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Physiochemical and bacteriological conditions along with the macroinvertebrate community structure were studied to evaluate water quality of the Big Blue River, in southeastern Nebraska. Samples were taken between November 7, 1978, and December 19, 1979, at six stations from the headwaters to lower reaches of the river. Some sample sites were below specific municipal and industrial effluents to evaluate better their impact on water quality. Parameters measured included pH, temperature, dissolved oxygen, suspended solids, conductivity, biochemical oxygen demand, nitrate, ammonia, and fecal coliforms. Dissolved oxygen and nitrate were significantly different ($p<0.05$) between stations, with the headwaters station exhibiting the greatest difference in water quality. Fecal coliforms were substantially higher at stations below Crete. The macroinvertebrate fauna comprised 42 and 66 taxa collected with Ekman grabs and multiplate artificial substrates, respectively. Average diversity values, using the Shannon-Weaver index, indicated all stations would be categorized as moderately polluted. Taxa collected at the stations showed a great deal of homogeneity. An exception was the headwaters site where pollution-associated taxa were found in abundance. Seasonal changes were an apparent factor affecting diversity of the macroinvertebrates. The results collected provide useful baseline information for future evaluation of water quality trends of the Big Blue River.

† † †

## INTRODUCTION

Stream environments are subjected to the effects of water resource developments and land use practices occurring in their watersheds. With the increased utilization of waters in recent years for many purposes, it is important to assess changes in water quality, especially since some minimum quality-standard is necessary before water can be used. Aquatic invertebrates, being constantly subjected to these changes, are an integrated expression of water quality over time. They are sensitive even to subtle changes and, consequently, are excellent indicators of pollution (Wilm and Dorris, 1968).

Published accounts of water quality studies are lacking from the Big Blue River. The present study was designed to describe water quality changes in the Big Blue River in southeastern Nebraska, as it flows from its headwaters to lower reaches. One of the primary objectives was to assess the changes over a one-year period in the benthic faunal assemblages and selected physiochemical parameters of the Big Blue River. Another objective was to document specific effects from municipal and industrial effluents on water quality by collecting data in close proximity to selected discharges. It is hoped the data collected will provide useful baseline information to facilitate interpretation of water quality trends of the Big Blue River.

## DESCRIPTION OF STUDY AREA

The Big Blue River (Fig. 1) drains approximately 11,810 km$^2$ in southeastern Nebraska (Anonymous, 1979a). The river extends into northeastern Kansas where it flows into the Kansas River near Manhattan.

The basin is well drained with substantial volume of flow in its lower reaches (Fig. 2). Using Horton's (1945) classification scheme, this river would be of the sixth order.

The loess soils and relatively flat topography of the basin are generally suited for intensive agriculture. Approximately 81% of the land area in the basin is under cultivation (Anonymous, 1979a). Irrigation is common in the basin with surface withdrawals from the Big Blue River substantially reducing the flow during summer months. Irrigation return flow also contributes nutrients and pesticides to the river.

