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The Limnology of Wyandotte County Lake, Kansas

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Bert E. Eustace and John D. Ransom*

INTRODUCTION

A primary objective of this study was to characterize the environmental quality of Wyandotte County Lake, which is subjected to recreational pressures of a large metropolitan area, by using species diversity indices based on benthic macroinvertebrate community structure at various depths and locations and relating those indices to physicochemical features. A community of benthic macroinvertebrates consists of species with various ranges of tolerance for organic and inorganic pollutants (Edwards, 1970; Ransom and Dorris, 1972; Ransom and Prophet, 1973). The extent of environmental stress in aquatic systems can be assessed by examination of benthic community structure through information theory (Margalef, 1956) and characterized by developing an index, of density per individual (d) (Ransom, 1969; Ransom and Dorris, 1972).

*This study originated as a master's thesis under the direction of Dr. John Ransom, Professor of Biology, Division of Biological Sciences, Emporia State University. Mr. Eustace is presently a biology teacher at Washington High School, Kansas City, Kansas.

DESCRIPTION OF THE STUDY AREA

Wyandotte County Lake was formed approximately 30 years ago by impounding Marshall Creek approximately 1.3 km from its confluence with the Missouri River at Pomeroy Bend, river mile 382 (Figure 1). It is located in the 607 ha Wyandotte County Park, with an entrance at 91st Street on Leavenworth Road, Kansas City, Kansas. The geology of the region consists of limestone, shale, and chert of the Pennsylvanian period. The topography is hilly and rolling, stabilized by mixed hardwoods, primarily of the oak-hickory association. The impoundment, a WPA project constructed with federal and county funds, was begun 17 December 1935. On 19 September 1937, as dam height was within three meters of completion, the structure collapsed. Reconstruction began 11 May 1938 under plans prepared by the U. S. Army Crops of Engineers. The dam proper was completed on 7 August 1941. Final work on the dam and spillway was completed on 9 December 1943 and the lake reached overflow capacity on 5 June 1947. At full capacity, the lake covers 135 ha at 820 MSL. At that elevation, the lake has approximately 21 km of shoreline. The long axis of the lake measures approximately 2.85 km, lying mainly in a direction from northeast to southwest. Marshall Creek Cove runs directly north for approximately one km, the axis of the lake then bends northeast and a straight line of 1.85 km will reach the face of the dam near its center. The basin receives drainage from Marshall Creek, several springs, and 2,023 ha of hilly, hardwood-covered watershed. The shoreline is precipitous around much of the basin, resulting in no littoral zone for those areas. An extensive growth of emergent, floating, and submerged vegetation occurred in Marshall Creek Cove, dominated by common cattail (*Typha latifolia* L.), American lotus (*Nelumbo lutea* (Willd.) Pers.), and pondweeds (*Potamogeton* spp.). Limited vegetation existed in the upper end of Wilson Cove and scattered growth of pondweed occurred at various shoaling areas. But, for the most part, the shoreline was not characterized by aquatic vegetation. In much of the lake basin, depth increased rapidly with distance from shore, with parts of the main channel and major coves achieving depths greater than 15 meters. The long axis of the lake is oriented such that prevailing winds have an uninterrupted approach to much of the surface. The long fetch results in sufficient eddy diffusion to help maintain oxygen at depths that would otherwise be anoxic during the summer, although a stable stratifiction develops in deeper waters. Based on data com-

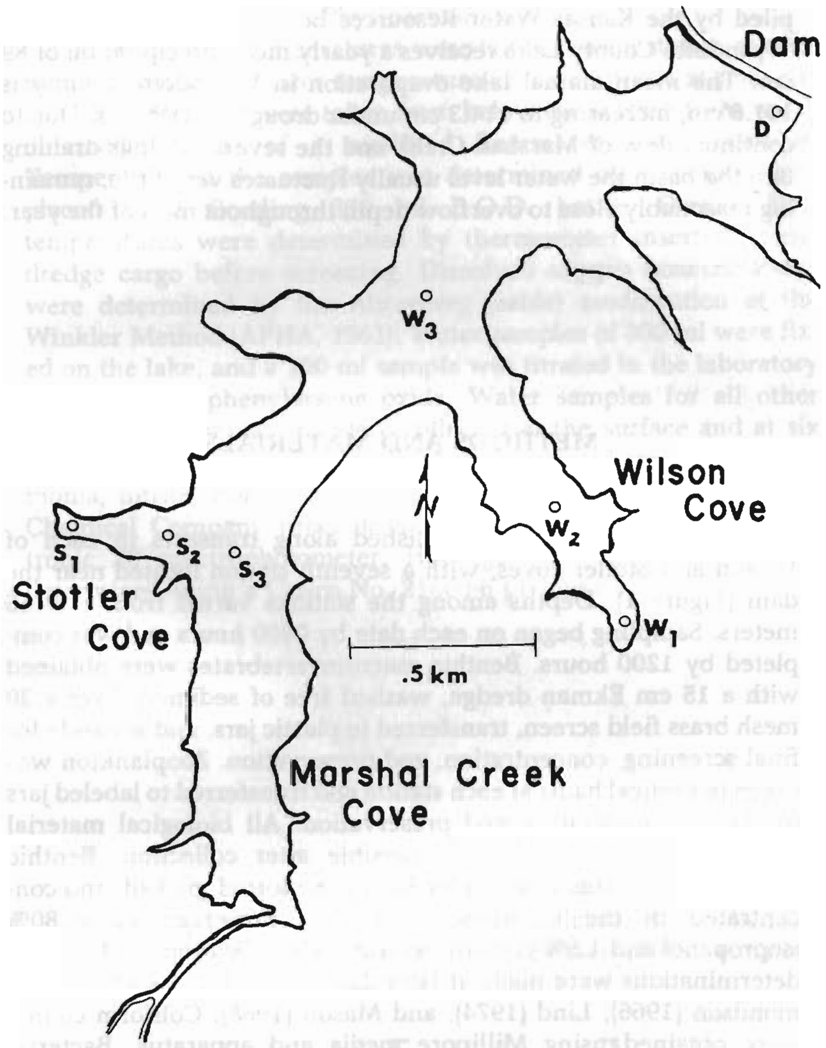

Figure 1. Wyandotte County Lake, Kansas. Circles indicate locations of stations.

piled by the Kansas Water Resources Board (1967), the region of Wyandotte County Lake receives a yearly mean precipitation of 89 cm. The mean annual lake evaporation in Wyandotte County is 101.6 cm, increasing to 114.3 cm under drought conditions. Due to continual flow of Marshall Creek and the several springs draining into the basin the water level usually fluctuates very little, remaining reasonably close to overflow depth throughout most of the year.

