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The Effect of a Renovated Sewage Treatment Plant on the Cottonwood River, Kansas

by

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EMPORIA, KANSAS

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The Effect of a Renovated Sewage Treatment Plant on the Cottonwood River, Kansas

by

Alan K. Benear and John D. Ranson*

ABSTRACT

Three sites on the Cottonwood River were sampled periodically for one year. Benthic macroinvertebrate community structure was analyzed using the species diversity index ($\bar{d}$). Total coliform, fecal coliform and fecal streptococcus populations were estimated using membrane filtration techniques. Water temperature, pH, and dissolved oxygen were measured. Inorganic nitrogen in the form of nitrates, nitrites, and ammonium was studied, as were orthophosphates and condensed phosphates.

During the absence of secondary treatment at the Emporia sewage treatment plant in November and December, 1978, the plant effluent caused a severe depression of $\bar{d}$ values at the station below the plant outfall. This indicated that the benthic community was subjected to heavy stress. This site on the river recovered by May, 1979, and remained only moderately stressed during the remainder of the study. Upstream from the sewage plant, both sampling sites showed moderate stress throughout the year. The upstream benthic communities were dominated by Trichoptera with Ephemeroptera, Coleoptera and Plecoptera well represented. The station downstream from the outfall was dominated by Diptera with Oligochaeta, Coleoptera and Trichoptera also represented. There were no significant differences in $\bar{d}$ values among the three stations.

Coliform populations were generally higher below the sewage treatment plant but there were no significant differences among stations. Fecal coliform to fecal streptococcus ratios were calculated. They showed the source of fecal contamination to be of human origin below the sewage plant but not of human origin above the plant.

The sewage plant effluent did not significantly lower dissolved oxygen values in the river downstream. The river was always slight-

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*Alan K. Benear is currently the laboratory technician at the Water Chemistry Laboratory at the Waste Water Treatment Plant in Emporia, Kansas. This study originated as a master's thesis in the Division of Biological Sciences at Emporia State University under the direction of Dr. John D. Ransom.

ly under saturation at all stations all year, but the depletion was not significant.

Water temperature closely followed the ambient air temperature. The pH values were in a narrow range between 6.1 and 8.0. There were no significant differences in temperature or pH among stations.

Inorganic nitrogen and phosphorus levels were generally higher below the sewage plant, but the differences were not significant, except for ammonium nitrogen which was significantly higher downstream from the sewage plant outfall.

Coliform bacteria populations and inorganic nitrogen and phosphorus all tended to increase during periods of storm-water runoff.

INTRODUCTION

In 1978, the city of Emporia, Kansas, in cooperation with the Environmental Protection Agency, renovated the city's sewage treatment plant. The renovation was undertaken to remedy the problem of sewage bypasses into the Cottonwood River during periods of runoff and high river flow. Secondly, the project was designed to upgrade treatment capabilities to head off problems created by population growth in the city. During renovation, portions of the treatment plant were taken out of service for repair or replacement. The resulting loss of treatment, especially secondary treatment, caused a poor quality of sewage effluent to be drained into the Cottonwood River. This study was undertaken to measure the effects of the activity at the sewage treatment plant and to acertain the quality of the river in general.

Prophet and Edwards (1973) last studied the Cottonwood River including the same stretch sampled in the current investigation. They found the river to be subjected to moderate environmental stress as measured by the species diversity index ($\bar{d}$). Periodic feedlot runoff adversely affected the environmental quality of the river but recovery was rapid when the organic loading was reduced. The feedlots are no longer functioning near the river.

Patrick (1970) discussed factors which affect benthic community structure. Rain storms and the resulting runoff scours the bottom and sides of a stream channel washing away most of the organisms in these habitats. Only those organisms survive which are adapted to living in the interstitial spaces of rocks and other places where strong currents are ameliorated. Predator-prey relationships can have an impact on species diversity. If a certain species' natural predator is absent from the environment, that species will tend to grow in relatively unchecked numbers. The number of species in a particular environment remains relatively stable over time in the absence of catastrophic events. A large number of taxa may be present over a period of time but many of the taxa may perform the same function at different times. Nutrients which are constantly fluxing through a stream environment determine to a large extent the species diversity of that environment. Finally, a pollutant may alter species diversity by increasing the nutrient level. Species tolerant of the pollutant may alter species diversity by increasing the nutrient level. Species tolerant of the pollutant will tend to become more abundant. The pollutant may result in a decreased predator pressure and an even larger abundance of the tolerant species.

One of the most common and widespread methods of evaluating species diversity is the species diversity index ($\bar{d}$). This statistical tool enables the researcher to distill large amounts of data into a single numerical index that clearly and briefly indicates the environmental quality of a certain habitat (Wilhm and Dorris, 1966). Godfrey (1978) reported that there are advantages and disadvantages to this method which will be explored later.

Another major parameter of environmental quality, particularly from a human point of view, is the coliform bacteria population of surface waters. Certain factors contribute to increased populations. The factors of concern here are the sewage treatment plant effluent and surface water runoff. Both have been shown to significantly increase coliform bacteria populations (Davis et al., 1977; Matson et al., 1978; Davenport et al., 1976). These increased populations of bacteria have consequences measured in health risks to the human population that may use the fecally contaminated waters for recreational purposes or for drinking. The increased populations of bacteria also affect benthic community species composition as the bacteria are a nutrient to many benthic macroinvertebrates (Moore, 1978).

Physicochemical parameters such as dissolved oxygen (D.O.) concentration, temperature and pH directly affect the quality of a stream. Inorganic phosphorus and nitrogen, being major nutrients, also can greatly affect an aquatic environment.

The study was undertaken to determine the effects on all of these parameters by the renovation of the Emporia sewage treatment plant. Perhaps the most persuasive argument for this study is one put forth by Rickert and Hines (1978). Put succinctly: "Good data can save money." The costs for sewage treatment facilities continue to rise and yet existing water quality data collected under monitoring and surveillance-type programs were found to be inadequate to define the critical cause-effect relationships that control river quality problems. There is a need for localized studies to assess and solve local problems.