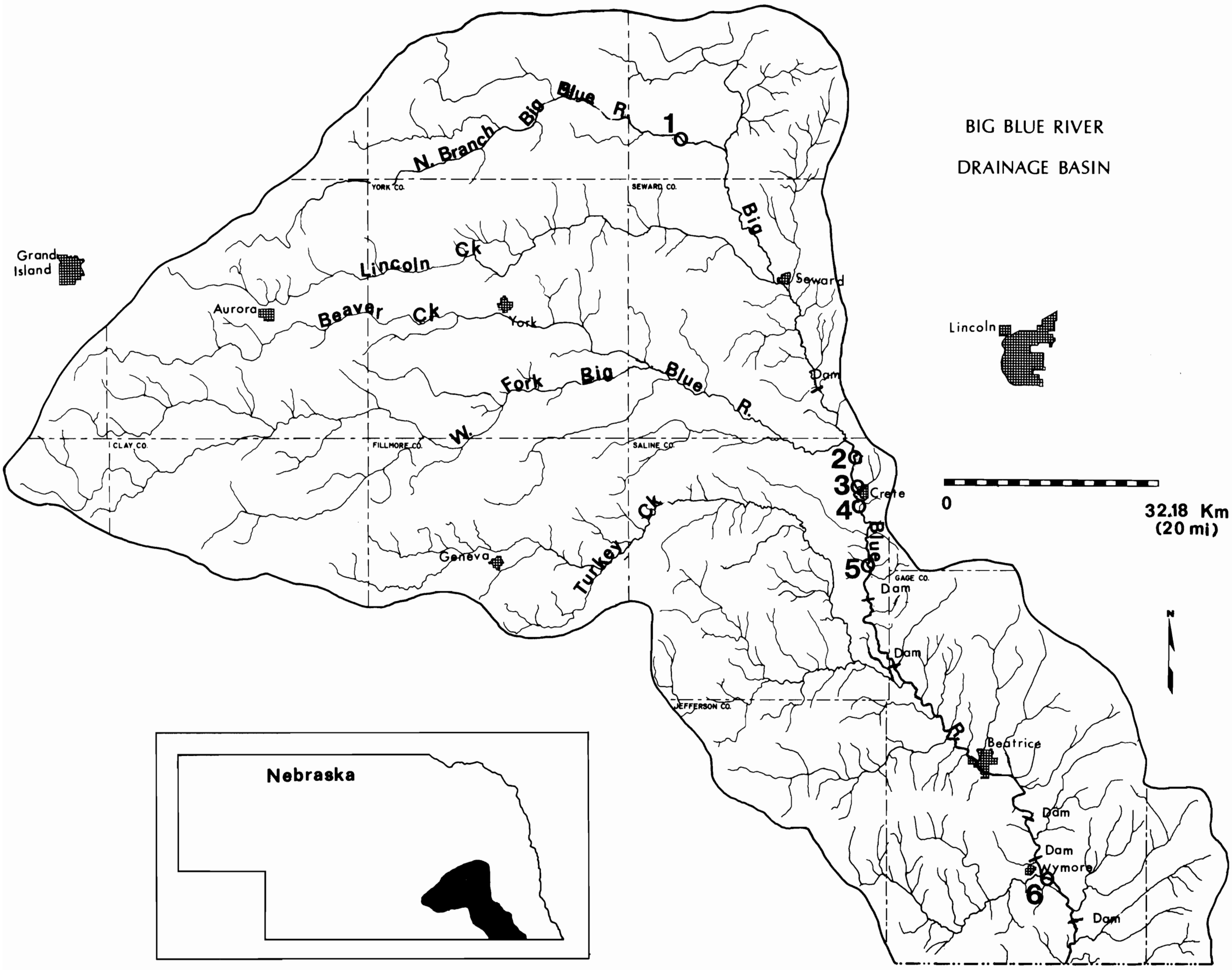


FIGURE 1. The Big Blue Basin in southeastern Nebraska showing the six sampling sites on the Big Blue River.

Livestock production is a major activity in the Big Blue Basin with more than 200 registered feedlots in the basin (Anonymous, 1976a). The accumulative effects of non-point runoff from numerous small livestock grazing and feeding activities undoubtedly is deleterious to the river's water quality.

Agribusiness, industrial, and sewage effluents enter at various points along the river. Three discharges of significance to this study, Allen Products Company (known as Alpo Pet Food Plant), Crete Municipal Sewage Treatment Facility, and Farmland Foods, are located in or near Crete, Nebraska. Allen Products employs secondary treatment with chlorination and typically discharged 0.01-0.02 $m^3$/sec during the study period. Crete's municipal sewage plant serves approximately 4,500 residents and discharges approximately 0.02-0.03 $m^3$/sec. Farmland Foods, a livestock processing plant, employs secondary treatment through chlorination. Discharge for the study period ranged 0.03-0.04 $m^3$/sec.

Six hydroelectric dams no longer in use located on the mid- to lower-reaches of the river impede flow for many kilometers (Fig. 1).

Annual precipitation ranges from 63.5 to 76.2 cm/yr for the basin with the majority falling during the spring and summer months (Anonymous, 1976a).

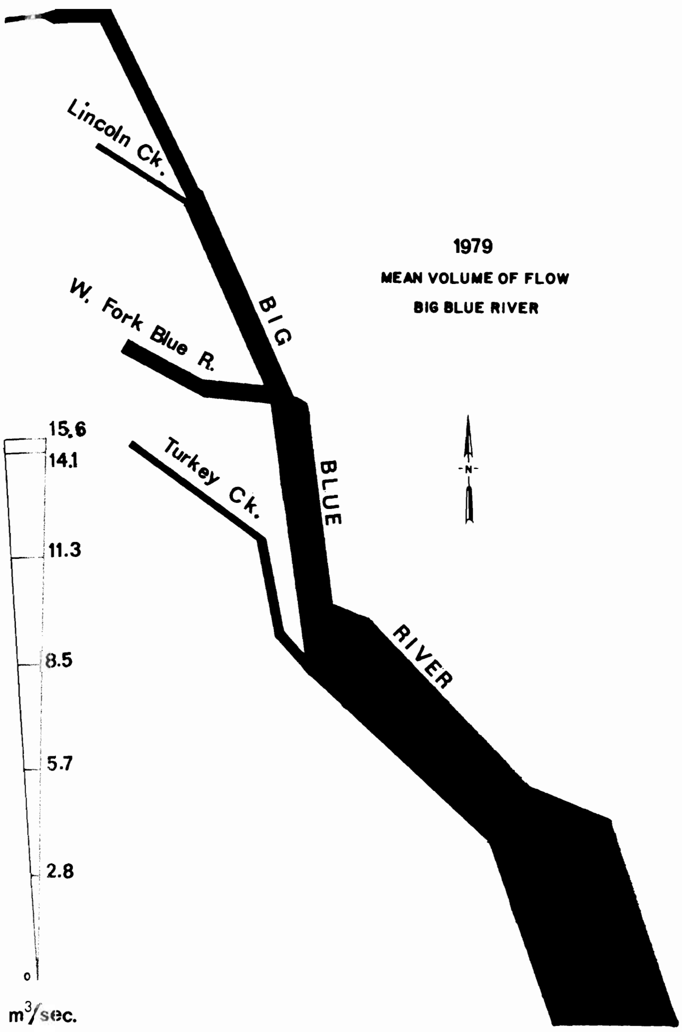


FIGURE 2. Mean volume of flow of the Big Blue River from its headwaters to the Nebraska–Kansas State Line, October, 1978, to September, 1979 (*after* Anonymous, 1979b).

Overland runoff from precipitation produces the primary source of flow with groundwater contributing a small amount to the total. The Big Blue River frequently exhibits large fluctuations of flow during heavy rainfall. During heavy runoff, massive amounts of sediment and organic matter characteristically are transported by the river. Channelization and various debris used for bank stabilization are common sights along the banks of the river. Bliss and Schainost (1973) reported that approximately 5.4% of original stream miles were lost to channelization as of 1973.

## DESCRIPTION OF STATIONS

Six stations were selected, based on their year-round accessibility, at various locations along the river for the collection of samples (Fig. 1). The sites were chosen to describe the impact of specific discharges from Crete, Nebraska, and to represent best the overall water quality of the Big Blue River from headwaters to lower reaches. All stations were far enough below selected discharges to ensure complete mixing had taken place.

*Station 1.* NE¼ Sec. 15, T. 13 N., R. 1 E., Butler County, approximately 0.8 km east of Surprise, Nebraska. This site represents the most upstream station. The stream is relatively small, 1.5–3.0 m in width. The gradient of the river is typically low (<30 cm/sec stream velocity) with the bottom type consisting primarily of muck and silt.

