SPECIES DIVERSITY OF BENTHIC MACROINVERTEBRATES IN IMPOUNDED AND UNIMPOUNDED STREAMS

By

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IN IMPOUNDED AND UNIMPOUNDED STREAMS

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CHAPTER I

INTRODUCTION

Stream order analysis is based on branching, with unbranched headwater tributaries designated as first order streams (Horton 1945). Two first order streams join to form a second order stream, with a third order stream being formed by the joining of two second order streams. Adventitious streams, those branches which enter a stream of higher order without passing through the hierarchical system, do not affect order.

Stream order analysis has several favored characteristics, making it good for biological analyses. Subjectivity of Horton's system is limited since a stream system can be classified from maps. Physico-chemical and biological parameters fit well into this classification. Pools and riffles occur as components of individual streams within orders, rather than being separate, independent entities. Language problems are reduced to a minimum by the numerical structure of the system. Stream characteristics are quantified allowing comparison of widely separated and physiographically distinct regions (Keuhne 1962).

With increase in stream order downstream, species diversity ($\bar{d}$), mean drainage area, stream length, and width generally increase (Harrel and Dorris 1968), while stream numbers, redundancy (R), and average gradient decrease (Harrel and Dorris 1968, Whiteside and McNatt 1972). Species found in low order streams are generally found in each higher order stream section within a drainage basin (Harrel and Dorris 1968). Longitudinal succession is characterized by large changes in physical features and fauna within relatively short distances (Shelford 1911, Sheldon 1967). Stream order and species diversity correlations are high (Harrel, Davis, and Dorris 1967). Increase in species diversity with stream order increase can be correlated with the attendant increase in available habitat and reduction in environmental fluctuations (Harrel and Dorris 1968) and is due to a complex, per-capita hierarchy of function within the community (Odum, Cantlon, and Kornicker 1960). Species number and stream depth are also closely correlated. In downstream areas larger populations are capable of being supported due to the increase in stream width (Sheldon 1967).

Stream conditions are drastically altered by impoundments (Brown, Liston, and Dennie 1967). Most studies of small watersheds indicate a change in stream order characteristics with impoundment. Thomas (1970) found that greatest productivity within impoundments occurred during the first years after construction. Stabilization of organic materials in newly inundated soils provide an improved habitat, with organic-favoring species gradually shifting from the headend to the downstream end. This indicates a decrease in organic detritus deposition in the downstream direction. Nursall (1952) found benthic river forms to be the first inhabitants of a newly constructed reservoir. Increased organic load, caused by inundation of the surrounding soils, create early eutrophic conditions in the reservoir later replaced by oligotrophic conditions. Other pre- and post-impoundment studies have shown bloodworm and sludgeworm population levels to drop, with intermediately tolerant midge and burrowing mayfly populations entering the community.

These forms provide more desirable food for fish. This change reflects a general improvement in the system and possibly might indicate an "increase" in stream order. Such an increase would not be due to increased branching upstream, but rather due to the similarity of the impoundment's characteristics to those of stream sections farther downstream. Upper reaches of streams newly inundated by an impoundment have also shown organism count increases, when before impoundment, were devoid of all organisms (Thomas 1970).

Downstream aquatic communities, due to uniform flow and improved water quality, have also benefited. In one study, ten organisms comprising only three species were collected per square foot in a downstream area. Three years after impoundment of this same stream, ten species with a total of 40 organisms per square foot, were collected in this same downstream area (Thomas 1970). Spence and Hynes (1971) found damming effects of a mainstream with hypolimnion release to resemble mild organic enrichment. Hilsenhoff's (1971) studies on insect and amphipod fauna downstream from a hypolimnion release dam show the same trends, with many species disappearing and others completely dominating the fauna. It should be noted that these last two studies dealt with impoundments of rather large drainage basins whose dams have hypolimnion drains.

Changes in benthic populations are most evident in areas affected by water level fluctuations (Fillion 1967). Reservoir water level fluctuations result in benthic organisms being frequently moved to different depth zones (Davis 1966, Nursall 1952). In unregulated streams, bottom scouring due to high water levels reduces productivity, and repeated flooding restricts rapid recovery. These effects remove the algae and rearrange or disorient other species. Numbers are reduced (Moffett 1936, Radford 1971). Some motile organisms are able to relocate between rocks and debris to prevent being scoured from stream beds and thus remain to carry on reproduction (Patrick 1970). Stream beds accustomed to periodic short term flooding, as with a dammed stream, are able to adjust over a period of years to these flood-like conditions. Consequently the substrate is less disturbed and better able to support stable insect populations at steady levels (Radford 1971).

The objectives of this study are to examine variation in species diversity of benthic macroinvertebrates:

1) among stream orders and
2) between dammed and undammed basins of the same stream order.

CHAPTER II

REVIEW OF LITERATURE

Determining criteria for describing a stream system is difficult. Geological stream classification divides a stream into stages of youth, maturity, and old age. A stream may be youthful at its headwaters, become mature downstream, and then become youthful again farther downstream, if it passes through an area of recent uplift. Some parameters of the youthful areas may be similar, such as pH and temperature, but others, such as discharge, may not (Leopold 1962).

Many other factors have been used in stream classification. Shelford (1911) classified streams on substrate preference of certain species. Ruttner (1953) based classification of communities on stream velocity. Gradient and stream width were used by Trautman (1942) and Huet (1959) to predict species distribution and define faunal regions. Thompson and Hunt (1930) believed numbers of fishes to be proportional to the drainage area of streams. Temperature effect on the physiology of the individual species was thought to be a means of stream classification by Burton and Odum (1945). Margalef (1960) built a classification based on algal associations. Wilhm and Dorris (1968) found benthic macroinvertebrate populations suitable for stream classification because their habitat and low mobility cause them to be more directly affected by substances in the environment than are more mobile organisms. Keuhne (1962) used Horton's stream order system

(1945) to describe the fish fauna in an eastern Kentucky stream. Presently only a few studies using several of these classifications together have been done.