DESCRIPTION OF AREA

The Cottonwood River which originates in Marion county, Kansas, flows through Chase and Lyon counties before its confluence with the Neosho River southeast of Emporia, Kansas. Three sampling sites were selected for study (Fig. 1). Station I, located approximately eight km west of Emporia at a closed county bridge, was used as a control station. It was upstream from the pollution source being studied and in a rural area. Station II, also upstream from the sewage treatment plant was located 50 to 100 meters downstream from a small dam and a state highway bridge in what is known as Soden's Grove. Station III was located near a dismantled railroad trestle approximately 500 meters downstream from the Emporia municipal sewage treatment plant outfall.

MATERIALS AND METHODS

Benthic Macroinvertebrates

A Surber square-foot sampler was used to periodically sample the benthic macroinvertebrates in riffle areas in the Cottonwood River. Two subsamples were taken at each station for each of the sampling dates except November and December, 1978, when one sample was taken at each station. Each subsample was transferred to a plastic container and preserved in ten per cent formaldehyde solution. In the laboratory the sample were washed in a 50 mesh screen to remove dirt and small debris. Benthic macroinvertebrates were handpicked from the samples and stored in 80 per cent isopropyl alcohol. The organisms were then sorted on the basis of gross morphology and later identified using Pennak (1953) and Edmondson (1959). Chironomidae head capsules were removed from the bodies and permanently mounted on microscope slides. Mason (1968) was used to identify the chironomids to genera.

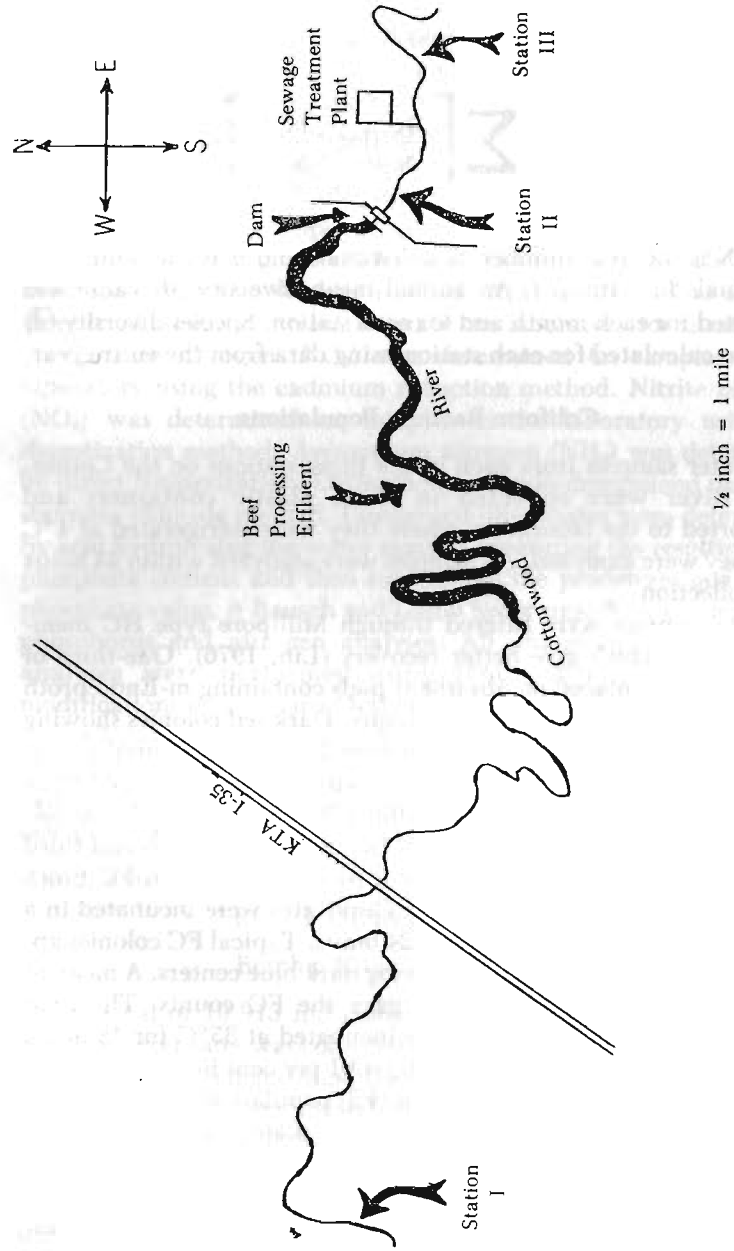

Figure 1. Approximate location of sampling stations.

A species diversity index ($\bar{d}$) was calculated using the Shannon-Weaver equation:

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

where N is the total number of individuals and n_i is the number of individuals in a taxon i. An annual mean diversity ($\bar{d}$) value was calculated for each month and for each station. Species diversity ($\bar{d}$) was also calculated for each station using data from the entire year.

Coliform Bacteria Populations

Water samples from each of the three stations on the Cottonwood River were collected in clean plastic containers and transported to the laboratory where they were refrigerated at 4°C until they were analyzed. All samples were analyzed within 24 hours after collection.

The samples were filtered through Millipore type HC membrane filters which give better recovery (Lin, 1976). One-third of the filters were placed on absorbent pads containing m-Endo broth MF and incubated at 37°C for 24 hours. Dark red colonies showing a green metallic sheen under fluorescent light were counted as coliform bacteria. Total coliform (TC) counts were determined from the mean of duplicate plates containing 30-300 colonies. Fecal coliform (FC) counts were determined by incubating the second third of the membrane filters on absorbent pads containing m-FC broth base and one per cent rosolic acid. Duplicates were incubated in a water bath at 44.5°C ± 0.5°C for 24 hours. Typical FC colonies appeared powder blue with many having dark blue centers. A mean of plates containing 30-300 colonies gave the FC counts. The final third of the membrane filters were incubated at 35°C for 48 hours on KF Streptococcus agar containing 0.01 per cent Bacto-TTC solution to determine fecal streptococcus (FS) populations. Enterococcus colonies appeared pink and red. Duplicate plates containing 30-300 colonies were counted and averaged.