*Station 2.* SE¼ Sec. 9, T. 8 N., R. 4 E., Saline County, 4.8 km north and 1.2 km west of 13th and Main streets in Crete. This station represents the mid-reaches of the river above the discharges under consideration at Crete. Substrate is shifting sand in the main channel with scattered patches of silt and clay. Typical current velocities averaged 30–45 cm/sec. Stream width varies between 20 and 30 m.

*Station 3.* SE¼ Sec. 33, T. 8 N., R. 4 E., Saline County, immediately west of Crete at the railroad bridge. This site represents water quality approximately 0.8 km downstream of Alpo Pet Foods of Crete. Substrate at this site is composed of shifting sand with some exposed gravel bars and compacted clay. Average current velocity measured 40–60 cm/sec.

*Station 4.* SE¼ Sec. 3, T. 7 N., R. 4 E., Saline County, at U.S. Geological Survey (USGS) gauging station 3.2 km south of Crete. This site is 2.6 km below the Crete Sewage Treatment effluent. Substrate at this site is composed of shifting sand bottom with scattered areas of clay and silt. Average current velocities measured 30–45 cm/sec.

*Station 5.* NE¼ Sec. 27, T. 7 N., R. 4 E., Saline County, 9.0 km south and 0.6 km east of Crete. This site is approximately 2.25 km downstream from Farmland discharge. Substrate at this site is typically sand with clay and silt patches. Average current velocity is usually 30–45 cm/sec. The stream at this point is typically 20–30 m wide.

*Station 6.* NE¼ Sec. 24, T. 1 N., R. 7 E., Gage County, 0.8 km west of Barneston. This station is part of the Department of Environmental Control's ambient network. Although the chemical parameters were sampled at this site, biologically important variables such as current and substrate were not comparable to the other five stations. Therefore it was necessary to take the biological samples at a site approximately 7 km upstream (NE¼ Sec. 27, T. 2 N., R. 7 E.). At this location the river is 30–50 m wide and the average current velocity is 40–60 cm/sec. Substrate consists primarily of shifting sand with scattered gravel and clay bars.

## METHOD AND MATERIALS

Physiochemical, bacteriological, and macroinvertebrate samples were collected at irregular intervals from November 7, 1978, through December 19, 1979. Although approximate monthly samples were taken, stations 1 and 6 were not sampled an equal number of times for macroinvertebrates compared with other stations. These two sites were added later in the sample program to provide additional information for comparison with other stations. Water quality parameters measured in the field from midstream grabs were pH, water temperature, and dissolved oxygen. A portable pH meter was used to measure hydrogen-ion concentration. Determinations of dissolved oxygen were made by the Azide modification of the Winkler method. Remaining parameters, determined in the laboratory, were suspended solids, conductivity, biochemical oxygen demand, nitrate, ammonia, and fecal coliforms. All determinations were made using procedures outlined in *Standard Methods* (Anonymous, 1976b). Physiochemical and bacteriological data for each site were compared by one-way analysis of variance. Current velocity was measured using a pygmy flow meter. Stream discharges were obtained through USGS gauging stations. Weather and water conditions, substrate, and ice cover usually were assessed at each site visit.

A 0.023 $m^2$ Ekman bottom sampler was used to collect quantitative benthos samples at each site on each sample date. These samples were taken in different substrates at random to increase the likelihood of collecting different taxa. Ekman grab samples were pooled for each site on each sample date and numbers of organisms per square meter calculated. Samples were reduced in the field by using a #70 (212 $\mu$m) sieve. Organisms and remaining debris were then preserved in a 10% formalin solution.

Two artificial substrates consisting of seven, 7.62-cm squares, by 0.64 cm thick plates of tempered masonite separated by 1.27-cm square spacers were set at each station to sample macroinvertebrates qualitatively. Hester and Dendy (1962) used a similar multiple plate sampler to collect macroinvertebrates to determine water quality. Each sampler used had a surface area of 948 $cm^2$. Two samplers were set in the main channel at each station. Samplers were anchored to fence posts and/or cement blocks using clips to facilitate collection. These were checked after at least four weeks of colonization. Samplers were retrieved with the aid of a dip net with 1000 $\mu$m meshing to ensure organisms were not lost. Samplers were then scraped and rinsed on site and returned to the stream. These samples were concentrated with a #30 sieve (595 $\mu$m) and preserved with 10% formalin solution.

Benthos was processed in the laboratory by examination under a dissecting microscope. The entire sample was examined under 7-30X magnification. In a few exceptions where samples contained large numbers of certain organisms, *i.e.,* chironomids and trichopterans, subsamples were randomly taken of the taxon. Each subsample was enumerated and identified to more specific taxa, and this estimate was expanded to a total estimate.

Invertebrates were identified to the lowest practicable taxonomic level, usually genus. Kaesler, Herricks, and Crossman (1978) found that generic or familial diversity reveals nearly as much about the condition of a macroinvertebrate community in streams as species diversity. Chironomid identification was aided by using CMC-10 mounting media and a compound microscope as outlined by Parrish (1975).

Taxonomic identifications were made with the aid of works by Mason (1973); McCafferty (1975); Edmunds, Jensen, and Berner (1976); Wiggins (1977); Merritt and Cummins (1978); Oliver, McClymott, and Roussel (1978); and Pennak (1978).

The Shannon-Weaver (1963) equation, $\overline{H} = -\Sigma P_i \log_2 P_i$, where: $P_i$ = the number of individuals in each taxon divided by the total individuals for all taxa was used to estimate total community diversity. This diversity index was applicable only to the multiplate artificial substrates. According to Kaesler, Herricks, and Crossman (1978), small samples ($<$100 individuals), such as those characteristically collected with Ekman grabs during this study, do not satisfy requirements of the equation.