METHODS AND MATERIALS

Biological

Three stations were established along transects in each of Wilson and Stotler coves, with a seventh station located near the dam (Figure 1). Depths among the stations varied from 1 to 15 meters. Sampling began on each date by 0800 hours and was completed by 1200 hours. Benthic macroinvertebrates were obtained with a 15 cm Ekman dredge, washed free of sediment over a 30 mesh brass field screen, transferred to plastic jars, and set aside for final screening, concentration, and preservation. Zooplankton was taken in vertical hauls at each station and transferred to labeled jars for later concentration and preservation. All biological material was refrigerated as soon as possible after collection. Benthic macroinvertebrates and zooplankton were sorted, picked, and concentrated in the laboratory and then preserved in a 80% isopropanol and 1.5% glycerin mixture. Identifications and density determinations were made at later dates using Pennak (1953), Edmondson (1966), Lind (1974), and Mason (1968). Coliform counts were obtained using Millipore media and apparatus. Bacterial counts were made only at the beginning and at the end of the study. With the exception of trace metals, all other data were collected on a monthly basis except during the summer. In the summer, sampling was at approximately two-week intervals. Benthic macroinvertebrates were recorded as numbers of individuals per dredge haul and per m². Zooplankton was expressed as numbers of individuals per species per liter. Coliform counts were calculated as organisms per 100 ml in each of two coves both from the surface and from six meters.

Physicochemical

Air and water temperatures were taken at each station at each sampling interval. Water temperatures were recorded at one, six, and 15 meters and were taken from below the surface from water obtained by use of a modified Kemmerer water sampler. Temperature of the samples was determined by a thermometer placed in a flooding 300 ml B.O.D. bottle. Dredge haul temperatures were determined by thermometer inserted in the dredge cargo before screening. Dissolved oxygen concentrations were determined by the Alsterberg (azide) modification of the Winkler Method (APHA, 1961). Water samples of 300 ml were fixed on the lake, and a 100-ml sample was titrated in the laboratory with 0.025 N phenylarsene oxide. Water samples for all other chemical determinations were collected at the surface and at six meters from stations S_2 and W_2. Nitrate, phosphate, sulfate, ammonia, nitrite, iron, and copper were determined by using Hach Chemical Company procedures on the Bausch and Lomb Spectronic 20 spectrophotometer. Hydrogen ion concentration was determined using a Cenco No. 21660-6 pH meter.

Statistical

Species diversity indices ($\bar{d}$) were calculated for benthic macroinvertebrates using the Shannon-Weaver (1949) equation

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

where N is the total number of individuals and n_i is the number of individuals of species *i*. An annual mean diversity index ($\bar{d}$) was calculated for each station by depth. Variations in individual species diversity ($\bar{d}$), oxygen concentrations, and concentrations of nitrate, phosphate, sulfate, and ammonia were evaluated using a Student t-test at p = .05 level of significance.

TABLE I. Total numbers of individual of each benthic invertebrate collected at each station.

Organisms in Dredge Samples	Station and Depth W$_1$	W$_2$	W$_3$	S$_1$	S$_2$	S$_3$	D
ANNELIDA							
OLIGOCHAETA							
Branchiura sowerbyi Bedd.	27	1	-	31	4	-	-
Limnodrilus sp.	105	150	1681	163	410	1520	839
MOLLUSCA							
GASTROPODA							
Physa sp.	-	-	-	1	1	-	-
Gyraulus sp.	-	-	-	1	1	1	-
ARTHROPODA							
INSECTA							
Diptera							
Ceratopogonidae							
Palpomyia sp.	31	28	-	187	38	9	1
Culicidae							
Chaoborous punctipennis Say	11	275	1098	23	298	685	2828
Chironomidae							
Tanypodinae							
Procladius sp.	29	14	5	4	59	26	2
Coelotanypus sp.	45	41	-	7	26	9	-
Tanypus sp.	1	-	-	2	4	-	-
Ablabesmyia sp.	1	-	-	4	-	-	-
Chironominae							
Chironomus sp. 1	91	117	25	8	35	57	4

TABLE I. (Continued)

Organisms in Dredge Samples	Station and Depth W$_1$	W$_2$	W$_3$	S$_1$	S$_2$	S$_3$	D
Chironomus sp. 2	3	9	2	-	48	22	-
Cryptochironomus sp. 1	191	-	-	41	85	4	-
Cryptochironomus sp. 2	-	-	-	-	8	-	-
Cryptochironomus sp. 3	-	-	-	4	-	-	-
Polypedilum sp.	40	-	-	5	-	-	1
Einfeldia sp.	182	2	1	51	-	-	-
Stenochironomus sp.	-	-	-	-	2	-	-
Paralauterborniella sp.	-	-	-	12	-	-	-
Microtendipes sp.	-	-	-	16	-	-	-
Tribelos sp.	-	1	-	-	-	-	-
Glyptotendipes sp.	-	-	-	1	-	-	-
Dicrotendipes sp.	2	-	-	2	-	1	-
Tanytarsus sp.	2	-	-	2	-	1	-
Orthocladinae							
Psectrocladius sp.	7	4	-	61	1	-	-
Ephemeroptera							
Baetidae							
Ephemerella sp.	-	-	-	1	-	-	-
Caenis sp.	3	-	-	10	1	-	-
Ephemeridae							
Hexagenia sp.	-	3	-	3	1	1	-
Total Taxa	16	12	6	24	17	11	6
Total Individuals	769	645	2812	639	1022	2335	2675

RESULTS AND DISCUSSION

Biological

Benthic Taxa Collected

A total of 11,897 individuals representing 28 taxa of benthic macroinvertebrates was collected (Table I). Sixteen taxa were collected at station W_1, 12 taxa at station W_2, 6 taxa at station W_3, 24 taxa at station S_1, 17 taxa at station S_2, 11 taxa at station S_3, and 6 taxa at station D. The total number of individuals collected at each station was 769, 645, 2,812, 639, 1,022, 2,335, and 2,675, respectively. The station providing the greatest species diversity produced the smallest number of individuals, and the station with the fewest species produced the greatest redundancy and the highest total count.

