THE EFFECT OF FEEDLOT RUNOFF ON COMMUNITY STRUCTURE IN THE COTTONWOOD RIVER, KANSAS

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TABLE OF CONTENTS

PAGE

LIST OF FIGURES

LIST OF TABLES

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INTRODUCTION

As attention of laymen, industry, and government has been increasingly directed to matters concerning environmental quality, it has become evident that many of the primary problems of air, water, and soil pollution of a given region result from sources, or situations, that are generally unique to that particular region. Throughout much of Kansas, agriculture is an important source of pollution. Fertilizers, pesticides, silt, irrigation return water, and feedlot runoff are representative of pollutants derived from agriculture.

Over the past decade, introduction of wastes derived from feedlot operations into surface waters has become a serious problem, not only in Kansas but throughout many central and southwestern states. The problem has developed due to increases in both concentration of livestock in feedlots and number of feedlots, especially those located along streams.

Up to 60,000 head of cattle may be concentrated in eight feedlots along the Cottonwood River between Emporia and Strong City, Kansas, a distance of approximately 43 km. The density per hectare may approximate 100 head (Grey, 1970). Miner et al. (1966) demonstrated that organic matter in runoff from a 2.54 cm rain on a 0.4 ha unsurfaced lot containing ten steers was equal to the untreated sewage of approximately 250 people. On this basis, animal wastes produced at the feedlots between Emporia and Strong City would equal the untreated sewage of approximately 1.5 million people.

All of such waste does not enter the Cottonwood River, yet quantities sufficient to produce severly polluted conditions are periodically introduced.

The immediate effect of feedlot runoff on the ecology of the Cottonwood River is most evident following a local rain of approximately 2 - 5 cm when river flow is low to normal. At such times, runoff results in a single massive point load or "slug" which moves downstream as a front. Water quality conditions within the "slug" differ from those in other stretches of the river due to a decreased dissolved oxygen level, an increased ammonia concentration, and increased fecal coliform and Streptococcus bacteria density within the "slug." Slug conditions often result in a fish kill which may extend several kilometers downstream. Fish kills and physicochemical measurements reflect conditions only during the presence of a "slug" and indicate little about the long term ecological effects of feedlot runoff on the river.

Any stream which contains fish or is capable of maintaining fish life must also maintain large and diverse communities of benthic invertebrates for fish food. Due to their habitat preference, low motility, and rather long life cycles, benthic invertebrate populations can be used to evaluate the degree of environmental stress (pollution) to which an aquatic community is being subjected. Initial attempts by researchers to use invertebrate populations for such purposes involved long lists of species or lengthy descriptions of associations of species which were cumbersome to use, required extensive taxonomic training, and usually proved to be of little value for determining the presence or absence of pollution.

// Several investigators attempted to classify bottom organisms according to pollution tolerances and to use those organisms as indicator species (Gaufin and Tarzwell, 1952; Surber, 1953). But, Gaufin and Tarzwell (1956) found the presence or absence of a particular species less reliable than population associations in determining the degree of pollution in streams. Analysis of community structure by methods derived from information theory was later proposed by Margalef (1956). If information and diversity are approximately the same, then diversity indices calculated from numbers of individuals and species in a sample should summarize large amounts of information about organisms (Margalef, 1961; Patten, 1962).//

Since some investigators (Mathis, 1965; Wilhm and Dorris, 1966; Harrell, 1966; Ransom, 1969) have recently used diversity indices to successfully analyze and characterize benthic community structure, that method was employed here. Thus, the primary objective of this study was to characterize community structure of benthic macroinvertebrates along selected reaches of the Cottonwood River above and below feedlot operations by use of species diversity indices and to use those results to evaluate the general environmental conditions in the river.

DESCRIPTION OF AREA

General Description

The Cottonwood River originates near Marion, Kansas, and flows southeast 120 km through Marion, Chase, and Lyon counties, and joins the Neosho River 14 km southeast of Emporia, Kansas. Stream elevation is 392 msl at Marion and 366 msl at Emporia, and the river has an average gradient of .46 m/km (Water Resources Data for Kansas, 1967). The mean volume of flow in the study reach was 1.4 cms.