## RESULTS AND DISCUSSION

### Physiochemical Characteristics

There were two significant differences in physiochemical characteristics measured among the six stations (Table I). Dissolved oxygen and nitrate values at station 1 were substantially different from those at the other sites. At station 1, nine of 13 oxygen values were less than 5 mg/1, generally accepted as the minimum concentration required for healthy aquatic life. All other sites had dissolved oxygen levels at or near saturation for the study period.

Lower values for nitrate generally were recorded at station 1 than at stations 2-6. Values at station 1 ranged from 0 to 2.3 mg/1 with a mean of 1.0 mg/1. The lowest value for stations 2-6 was 1.1 mg/1 with the means for these stations ranging from 2.0 to 2.4 mg/1. The higher nitrate values downstream of station 1 could be the result of the accumulation of effluents from municipalities and agricultural runoff.

Total ammonia and biological oxygen demands were somewhat higher at station 1 than at the remaining sites although the differences were not statistically significant.

TABLE I. Mean values and ranges of physiochemical characteristics of six sites on the Blue River, November 1978 to December 1979.

| Parameter | Stations 1 | 2 | 3 | 4 | 5 | 6 | F† Value |
|---|---|---|---|---|---|---|---|
| Temperature (C) | (14)* 7.8 0.0-27.0 | (11) 9.2 0.5-24.5 | (11) 9.9 0.5-24.5 | (11) 9.9 0.5-23.0 | (10) 10.4 0.5-23.0 | (13) 6.5 0.0-22.5 | 0.369 |
| Dissolved Oxygen (mg/1) | (13) 3.9 0.5-8.6 | (12) 9.6 6.8-12.2 | (11) 9.3 6.7-14.2 | (12) 9.7 7.0-13.6 | (12) 9.0 4.3-14.2 | (13) 10.5 7.8-14.9 | 13.467** |
| pH | (10) 7.2 6.3-7.9 | (10) 7.8 6.9-8.3 | (10) 7.8 7.0-8.3 | (10) 7.6 6.8-8.1 | (10) 7.6 6.8-8.1 | ( 8) 7.7 7.1-8.0 | .2.852 |
| Suspended Solids (mg/1) | (11) 371 22-2,810 | (10) 369 6-1,660 | (10) 332 7-1,180 | ( 9) 371 1-1,660 | ( 9) 352 6-1,640 | ( 8) 256 8-1,780 | 0.062 |
| Conductivity (μmhos/cm) | (14) 484 150-760 | (12) 482 170-650 | (12) 485 170-670 | (12) 586 170-660 | (12) 500 160-740 | (13) 536 130-760 | 0.201 |
| Nitrate (mg/1) | (14) 1.0 0.0-2.3 | (12) 2.2 1.1-3.0 | (12) 2.1 1.3-2.7 | (12) 2.0 1.4-2.9 | (12) 2.4 1.3-3.2 | (13) 2.1 1.3-2.8 | 7.813** |
| Total Ammonia (mg/1) | (14) 0.88 0.30-5.00 | (12) 0.40 0.01-1.40 | (12) 0.44 0.02-1.40 | (12) 0.47 0.03-1.40 | (12) 0.47 0.02-1.30 | (13) 0.35 0.02-1.10 | 1.026 |
| BOD (mg/1) | (14) 9.8 2.5-33.0 | (12) 5.3 2.4-15.1 | (12) 5.8 0.7-15.8 | (12) 6.3 2.4-15.8 | (12) 6.0 0.8-15.9 | (13) 5.6 1.9-16.3 | 1.630 |
| Fecal Coliform (100ml) | (14) 3,325 10-20,000 | (11) 1,356 93-6,800 | (12) 1,127 0-5,100 | (12) 8,594 900-60,000 | (12) 9,518 28-75,000 | (13) 12,574 5-60,000 | 1.304 |

†F values are from analysis of variance for comparison of the means.

*Values in parentheses are the number of measurements taken for the parameter.

**Significant difference at the 0.05-level between stations.

At station 1 the highest value for ammonia was 5.0 mg/1 whereas the highest value for stations 2-6 was 1.4 mg/1. At all the sites the total ammonia concentrations were highest in the spring months (March-May) and lowest in the summer months (June-September).

Un-ionized ammonia, the fraction toxic to aquatic life, was figured taking into consideration temperature and pH as outlined by Thurston, Russo, and Emerson (1974). No value exceeded the recommended water quality criterion of 0.025 mg/1, the level above which is considered harmful to freshwater aquatic life (Anonymous, 1970).

Station 1 had the highest biochemical oxygen demand of 33 mg/1 while stations 2-5 never exceeded 16.3 mg/1. The difference between the chemical parameters in the upper

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TABLE II. (Continued).

| Taxon | Station 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Hemiptera | | | | | | |
| Corixidae | | | | X | | |
| Odonata | | | | | | |
| *Gomphus* sp. | | | | | X | |
| Plecoptera | | | | | | |
| *Isoperla* sp. | | X | X | | | |
| Tricoptera | | | | | | |
| *Cheumatopsyche* sp. | | X | X | | | X |
| *Hydropsyche* sp. | | X | X | | | X |
| *Polycentropus* sp. | | | | | X | |
| *Potamyia* sp. | | X | X | X | X | X |
| Nematoda | X | | | | | X |

For the most part the taxa collected were facultative organisms (those having a wide range of tolerance and frequently associated with moderate levels of organic pollution) or clean water organisms intolerant of even moderate reductions in dissolved oxygen. One exception was station 1, where large numbers of pollution-associated taxa were collected. Some of these were: *Procladius* sp. (Chironomidae), Oligochaeta (aquatic worms), *Physa* sp. (pulmonate snails), and Hirudinea (leeches). Mason, Anderson, Kreis, and Johnson (1970) found these taxa capable of withstanding extended periods of low dissolved oxygen.

It was apparent from the large numbers of omnivorous and filter-feeding macroinvertebrates collected, especially on artificial substrates, that the Blue River receives a considerable amount of organic enrichment.