The FC count was divided by the FS count for each station. This FC/FS ratio was used to determine the origin of the fecal contamination.

Physicochemical Parameters

Water temperature was determined on site with a standard mercury thermometer. Ambient air temperature and precipitation data were obtained from the Emporia Gazette (1978-1979).

Water samples were transported in plastic containers to the laboratory and pH determinations were made as soom as possible using a Corning model 5 pH meter. These measurements occurred within two hours of sample collection.

Dissolved oxygen (D.O.) was determined by the azide modification of the Winkler method (APHA, 1975). The samples were fixed on site and transported to the laboratory for titration.

Nitrate nitrogen (NO_3) was determined on samples in the laboratory using the cadmium reduction method. Nitrite nitrogen (NO_2) was determined on samples in the laboratory using the diazotization method. Ammonium nitrogen (NH_4) was determined by direct Nesslerization. Orthophosphate was determined using the stannous chloride method. Condensed phosphates were determined by acid hydrolyzing the water sample, measuring the resulting total phosphate content and then subtracting the predetermined orthophosphate value. A Bausch and Lomb Spectronic 20 was used for all phosphorus and nitrogen analyses. All phosphorus and nitrogen analyses were performed using HACH Chemical Company modifications of Standard Methods (APHA, 1975).

All data were compared by the t-test at the .05 level of confidence for significance. Linear regression and correlation (r) were calculated for the data. A Monroe model 1785 programmable calculator was used for all statistical analyses.

RESULTS AND DISCUSSION

Benthic Community Structure

A total of 19,913 individuals representing 44 taxa of benthic macroinvertebrates was collected in this study (Table 1). There were 30 taxa represented at station III which compares favorably with the 34 taxa collected at both station I and station II. Stations II and III were most similar with 72 per cent of the taxa in common (Table 2). Stations I and III were least similar but still had 61 per cent of taxa in common. A relatively low number of individuals was collected at station III in comparison to station I and station II (Table 3). The station I benthic macroinvertebrates were dominated by Trichoptera which constituted 69 per cent of the individuals present. Ephemeroptera, Coleoptera and Diptera each represented nine per cent of the total benthic community at station I. Station II was also dominated by trichopterans with 54 per cent followed by Diptera with 19 per cent and Coleoptera with 16 per cent. Station III, in contrast, was dipteran dominated with 65 per cent of the total. Trichopterans composed only 20 per cent of the benthic community at station III. The percentage of Plecoptera and Ephemeroptera decreased from station I to station III while oligochaetes and dipterans increased.

Table 1. Taxa list of benthic macroinvertebrates collected in the Cottonwood River.

Phylum Annelida

Hirudinea
- Glossiphoniidae
  - *Helobdella sp.*

Oligochaeta
- Tubificidae
  - *Branchiura sowerbyi*
- Lumbricidae

Phylum Mollusca

Gastropoda
- Physidae
  - *Physa* sp.
- Planorbidae
  - *Pormenetus* sp.
- Viviparidae
  - *Viviparus* sp.
- Valvatidae
  - *Valvata* sp.
- Bulimidae
  - *Paludestrina* sp.

Pelecypoda
- Sphaeriidae
  - *Sphaerium* sp.

Phylum Arthropoda

Insecta
- Trichoptera
  - Hydropsychidae
    - *Hydropsyche* sp.
    - *Cheumatopsyche* sp.
  - Hydroptilidae
    - *Hydroptila* sp.
- Ephemeroptera
  - Potamanthidae
    - *Potamanthus* sp.
  - Polymitarcidae
    - *Ephoron* sp.
  - Siphlonuridae
    - *Isonychia* sp.
  - Tricorythidae
    - *Tricorythodes* sp.
  - Caendae
    - *Brachycercus* sp.
  - Habrophlebia
    - *Choroterpes* sp.
  - Heptageniidae
    - *Epeorus (Iron)* sp.
    - *Stenonema* sp.
    - *Cinygma* sp.
  - Baetidae
    - *Centroptilum* sp.
- Coleoptera
  - Elmidae
    - *Stenelmis* sp.
- Odonata
  - Gomphidae
    - *Ophiogomphus* sp.
- Megaloptera
  - Corydalidae
    - *Corydalus cornutus* L.
- Lepidoptera
  - *Cataclysta* sp.
- Plecoptera
  - Perlidae
    - *Perlesta placida*
    - *Neoperla clymene*

Nemouridae
Taentopteryx sp.
Hemiptara
Corixidae
Diptera
Simuliidae
Tabanidae
Tabanus sp.
Tipulidae
Hexatoma sp.
Chironomidae
Ablabesmyia sp.
Cricotopus sp.
Tanytarsus sp.
Chironomus (Cryptochironomus) sp.
Chironomus (Cryptochironomus) pectinatellae
Polypedilum sp.
Chironomus (Tribelos) sp.
Chironomus (Dicrotendipes) sp.
Pseudochironomus sp.
Nanocladius sp.

Station III, below the sewage plant outfall, was clearly differentiated from stations I and II on the basis of community composition, but there were no significant differences in the species diversity indices ($\bar{d}$) for the three sampling stations (Table 4). The diversity indices resulting from this study indicated that all three stations on the Cottonwood River were subjected to moderate environmental stress for most of the year. Little change has occurred since Prophet and Edwards (1973) reported moderate environmental stress in the Cottonwood River in the vicinity of Emporia. At that time pollution in the river was attributed primarily to feedlot runoff. They also reported that Trichoptera, Ephemeroptera, Coleoptera, Diptera and the pelecypod, *Sphaerium*, dominated the benthic fauna in the river. This correlates well with the current study except that *Sphaerium* was not found in abundance in 1978-1979.

Table 2. Percent commonness of taxa among stations.

Stations	Total Taxa Collected	Number of Taxa in Common	Per Cent Commonness
I and II	42	29	69
I and III	41	25	61
II and III	39	28	72

Table 3. Benthic community per cent composition in the Cottonwood River.