Sources of Pollution

Both domestic wastes from Strong City, Cottonwood Falls and Emporia, and wastes from cattle feedlots enter the river along the study reach (Fig. 1). The Strong City and Emporia sewage treatment plants employ secondary treatment using a trickling filter while a lagoon system is used for handling domestic sewage at Cottonwood Falls. Runoff from three feedlots west of Strong City flows into the river via either a ditch or small stream. The three feedlots maintain approximately 20,000 head of cattle (Grey, 1970). Two other feedlots are downstream from Strong City and Cottonwood Falls and upstream from Emporia. The smaller of the two maintains approximately 2,500 head of cattle and has a lagoon system to handle runoff. The other feedlot maintains approximately 16,000 head of cattle, and is 27 km above Emporia. Further downstream three feedlots in Emporia maintain approximately 20,000

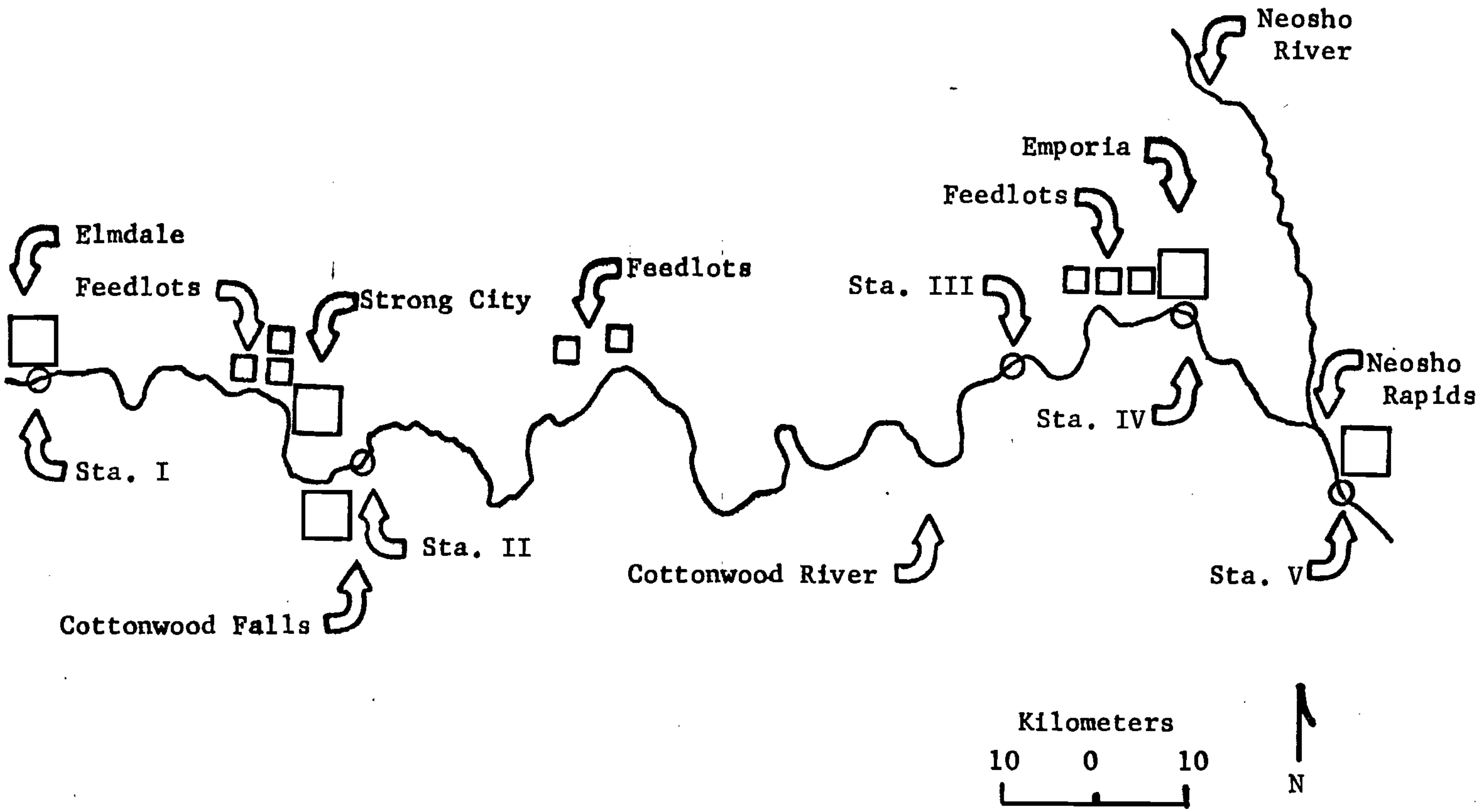

Figure 1. Approximate Locations of Sampling Stations.