Physicochemical conditions have been shown to affect benthic macroinvertebrate species diversity in streams and impoundments. Johnson (1971) demonstrated that temperature, depth, and pressure significantly influence lake diversity. Miller (1941) and Woodall (1972) stated higher temperatures (sometimes caused by clear-cutting) in shallow areas improve chances for species diversity development. Unseasonably high winter water temperatures, however, might cause some insect larvae to emerge as much as 5 months early (Nebeker 1971), thereby giving distorted $\bar{d}$ values. Improved oxygenation has been shown to encourage the colonization of protected areas by new species (Petr 1971).

Substrate diversity is also of importance to benthic macroinvertebrate species diversity (Harman 1972). On freshly inundated soil, due to its highly variable nature, benthos are found on a large diversity of substrate types. In such a newly accessible habitat, new species achieve high invasion rates and low extinction rates. Eventually, extinction rates for established species will increase and colonization rates will decrease until a relatively steady-state equilibrium is established (Dickson 1972). Trees remaining in these newly flooded basins contribute heavily to substrates available for colonization (McLachlan 1972). In an older body of water certain species seem to occupy only certain substrate types, thereby placing considerable importance on the physical properties of the substrate particles (Petr 1971). McLachlan (1972) found richest fauna in areas where sedimentation was lowest and benthic algae well developed. Nuttall

(1972) and Hamilton (1961) determined that poor incidence of macroinvertebrates, particularly mayflies and stoneflies, was associated with unstable shifting sand deposits, rather than turbidity or abrasion caused by suspended particles. Exception is found with tubificids, which dominate sandy areas due to their burrowing behavior. Vascular vegetation was shown by Johnson (1971) and Miller (1941) to be the major factor affecting species composition in streams, although flow rate, gradient, and other substrates also influence distribution (Woodall 1972). Presence of food and case-making materials, both supplied by vegetation, have also been shown to account for composition differences (Woodall 1972). Crossman (1974) demonstrated that macroinvertebrates tend to colonize areas with rocks of a particular size range. Additional living space provided by rubble is correlated with the probability that organic matter will lodge among these stones and provide food (Hynes 1970). Nuttall (1972) found that in stream areas unaffected by heavy silting, animals typical to a healthy river fauna are present. Johnson (1971) showed position in the trophic gradient to play an important role in species diversity.

Within an impoundment longitudinal succession develops partially due to the inflow of allochthonous material during floods, resulting greatest in areas under direct influence of the inflowing rivers rather than in those areas next ot the dam (Petr 1971). This allochthonous material is the main source of energy for primary consumers when aquatic vegetation is sparse (Woodall 1972). Downstream of an impoundment, uniformity of conditions brought about by increased discharge helps stream basins maintain average seasonal conditions (Young 1972).

Coleman (1970) found benthic macroinvertebrates capable of considerable lateral movement. In reservoirs downward distribution is limited during the first years at shallow depths by poor oxygenation (Petr 1971). McLachlan (1972) found no indication of a preferred depth zone in the epilimnion (or the hypolimnion in winter), but only in the presence of the thermocline. Ransom (1972) found chaoborids in deep water sediments throughout the year and present under the hypolimnion during summer, while chironomids were the predominant fauna of the shallow waters, and in deeper waters during spring and winter (Paterson 1971). Species aggregation in all seasons is a general phenomena since no evidence exists that species are normally randomly distributed (Paterson 1971).

Clifford (1966) found that intermittent streams, even during the summer periods of low flow and no flow, maintain a semblance of the aquatic environment at all times. Presence of water in the bed sub-surface allows aquatic fauna survival either in the seepage itself, or in water-saturated air spaces above the seepage. These conditions for survival are dependent on stream gradient and the local geology. Intermittent stream beds comprised chiefly of bed rock, in contrast, are not capable of being exploited by large numbers of animals due to the large dead water regions. During flood times, entire riffles are scoured, old pools are destroyed, and others are formed definitely having strong affects on benthic macroinvertebrate assemblages. Characteristically, the fauna of a stream may provide a better over-all reflection of stream conditions than those physicochemical parameters mentioned above.

CHAPTER III

DESCRIPTION OF THE STUDY AREA

Robinson Creek and Quapaw Creek watersheds, located in south and south central Lincoln County, respectively comprise 163 km^2 and 399 km^2 of the Deep Fork North Canadian River basin. Robinson Creek begins 4.8 km west and 3.2 km south of Prague and then flows northerly for 19.3 km before entering the Deep Fork. Quapaw Creek begins 16 km west of Meeker, flows east to 1.6 km north of Meeker, and then northeasterly, entering the Deep Fork 1.6 km northeast of Sparks, Oklahoma (SCS 1964, Prelim. Invest. Rep. 1975).

Within Quapaw Creek watershed 17 floodwater retarding structures have been built. Two additional structures for floodwater retention, municipal water storage, and recreational needs have also been constructed (SCS 1964).

Eighty percent of Quapaw Creek basin is open pasture or rangeland of a mixed-grass prairie association, with an additional 17% in croplands. Robinson Creek watershed is 28% pasture, 36% range, 24% forest, 10% croplands, and 2% miscellaneous (SCS 1964, Prelim. Invest. Rep. 1975). Principal forest species of the two watersheds are post oak (*Quercus stellata*) and blackjack oak (*Quercus marilandica*), with occasional hickory (*Carya* sp.) and black oak (*Quercus velutina*) in the uplands (Forest Service 1959, Prelim. Invest. Rep. 1975). Bottom land principal forest species in Robinson Creek watershed are cottonwood (Populus sp.), pecan (Carya illinoensis), hackberry (Celtis sp.), elm (Ulmus sp.), and ash (Fraxinus sp.) (Prelim. Invest. Rep. 1975). Oil and gas production is extensive throughout the Quapaw Creek basin, but is less developed in Robinson Creek basin (SCS 1964). Moderately or gently rolling to hilly topography typifies both of the basin landscapes (SCS 1970). Of the total 39,886 ha Quapaw Creek basin size, only 2917 ha are in the flood plain (SCS 1964). This quantity has not been measured yet in the Robinson Creek watershed.

Quapaw Creek, dendritic in drainage pattern, is a sixth order stream throughout most of its length. Of the more than 1600 tributaries in Quapaw Creek basin there are 172 ha of channels. Flood plain widths vary from 267 to 625 m from the upper reaches to the lower reaches, respectively. Mean sea elevation is 239 to 360 m with range in channel slopes from 0.28 to over 3.41 m/km (SCS 1964).