Order	Station I	Station II	Station III
Oligochaeta	0.088	2.894	5.146
Hirudinea	0	0.010	0
Gastropoda	0.132	0.154	0.296
Pelecypoda	0.632	0.145	0.074
Trichoptera	69.306	54.273	19.548
Ephemeroptera	8.728	4.369	3.924
Coleoptera	8.963	4.369	3.924
Odonata	0.059	0	0
Megaloptera	0.103	0.125	0
Lepidoptera	0.029	0.039	0
Plecoptera	2.983	1.997	0.296
Hemiptera	0	0.019	0
Diptera	8.977	19.618	64.902
Totals	6,806 individuals in 34 taxa	10,368 individuals in 34 taxa	2,701 individuals in 34 taxa

Table 4. Species diversity indices ($\bar{d}$) by station and date, monthly mean $\bar{d}$ and annual $\bar{d}$.

Date	Station I	Station II	Station III
October 1978	1.81	3.04	1.86
November 1978	2.33	2.13	0.94
December 1978	1.58	2.82	0.83
March 1979	—	2.13	—
April 1979	—	2.13	—
May 1979	1.82	2.69	3.15
August 1979	2.53	2.00	2.82
September 1979	2.62	1.75	2.49
Monthy mean d	2.09	2.49	2.02
Annual d	2.32	2.68	2.87

Wilhm and Dorris (1966) found diversity indices to be precise measures of stream conditions. Benthic macroinvertebrates, because of their habitat preference and low motility, are ideal indicators of environmental quality. Measures derived from information theory, diversity per individual, $\bar{d}$, and redundancy, are advantageous because they summarize large amounts of information about numbers and kinds of organisms, and they clearly and briefly provide a numerical index of environmental conditions. A $\bar{d}$ value of zero to one indicates heavy pollution, a value of one to three indicates moderate pollution and a value of three or more indicates a clean aquatic environment.

Diversity indices are not without their drawbacks as Wilhm and Dorris (1966) noted. Environmental conditions other than pollution influence community structure. Godfrey (1978) noted this too. Diversity differences can be attributed to other environmental factors which are unrelated to pollution. Current speed and depth are primary factors which control benthic community structure (Slobodchikoff and Parrot, 1977). Godfrey found that no consideration of taxonomic composition of a community along with diversity index values could equate a *Tubifex*-Tendipedidae-*Asellus* community with a Plecoptera-Ephemeroptera-Trichoptera community. This is, indeed, the case for this study. The highest annual $\bar{d}$ was 2.87 at station III. Yet, the Trichoptera-Ephemeroptera-Coleoptera dominated community at stations I and II with its sprinkling of Plecoptera, Odonata, Megaloptera and Lepidoptera, was clearly preferable to station III with its dipterans and oligochaetes.

The annual $\bar{d}$ value also masks the effects of the sewage plant renovation on the river. Monthly $\bar{d}$ values show that station III was heavily polluted during November and December of 1978. *Chironomus (Chironomus)* sp. accounted for 79 per cent of the community in November and 84 per cent in December. *C. (Chironomus)* sp. was not found at any time at stations I and II, nor was it collected at station III in 1979. By May, 1979, the river at station III recovered due to the restoration of the secondary treatment process at the sewage plant.

As mentioned before, the major factors found to influence community structure are current velocity and depth. The Cottonwood River is subject to great seasonal variation in both these parameters, ranging from less than a meter in depth and moderate current to a very swift current, several meters deep following significant precipitation. During this investigation, high flows occurred in March, 1979, following rain and the melt of several centimeters of

snow and again in June, 1979, following rain. Siegfried and Knight (1977) found that flooding reduced the benthic standing crop by 95 per cent. They concluded that an annual disruption of fauna may result in less varied fauna than would otherwise exist. This appears to be the case for the Cottonwood River in this study. Although non-point sources of pollution could contribute to lower diversity indices, it is difficult to prove. A more plausible explanation is that the two floods that occurred during this study, not pollution, wiped out the standing crop, and diversity indices were less than three because the benthic community was in the process of reestablishing itself. This argument applies only to stations I and II, and to station III after May, 1979.

Siegfried and Knight (1977) also found that standing crop and, hence, diversity values depend on emergence patterns. Sala et al. (1977) also found that the amount of preciptation and discharge from a sewage plant, which varied seasonally, affected benthic community structure. In another study the number of taxa and individual density were generally low in late autumn and winter probably reflecting low temperatures (Wilhm et al., 1978). This condition resulted in relatively high diversity indices. Maximum density usually occurred in early autumn during the reproductive cycle of several dipterans and ephemeropterans and resulted in low diversity values. The net result was that diversity appeared to be more closely related to seasonal cycles than to effluents. Heavy populations of Trichoptera during certain periods of this study could have been the cause of low $\bar{d}$ values. Pollution may not have been the culprit of low community diversity in the Cottonwood River.

While station III is a classic example of how pollution affects community structure, the comparison between stations I and II is a more difficult one to explain. The correlation value (r) for these two stations was -0.95, a very high negative correlation (Fig. 2). The r value was -0.24 for stations II and III and +0.33 for stations I and III, relatively low correlations in both cases. There is a lagoon effluent outfall from a large beef processing plant and a small dam between station I and II (Fig. 1). Presumbly the differences in community structure between stations I and II were due to one or the other, or both of these factors. The data collected in this study are insufficient to draw any firm conclusions on this point.