head of cattle. Several tributaries join the river along the study reach which could possibly introduce significant amounts of pollutants. As an example, runoff from a feedlot northeast of Emporia flows into a ditch which runs about 11 km before entering the river.

Description of Stations

Five stations were selected for study (Fig. 1). Station I was the control and was located 21 km above the nearest feedlot. Station II was 16 km below the three feedlots in the vicinity of Cottonwood Falls and Strong City, 14 km below the sewage treatment plant at Strong City, and about 1 km below the sewage lagoon at Cottonwood Falls. Four tributaries enter the river between Station II and the three feedlots above Station II. The drainage basins of the four tributaries consist of both cultivated and pasture land. Fox Creek, Prather Creek, Spring Creek, and Buck Creek join the river below the feedlots at 2, 7, 10, and 14 km respectively. Station III was upstream from Emporia and 27 km below the nearest feedlot. Station IV was midway between the three Emporia feedlots and Emporia's sewage treatment plant. Station V was 7 km below the confluence of the Neosho and Cottonwood Rivers, 21 km below the Emporia feedlots, and 19 km below the city of Emporia's sewage treatment plant.

The river in the reaches of the study area was characterized by alternating pool and riffle areas, and was predominantly sand

and silt in the pools. Depth was maximum at Station V while it was similar at Stations I and II, and at Stations III and IV (Table I). Stream velocity was greatest at Station I, least at Station V, and intermediate at Stations II, III, and IV.

TABLE I. Stream morphometry and flow by station.

Station	Width (m)	Depth (cm)	Current (mps)	Flow (cms)
I	20.6	27.5	.64	1.3
II	42.1	26.7	.55	2.1
III	9.6	22.0	.57	1.2
IV	28.4	21.1	.46	1.1
V	45.7	33.9	.35	1.2

PROCEDURES

Biological

Two bottom samples were taken periodically with a Surber square foot sampler. One pool and one riffle sample was taken at each station from September, 1968, to October, 1969. Samples were washed in the field through an 80 mesh screen. Remaining debris and organisms were transferred to plastic containers and preserved in 80 % isopropyl alcohol. Samples were returned to the laboratory and washed through a series of U.S. soil sieves. Collected organisms were preserved in 80 % isopropyl alcohol for later identification and counting. Ash-free biomass was determined by drying at 100 C for three hours and burning in a muffle furnace at 500 C for one hour. Mean calorie content/gram dry-mass was determined using a Parr Instrument Co. Model No. 1300 plain calorimeter.

Species Diversity Indices

Density, ash-free biomass, and calorie content were used to calculate d, d_{max}, d_{min}, $\bar{d}$ and R for each station on each sampling date. Since $\bar{d}$ numbers are small and dimensionless, making them easier to use in evaluating community structure, d, d_{max}, d_{min}, and R are included in an appendix for reference only. Calculations were determined by the following equations from Patten (1962) as modified by Ransom (1969).

$$d = \sum_{i=1}^{s} n_i \log_2 \frac{n_i}{n}$$

$$\bar{d} = -\sum_{i=1}^{s} \frac{n_i}{n} \log_2 \frac{n_i}{n}$$

$$d_{max} = \log_2 n! - s \log_2 \left(\frac{n}{s}\right)!$$

$$d_{min} = \log_2 n! - \log_2 \left[n - (s-1)\right]!$$

$$R = \frac{d_{max} - d}{d_{max} - d_{min}}$$

where n_i is the number of individuals of species i, n is the total number of individuals, and s is the number of species.

Species diversity ($\bar{d}$) values were subjected to the t-test at the .05 level. All statistical computations were conducted by the Kansas State Teachers College Data Processing Center.