Robinson Creek, with more of a trellace type drainage than dendritic, is a fifth order stream throughout most of its length. Stream numbers total 610 in Robinson Creek basin and flood plain widths range from 60 m at upstream locations to more than 2 km at locations just south of its confluence with the Deep Fork. Mean sea elevation ranges from 238 m at point of confluence to 317 m upstream. Channel slope and area in stream channels have not been calculated (Prelim. Invest. Rep. 1975).

Robinson Creek and Quapaw Creek basins lie entirely in the Wellington formation of the Permian age, consisting of resistant and nonresistant sandstones, shales, and a few thin limestones. The two land resource soil types are Darnell-Stephenville, cross-timber forested uplands and Renfrow-Bonham-Vernon, reddish prairie uplands

(SCS 1964, Prelim. Invest. Rep. 1975). The two may be referred to simply as sand and clay, respectively (SCS 1970). Because of gentle basin slope neither of the soil types allow the water to percolate through the soil, but rather force the water to quickly run off (SCS 1970). In both basins upland soils of both sand and clay are medium in texture, slowly permeable, and moderately productive, while floodplain soils are much darker, more textured and permeable, and very productive (SCS 1964, Prelim. Invest. Rep. 1975).

Robinson Creek and Quapaw Creek watersheds have warm-temperate continental climates with monthly temperature means ranging from 3.89C in January to 28.33C in August, with a mean annual temperature of 16.35C (SCS 1970). Rainfall in Quapaw Creek basin measured at Meeker averaged 88.6 cm/year (SCS 1964) with 32% falling in the spring, 30% in the summer, 24% in fall, and 14% in winter (SCS 1970). Average precipitation in Robinson Creek watershed is 93.98 cm/year with a mean runoff of 12.7 cm/year (Prelim. Invest. Rep. 1975). Frost free days in Robinson Creek and Quapaw Creek basins average 210 days/year and 217 days/year, respectively, extending approximately from the first of April to the first week of November (SCS 1964, Prelim. Invest. Rep. 1975).

CHAPTER IV

METHODS

Quapaw Creek and Robinson Creek basins were sampled during two seasons. A winter sample was taken 8 February to 12 April 1975. A summer sample was taken 2 May to 28 June 1975. Benthic macroinvertebrates were sampled at 20 stations on third, fourth, fifth and sixth order stream sections in Quapaw Creek basin (Figure 1). Two sampling stations each were established in Quapaw Creek basin on both clay and sand soils in each of the following groups: (1) third order dammed streams, (2) fourth order dammed streams, (3) fourth order undammed streams, (4) fifth order dammed streams, and (5) sixth order dammed streams. At each station four multiple-plate artificial substrate samplers were placed. A total of eighty samplers were distributed (2 soils X 5 groups X 2 stations X 4 samplers).

In Robinson Creek watershed no impoundments exist. Six stations located on third, fourth, and fifth order streams in Robinson Creek basin were also sampled (Figure 1). Even though most third order streams are intermittent, samplers were distributed in this order where stream flow permitted. Within the hierarchical structure of Robinson Creek watershed no sand soils are present, therefore only clay basins of orders three, four, and five were sampled. A total of 24 samplers (1 soil X 3 groupings, or orders X 2 stations X 4 samplers) were

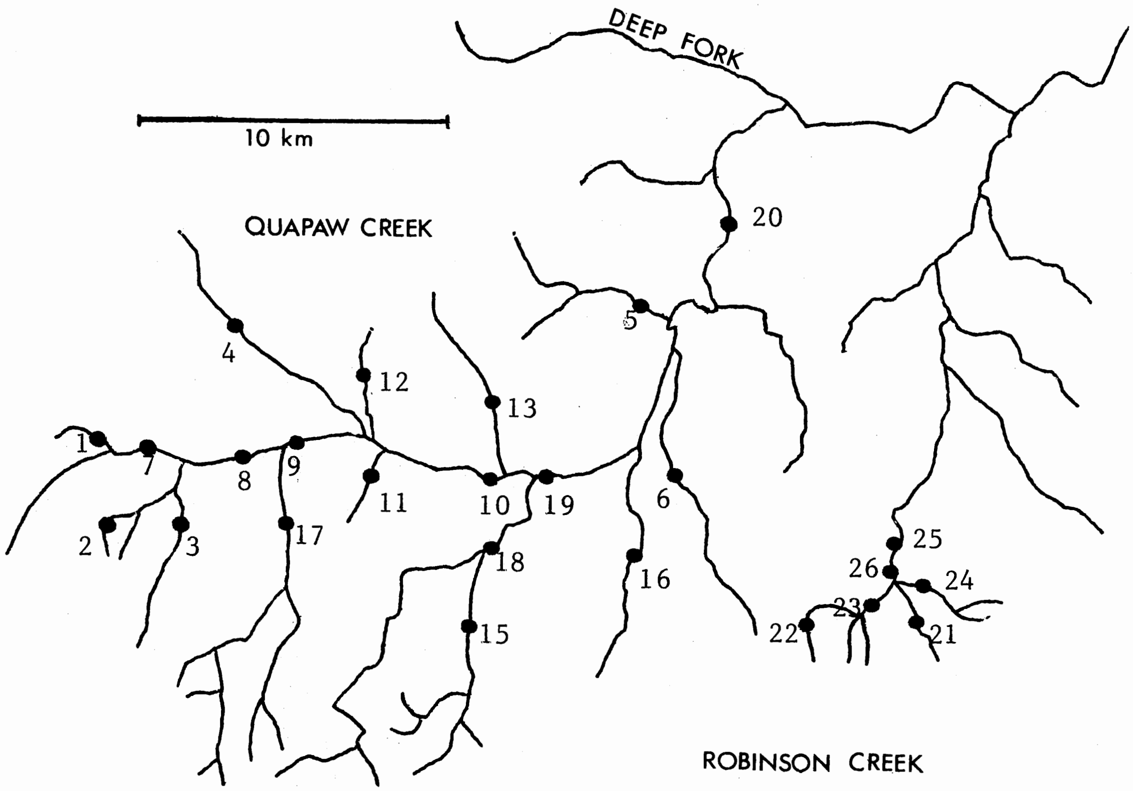

Figure 1. Map of Quapaw and Robinson Creek Basins

Quapaw Creek Stations

1 - 10; sand
11 - 20; clay
1,2,11,12; 3rd order dammed
3,4,13; 4th order dammed
5,6,15,16; 4th order undammed
7,8,17,18; 5th order dammed
9,10,19,20; 6th order dammed

Robinson Creek Stations

21 - 26; clay
21, 22; 3rd order undammed
23, 24; 4th order undammed
25, 26; 5th order undammed

placed. The streams were sampled twice, once in late winter, and again in mid-summer.