Coliform Bacteria Populations

Coliform counts were generally higher at station III than at station I or II (Fig. 3) statistical tests revealed no significant differences

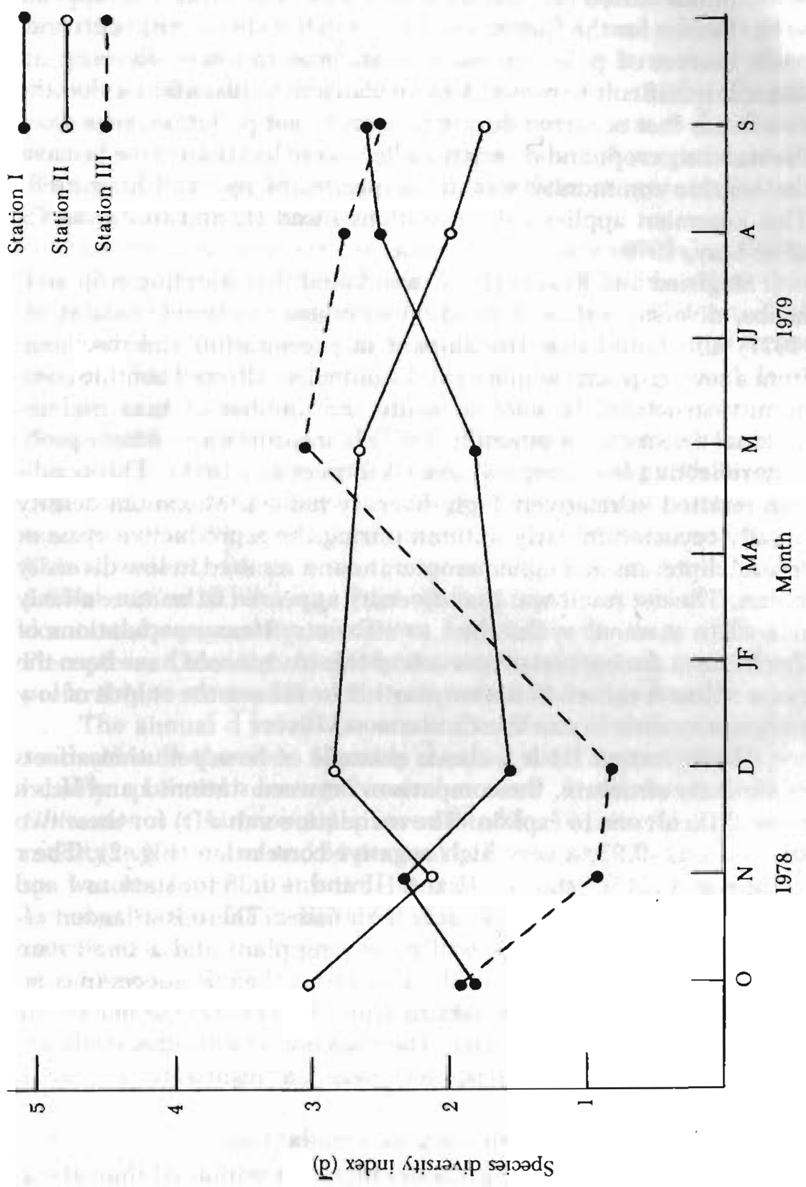

Figure 2. Species diversity indices in the Cottonwood River.

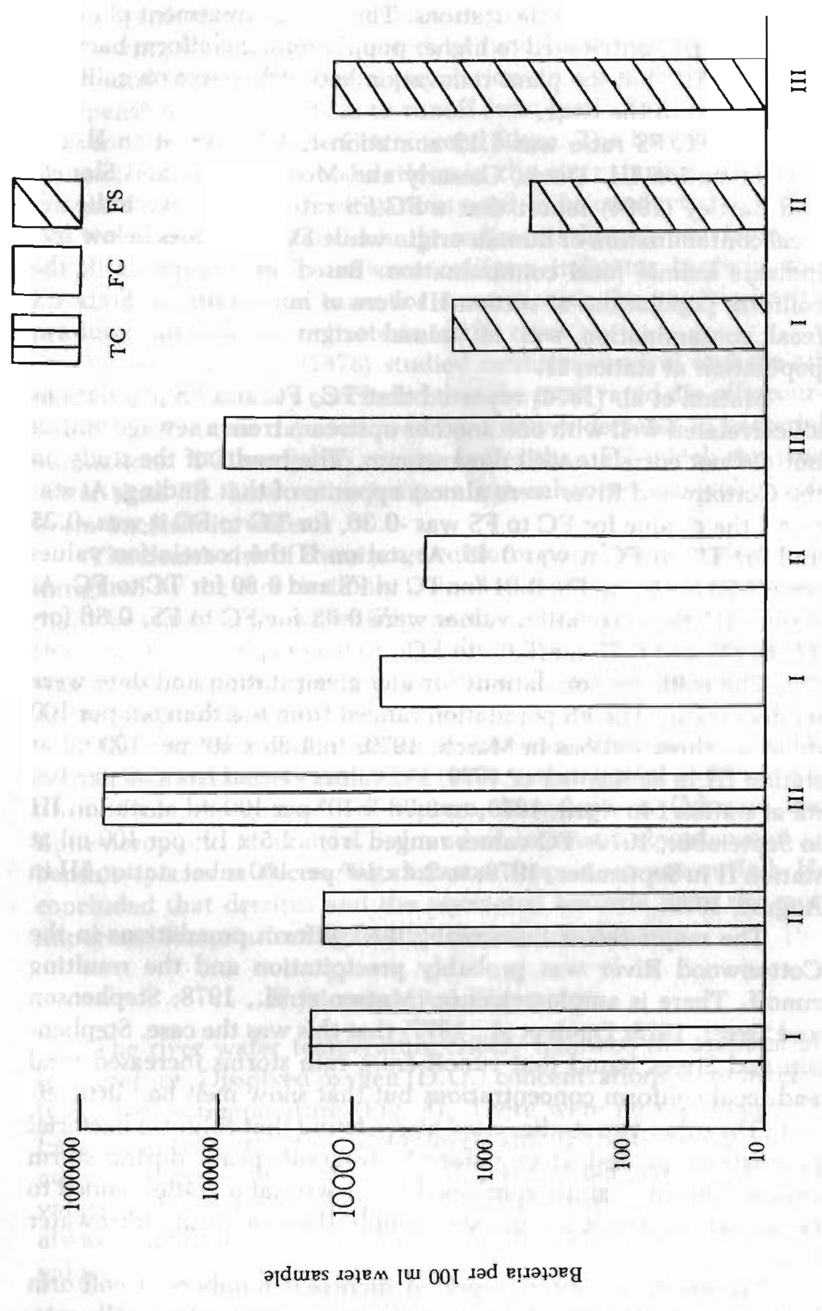

Figure 3. Mean annual coliform populations in the Cottonwood River.

in the means for any of the stations. The sewage treatment plant effluent clearly contributed to higher populations of coliform bacteria at station III, but the plant renovation had little effect on coliform populations in the river.