RESULTS AND DISCUSSION

Community Structure

Mean Annual Species Diversity by Station

The manner in which individuals are distributed among species in a community is defined by the numerical index, $\bar{d}$. As the probability of collecting a species increases, $\bar{d}$ decreases and as the probability decreases, $\bar{d}$ increases. In a polluted aquatic environment there generally is a large number of individuals, but few species. Therefore the probability is high that an individual in a sample will belong to a species already collected, hence $\bar{d}$ will be low. In a clean water environment the number of species is generally large, and the probability of collecting a particular species previously collected is low.

In aquatic communities $\bar{d}$ values generally range from zero to slightly larger than four. Wilhm and Dorris (1966), in a study of a stream receiving domestic and oil refinery effluents, found that $\bar{d}$ values less than one were indicative of heavy pollution, values from one to three represented areas of moderate pollution, and values exceeding three indicated clean water environments when $\bar{d}$ values were calculated from density data.

Mean annual $\bar{d}$ for each station was calculated and each station's diversity was compared with that of every other station (Fig. 2). Diversity per individual ($\bar{d}$) values for each station on each collection date are included in the appendix for reference. The results

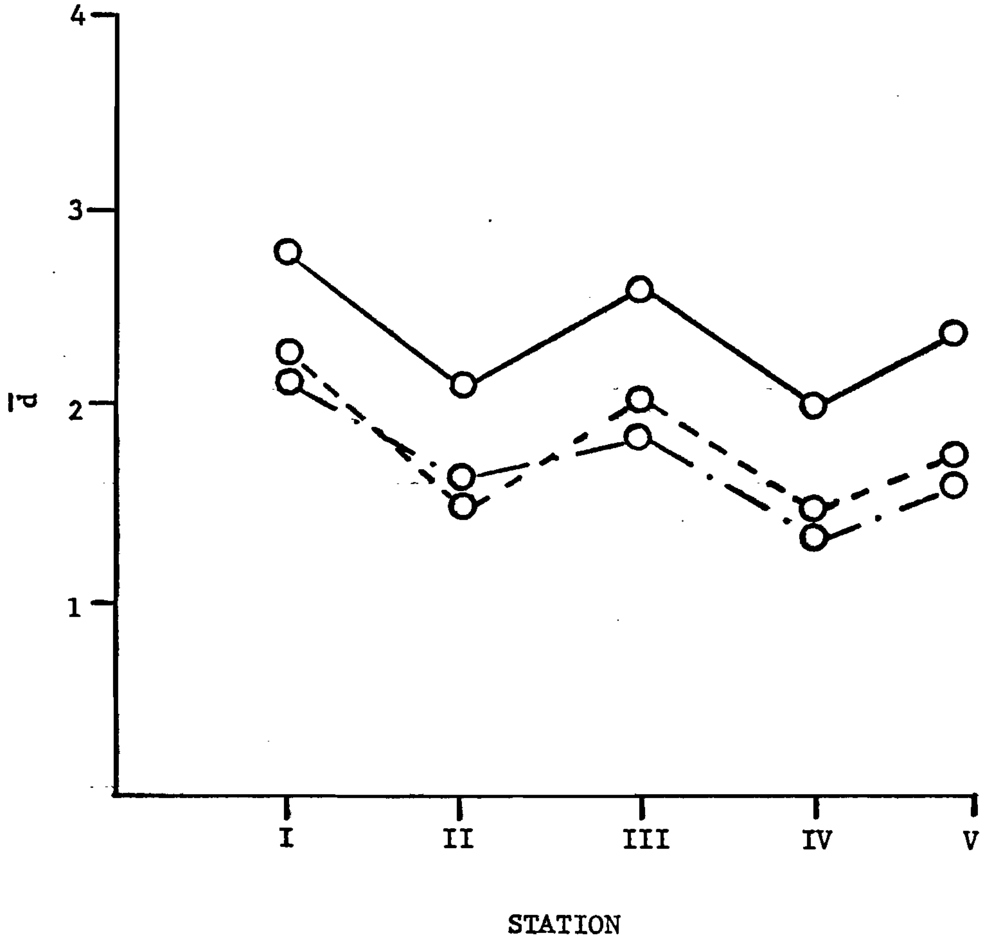

Figure 2. Mean Annual Variations in Diversity per Individual ($\bar{d}$) by Station. Density = (————), Biomass = (—— · ——), Calories = (– – – –).

