entomostracans were scarce during periods of decreased flow or, in some cases in the Verdigris River, when flow of water ceased altogether. The limiting effect of water levels on plankton has been reported by Galtsoff (1924) and Wiebe (1930).

Organic seston may be used as an index to the standing crop of plankton (Andrews 1953); however, during this study, there was no apparent relationship between the organic seston and abundance of entomostracans. This condition was due primarily to the fact that much of the organic seston was attributed to resuspended bottom matter. While there was no definite relationship between the abundance of entomostracans and turbidity, the relatively low turbidity of both rivers during much of the study may have affected the collection of entomostraca. Low turbidities could have enabled the entomostracans to detect and, thus, evade the Kemmerer Water Sampler. Such a phenomenon was suggested by Andrews (1949).

SUMMARY

1. Seasonal variations of physical-chemical conditions and entomostraca in the Fall River, an impounded stream, and the Verdigris River, a non-impounded stream, from April 3, 1954, to March 12, 1955, are presented.

2. Data collected at stations located on the Fall and Verdigris rivers between Neodesha and Independence, Kansas, consisted of quantitative planton samples, water temperature, water flow, turbidity, seston, free carbon dioxide, pH, methyl orange alkalinity, dissolved oxygen, and total hardness determinations.

3. Monthly mean ranges for the physical-chemical conditions of the Fall River stations were water temperature 3.5° to 35.5°C; water flow 3.5 to 306.5 cfs.; turbidity less than 10 to 97 ppm.; total seston 4.4 to 32.1 mg./liter; organic seston 1.3 to 18 mg./liter; free carbon dioxide zero to 6.6 ppm.; methyl orange alkalinity 106 to 184 ppm.; dissolved oxygen 3.9 to 14.2 ppm.; and total hardness 109 to 336 ppm. The pH of the Fall River ranged from 6.9 to 8.4.

4. The ranges of the monthly means of the physical-chemical conditions of the Verdigris River were water temperature 3.1° to 32.7°C.; water flow zero to 1221.8 cfs.; turbidity less than 10 to 538 ppm.; total seston 4.5 to 294.7 mg./liter; organic seston 0.4 to 88.8 mg./liter; free carbon dioxide zero to 12.9 ppm.; methyl orange alkalinity 53 to 202 ppm.; dissolved oxygen 4.1 to 13.9 ppm.; and total hardness 98 to 438 ppm. The pH of the Verdigris River ranged from 7.0 to 8.4.

5. The maximum surface temperature recorded in the Fall River was 39.2° at Station V on July 23, 1954, while the minimum was 1.5°C. at Station II on January 29, and February 12, 1955.

6. The maximum surface temperature recorded in the Verdigris River was 37.2° at Station IX on July 17, 1954, while the minimum was 0.7°C. at Station I on February 12, 1955.

7. A total of 32 species of entomostracans were collected from the 4 Fall River stations, while 33 species were collected from the 4 Verdigris River stations. Cladocerans were more abundant in both rivers than were copepods. Cladocera were more than twice as abundant in the Fall River as in the Verdigris River.

8. Cladocera constituted 88.7 per cent of the entomostraca collected from the Fall River and 67 per cent of the entomostraca collected from the Verdigris River.

9. *Moina brachiata* was the most abundant and *Chydorus sphaericus* was the second most abundant species of entomostracan collected.

10. *Moina brachiata* and *Simocephalus serrulatus* composed more than 80 per cent of entomostraca collected from the Fall River, and *Chydorus sphaericus* and *Simocephalus vetulus* accounted for about 47 per cent of the entomostraca collected from the Verdigris River.

11. *Diaphanosoma brachyurum* and *Moina brachiata* appeared to be summer forms. *Bosmina longirostris* and *Chydorus sphaericus* appeared to be spring forms.

12. *Simocephalus vetulus* appeared to be the only winter form of Cladocera that was collected.

13. *Cyclops vernalis* was the most common and the most abundant copepod, while *Eucyclops agilis* was the second most abundant copepod collected from either river.

14. *Cyclops vernalis* and *Eucyclops agilis* appeared to be year-round forms, while *Cyclops bicuspidatus* appeared to be a spring and winter form.

15. Water flow and water temperature appeared to be the main limiting factors. In general, the entomostracans were scarce during periods of minimum discharge and high water temperature. There appeared to be no obvious relationship between the abundance of entomostracans and any of the chemical conditions that were studied.

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