Nineteen of the 28 taxa (12% of the total number of individuals collected) were midges of the family Chironomidae. According to Mason (1968), these organisms are of major consequence in the food chain between algae and macroinvertebrates, and between the larger macroinvertebrates and fishes. Chironomid larvae are chiefly herbivorous and feed on algae, higher aquatic plants, and organic detritus (Pennak, 1953). The pinkish-to-very-deep-red coloration of most of the more abundant species is caused by dissolved erythrocruorin in the blood, providing the basis for the common appellation "bloodworm." The substance acts as a respiratory pigment similar to hemoglobin and may be of special significance to larvae living in water with very low levels of dissolved oxygen. In Wyandotte County Lake, however, only 158 of a total of 1,161 chironomids (13.6%) were collected at depths greater than six meters. It was found that 96 (60%) of the chironomids collected below six meters were of the genus *Chironomus,* a taxon characterized by the most brilliant erythrocruorin color. *Procladius* sp. formed 21% of the chironomids from below six meters, although it was absent when the environment was anoxic at 15 meters. Cole (1975) asserts that *Procladius* sp. is not a permanent member of the profundal benthic community because it is absent during the period of summer anoxia in dimictic temperate lakes.

The greatest abundance and diversity of chironomids occurred at stations W_1 and S_1 at a depth of one meter. The greatest abundance of chironomids occurred in a soft substrate, mixed with a heavy burden of fine-textured organic detritus, but diversity was greatest in sediments of a fine sandy-silt substrate mixed with a large proportion of finely-divided organic material. In both cases, the organic component appeared to be primarily of allochthonous origin, the bulk of which seemed to consist of leaf material from the mixed hardwoods rooted over most of the adjacent watershed. A considerable quantity of filamentous algae was also present over the substrate at the one meter depth. Pennak (1953) stated that certain genera within the chironomid family have adapted well to living in water where concentrations of dissolved oxygen are low and where lake bottoms are composed of fine silt. The distribution of chironomids and other macroinvertebrates collected in this study seemed to bear this out. The exception occurred at depths where the sediment became sapropel and the oxygen tension reached zero during the summer stagnation. At such time and places, the lake became the exclusive domain of the vertically-migrating "phantom midge," *Chaoborus punctipennis* Say, and the oligochaete, *Limnodrilus* sp.

Two species of oligochaetes, *Limnodrilus* sp. and *Branchiura sowerbyi* Bedd., were collected. *Limnodrilus* sp. was the most abundant, representing 41% of the total macroinvertebrates collected throughout the study. This organism occurred at all depths, but was most abundant at the three 15 meters deep stations. *B. sowerbyi* Bedd. contributed only 0.5% of the total collection, with 58 of the 63 specimens collected being taken at a depth of one meter.

The larvae of the biting midge, *Palpomyia* sp. formed only 2% of the total collection, occurring almost exclusively (97%) at depths of six meters or less.

Two species of pelecypods and three species of ephemeropterans were collected, both in extremely small numbers.

Distribution and Seasonal Changes in Numbers of Benthic Organisms

Only two benthic species were collected in sufficient numbers to establish a pattern of seasonal changes in numbers. Seasonal trends of selected organisms are shown in Table II. *Limnodrilus* sp. demonstrated a seasonal population trend of decrease through the summer and increase through fall, winter, and spring. Pennak (1953) reported tubificids able to endure summer and winter periods of stagnation, and one-third of a group of test *Tubifex* worms surviving anoxic conditions for 48 days at 0 to 2°C. At higher temperatures the fraction was progressively smaller. When the hypolimnion was anoxic in Wyandotte County Lake, temperatures ranged from 12.5 to 16°C. The higher temperature might make anoxic conditions lethal for a great number of these

TABLE II. Seasonal changes by selected benthic macroinvertebrates expressed as individuals per m² on each sampling date.

Organisms	3/30	5/4	6/2	6/20	7/12	7/26	8/10	9/17	10/8	10/28	11/18
OLIGOCHAETA											
Limnodrilus sp.	22175	3052	47908	31286	15021	21777	19904	3555	9511	7821	12312
DIPTERA											
CULICIDAE											
C. punctipennis Say	7265	36173	18132	14577	6622	9821	13243	12044	12976	10843	60527
CHIRONOMIDAE											
Procladius sp.	1866	1911	488	88	133	—	178	933	—	132	399
Coelotanypus sp.	622	132	222	132	710	355	88	711	622	1556	578
Chironomus sp. 1	2755	1066	1599	1155	800	1866	444	133	44	3511	5154
Chironomus sp. 2	222	844	133	1555	355	222	44	—	266	489	
Cryptochironomus sp. 1	311	978	—	1022	3733	1955	2977	133	356	177	222

hardy organisms. Most likely the population was not subjected to anoxic conditions during the winter because measurements taken near the end of November disclosed a minimum of 6.8 mg/liter dissolved oxygen at 15 meters.

The other species exhibiting a definite seasonal trend was *C. punctipennis* Say. Numbers of this organism increased during the spring and fall and decreased during the summer and winter. Ransom (1969) noted that midge eggs that had fallen to the lake bottom did not hatch if the bottom water was anoxic. They remained dormant until oxygen was available. Likewise, low temperature delayed hatching. The combined effects of variations in oxygen tension and temperature suggest an explanation for the presence of spring and fall concentrations of *C. punctipennis* larvae. The decrease in larval numbers during the summer undoubtedly reflected emergence as adults and agreed with Horner (1977). Probably there was an increase in predation and cannibalism, too. The latter may be of considerable significance, for many of the individuals examined were found to have been in the process of consuming members of earlier instars when collected. The cannibalistic propensity of *C. punctipennis* and its predator role in the larval state is well known (Reid, 1961; Ransom, 1969).

Species distribution by depth was demonstrated by comparing the relative abundance of selected taxa at depths of one, six, and 15 meters (Table III). This was done by obtaining the total number of individuals of each taxa at a given depth and dividing that total by the number of stations at that depth. Fifteen taxa were most abundant at one meter, two were equally abundant at one and six meters, nine were most abundant at six meters and *Limnodrilus* and *Chaoborus* increased in population density with depth, reaching their maximum densities at 15 meters.