indicate there was some source(s) of pollution below Station I, and that there tended to be a decrease in diversity downstream from Station I. They also suggest that stations at a greater distance downstream from a pollution source undergo greater recovery of diversity than those closer to a source of pollution. That is, some indication of a positive correlation between $\bar{d}$ and distance from a pollution source was found. That phenomenon was noticed early in this investigation and a series of six additional samples were taken below the Emporia feedlots. The results supported the inference that there is recovery in diversity downstream from pollution sources (Fig. 3).

The t-test at the .05 level revealed no significant difference in mean annual $\bar{d}$'s calculated from numbers of individuals between Stations I and III (Fig. 2). But both Stations I and III were significantly different from all other stations. There was no significant difference among those stations (Stations II, IV, and V) nearest pollution sources. The best indication of the effect of feedlot runoff on community structure was the decrease in diversity downstream. Diversity per individual was highest at Station I, the control station, and lowest at Station IV. There was significant recovery in diversity at Station III. This was probably due to considerable dilution of pollutants over the 27 km stretch between Station III and its nearest upstream pollution source with the result being an improved environment for benthic invertebrates. There was also slight recovery in diversity at Station V, but this proved to be insignificant. As could be

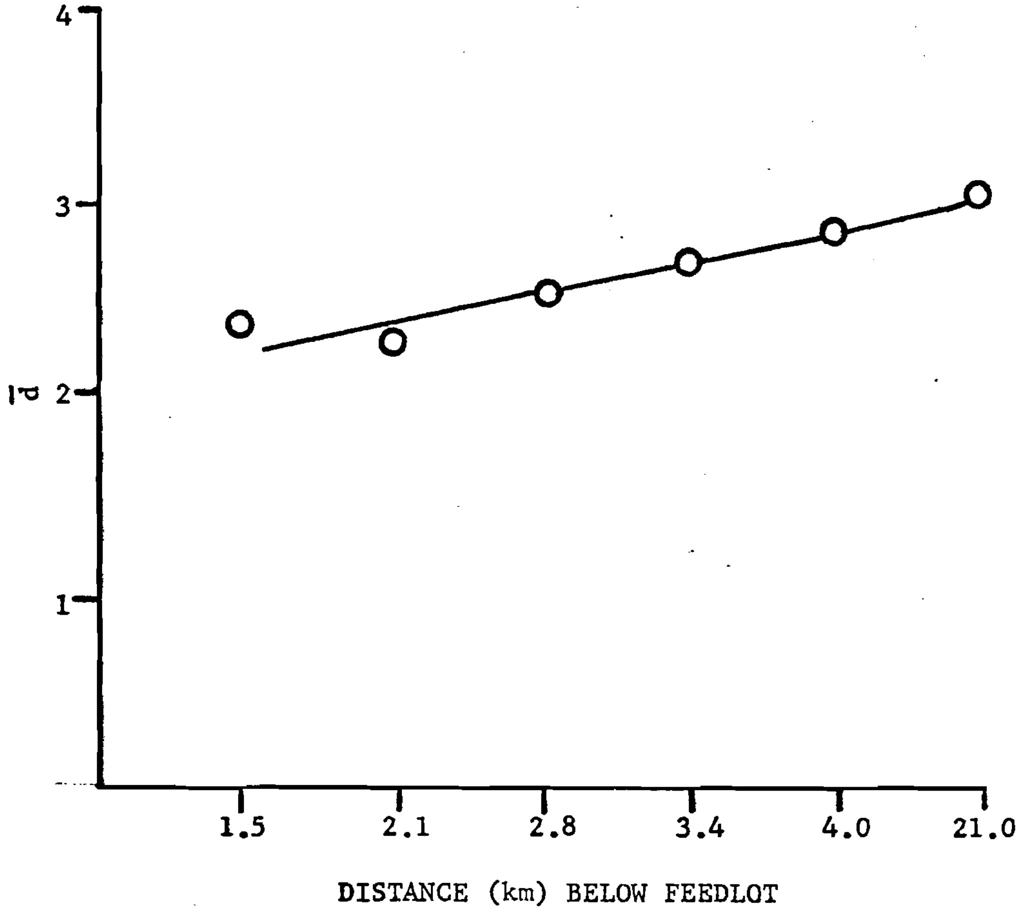

Figure 3. Mean Variations in Diversity per Individual ($\bar{d}$) by Series Samples.

expected, Stations II and IV were closest to pollution sources and they were the stations where lowest diversity occurred.