Each sampler consisted of seven 10 cm^2 tempered masonite plates, separated by nine 2.54 cm^2 spacers, 0.3175 cm thick. Plates and spacers were assembled on a 9.5 cm length of 0.635 cm threaded rod. Spacers were placed between the 10 cm^2 plates in such a manner that there were four single spaces, one double space, and one triple space (EPA 1973, McDaniel 1974).

Samplers were exposed for 6 weeks (APHA 1971, EPA 1973). A one gallon tin can was placed around samplers during collection to prevent loss of invertebrates. In the laboratory, samplers were disassembled and washed in a #30 U.S. standard sieve. Organisms were stored in 5% formalin (APHA 1971). Identification of the benthic macroinvertebrates and numbers of species and individuals were determined to enable the calculation of species diversity, $\bar{d} = -\Sigma(n_i/n) \log_2 (n_i/n)$, where n = total number of individuals, and n_i = sample estimate of number of individuals in the ith species (Shannon and Weaver 1949).

CHAPTER V

RESULTS

Of 160 samplers placed in Quapaw Creek 111 were recovered. Fourteen samplers were lost during winter and 35 in summer. Of 48 samplers placed in Robinson Creek, six were lost in winter and four during summer. Lost samplers were washed downstream during high flow, thrown on the bank by floodwaters and left to dry, or heavily silted in. Loss of samplers resulting in a number less than four per station give unreliable results. Wilhm (1970) showed asymptotic diversity values would not likely be reached without adequate sample pooling. In addition, large numbers of missing samplers made statistical analysis difficult because of potential changes in the experimental model.

Basin Morphology and Longitudinal Succession

Stream order parameters of Robinson Creek are all of lower magnitude than those of Quapaw Creek, although the change with stream order in stream numbers, stream length, and mean drainage area is similar in each basin (Figure 2, Table I).

Seventy-one taxa were found in winter and summer samples. Winter samples contained 67 taxa, 26 of which were found only in winter, while summer samples contained 47 taxa, five of which were found only in summer (Appendix).

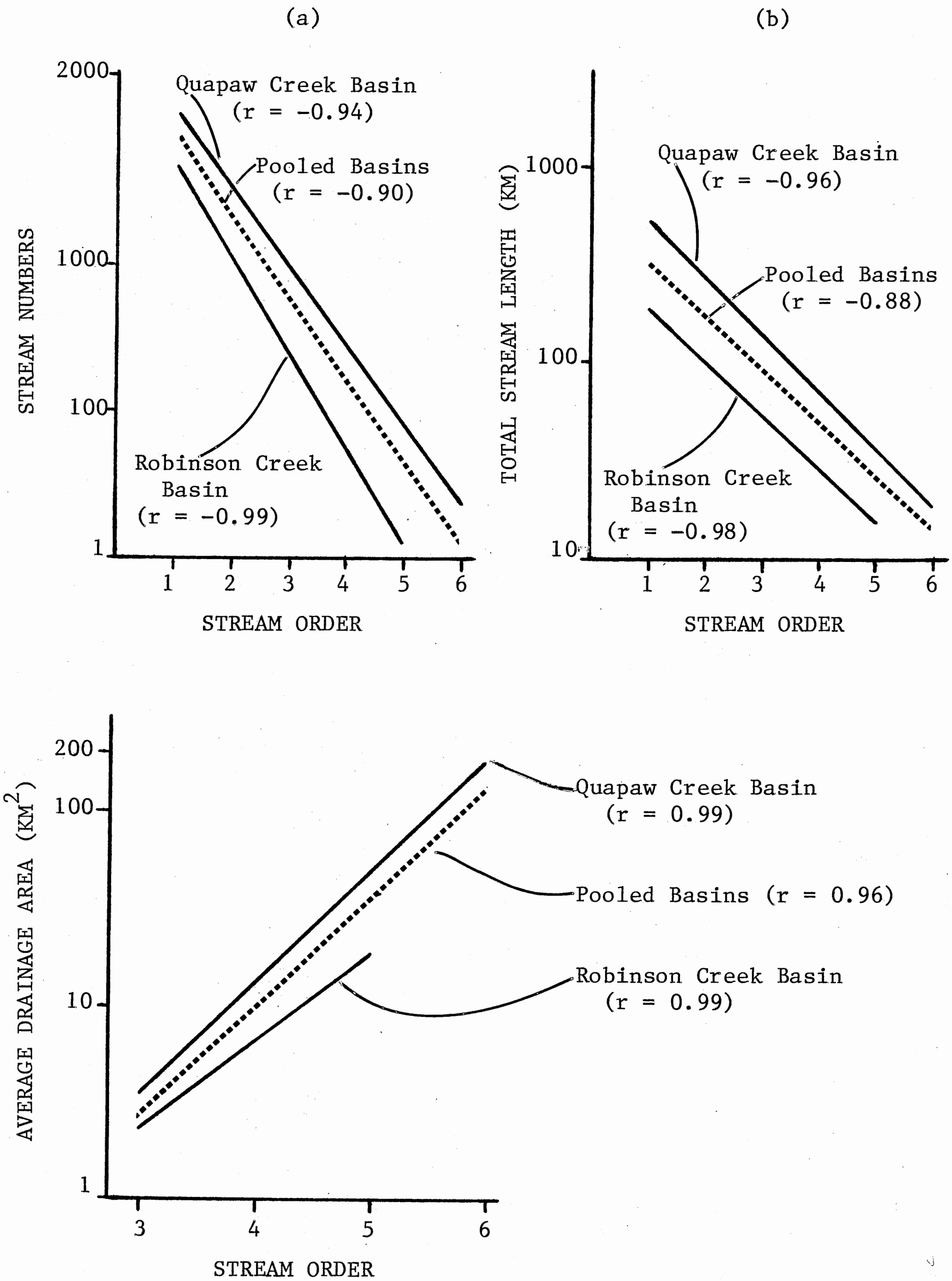

Figure 2. Comparison of Stream Order and Stream Order Parameters

TABLE I

STREAM ORDER PARAMETER VALUES FOR
QUAPAW AND ROBINSON CREEKS

	Quapaw Creek	Robinson Creek
Bifurcation Ratio	4.22	4.93
Stream Length Ratio	2.82	2.72
Drainage Density	8.30	4.72
Stream Frequency	19.15	9.68