Species Diversity Background

The species diversity index ($\bar{d}$) is a tool of universal acceptance among aquatic biologists as a means of evaluating water quality or habitat fitness. The use of $\bar{d}$ has superseded the reliance upon one or two "indicator organisms" as stress indicators which was proposed by Richardson (1928), Beck (1955), and Gaufin and Tarzwell (1952). Patrick (1949) was one of the first researchers to show that an approach to combining the number of species of plants and animals, with the numbers of individuals of each, could be a more accurate means of assessing water quality. Many aquatic macroinvertebrates are sub-adult insects who spend a year or more in close proximity to where they were hatched. Their relatively long life span as a completely aquatic organism and their lack of mobility make them natural monitors of physical and chemical conditions in aquatic systems (Pennak, 1953; Tarzwell, 1965; Mathis, 1968). Species diversity indices based on the Shannon and Weaver (1949) equation have been used by Patten (1962), Wilhm and Dorris (1966), Harrel and Dorris (1968), Mathis (1968), Mathis and Dorris (1968), Wilhm (1970), Ransom (1969) Ransom and Dorris (1972), and Ransom and Prophet (1974) to analyze community structure in streams and reservoirs.

TABLE III. Relative abundance of selected benthic macroinvertebrates by depth.

Organism	Depth in meters 1	6	15
Branchiura sp.	29.0	2.5	0.0
Limnodrilus sp.	134.0	280.0	1347.0
Physa sp.	0.5	0.5	0.0
Gyraulus sp.	0.5	0.5	0.3
Caenis sp.	6.5	0.5	0.0
Ephemerella sp.	0.5	0.0	0.0
Hexagenia sp.	1.5	2.0	0.3
Chaoborous sp.	23.0	287.0	1537.0
Procladius sp.	17.0	37.0	11.0
Coelotanypus sp.	26.0	34.0	3.0
Tanypus sp.	1.5	2.0	0.0
Ablabesmyia sp.	2.5	0.0	0.0
Chironomus sp. 1	50.0	76.0	29.0
Chironomus sp. 2	1.5	29.0	7.3
Cryptochironomus sp. 1	116.0	43.0	1.3
Cryptochironomus sp. 2	0.0	4.0	0.0
Cryptochironomus sp. 3	2.0	0.0	0.0
Polypedilum sp.	23.0	0.0	0.3
Einfeldia sp.	117.0	1.0	0.3
Stenochironomus sp.	0.0	1.0	0.0
Paralauterborniella sp.	6.0	0.0	0.0
Microtendipes sp.	8.0	0.0	0.0
Tribelos sp.	0.0	0.5	0.0
Glyptotendipes sp.	0.5	0.5	0.0
Dicrotendipes sp.	0.5	0.0	0.0
Tanytarsus sp.	2.0	0.0	0.3
Psectrocladius sp.	34.0	2.5	0.0
Palpomyia sp.	109.0	33.0	3.3

The species diversity index ($\bar{d}$) reflects the manner in which individuals are distributed among species in a community. Assuming a community to be entirely free of pollution stress, a collection of benthic macroinvertebrates would be found to contain a wide diversity of species, each represented by relatively few individuals. At the other extreme, a community under intense stress would be devoid of many of the intolerant species or, at best, be represented by very few individuals. A community exposed to pollution may be dominated by only one or two species whose numbers reach tremendous proportions, either from lack of competition or from an ability to thrive under the precise kind and level of pollution that proved limiting to many other species. As pollution increases from zero to high levels, the probability of collecting a species decreases and $\bar{d}$ decreases. It is not necessary that any species disappear in order for the value of $\bar{d}$ to decrease, only that they fail to flourish while a few other species do. In water containing pollutants, the probability is high that an individual in a sample will be of a species already collected, causing $\bar{d}$ to drop. The opposite is true in unpolluted water. The expected range of $\bar{d}$ values is from zero to five in aquatic environments. Values less than one represent grossly polluted streams or lakes. Values from one to three represent areas of moderate pollution. Values greater than three are found in clean water environments (Wilhm and Dorris, 1966; Wilhm, 1970).

Species Diversity Analyses

A $\bar{d}$ value was calculated for pooled samples as well as for individual stations for each sampling date (Table IV); the annual means for each station and for pooled samples were also calculated. Throughout this study, the highest recorded $\bar{d}$ was 3.08 at station S_1 on 22 June 1977 and the lowest $\bar{d}$ was 0.29 at station W_3 on 12 July 1977 and station D on 8 November 1977. The mean annual $\bar{d}$ was less than 1.0 at all stations having a depth of nine meters or more. The highest mean $\bar{d}$ occurred at stations S_1 and W_1 which had depths of only one meter. The relatively low $\bar{d}$ for pooled samples, 1.43, reflected the effects of the stress of low oxygen concentrations frequently experienced by the benthos at the deeper sampling stations.

TABLE IV. A comparison of $\bar{d}$ values for individual stations and pooled samples by sampling dates and annual means.

Date	Station D (15m)	S_1 (1m)	S_2 (6m)	S_3 (9m)	W_1 (1m)	W_2 (6m)	W_3 (15m)	Mean for Date
3/30/78	0.80	1.96	2.16	1.58	1.77	2.35	0.64	1.61
5/4/78	0.79	1.66	1.70	1.60	2.18	1.44	1.03	1.49
6/2/77	0.75	1.13	0.93	0.56	1.20	1.71	0.83	1.02
6/22/79	0.90	3.08	1.74	0.34	2.80	0.41	0.85	1.45
7/12/79	1.00	2.31	2.10	0.27	2.11	0.58	0.29	1.24
7/26/77	0.97	1.84	1.30	0.54	2.36	0.30	0.44	1.11
8/10/77	0.98	2.78	0.78	1.05	2.29	0.17	0.36	1.20
9/17/77	0.74	2.70	2.52	——	2.40	1.17	——	1.91
10/28/77	0.87	2.24	1.44	1.79	——	——	——	1.59
11/8/77	0.29	1.49	1.69	0.91	2.66	2.89	1.41	1.62
mean $\bar{d}$	0.82	2.10	1.71	0.96	2.13	1.26	0.73	1.43

The species diversity values of individual stations were subjected to a Student t-test at p = .05 level of significance. This was first done by dates, producing 55 combinations for comparison; there was one significant difference, and that occurred between the samples obtained in June and September. Another set of comparisons was made by pairing $\bar{d}$ values by station. Since these comparison were made on data from stations as shallow as one meter and as deep as 15 meters, significant differences were expected. Comparing the data by stations produced 21 combinations, 11 of which revealed ($\bar{d}$) values of significant difference (Table V).