The FC/FS ratio was 4.12 at station I, 4.74 at station II and 6.37 at station III. Davis, Casserly and Moore (1977) and Slanetz and Bartley (1964) report that a FC/FS ratio above five indicates fecal contamination of human origin while FC/FS values below five indicate animal fecal contamination. Based on this standard, the coliform populations at station III were of human origin. Station I fecal contamination was of animal origin as was the coliform population at station II.

Matson et al. (1978) reported that TC, FC and FS populations all correlated well with one another upstream from a sewage outfall but did not correlate well downstream. The results of the study on the Cottonwood River were almost opposite of that finding. At station I the r value for FC to FS was -0.36, for TC to FC it was -0.35 and for TC to FC it was 0.48. At station II the correlation values were 0.20 for FC to FS, 0.91 for TC to FS and 0.60 for TC to FC. At station III the correlation values were 0.98 for FC to FS, 0.86 for TC to FC and 0.75 for T.C. to FC.

The coliform populations for any given station and date were wildly erratic. The FS population ranged from less than ten per 100 ml at all three stations in March, 1979, to 4.28 x 10^4 per 100 ml at station III in September of 1979. FC values ranged from 30 per 100 ml at station I in April, 1979, to 3.78 X 10^5 per 100 ml at station III in September, 1979. TC values ranged from 2.5 x 10^3 per 100 ml at station II in September, 1979, to 2.4 x 10^6 per 100 ml at station III in August, 1979.

The major factor influencing the coliform populations in the Cottonwood River was probably precipitation and the resulting runoff. There is ample evidence (Matson et al., 1978; Stephenson and Street, 1978; Davis et al., 1977) that this was the case. Stephenson and Street found that runoff from rain storms increased total and fecal coliform concentrations but that snow melt had little effect. The other two studies cited above found that coliform bacterial populations peaked at or before hydrograph peaks during storm events. The latter study concluded that bacterial densities tended to be higher in urban stormwater runoff than in rural stormwater runoff.

Matson et al. (1978) reported increased numbers of coliform bacteria in sediments downstream from sewage plant effluents. There were many more bacteria in the sediments than in the overflowing water. During periods of runoff and high stream flow, they found increased bacterial populations in water due as much to resuspension of sediments as to runoff from land. This has implications for this study on the Cottonwood River. The Emporia sewage plant clearly increased populations in the river during periods of normal flow. Further investigations need to be conducted to ascertain the coliform populations in the sediments downstream from the plant. The relationship between coliform indicator bacteria and human pathogens gives cause for concern over the possible health risks associated with the bacteria in the river.

Davenport et al. (1976) studied coliform survival and die-off rates in a stream. They concluded that the most rapid die-off occurred in the first two days followed by a slower decrease in bacterial populations. TC tended to survive better than FC which survived better than FS. Low water temperature enhanced survival of coliform bacteria in water.

The health risk of these large coliform populations in streams is mitigated by the fact that only a small percentage of them may actually be viable in the water (Zimmerman et al., 1978). It was found that only five to 36 per cent of the coliform population in freshwater was actually respiring at any one time. This may be due to low water temperatures.

The coliform populations are a significant food source for many benthic macroinvertebrates. Sarai (1976) isolated total and fecal coliforms from the guts of Trichoptera, Megaloptera, Odonata and Ephemeroptera. Moore (1978) found an increased abundance of all benthic species at decreasing distances from a sewage outfall. He concluded that detritus and the associated bacteria were the most important factor affecting benthic population densities.

Physicochmeical Parameters

The river water temperature closely followed the ambient air temperature. Dissolved oxygen (D.O.) concentrations were inversely related to temperature (Fig. 4). There were no significant differences in temperature or D.O. levels among the three stations. In addition there were no significant differences between actual D.O. values and the theoretical D.O. saturation curve. The water was always slightly less saturated than the theoretical saturation D.O. value.