The low diversity at Station II may be in part attributed to the introduction of domestic wastes from the sewage treatment facilities at both Strong City and Cottonwood Falls. But the series of samples taken below the Emporia feedlots at the 2.8 km sampling site, below Emporia's sewage treatment facility, had a higher diversity than the 2.1 km site above the treatment plant (Fig. 3). Therefore, the introduction of domestic wastes from the Emporia plant appeared to have no significant effect on diversity and from this it was inferred that the Strong City and Cottonwood Falls domestic effluents had little or no effect on community structure.

In accordance with the findings of Wilhm and Dorris (1966) mean annual $\bar{d}$'s indicated all stations were moderately polluted with Station IV being the heaviest polluted, and Station I being the cleanest environment.

There was a significant difference between $\bar{d}$'s calculated from number of individuals as basic data and $\bar{d}$'s calculated from ash-free biomass as basic data at Stations I, III, and V, but no significant difference occurred at Stations II and IV. There was also a significant difference between $\bar{d}$'s calculated from number of individuals as basic data and $\bar{d}$'s calculated from calories as basic data at those same stations. In a study of Keystone Reservior, Oklahoma, Ransom (1969) found that the species contributing the largest number of individuals did not always contribute the largest portion of total community biomass. This accounts for the occasional significant differences in $\bar{d}$'s when different types of basic data are used. Depending on the use of diversity indices there may be some value in selecting which basic data one might use. As an example, a comparison could not be made between a $\bar{d}$ calculated from density data and one calculated from biomass data. Furthermore, calorie data are of value in determining which species contributed the largest amount of energy per gram dry-mass since benthics are of considerable value as fish food. There was no significant different at the .05 level between $\bar{d}$'s calculated from ash-free biomass as basic data and $\bar{d}$'s calculated from calories as basic data.

Species Collected, Per Cent Commonness, Mean Annual Density, Ash-Free Biomass and Calorie Content

Sixty-two species of benthic organisms were collected from all stations during the study. Fifty-four were collected at Station I, 37 at Station II, 39 at Station III, 24 at Station IV, and 37 at Station V. The decrease in species below Station I, the control, was indicative of source(s) of pollution downstream from Station I. The increase in number of species at Stations III and V was indicative of a recovery in diversity due to their distance downstream from pollution sources, while the smaller number of species collected at those stations (Stations II and IV) nearest pollution sources was indicative of little or no recovery in diversity. Stations II and III appeared to be most similar (Table II). Seventy-four per cent of the 43 species known to occur at these two stations were present at each station. There was less similarity in associated species between Stations I and V. The significance of per cent commonness comparisons is difficult to ascertain because the number of individuals of the species involved is not taken into consideration.

Mean annual density, ash-free biomass and calorie content was maximum at Station II, while Station V had the least annual ash-free biomass and calorie content (Table III). The increase in density, ash-free biomass and calorie content at Station II was accompanied by a decrease in number of species from 54 at Station I to 37 at Station II and, as noted earlier, this resulted in a low diversity index at Station II. Distinct longitudinal differences in number of individuals, ash-free biomass, and calorie content existed at all stations except Station II. Station IV had the least number of individuals. Numbers of individuals decreased from 5,469/m^2 at Station I to 2,545 and 2,773 at Stations IV and V respectively. Ash-free biomass decreased from 3,511 mg/m^2 at Station I to 1,271 at Station V, and calorie content/m^2 decreased from 24,810 calories to 6,179. Seventy per cent of the density, 90 % of the ash-free biomass, and 93 % of the calorie content was represented by three species, _Sphaerium striatum_ (Lam.), _Hydropsyche_ sp., and _Cheumatopsyche_ sp., that have been shown to be tolerant of organic pollution

TABLE II. Per cent commonness of species among stations.