Zooplankton

Two genera of copepods, five genera of cladocerans, and a single genus of ostracod were observed in plankton samples (Table IV). The two genera of copepods, *Cyclops* and *Diaptomus*, were present in all samples. *Cyclops* reached a maximum density of 60 adults per liter in June and *Diaptomus* reached a maximum density of 30 adults per liter in early October. Throughout the study, however, *Cyclops* exceeded *Diaptomus* by only 10%. This order of abundance was the inverse of that reported by Prophet (1965) from

Lyon County, Kansas State Lake. In that study, *Diaptomus siciloides* was the most characteristic copepod with *D. pallidus* never abundant, but generally present. *Cyclops bicuspidatus thomasi* tended to be more numerous in Lyon County State Lake during the cooler months but absent during the warmer periods, July through October. At the time of the Lyon County study, however, the lake was much smaller than its 55-ha spillway level, with a maximum reported depth at that time of only 3.96 m. During August, the water was homothermous for all depths at approximately 26.6 C. In Wyandotte County Lake, when the surface temperature was at a maximum of 27.9°C, it was 25.7°C at 6 m, and 19.0°C at 15 m. The opportunity to avoid the higher temperature and related stress may be sufficient to explain the dominance of *Cyclops* in Wyandotte County Lake. The two studies show *Diaptomus* present in all months.

TABLE V. Results of test of significance by station using the Student t-test at p = .05 level of significance. Significant difference (X); no significant difference, (0).

Station	S_2	S_3	W_1	W_2	W_3	D
S_1	O	X	O	X	X	X
S_2		X	O	O	X	X
S_3			X	O	O	O
W_1				X	X	X
W_2					O	O
W_3						O

Among the Cladocera, *Daphnia* was present in all samples reaching a maximum density of 46 individuals per liter in August. *Bosmina*, present in all samples except those taken in July, reached a maximum density of 73 individuals per liter in mid-September. *Diaphanosoma* was collected only three times, occurring from June to early October. *Simocephalus* was taken in three consecutive samples from July to mid-September, and *Ceriodaphnia* was scarce, taken only once in mid-September. The occurrence of *Daphnia* and *Bosmina* on a regular basis throughout the year and of *Diaphanosoma* only during June through October is in agreement with the data for these species reported by Prophet (1965) on Lyon County Lake.

TABLE VI. Population density per liter of adult zooplankters.

Organisms	3/30	5/4	6/2	6/20	7/12	7/26	8/10	9/17	10/8	10/28	11/18
COPEPODA											
Diaptomus sp.	16	18	11	17	15	16	7	12	30	26	21
Cyclops sp.	12	10	60	25	9	7	23	13	16	16	19
CLADOCERA											
Daphnia sp.	7	24	13	15	20	30	46	38	36	16	17
Bosmina sp.	6	9	10	2	—	—	61	73	23	14	5
Diaphanosoma sp.	—	—	—	15	—	12	—	—	5	—	—
Simocephalus sp.	—	—	—	—	—	21	40	15	—	—	—
Ceriodaphnia sp.	—	—	—	—	—	—	—	19	—	—	—
OSTRACODA											
Darwinula sp.	—	—	—	—	4	—	—	—	—	—	—

Coliform Bacteria

Coliform bacteria densities were surveyed twice during the study, using Millipore membrane filters and EMB broth. Water samples were taken from the surface and at six meters from stations in Wilson and Stotler coves. Dilutions were made with autoclaved lake water. The mean count from five plates was used as a density measure at each location. Densities were higher at six meters than at the surface, and higher in Wilson Cove than in Stotler Cove. Mean coliform counts in Wilson Cove were 22.5 per 100 ml at the surface and 116.0 per 100 ml at six meters. In Stotler Cove, the counts averaged 14.5 per 100 ml and 97.0 per 100 ml, respectively. Mean count for all dates and depths, combined, was 62 per 100 ml.

Physicochemical

pH

Two stations were sampled at both the surface and the bottom in alternate coves on alternate sampling dates. Little difference was observed in pH when comparisons were made by depth or date. The 11 reading taken from the surface ranged from 7.4 to 8.6, and measurements from six meters ranged from 6.4 to 8.3. Only one measurement dropped into the acid range. The reading of 6.4 was obtained at six meters in mid-September. The dissolved oxygen at that depth and date was 3.9 mg per liter. The lowest combination of dissolved oxygen and pH was 0.5 mg/liter at pH 7.4.

Thermal Conditions

The lake tended to be relatively homothermous throughout much of the year, but was strongly stratified during the summer months. Surface water temperatures usually exceeded 25°C during summer, when temperature differentials between the surface and hypolimnion ranged from 10 to 15°C. Sediment temperatures in dredge samples reflected water temperatures occurring at different depths in the lake, as expected (Figure 2). Mean sediment temperatures at stations located in one meter of water were higher and exhibited a greater seasonal variation than did sediment temperatures at stations having depths of nine meters or more.