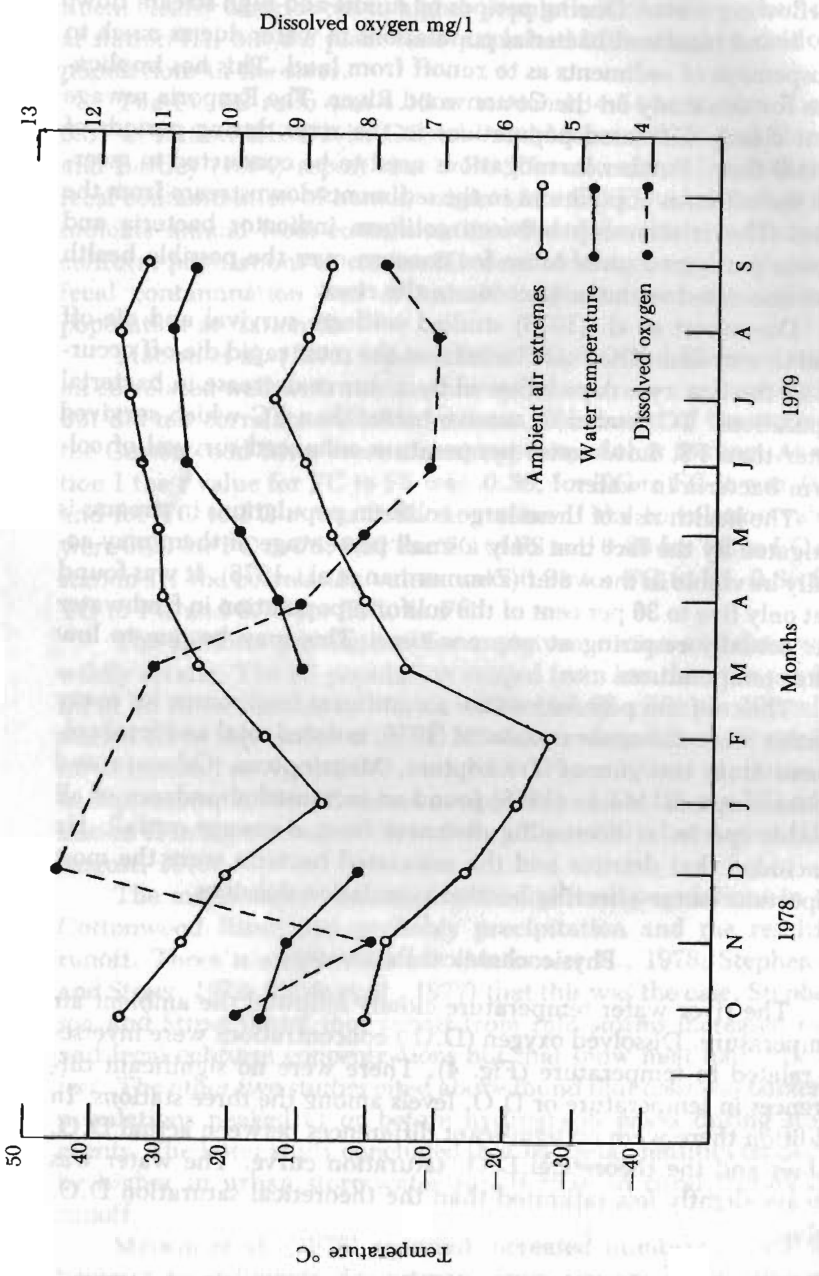

Figure 4. Ambient air and water temperatures, and dissolved oxygen in the Cottonwood River.

The pH varied little during the study. High values were 8.0 recorded at station II in March, 1979, and at station III in May, 1979. The low pH value was 6.1 recorded at station III in December, 1978. There were no significant differences in pH among the three stations.

Nitrate nitrogen (NO_3) levels were greatest at station I and least at station III (Fig. 5). There were no significant differences among the three stations. Nitrite nitrogen (NO_2) was greatest at station III and least at station I. Again, there were no significant differences among the three stations. Ammonium nitrogen (NH_4) was greatest at station III and least at station I. There were no significant differences between stations II and III or between stations I and II. There was a significant difference in NH_4 values between station I and station III.

Strom et al. (1976) studied nitrogen levels and nitrifying bacteria at various stages in a sewage plant and in the plant effluent. They concluded that nitrification of ammonium nitrogen in the receiving stream consumed significant amounts of D.O. In the past this form of pollution was masked by carbonaceous oxygen demand and has only recently been demonstrated to be a significant environmental problem. Most conventional sewage treatment processes do not affect inorganic nitrogen levels. Ricket and Hines (1978) came to these same conclusions.

Phosphate values were slightly higher at station III than elsewhere in the river (Fig. 6). There were no significant differences in phosphate levels among the sampling stations.

Precipitation related runoff was the greatest factor which affected nitrogen and phosphate levels in the Cottonwood River (Fig. 7). Sala et al. (1977) reported extremes in physicochemical parameters caused by precipitation and subsequent runoff. They also concluded that phosphates and nitrates played a significant role in supressing species diversity index values below a sewage plant outfall. They reported that the benthic community below the outfall was composed of 42 per cent oligochaetes and 58 per cent dipterans of which 50 per cent was *Chironomus* sp. This lends credence to the findings of this study on the Cottonwood River.

The Emporia sewage plant renovation had little effect on the physicochemical parameters in the Cottonwood River. Since a secondary treatment plant does little to remove inorganic phosphorus and nitrogen, continued environmental stress is likely to be detected below the sewage plant outfall. This can be expected to depress diversity indices when compared to upstream community