Stations	Total sp. collected	Number sp. in common	% Commonness
I and II	57	34	60
I and III	57	36	63
I and IV	56	22	39
I and V	57	34	60
II and III	43	32	74
II and IV	39	23	59
II and V	45	29	64
III and IV	42	21	50
III and V	45	29	64
IV and V	40	21	53

TABLE III. Mean annual density/m^2, calorie content in cal/g/m^2, and ash-free biomass in mg/m^2 by station.

Station	Density/m^2	cal/g/m^2	Ash-free wt/mg/m^2
I	5649	24,810	3,511
II	8473	62,730	6,930
III	3272	15,345	2,298
IV	2545	8,055	1,686
V	2773	6,179	1,271

(Wurtz, 1956; Roback, 1962) which may be indicative of why they were abundant below sources of pollution.

Although there were several possible sources of pollution other than that from feedlots, runoff from feedlots did appear to have a significant effect on community diversity. This can be seen by the decreasing diversity downstream from Station I, by an increase in diversity at those stations farthest downstream from feedlots, and by the higher diversity downstream from Emporia's sewage treatment plant which inferred that the Strong City and Cottonwood Falls domestic effluents had little or no effect on community structure.

Additional studies are needed to: (1) pinpoint the effect of various sources of pollution such as the sewage treatment plants in Strong City and Cottonwood Falls, individual feedlots, and effluents from Iowa Beef Packers; (2) determine the presence of any significant introduction of drift organisms from tributaries into the main channel of the river; (3) evaluate the effects of the possible introduction of pollutants from tributaries; (4) determine the direct effect on community structure of a "slug" moving downstream.

SUMMARY

Five stations on the Cottonwood and Neosho rivers were sampled periodically from September, 1968, to October, 1969. Benthic invertebrate community structure was subjected to conventional and species diversity analyses.

Mean annual diversity ($\bar{d}$) was greatest at the control, Station I. Station III, which is 27 km below the nearest feedlot, showed some recovery in diversity while Stations II and IV were near feedlots and had low diversity. There was a positive correlation between $\bar{d}$ values and distance below pollution sources in a series of six samples taken in addition to regular sampling. The t-test at the .05 level revealed no significant difference in mean annual $\bar{d}$'s calculated from number of individuals as basic data between Stations I and III, and no significant difference among those stations nearest feedlot effluents, Stations II, IV, and V. But there was a significant difference between Stations I and III on the one hand and all other stations on the other. There was a significant difference between $\bar{d}$'s calculated from number of individuals as basic data and $\bar{d}$'s calculated from both ash-free biomass and calories as basic data at Stations I, III, and V. There was no significant difference in $\bar{d}$'s calculated from biomass as basic data and from calories as basic data.

Sixty-two species of benthic organisms were collected from all stations during the study. Fifty-four were collected at Station I, 37 at Station II, 39 at Station III, 24 at Station IV, and 37 at Station V. Stations II and III had the greater per cent commonness while less similarity in species composition occurred between Station IV and all other stations.

The greatest biomass, calorie content, and number of individuals occurred at Station II. Those organisms capable of surviving organic enrichment, *Sphaerium striatum* (Lam.), *Hydropsyche* sp., and *Cheumatopsyche* sp., contributed 70 % of the density, 93 % of the calorie content, and 90 % of the biomass.

LITERATURE CITED

Gaufin, A. R., and C. M. Tarzwell. 1952. Aquatic invertebrates as indicators of stream pollution. Publ. Health Rep. 67:57-67.

___________. 1956. Aquatic macroinvertebrate communities as indicators of organic pollution in Lytle Creek. Sew. and Ind. Wastes. 38:906-924.

Grey, M. 1970. Personal communication. Acting Director of Water Resources Board, Kansas Dept. of Health.

Harrell, R. C. 1966. Stream order and community structure of benthic macroinvertebrates and fishes in an intermittent stream. Unpubl. Ph.D. Thesis, Oklahoma State Univ., 76 p.

Margalef, R. 1956. Informacion y diversidad especfica en las cominudades de organismos. Inv. Pesq. 3:99-106.