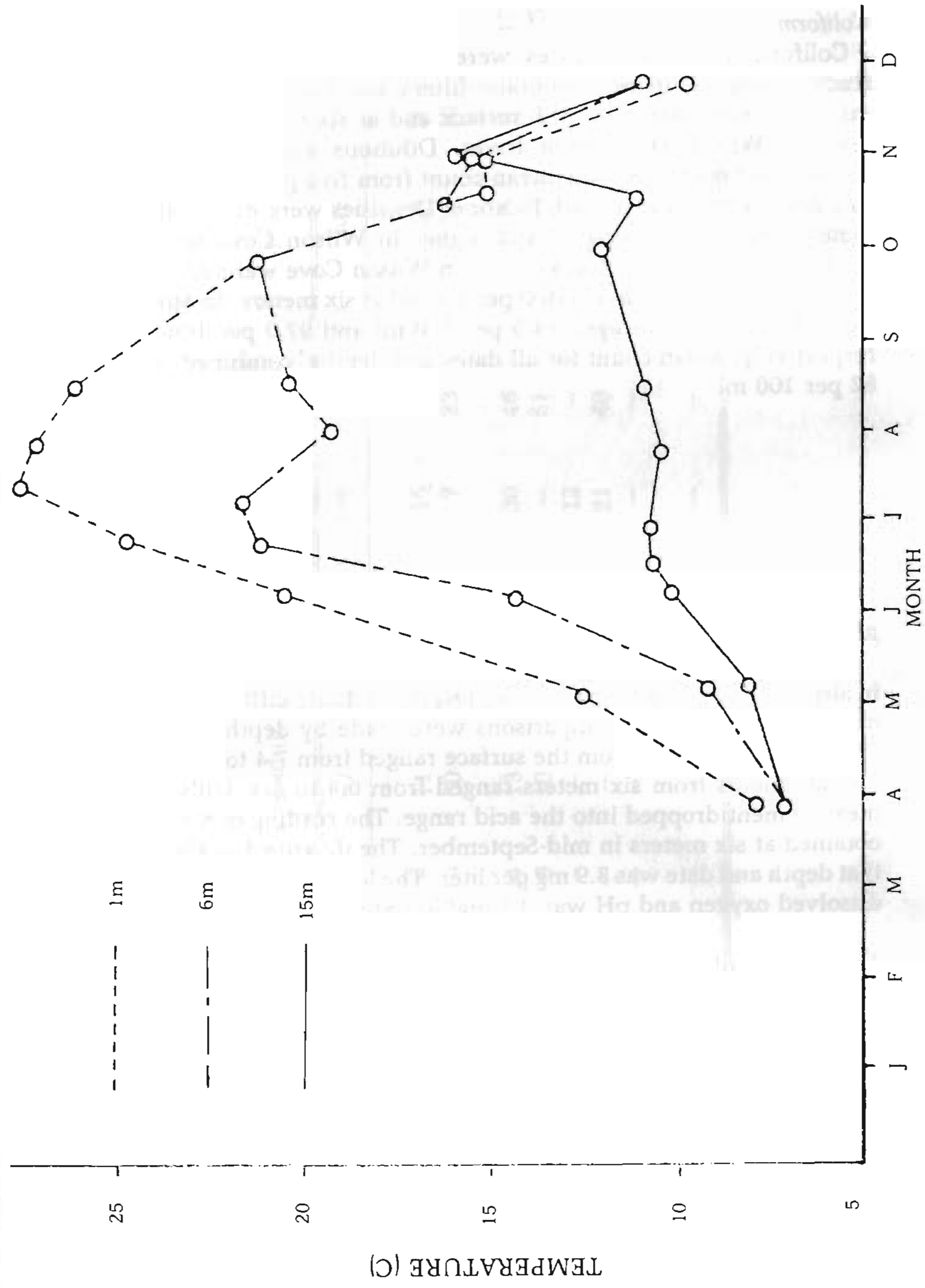

Figure 2. Mean temperature of sediments in dredge samples from 1, 6, and 15 meters.

Transparency

Secchi disc transparency varied from 0.53 to 2.50 m. In general, light penetration was greatest during the summer and lowest during the spring and early fall. Increased light penetration during early summer was probably due to a more direct angle of solar insolation as well as a depletion of nutrients in the euphotic zone by the spring pulse of planktonic algae. The interval of minimum transparency in the fall was probably due to a combination of circulating sediments expected with the fall holomixis, decreasing angle of solar insolation, and a moderate pulse of phytoplankton, using the increased nutrients available in the circulating sediments.

In a study of Lyon County Kansas State Lake Prophet et al. (1967) developed a conversion factor for the comparison of Secchi disc readings with those obtained by Whitney Underwater Photometer. Their research indicated the compensation level or lower edge of the euphotic zone (depth at which light intensity is only 1% of surface brightness) lay at 3.5 times the depth at which the Secchi disc became invisible. On this basis, the average annual depth of the euphotic zone for Wyandotte County Lake was 4.66 m.

Dissolved Oxygen

The mean monthly dissolved oxygen concentrations at the surface and at 15 m varied inversely with water temperature (Figure 3). The surface concentrations ranged from 10.8 mg per liter in March to 5.6 mg per liter in mid-September. At 15 meters oxygen ranged from 10.9 mg per liter in March to depletion by early August. After reaching these seasonal low points, oxygen became more abundant at all depths and, by mid-November the concentration at any depth was within 0.5 mg per liter of the concentration at any other depth. There was a period of at least 52 consecutive days during the study that hypolimnetic oxygen was depleted, or present in a concentration not greater than 0.5 mg per liter. Temperature of the hypolimnion over that time interval ranged from 13.5 to 19.0 °C. Such a combination of environmental pressures produced sufficient stress to explain the paucity of benthic macroinvertebrates collected at 15 meters during the summer. Concentrations of dissolved oxygen were compared, using the t-test at $p = .05$ level of significance. There were no significant differences between surface concentrations or between bottom concentrations among stations; however, there was a significant difference between surface and bottom concentrations during most months of the study at individual stations.