Table IV presents the frequency of occurrence and average number of organisms collected for the 26 most common taxa (collected from at least five stations) using both collecting techniques. There is a striking difference in the faunal assemblage of station 1 and the downstream sites. Several taxa which occurred at stations 2–6 were not collected at station 1. Even though collecting effort was less for station 1, these common taxa should have been collected if they occurred at this site. The reduced number of taxa at this uppermost station indicates an unfavorable habitat for many taxa common in other parts of the river. The average number of individuals collected per visit was, in most cases, also less at

TABLE III. Macroinvertebrate taxa from artificial multiplate samplers collected at six stations on the Big Blue River, November 7, 1978, to December 19, 1979.

| Taxon | Station 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Annelida | | | | | | |
| Hirudinea | X | | | | | |
| Oligochaeta | X | X | X | X | X | X |
| Arthropoda | | | | | | |
| Arachnida | | | | | | |
| Hydracarina | X | X | | X | | |
| Crustacea | | | | | | |
| Amphipoda | | | | | | |
| *Gammarus* sp. | | X | | | | X |
| Decapoda | | | | | | |
| *Oronectes* sp. | X | | X | X | X | |
| Insecta | | | | | | |
| Coleoptera | | | | | | |
| *Dubiraphia* sp. | X | | | | | |
| *Hydroporus* sp. | | X | | | | |
| *Macronychus* sp. | | X | X | X | X | |
| *Stenelmis* sp. | X | X | X | X | X | X |
| Diptera | | | | | | |
| Ceratopogonidae | | | | | | |
| *Palpomyia* sp. | X | X | X | X | X | X |
| Chironomidae | | | | | | |
| *Ablabesmyia* sp. | | X | X | X | | |
| *Chironomus* sp. | X | X | | | X | |
| *Corynoneura* sp. | | X | | | | |
| *Cricotopus* sp. | | X | X | X | X | |
| *Cryptochironomus* sp. | X | X | | | | |
| *Dicrotendipes* sp. | X | X | X | X | X | X |
| *Eukiefferiella* sp. | X | X | | | | |
| *Glyptotendipes* sp. | X | | | | | X |
| *Larsia* sp. | | X | X | X | X | |
| *Orthoclodius* sp. | X | X | X | X | X | X |
| *Parachironomus* sp. | X | | | X | | |
| *Paralauterborniella* sp. | X | | | | X | |
| *Polypedilum* sp. | X | X | X | X | X | X |
| *Procladius* sp. | X | | | | X | |
| *Psectrocladius* sp. | X | X | X | X | X | X |
| *Pseudochironomus* sp. | | | | | | X |
| *Rheotanytarsus* sp. | X | X | X | X | X | X |
| *Stenochironomus* sp. | | X | | | X | X |
| *Tanytarsus* sp. | X | X | X | X | X | X |
| *Thienemannimyia* – group | X | X | X | X | X | X |
| *Tribelos* sp. | X | | | | | |
| *Trichocladius* sp. | | X | X | X | X | X |
| *Trissocladius* sp. | | X | | | | |
| Empididae | | X | X | X | X | X |
| Psychodidae | | | | | | |
| *Pericoma* sp. | | X | | | | |
| Rhagionidae | | | | | | |
| *Atherix* sp. | | X | | | | |
| Simuliidae | | | | | | |
| *Simulium* sp. | | X | X | X | X | X |
| Stratiomyidae | | | X | | | |

TABLE III. (Continued).

| Taxon | Station 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Ephemeroptera | | | | | | |
| *Baetis* sp. | X | X | X | X | X | X |
| *Brachycerus* sp. | | X | | | X | |
| *Caenis* sp. | X | X | X | X | X | X |
| *Heptagenia* sp. | | X | X | X | X | X |
| *Hexagenia limbata* | | X | | | | |
| *Isonychia* sp. | | X | X | X | X | X |
| *Stenacron* sp. | X | X | X | X | X | X |
| *Stenonema* sp. | | X | X | X | X | X |
| *Tricorythodes* sp. | | X | X | X | X | X |
| Hemiptera | | | | | | |
| Corixidae | | X | | | | |
| Veliidae | | | | | X | |
| Megaloptera | | | | | | |
| *Corydalus cornutus* | | X | | X | X | X |
| Odonata | | | | | | |
| *Argia* sp. | X | | | | X | |
| *Coenagrion* sp. | | | | X | | |
| *Gomphus* sp. | | X | X | X | | |
| *Ophiogomphus* sp. | | | | X | | |
| Plecoptera | | | | | | |
| *Acroneuria* sp. | | | | | | X |
| *Isoperla* sp. | | X | X | X | X | |
| *Taeniopteryx* sp. | | | X | X | | |
| Tricoptera | | | | | | |
| *Cheumatopsyche* sp. | X | X | X | X | X | X |
| *Cyrnellus fraternus* | X | | | | | |
| *Hydropsyche* sp. | | X | X | X | X | X |
| *Nectopsyche* sp. | | X | X | X | X | |
| *Polycentropus* sp. | | X | X | X | X | |
| *Potamyia flava* | | X | X | X | X | X |
| Mollusca | | | | | | |
| Gastropoda | | | | | | |
| *Gyraulus* sp. | X | | | | | |
| *Physa* sp. | X | | | | | |
| Nematoda | | X | | X | | |

station 1 than at the remaining stations. Reasons for the depauperate community at this site may be the combined physical effects of reduced current, muck and silt substrate, in combination with pollutional effects magnified by little flow.

Of the ephemeropterans collected, *Stenonema* sp. was the most abundant and frequently collected. Unlike at the other sites, *Stenacron* sp. and *Caenis* sp. dominated the mayflies at station 1. *Isonychia* sp. was commonly collected, with unusually large numbers found on artificial substrates at stations 2-6 during the August collections. Ekman grabs often contained many burrowing mayflies, especially when compacted clay substrate was sampled. *Pentagenia vittigera* was the most common burrowing mayfly taken. *Brachycerus* sp. and *Tortopus primus* were rarely collected mayflies, represented by only a few individuals.