Eleven taxa were confined to clay soils during winter while 11 were confined to clay in summer. Thirteen were confined to sand in winter, and eight were confined to sand in summer. Longitudinal succession was mostly by addition of taxa, although some replacement took place. Numbers of taxa by increasing stream order were 55, 33, 40 and 42. Eight taxa were restricted to third order streams while two additional taxa were restricted to third and fourth order streams. Four taxa were restricted to fourth order streams and four others were restricted to sixth order streams (Appendix).

Several genera (Cladotanytarsus, Agabus, Pseudochironomus, Zavrelimyia, and Rheotanytarsus) occurred in third order streams and in fifth (or sixth) order streams. Some genera scattered among all orders on an annual basis were found only in single orders seasonally.

Annual Species Diversity

Data from the two seasonal samples were combined to calculate an annual mean. On an annual basis species diversity was higher on clay soils in Quapaw Creek basin than in Robinson Creek basin except that little difference existed among third order streams (Figure 3).

Species diversity was considerably higher even in streams on sand soils in Quapaw Creek basin than on clay soil streams of Robinson Creek basin (Figure 3). Species diversity was higher in third order and fourth order streams on sand soils, dammed as well as undammed, than in the clay soil streams of either basin.

In the impounded Quapaw Creek basin diversity on clay soils increased with stream order on an annual basis, while in the unimpounded Robinson Creek basin annual diversity decreased with stream

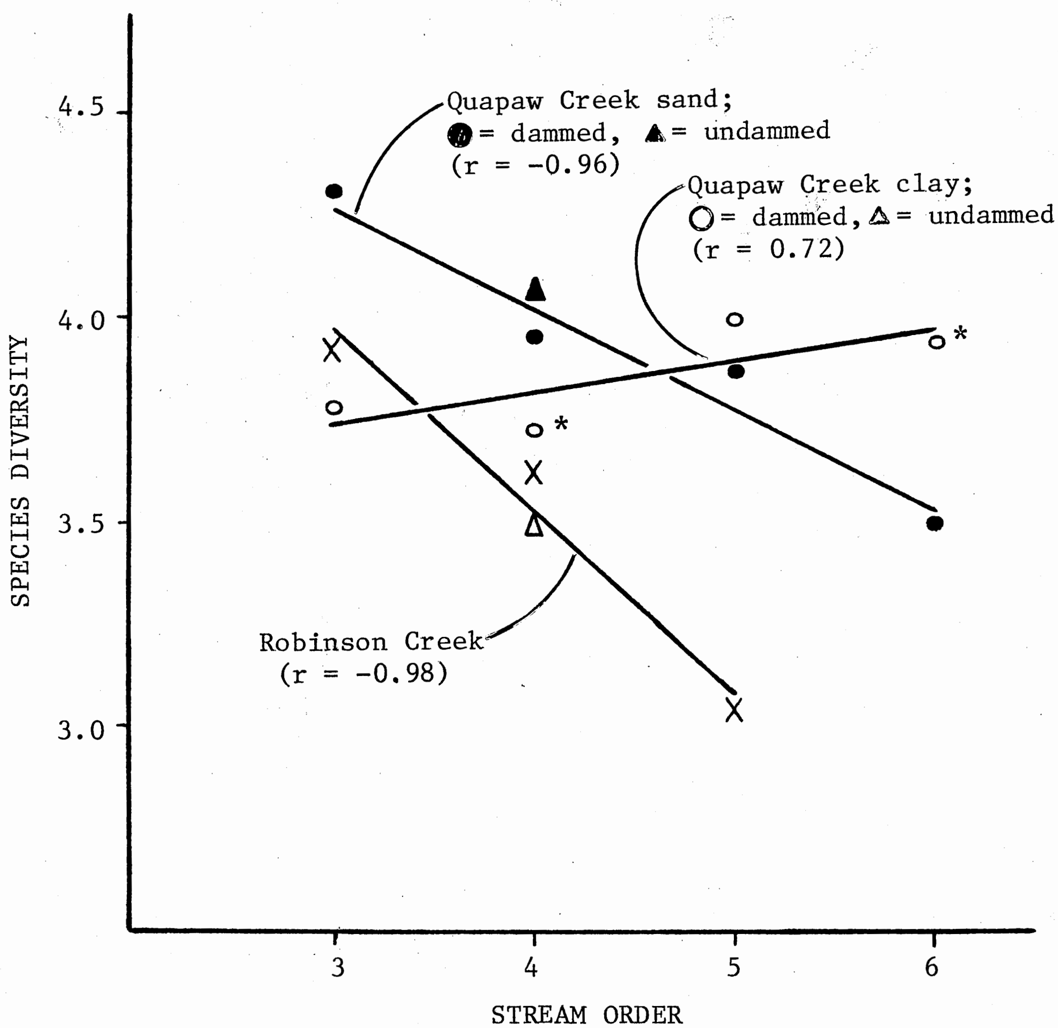

Figure 3. Mean Annual Benthic Macroinvertebrate Species Diversity (*Diversities obtained for stations where large numbers of samplers were lost.)

order (Figure 3). Sand soils in the Quapaw Creek basin also decreased with stream order, but not as drastically as that of Robinson Creek clay soil diversity.

Seasonal Species Diversity

Further differences appear when the data for seasonal samples are examined. Significant differences ($\alpha = 0.05$) exist among streams in impounded and unimpounded basins on clay soils in Quapaw Creek and Robinson Creek, respectively. In the impounded Quapaw Creek basin diversity on clay soils increased with stream order at about the same rate in winter as in summer, although summer diversity was generally lower than winter, probably because of insect emergence (Figures 4 and 5). Sand soils exhibited similar trends in diversity as clay although increase in summer was somewhat less.