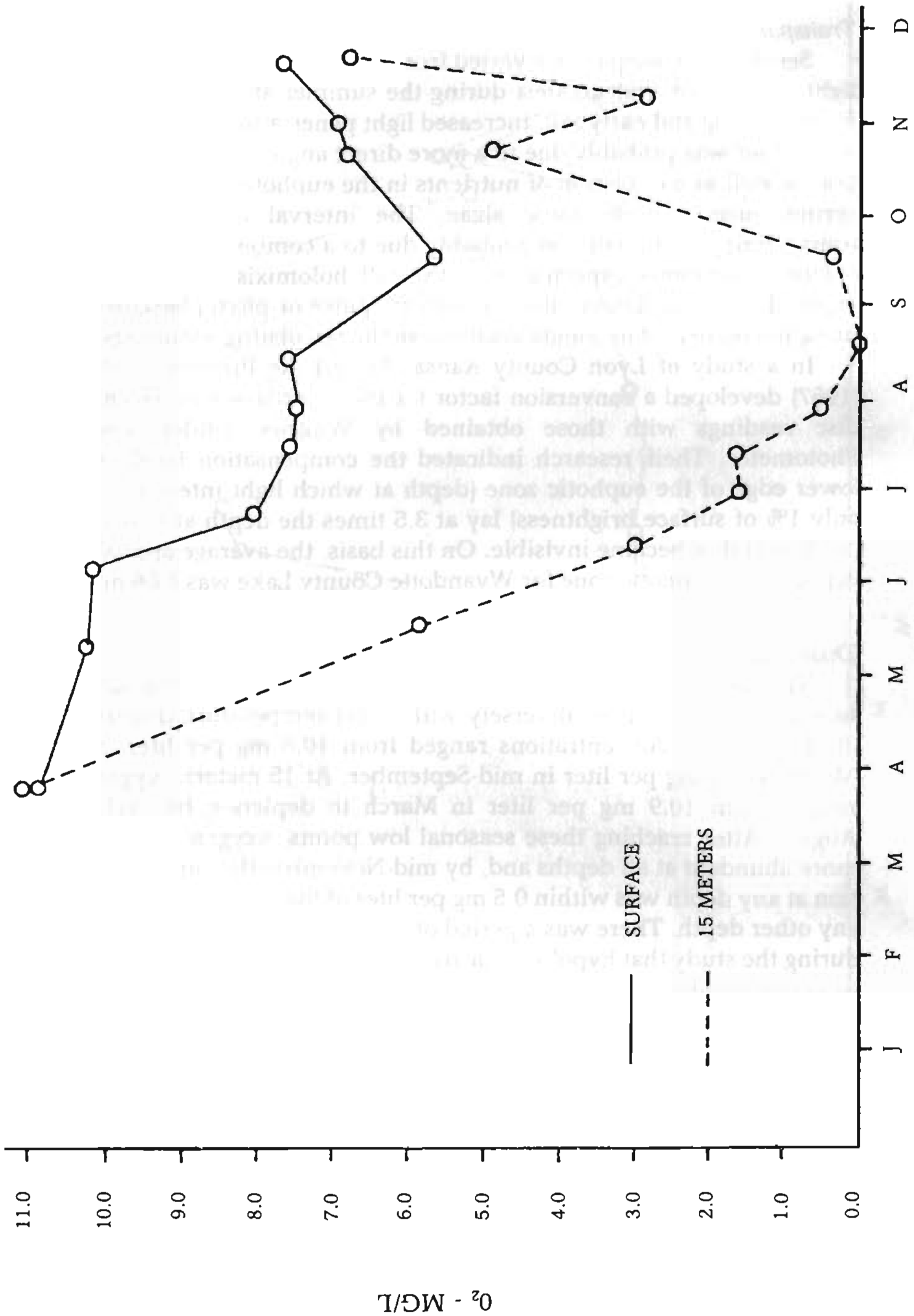

Figure 3. Monthly mean concentration of dissolved oxygen at the surface and at fifteen meters.

Nitrate and Phosphate

Nitrate and phosphate values, taken at depths of one and six meters, were relatively high when compared with other eastern Kansas impoundments. Differences were noted among sampling dates and depths, but were too slight to suggest definite trends (Table VII). Using the t-test, at p = .05 level of significance, there were no significant differences between nitrate levels at any depth, nor between phosphate levels at any depth. Prophet et al. (1970) reported phosphate means from June throught August in Council Grove Reservoir, Marion Reservoir, and John Redmond Reservoir to be 0.09, 0.18, and 0.33 mg per liter, respectively. The three-month mean for Wyandotte County Lake was 0.08 mg per liter, almost identical to Council Grove Reservoir, but considerably less than the other two impoundments. John Redmond Reservior was known to receive periodic effluents from commercial livestock feedlots. Nitrate means for the three reservoirs were 0.95, 0.37, and 0.90 mg per liter, respectively. Wyandotte County Lake had a mean reading of 9.95 mg per liter for the same time of year. The over-all phosphate mean for Wyandotte County Lake was 0.16 mg per liter; the nitrate mean was 11.4 mg per liter.

TABLE VII. Orthophosphate and nitrate nitrogen in Wyandotte County Lake by depth, concentrations in mg per liter.

Date	Phosphate		Nitrate	
	1 m	6 m	1 m	6 m
3/30	0.07	0.07	15.0	17.0
5/4	0.06	0.08	17.0	6.0
6/2	0.07	0.07	11.0	15.0
6/22	0.06	0.07	9.0	8.5
7/12	0.07	0.14	7.5	7.5
7/26	0.06	0.14	7.0	10.0
8/10	0.07	0.09	10.0	10.0
9/17	0.21	0.23	10.5	10.5
10/8	0.17	0.17	11.0	11.5
10/28	0.09	0.60	18.0	11.0
11/18	0.09	0.09	13.0	15.0

The summer mean diversity per individual ($\bar{d}$) of Council Grove, John Redmond, and Marion Reservoirs, based on zooplankton, was 2.86, 2.57, and 2.50, respectively. Organisms in all three reservoirs were exposed to moderate stress on the basis of the $\bar{d}$ assessment. Based on benthic macroinvertebrates at comparable dates and depths, Wyandotte County Lake produced a $\bar{d}$ value of 1.68. It is possible that the much higher nitrate level in Wyandotte County Lake is significant in the cause of the lower $\bar{d}$ value, since the phosphate, sulfate, and ammonia levels are lower than the other three impoundments, and the pH and dissolved oxygen values indicate favorable conditions. As a further means of comparison, Hulen and Angino (1979) cited the FWPCA (now EPA) in 1968 as stating that the total phosphate in flowing streams should not exceed 0.30 mg/liter. The same agency set the acceptable drinking water standard regarding nitrate nitrogen at a maximum of 45 mg/liter. Wyandotte County Lake fits easily beneath these limits regarding both nutrients. From the viewpoint of the aquatic biologist, the unpolluted range for phosphate is from 0.01 to 0.03 mg per liter. High phosphate ranges from 0.03 to 0.30 mg per liter. A normal ratio between nitrate and phosphate is 10 nitrate : 1 phosphate (Ransom, 1973). Compared to these categories, the yearly mean of 0.16 mg per liter phosphate in Wyandotte County Lake is high, but not exceptionally so, and the lake ratio of 70 nitrate : 1 phosphate indicates an unusual source of nitrate. High nitrate levels in reservoirs are sometimes due to nitrogen fixation by Cyanophyta when there is no other important known source of nitrate (Prophet et al., 1970). The water color in Wyandotte County Lake sometimes suggested the presence of blue-green organisms. There is no other known source for the observed high nitrate levels, with the possible exceptions of septic tanks, normal allochthonous organic material and, perhaps, deliberate fertilization.