Trichopterans were very frequently collected. Hydropsychidae, of which *Cheumatopsyche* sp., *Potamyia* sp., and *Hydropsyche* sp. are members, was the most commonly collected family. This family is very sensitive to silt pollution. At station 1 there was only one genus, *Cheumatopsyche,* collected which was represented by few individuals. Often a fine layer of silt covered the artificial substrate plates at station 1, which could offer one explanation for this reduction. It is interesting to note that the most abundant caddis fly belonged to the genus *Potamyia* except at station 6 where *Hydropsyche* dominated in total numbers. Perhaps the catchment of silt by the old hydroelectric dams favors this genus. *Cyrnellus fraternus* was collected only at station 1. According to Mason, Lewis, and Anderson (1971) this species occurs in warm-water streams and is tolerant of mild forms of pollution.

The plecopterans, which are considered to be some of the best clean-water indicators, were rarely collected and never abundant. Only during fall or winter months (November and December) were they found. *Isoperla* sp. was the most frequently collected stonefly occurring at four of the sites, and in all cases the nymphs were early instars.

Megalopterans, of which *Corydalus cornutus* was the only species collected, occurred at four of the stations. This species was never abundant, being found only on artificial substrates. Hellgramites characteristically need well oxygenated waters to survive which indicates relatively good water quality exists at sites collected.

*Stenelmis* sp. was the most common beetle larvae collected. Members of *Stenelmis* were abundant only at station 1.

Chironomidae was by far the most abundant and diverse taxon of invertebrates collected. The midges *Polypedilum* sp., *Rheotanytarsus* sp., *Orthocladius* sp., and *Thienemannimyia*-group were ubiquitous at all the locations sampled.

*Simulium* was frequently collected except at station 1, where it was not found. Little current and heavy sediment

TABLE IV. Frequency of occurrence and average number of common taxa (five of six stations found) collected from the six stations on the Big Blue River (November, 1978-December, 1979). This table represents all methods of collection pooled. Numbers in parentheses are average number collected for all samples.

| Taxon | Station 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Annelida | | | | | | | | | | | | |
| Oligochaeta | 100 | (52) | 100 | (22) | 82 | (31) | 90 | (29) | 100 | (42) | 57 | (20) |
| Arthropoda | | | | | | | | | | | | |
| Insecta | | | | | | | | | | | | |
| Coleoptera | | | | | | | | | | | | |
| *Stenelmis* sp. | 60 | (29) | 45 | (5) | 36 | (3) | 50 | (3) | 27 | (4) | 57 | (3) |
| Diptera | | | | | | | | | | | | |
| Ceratopogonidae | | | | | | | | | | | | |
| *Palpomyia* sp. | 80 | (4) | 45 | (7) | 82 | (5) | 30 | (2) | 55 | (2) | 28 | (1) |
| Chironomidae | | | | | | | | | | | | |
| *Cryptochironomus* sp. | 40 | (15) | 27 | (6) | 36 | (11) | | | 10 | (5) | | |
| *Dicrotendipes* sp. | 60 | (42) | 18 | (8) | 10 | (66) | 10 | (1) | 18 | (50) | 28 | (197) |
| *Larsia* sp. | | | 63 | (8) | 45 | (12) | 20 | (5) | 27 | (24) | 14 | (4) |
| *Orthocladius* sp. | 20 | (2) | 54 | (43) | 63 | (363) | 50 | (177) | 45 | (74) | 28 | (10) |
| *Paralauterborniella* sp. | 40 | (52) | 10 | (4) | | | 10 | (1) | 18 | (5) | 28 | (1) |
| *Polypedilum* sp. | 60 | (30) | 100 | (75) | 82 | (71) | 100 | (37) | 90 | (54) | 100 | (131) |
| *Psectrocladius* sp. | 60 | (7) | 10 | (37) | 27 | (18) | 40 | (14) | 18 | (3) | 14 | (96) |
| *Rheotanytarsus* sp. | 60 | (19) | 63 | (26) | 55 | (25) | 60 | (10) | 55 | (37) | 85 | (277) |
| *Tanytarsus* sp. | 20 | (5) | 54 | (8) | 36 | (67) | 40 | (4) | 36 | (26) | 14 | (96) |
| *Thienemannimyia* – group | 100 | (46) | 63 | (12) | 36 | (13) | 60 | (16) | 72 | (11) | 85 | (9) |
| *Trichocladius* sp. | | | 45 | (4) | 27 | (11) | 60 | (7) | 36 | (3) | 14 | (10) |
| Empididae | | | 36 | (2) | 45 | (3) | 50 | (3) | 36 | (6) | 57 | (3) |
| Simuliidae | | | | | | | | | | | | |
| *Simulium* sp. | | | 72 | (387) | 72 | (408) | 90 | (141) | 81 | (57) | 85 | (93) |
| Ephemeroptera | | | | | | | | | | | | |
| *Baetis* sp. | 20 | (1) | 78 | (9) | 64 | (32) | 70 | (16) | 64 | (11) | 71 | (38) |
| *Caenis* sp. | 80 | (4) | 45 | (71) | 27 | (13) | 20 | (54) | 36 | (48) | 43 | (9) |
| *Heptagenia* sp. | | | 33 | (4) | 27 | (2) | 40 | (2) | 18 | (8) | 57 | (7) |
| *Isonychia* sp. | | | 78 | (64) | 55 | (6) | 30 | (47) | 45 | (42) | 57 | (71) |
| *Stenacron* sp. | 100 | (53) | 45 | (3) | 45 | (3) | 50 | (4) | 45 | (7) | 43 | (3) |
| *Stenonema* sp. | | | 100 | (86) | 90 | (89) | 80 | (77) | 82 | (112) | 85 | (100) |
| *Tricorythodes* sp. | | | 45 | (10) | 18 | (10) | 20 | (12) | 18 | (9) | 57 | (2) |
| Tricoptera | | | | | | | | | | | | |
| *Cheumatopsyche* sp. | 40 | (3) | 100 | (106) | 73 | (27) | 70 | (4) | 63 | (34) | 71 | (36) |
| *Hydropsyche* sp. | | | 100 | (57) | 82 | (49) | 70 | (40) | 82 | (37) | 85 | (418) |
| *Potamyia flava* | | | 100 | (464) | 82 | (222) | 80 | (124) | 73 | (177) | 85 | (214) |