___________. 1961. Communication of structure in planktonic populations. Limnol. and Oceanog. 6:124-128.

Mathis, B. J. 1965. Community structure of benthic macroinvertebrates in an intermittent stream receiving oil field brines. Unpubl. Ph.D., Thesis, Oklahoma State Univ., 52 p.

Miner, J. R., R. I. Lipper, L. R. Fina, and J. W. Funk. 1966. Cattle feedlot runoff -- Its nature and variation. J. Water Pollution Control Fed. 38:1582-1591.

Patten, B. C. 1962. Species diversity in net phytoplankton of Raritan Bay. J. Mar. Res. 20:57-75.

Ransom, J. D. 1969. Community structure on benthic macroinvertebrates and related physicochemical conditions in Keystone Reservoir, Oklahoma. Unpubl. Ph.D., Thesis, Oklahoma State Univ. 57p.

Roback, S. S. 1962. Environmental requirements of Trichoptera. U. S. Dept. of Health Education and Welfare. Pub. Health Ser. Publ. No. 999-WP-25.

Surber, E. W. 1953. Biological effects of pollution in Michigan waters. Sew. Ind. Wastes. 25:79.

Water Resources Data for Kansas. 1967. Surface water records. U. S. Dept. of the Interior Geological Survey, Water Resources Division.

Wilhm, J. L. and T. C. Dorris. 1966. Species diversity of benthic macroinvertebrates in a stream receiving domestic and oil refinery effluents. Am. Mid. Nat. 76(2):427-449.

Wurtz, C. B. 1956. Fresh-water mollusks and stream pollution. The Nautilus. 69:96-100.

APPENDIX

TABLE IV. Values of d, d_{max}, d_{min}, and R obtained with numbers of individuals as basic data by collection.

	STATION									
	I		II		III		IV		V	
Sampling Date	d d_{max}	d_{min} R	d d_{max}	d_{min} R	d d_{max}	d_{min} R	d d_{max}	d_{min} R	d d_{max}	d_{min} R
12 Sept. 68	85270 46618	449 .46	65783 34649	264 .34	98 112	32 .21	20754 10411	89 .50	13246 24478	213 .46
29 Oct. 68	85270 52773	355 .41	328211 136748	371 .58	99 110	30 .22	20742 10398	91 .51	34271 18919	221 .45
9 Dec. 68	32443 19094	442 .42	10362 6643	127 .36	94379 46422	302 .51	53619 24367	179 .55	1088 992	99 .10
2 Feb. 69	15060 11093	280 .27	40416 17370	289 .57	1162 905	61 .23	161 159	25 .20	1244 984	61 .23
30 July 69	5766 4154	198 .29	3053 1864	79 .40	742 723	71 .29	371 367	36 .13	1066 844	52 .22
8 Aug. 69	3632 2648	119 .28	3104 1832	81 .41	1161 904	60 .24	1694 922	64 .47	1832 1328	56 .28
15 Aug. 69	1156 900	108 .24	5100 2092	85 .60	932 735	66 .23	716 547	25 .24	1834 1295	58 .27
27 Aug. 69	12741 3530	274 .34	25262 17423	262 .31	3987 2977	112 .26	945 773	66 .20	34271 18918	221 .45
5 Sept. 69	3624 2461	119 .33	1429 951	54 .35	2138 1859	136 .14	808 658	72 .20	1065 843	52 .21
2 Oct. 69	2689 2240	150 .18	19516 8491	184 .57	1242 1102	109 .12	160 159	26 .18	0 0	0 0

TABLE V. Variation in $\bar{d}$ by sampling date.

	STATION				
Sampling Date	I	II	III	IV	V
12 Sept. 68	2.76	2.86	2.73	1.50	2.24
29 Oct. 68	2.78	1.90	2.72	1.49	2.20
9 Dec. 68	3.31	1.73	3.27	2.03	0
2 Feb. 69	3.41	1.94	2.23	2.02	2.32
30 July 69	2.49	1.97	3.05	2.38	2.18
8 Aug. 69	2.65	1.90	2.23	1.51	1.98
15 Aug. 69	2.36	1.29	2.41	1.93	2.74
27 Aug. 69	2.82	2.04	2.40	2.21	3.20
5 Sept. 69	3.08	3.05	2.62	2.56	2.29
2 Oct. 69	2.95	1.83	3.34	2.55	2.32