In unimpounded Robinson Creek basin, however, great difference existed between summer and winter on clay soils. Winter diversity was about the same in all streams, but summer diversity decreased sharply downstream with increasing order.

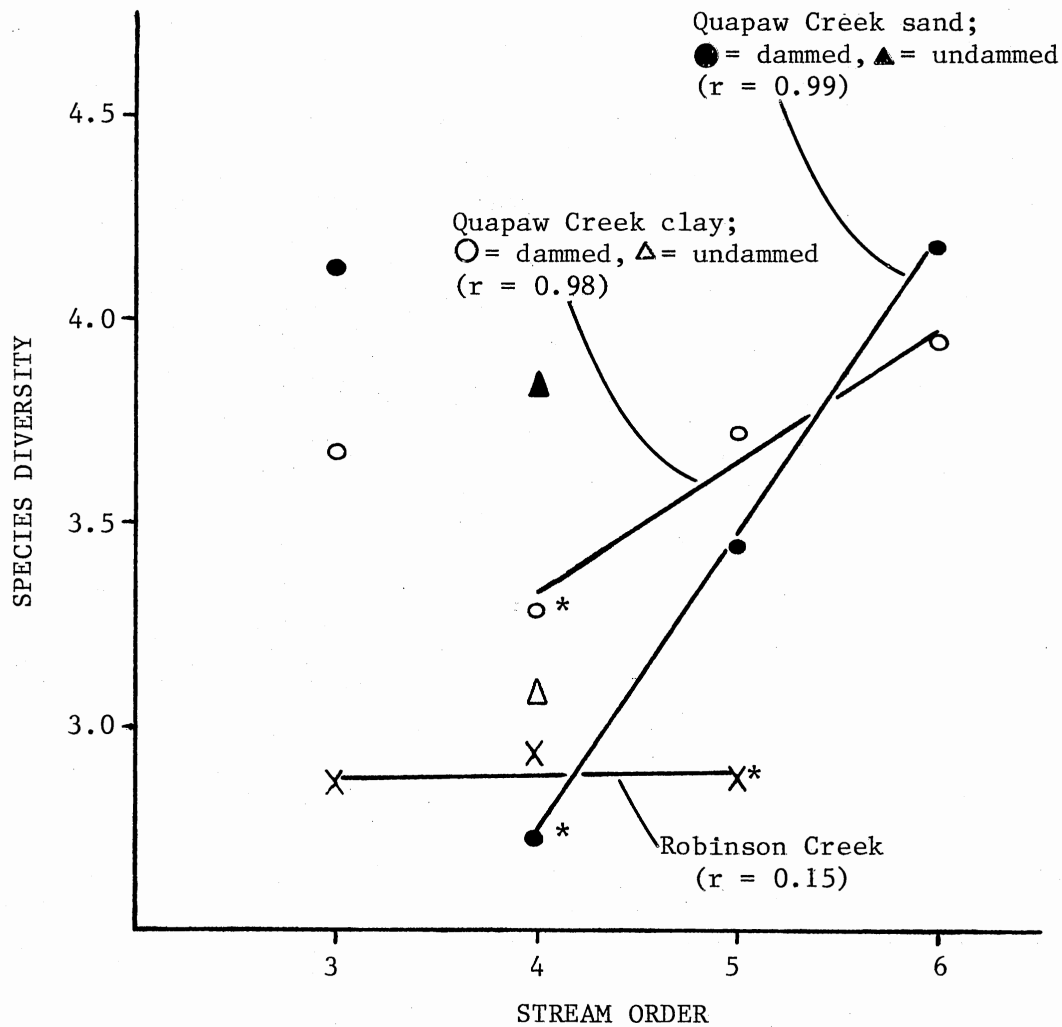

Figure 4. Winter Benthic Macroinvertebrate Species Diversity (*Diversities obtained for stations where large numbers of samplers were lost)