loading typical at this site certainly could explain the absence of this genus which, according to Marsh and Waters (1980), are unfavorable conditions for blackflies. On occasion this taxon made up a large percentage of total numbers collected. One collection in December 1978 at station 3 contained 1,204 blackflies which represented 85% of the total numbers.

*Palpomyia* sp. and Empididae were other Diptera which were frequently collected at sites sampled.

Oligochaeta was the most frequently collected taxon at all sites. However, oligochaetes occurred in great numbers only at station 1.

Tables V and VI summarize the numbers of organisms collected using Ekman grabs and artificial substrates. It should be kept in mind that stations 1 and 6 did not receive sampling efforts equal to those for stations 2-5 and thus the numbers are not strictly comparable between stations.

Estimates for Ekman grabs ranged from 152 to 19,349 individuals/m$^2$ for stations 2 and 3, respectively. One explanation for the great variability in values could be the variety of substrates sampled which harbor different communities and densities of organisms. Hynes (1970) pointed out that random sampling of a stream bottom provides at best only a very rough estimate due to the great variability of faunal densities and composition.

The May 30 collections had a mean low of 402 individuals/m$^2$ while the February collection had a mean high of 8,299 individuals/m$^2$. The low averages in May and July are indicative of spring emergence and avoidance of the warm period of the year by the invertebrate fauna. This is a common pattern, characteristic of temperate regions.

Table V indicates that a slight decrease in average density occurs at stations 4 and 5 below the Crete municipal effluent and Farmland Foods, respectively. However, the average number of taxa collected did not change much for stations 2-5.

Percentage composition by numerical abundance for the major taxa at all stations using Ekman grabs was: Chironomidae 66%, Oligochaeta 14%, Trichoptera 12%, Ephemeroptera 5%, Ceratopogonidae 2%, and *Simulium* 1%.

TABLE V. Number of individuals/m$^2$ obtained from Ekman grabs at six sampling locations on the Big Blue River. Each value represents two Ekman grabs pooled. Below are average and total number of taxa, and average and total number of individuals collected for each station.

| | Station | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | 1 | 2 | 3 | 4 | 5 | 6 | $\bar{x}$ |
| 1978 November 7 | | 630 | 739 | 370 | 1,739 | | 870 |
| December 11 | | 2,196 | 1,457 | 1,109 | 1,152 | | 1,479 |
| 1979 February 13 | | 9,174 | 19,349 | 2,913 | 1,761 | | 8,299 |
| April 9 | | 957 | 870 | 2,761 | 2,761 | | 1,837 |
| May 30 | | 152 | 283 | 696 | 478 | | 402 |
| July 11 | | 522 | 652 | 457 | 761 | 1,717 | 822 |
| August 9 | 4,176 | 913 | 4,522 | 1,500 | 1,631 | 5,913 | 2,834 |
| $\bar{x}$ | 2,522 | 2,077 | 3,982 | 1,400 | 1,469 | 3,315 | |
| Average number of taxa | | 6 | 9 | 6 | 6 | 10 | |
| Total number of taxa | 13 | 21 | 28 | 21 | 18 | 18 | |
| Average number of individuals | | 96 | 183 | 64 | 68 | 176 | |
| Total number of individuals | 193 | 669 | 1,282 | 451 | 473 | 351 | |

TABLE VI. Diversity ($\bar{H}$) values obtained from artificial substrates at the six sampling locations on the Big Blue River. Below are average and total number of taxa, and total number of individuals collected for each station.

| | Station | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | 1 | 2 | 3 | 4 | 5 | 6 | $\bar{x}$ |
| 1978 November 7 | | 2.60[*] | 2.57 | 2.74 | 2.89 | | 2.70 |
| December 5 | | 2.37 | 2.61 | 2.33 | 2.67 | | 2.50 |
| 1979 February 12 | | 1.15 | 1.09 | 2.86 | --- | | 1.70 |
| May 30 | | ---[†] | --- | 2.73 | 2.67 | 2.48 | 2.63 |
| July 11 | | 2.80 | 2.27 | --- | 2.46 | --- | 2.51 |
| August 9 | 2.49 | 2.53 | 2.32 | 3.16 | 2.54 | 2.64 | 2.61 |
| September 13 | 3.21 | 2.20 | 2.42 | --- | 3.05 | 2.00 | 2.58 |
| October 16 | 2.83 | 2.91 | 2.40 | 2.90 | 2.52 | 2.38 | 2.66 |
| November 20 | 3.64 | 2.46 | 3.64 | 3.09 | 3.24 | 3.59 | 3.28 |
| December 19 | 1.55 | 2.31 | 1.39 | 2.32 | 2.56 | 2.18 | 2.05 |
| $\bar{x}$ | 2.74 | 2.37 | 2.30 | 2.77 | 2.73 | 2.55 | |
| Average number of taxa | 15 | 16 | 14 | 16 | 15 | 16 | |
| Total number of taxa | 30 | 47 | 34 | 39 | 38 | 29 | |
| Total number of individuals | 1,893 | 12,022 | 10,899 | 5,374 | 5,757 | 8,991 | |

[*] Diversity values are from two samples pooled on each date.