Ammonia

Ammonia nitrogen was relatively low when compared to other eastern Kansas impoundments. Concentrations are shown in Table VIII for depths of one and six meters. The yearly mean for readings taken at depths of one and 6 meters was 0.73 mg/liter. This value is below the 1.0 mg per liter standard for unpolluted water. The yearly maximum concentration was 1.26 mg per liter, recorded from a six meter sample in mid-November. The yearly minimum concentration was 0.18 mg per liter, recorded from surface samples in early June, late July, and early August. Ammonia concentrations tended to be highest at both the surface and at six meters in early spring and late fall. Concentrations were lowest at those depths from May through July. No samples were taken at 15 meters, but ammonia would have undoubtedly been high at that depth, especially from late July to mid-September when the oxygen concentration at that depth ranged from 0.0 to 0.5 mg per liter. Funk (1973) reported ammonia concentrations for John Redmond Reservoir by one-meter increments to a depth of 4 meters. The annual mean of all depths combined was 1.37 mg per liter. Prophet et al. (1970) reported concentrations for June through August, 1968, from Council Grove, John Redmond, and Marion reservoirs as 0.70, 0.74, and 1.00 mg per liter, respectively. The mean depth of the deepest of the three reservoirs was 4.4 meters. During the same time of year, Wyandotte County Lake produced a mean concentration of 0.50 mg per liter to depths including six meters. Mean ammonia concentrations were compared by depth using the t-test at $p = .05$ level of significance. There were no significant differences in surface concentrations, bottom concentrations, or surface-to-bottom concentrations.

TABLE VIII. Sulfate and ammonia nitrogen concentration by depth in Wyandotte County Lake at selected depths, concentration in mg. per liter.

Date	Sulfate		Ammonia	
	1 m	6 m	1 m	6 m
3/30	22.0	21.8	1.09	1.08
5/4	21.5	20.0	0.54	0.68
6/2	18.0	16.5	0.18	0.58
6/22	21.8	17.5	0.42	0.83
7/12	18.0	16.5	0.30	0.36
7/26	15.0	12.5	0.18	0.80
8/10	0.33	0.28	0.18	1.19
9/17	15.0	16.5	0.77	0.80
10/8	12.5	12.0	0.77	0.74
10/28	20.0	20.0	1.11	1.19
11/18	20.0	19.5	1.08	1.26

Sulfate

Sulfate was generally low throughout the study when compared to a normal standard of from 10 to 70 mg/liter (Table VIII). Concentrations ranged from 12.0 to 22.0 mg per liter, with a combined mean from depths of one and six meters of 17.8 mg per liter. No seasonal trends were apparent. Sulfate enters a body of water with rain or through solution of sulfate compounds in the watershed. A short supply of the anion will lower primary production by inhibiting the growth of phytoplankton. Sulfate is the sulfur source for protein metabolism in producer organisms (Reid, 1961). Prophet et al. (1970) reported sulfate concentrations from 16.7 to 178.3 mg per liter for the three Neosho River impoundments, and Funk (1973) reported data showing a yearly mean of 57.4 mg per liter in John Redmond Reservoir, for depths to four meters. Although sulfate was relatively low in Wyandotte County Lake, it was not limiting since concentrations remained above 12.0 mg per liter thoughout the study. At depths approaching 15 meters and during anoxia of the hypolimnion, sulfur bacteria were reducing sulfate to hydrogen sulfide. The characteristic odor of the gas accompanied dredge hauls lifted from those depths. Sulfate concentrations were compared using the t-test at $p = .05$ level of significance. There were no significant differences among surface concentrations, bottom concentrations, or surface-to-bottom concentrations.

Nitrite

Nitrite was slightly more abundant than the unpolluted standard of 0.001 to .01 mg per liter. Concentrations ranged from 0.027 to 0.024 mg per liter, with a combined mean from depths one and six meters of 0.026 mg/liter. No seasonal trend was apparent, but the data suggest a tendency to be slightly lower during the summer.

Trace Metals

Two trace metals, copper and iron, were measured at the beginning and end of the study. Copper ranged from 1.09 to 1.95 mg per liter, while iron ranged from 0.06 to 0.1 per liter. Both are insoluble in oxidized states and in intensely reducing environments where they form sulfides. Hydrous copper sulfate has long been used as an algacide in aquatic systems. It accumulates as copper carbonate in the sediments of hard water lakes where it may be detrimental to bottom fauna (Cole, 1975).

SUMMARY

A limnological study was conducted on the 135 ha Wyandotte County Lake, located in the County Park at 91st Street and Leavenworth Road in Kansas City, Kansas. Water quality data were established by determining physicochemical parameters and sampling the benthic macroinvertebrates community from 1 June 1977 to 18 November 1977 and from 20 March 1978 to 5 May 1978. Seven stations were established over the lake at depths from one to 15 meters. A total of 28 taxa consisting of 11,897 individuals of benthic macroinvertebrates was collected. Eight genera of zooplankton were collected. Individual species diversity (d) indices for benthic macroinvertebrates were calculated for each station by depth and mean monthly variations in $\bar{d}$ were calculated with all depths combined. Annual d values ranged from 1.0 to 1.9, with an annual mean of 1.4, indicating moderate stress in the aquatic system. Coliform counts averaged 62 per 100 ml. Thermal conditions were as expected for seasonal variations in a moderately-deep temperate lake with a spring and fall holomixis and a well-established direct stratification in mid-summer. Oxygen was present in the summer at concentrations from 2.5 to 7.7 mg per liter, and at depths from 8 to 15 meters oxygen was likely to depleted. Secchi disc transparency varied from 0.53 to 2.50 meters. The mean indicated the lake euphotic zone averaged 4.66 meters. Nitrate was high, ranging from 6.0 to 17.0 mg per liter, with an annual mean of 11.41 mg per liter. Phosphate ranged closer to normal, with a minimum of 0.06 and a maximum of 0.23 mg per liter. Mean annual phosphate was 0.16 mg per liter. The nitrate : phosphate ratio was 70 : 1, suggesting an important outside source of nitrate. Ammonia nitrogen showed a yearly mean of 0.73 mg per liter, within the limits for unpolluted water. Sulfate was low, ranging from 12.0 to 22.0 mg per liter, with an annual mean to 6 meters of 17.8 mg per liter. Nitrite was slightly above unpolluted standards, ranging from 0.001 to 0.26 mg per liter, with an annual mean of 0.026 mg per liter. Trace metals were measured at the beginning and end of the study. Copper ranged from 1.09 to 1.95 mg per liter. Iron ranged from 0.06 to 0.1 mg per liter. Wyandotte County Lake appeared to be a moderately enriched system.

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