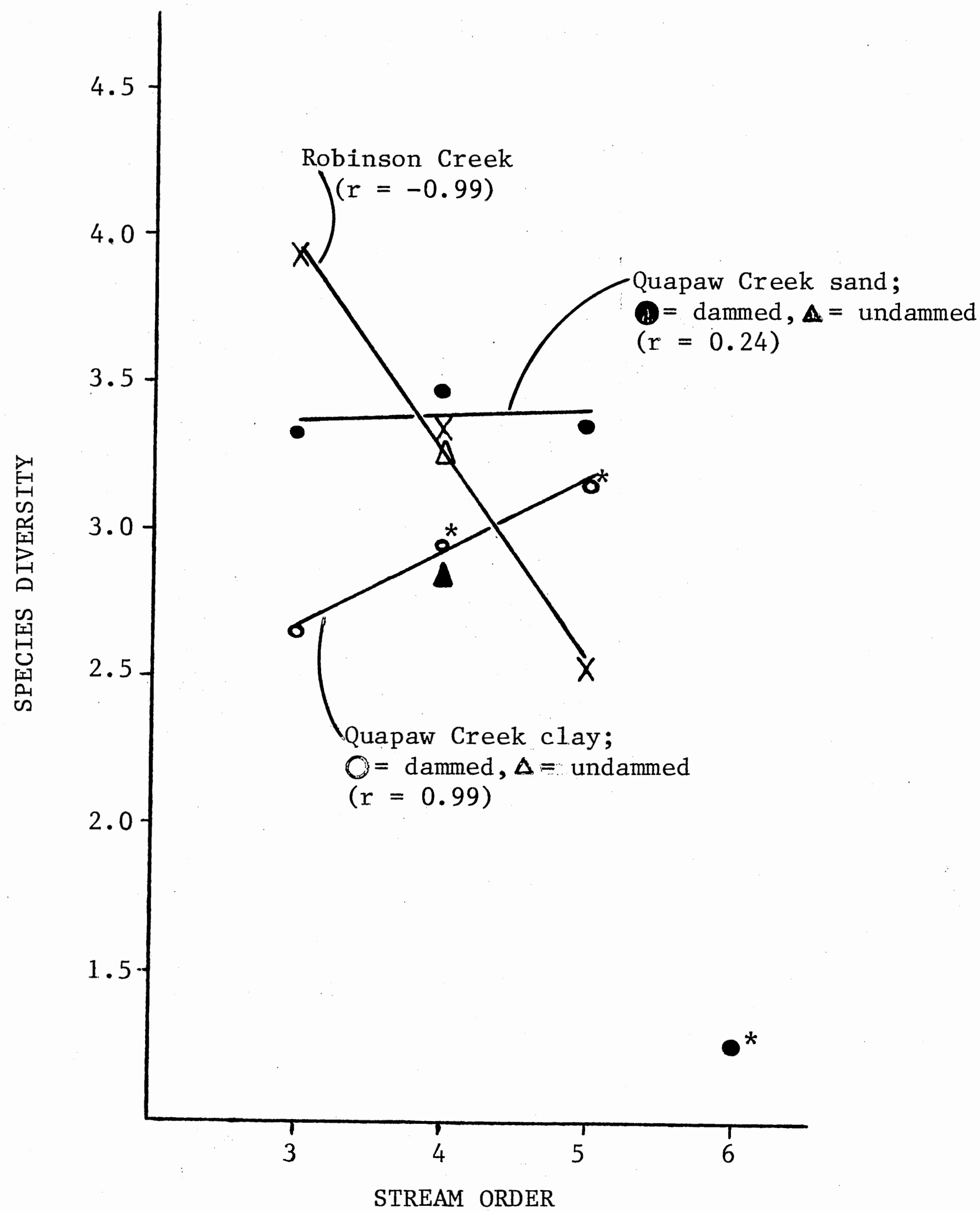

Figure 5. Summer Benthic Macroinvertebrate Species Diversity (*Diversities obtained for stations where large numbers of samplers were lost.)

CHAPTER VI

DISCUSSION

Since stream order parameter values for Robinson Creek basin, including species diversity, are not significantly different from those of Quapaw Creek basin, conditions in one basin can be used to predict similar conditions in the other basin.

Restriction of genera to particular soil types is related to behavioral and ecological demands of the particular organism. Restriction of genera to certain stream orders identifies habitat characteristic of the particular organism, since habitat changes with changing stream order. Genera found in several orders, whether in hierarchical sequence or not, would indicate an existent similarity in these orders; e.g., genera occurring in third and fifth (or sixth) order streams indicate a similarity in these orders, possibly resulting from controlled and extended release of water from the upstream impoundments.

Difference in species diversity, both annual and seasonal, between the two basins appear to be the result of changes in the physical stream environment brought about by the upstream impoundments. Upstream impoundments improved the stream habitat for bottom dwelling organisms and for attached forms to the extent that the impoundments prolonged stream flow duration in the lower stream orders (upstream channels) and reduced flood height and bottom scouring.

Diversity in third order streams in Quapaw Creek basin in winter was much higher than in fourth order streams. Areas downstream (fourth order streams) apparently benefited much less since percentage of impounded water was less. Fall and winter runoff was stored in the impoundments and released through the winter. This maintained sufficient stream flow to allow macroinvertebrate colonization of streams which normally would have been dry and devoid of animal life. The heavy rains of spring appear to have flushed and scoured streams of all orders, resulting in reduced summer diversity. This effect was most pronounced in Robinson Creek, where diversity was progressively reduced downstream. The effect was also severe in sixth order Quapaw Creek streams on sand. Third order streams, however, again benefited following spring rains due to the avoidance of severe scouring because of upstream impoundments.

Stations on unimpounded fourth order streams on clay soil in Quapaw Creek basin were compared with similar streams in Robinson Creek basin and no significant difference existed ($\alpha = 0.05$). However, annual species diversity on clay soils of impounded basins was greater than that of the unimpounded basins of Quapaw Creek and Robinson Creek. On sand soils in Quapaw Creek basin only a small difference existed between impounded and unimpounded basins, the latter being greater (Figure 3).

Leopold and Maddock (1954) have argued that upstream impoundments do not appreciably reduce flooding in downstream higher orders, since too large an area of the basin lies unprotected. The author's data supports this argument since species diversity on the sixth order stream in Quapaw Creek basin was greatly reduced in summer, following unusually heavy spring rains.

Even so, species diversity increased through the fifth order on impounded streams on clay, and was only slightly reduced from fourth to fifth order in impounded streams on sand soils. Diversity, however, progressively and drastically decreased downstream in Robinson Creek basin which has no flood control impoundments.

CHAPTER VII

SUMMARY

1. The objectives of the study were to determine the effect of upstream flood control impoundments by comparing species diversity of benthic macroinvertebrates in Quapaw Creek basin, with impoundments, and Robinson Creek basin, without impoundments.
2. Stream order parameter values of Robinson Creek basin, including species diversity, are smaller but not significantly different ($\alpha = 0.05$) from those of Quapaw Creek basin. Thus, conditions in one basin can be used to predict similar conditions in the other basin.
3. Annual species diversity was generally greater in impounded streams.
4. Species diversity increased downstream in impounded streams on clay soils, but decreased markedly downstream in unimpounded streams on clay soils of the type common to both basins.
5. In impounded streams in Quapaw Creek basin, species diversity was lower in summer but increased downstream in the same manner in winter as well as summer. In unimpounded streams in Robinson Creek basin, diversity was about the same in all orders in winter, but decreased drastically downstream in summer, probably as a result of heavy spring floods.

6. Even partial upstream impoundment appreciably improves environmental conditions downstream such that species diversity is increased.