[†] Hyphens indicate samplers were partially buried or missing.

Diversity within an aquatic community, whether measured by number of taxa or some sort of index describing the number of individuals in relation to the number of taxa, generally declines with degradation of water quality. Monthly diversity ($\bar{H}$) values ranged from 1.09 at station 3 to 3.64 at stations 1 and 3 (Table VI). Wilm and Dorris (1968), who evaluated numerous $\bar{H}$ values from many sources, suggested that values between 1 and 3 were indicative of moderate pollution. Values approaching 4 were typical of unpolluted streams while values below 1 were indications of a stressed community affected by heavy pollution. The mean annual values for all six stations fall between 1.00 and 3.00 and indicate moderately polluted waters (Fig. 3). There was no value less than 1.00 and in a few instances index values approached 4.00.

The wide range in diversity values at each site can be attributed partially to seasonal changes in the macroinvertebrate community. Unusually low diversity occurred during February (Table VI) due to the predominance of *Simulium* contributing substantially to the total number, which was unlike the rest of the year. High diversity values, approaching or exceeding 3.00, were recorded for all stations during late fall (November 20). According to Hynes (1970), this seasonal variation can be attributed to emergence patterns, streamflow variations, or the input of detrital material.

The mean diversity value for station 1 is surprisingly higher and somewhat contradictory to the types of taxa and reduced numbers of individuals collected when compared to other stations. The relatively high diversity ($\bar{H}$) values recorded for station 1 were due to the large variety of chironomids. Much equitability of individuals among the various genera was found. Although $\bar{H}$ is a useful index of community structure, it should not be interpreted alone when evaluating water quality as was apparent in this study. Indices used to evaluate the health of a biotic community are by no means a substitute for interpretations made based upon a thorough knowledge of the taxonomic composition found.

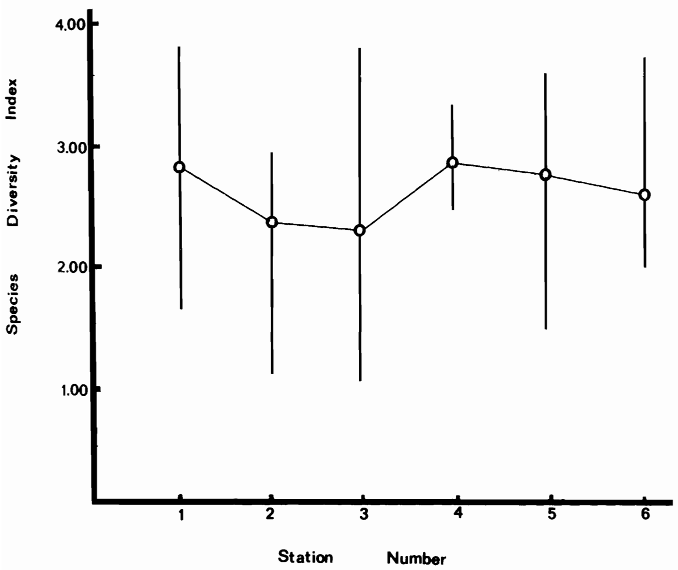


FIGURE 3. Mean species diversity ($\bar{H}$) and ranges calculated for macroinvertebrate data collected from multiplate samplers, November 7, 1978, to December 19, 1979.

There was no apparent difference in diversity between stations above and below the selected discharges. Annual values for $\bar{H}$ were all similar along with the average and total number of taxa collected per visit. As with Ekman grabs, artificial substrates collected fewer individuals at sites 4 and 5 than sites 1 and 2. Interpreting these reductions as a result of pollution effects from the selected discharges is questionable, especially when diversity and taxonomic composition were not noticeably different at these stations.

Pesek (1974) studied macroinvertebrates using multiple plate samplers in Salt Creek. Salt Creek is a smaller stream than the Big Blue. However, it is in the same geographical area, being approximately 32 km east of the Big Blue. Percentage composition of major taxa for Salt Creek was: *Chironomus* 36%, Chironomidae 23%, Ephemeroptera 10%, Trichoptera 6%, *Simulium* 4%, Oligochaeta 3%. Major taxa by percentage composition for all samples on the Blue River using artificial substrates for this study were: Trichoptera 35%, Chironomidae 26%, *Simulium* 19%, Ephemeroptera 16%, Oligochaeta 3%. Chironomids were collected abundantly on both streams. Trichopterans and *Simulium* made up a much greater part of the Blue River collection than of Salt Creek findings.

## CONCLUSIONS

1. The kinds of taxa and diversity values found for the sites sampled during this investigation indicate the Blue River is moderately polluted. Organic enrichment was apparent with the numbers and types of organisms collected.

2. The stations below selected discharges in close proximity to Crete, Nebraska, showed much homogeneity in chemical and biological parameters measured. One major exception was the fecal coliform parameter which was noticeably higher below Crete and downstream sites. In respect to this parameter, Crete's unchlorinated municipal treatment effluent seems to be contributing to the degradation of stream quality.

3. The upper headwaters (station 1) showed the greatest degree of degradation of water quality both chemically and biologically. Organic matter and silt were obvious pollutants at this site. The numbers and kinds of organisms found at this site were indicative of a stressed community.

4. Artificial substrates were more effective in collecting a greater variety of taxa than Ekman grabs. Selectivity of sampling methods should be an important consideration when using macroinvertebrates as indicators.

5. Seasonal changes affected the diversity of the macroinvertebrate community found during this investigation. A water quality study using macroinvertebrates as indicators should account for seasonal changes; otherwise interpretation of results may be misleading.

6. Considerable variability in benthic invertebrate densities was found at all stations. At best they are only very rough estimates and any quantitative results should be cautiously interpreted.

7. Diversity indices should not be interpreted alone when evaluating water quality. As shown by this study diversity values for station 1 were somewhat contradictory to physiochemical results and types of organisms collected.

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