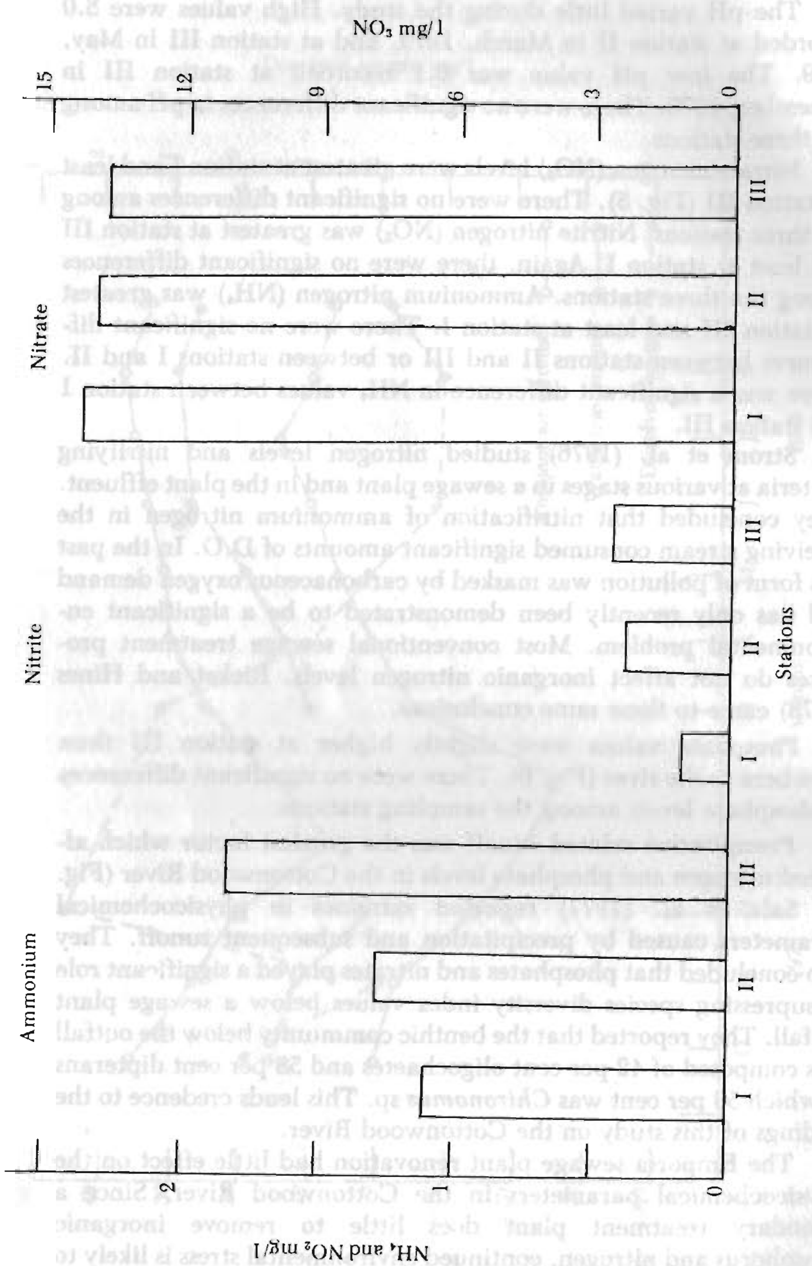

Figure 5. Mean annual nitrogren in the Cottonwood River.

structure. Further studies of this type would be fruitful in monitoring the quality of the Cottonwood River below the sewage plant. Although little can be done to make the river completely clean and give high diversity indices, severe disruptions in community structure such as occurred in November and December of 1978, should be avoided in the future.

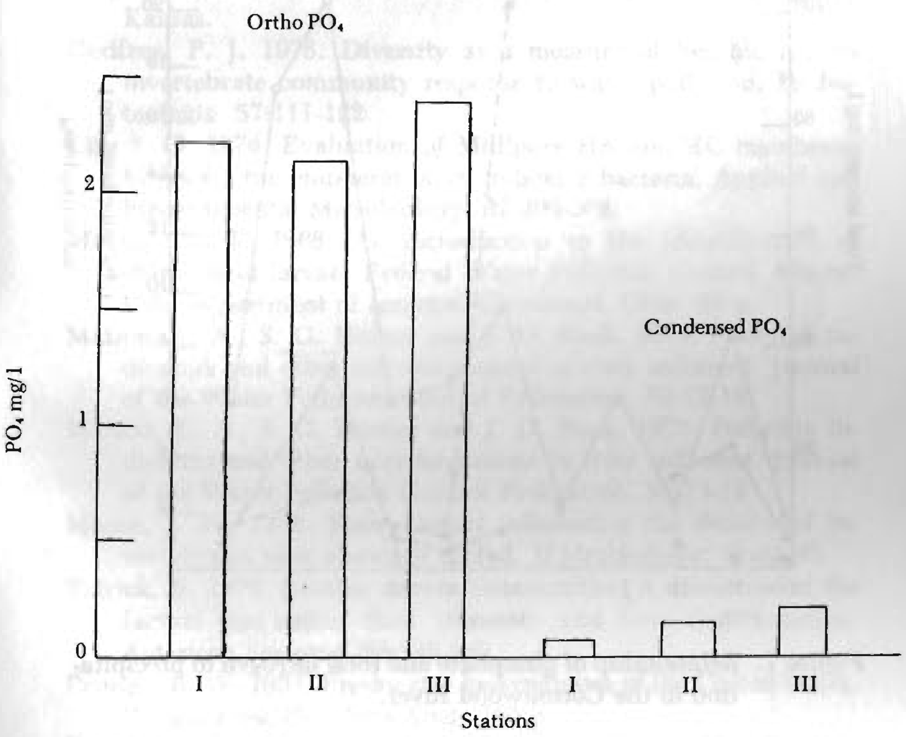

Figure 6. Mean annual phosphorus in the Cottonwood River.

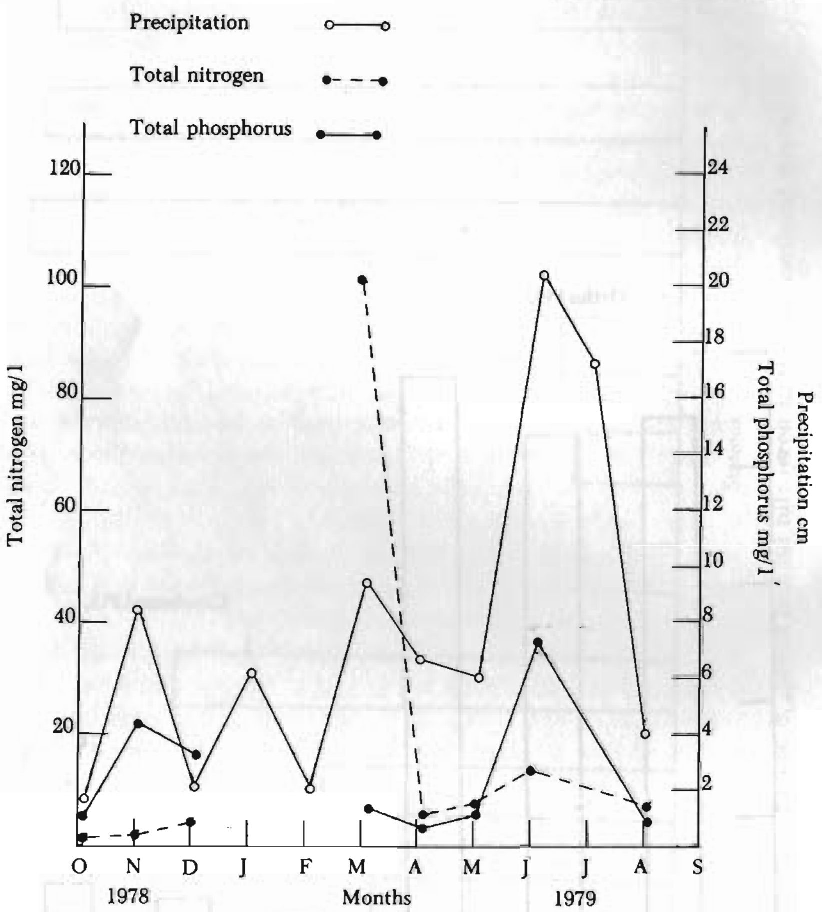

Figure 7. Relationship of phosphate and total nitrogen to precipitation in the Cottonwood River.

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