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APPENDIX

TABLE II

DENSITY OF BENTHIC MACROINVERTEBRATES IN QUAPAW CREEK BASIN BY STREAM ORDER*

Organism	Stream Order			
	3	4	5	6
Psectrocladius *sp.* A	32			
Chaetogaster	6			
Tipula	1			
Parachironomus	9			
Agrion	3			
Tanypus	1			
Cryptochironomus	4			
Dero digitata	47			
Nais variabilis	4			
Procladius	2	1		
Astacidae	4	1		
Podura		1		
Hydrophilidae		1		
Chironomus		4		
Unidentified B1		9		
Unidentified B2		1		
Limnodrilus hoffmeisteri	50	10	7	
Hydra	279		2	
Eukiefferiella	8		2	
Pseudochironomus	1		1	
Zavrelimyia	1		1	
Unidentified D	1		1	
Nais elinguis	114		25	
Immature tubificid with hair chaetae	50		3	
Cladotanytarsus	11		1	
Ablabesmyia	38	22	14	3
Conchapelopia	19	4	22	52
Cricotopus	14	23	116	99
Dicrotendipes	125	5	26	78
Diplocladius	7	1	1	7
Micropsectra	28	2	18	17
Orthocladius	63	25	49	83
Pentaneura	11	2	5	4
Polypedilum	248	19	53	128
Rheotanytarsus	9	1	4	9
Tanytarsus	62	3	27	45
Thienemanniella	151	3	3	11
Trissocladius	12	8	33	23
Chironominae pupae	37	5	4	24
Orthocladinae pupae	33	13	22	33
Tanypodinae pupae	11	1	9	3
Simulium pupae	66	6	9	14
Argia	7	4	4	16
Caenis	102	35	86	77
Physa	83	17	6	1
Stillobezzia	18	1	6	2
Immature tubificid without hair chaetae	41	3	10	4
Psectrocladius *sp.* B	24		6	11
Tribelos	7		2	3
Agabus	1		1	1
Cheumatopsyche	18		14	2
Simulidae	2		8	21
Stenonema *sp.* A	1		54	133
Chrysops	3			1
Hexagenia	5			5
Hydroporinae	1			6
Lirceus	216			18
Berosus	3	3		1
Hyalella azteca	2	16		2
Gomphus		2		1
Empididae			4	1
Asellidae			10	5
Clinotanypus				1
Glyptotendipes				1
Rhizelmis				1
Perlesta placida				15
Stenonema *sp.* B				2

*Density is numbers/station, 0.52 m^2 total area.

TABLE III

DENSITY OF BENTHIC MACROINVERTEBRATES IN ROBINSON CREEK BASIN BY STREAM ORDER*

	STREAM ORDER		
Organism	3	4	5
Cryptochironomus	1		
Rheotanytarsus	1		
Agabus	1		
Microtendipes	1		
Unidentified C	11		
Limnodrilus hoffmeisteri	15		
Cricotopus	1	2	
Dicrotendipes	8	6	
Trissocladius	2	2	
Orthocladinae pupae	2	5	
Physa	4	1	
Stillobezzia	2	1	
Psectrocladius sp. B		1	
Tanypodinae pupae		3	
Simulium pupae		1	
Argia		4	
Astacidae		1	
Unidentified A		1	
Thienemanniella	1		1
Ablabesmyia	6	11	5
Conchapelopia	2	1	3
Micropsectra	8	13	9
Polypedilum	1	3	1
Tanytarsus	5	1	1
Tribelos	1	2	2
Chironomidae pupae	2	7	1
Caenis	43	52	18
Hyalella azteca	6	35	5
Hydroporinae	12	5	1
Lirceus	9	11	3
Stenonema sp. A	1	5	36
Immature tubificid with hair chaetae	4	3	2
Dero digitata	5	1	1
Nais elinguis		33	5
Orthocladius			2

*Density is numbers/station, 0.52 m^2 total area.

TABLE IV

BENTHIC MACROINVERTEBRATES FOUND SEASONALLY

Winter 1975		Summer 1975
Agrion	*Procladius*	*Chironomus*
Asellidae	*Psectrocladius sp.* B	*Helisoma*
Chaetogaster	*Pseudochironomus*	*Microtendipes*
Chrysops	*Rhizelmis*	*Parachironomus*
Cladotanytarsus	*Stenonema sp.* B	Unidentified C
Clinotanypus	*Tanypus*	
Diplocladius	*Tipula*	
Glyptotendipes	*Zavrelimyia*	
Hexagenia	Hydrophilidae	
Nais variabilis	Unidentified A	
Pentaneura	Unidentified B1	
Perlesta placida	Unidentified B2	
Podura	Unidentified D	

TABLE V

BENTHIC MACROINVERTEBRATES CHARACTERISTIC
OF SAND AND CLAY SOILS BY SEASON

Winter 1975		Summer 1975	
Clay	Sand	Clay	Sand
Agrion	*Chaetogaster*	*Agabus*	*Berosus*
Dero digitata	*Clinotanypus*	*Chironomus*	Empididae
Gomphus	*Cryptochironomus*	*Dero digitata*	*Eukiefferiella*
Limnodrilus hoffmeisteri	*Eukieffereliella*	*Hydra*	*Gomphus*
Nais variabilis	*Glyptotendipes*	*Lirceus*	*Helisoma*
Podura	*Psectrocladius sp.* B	*Micropsectra*	*Parachironomus*
Rhizelmis	*Pseudochironomus*	*Microtendipes*	*Psectrocladius sp.* A
Stenonema sp. B	*Tanypus*	*Orthocladius*	Simuliidae
Tipula	*Zavrelimyia*	*Trissocladius*	
Hydrophilidae	Unidentified B1	Hydroporinae	
Unidentified A	Unidentified B2	Unidentified C	
	Unidentified D		
	Immature tubificid without hair setae		

TABLE VI

DENSITY OF BENTHIC MACROINVERTEBRATES IN QUAPAW CREEK BASIN ON SAND SOIL IN WINTER*

Taxa	Station 1	2	3	4	5	6	7	8	9	10
Ablabesmyia	17	1		1					1	
Agabus		1								
Argia									2	8
Asellidae					2				1	
Astacidae	3									
Berosus									1	
Caenis	21	2		5	4	9	4	1	15	3
Chaetogaster		6								
Cheumatopsyche									1	
Chironominae pupae	12	3			1	1		2	3	
Chrysops	1								1	
Cladotanytarsus	1	10								
Clinotanypus										1
Conchapelopia	2				1			3	2	18
Cricotopus	4					4	7	32	13	14
Cryptochironomus		3								
Dicrotendipes	62	17			1	1		4		20
Diplocladius								1		5
Empididae								1		
Eukiefferiella	8									
Glyptotendipes										1
Hexagenia		2								
Hyalella azteca				1						2
Hydra	1									
Hydroporinae	1									
Lirceus						8				4
Micropsectra	21	3					2	3	1	15
Nais elinguis	57	18				4		6		
Orthocladinae pupae	10	7		4	3	4		11	2	3
Orthocladius	16	5		22	1	1	4	24	8	21
Pentaneura	5	6		2			2			2
Perlesta placida						3				1
Physa anatina	1	2								
Polypedilum	41	13					4	8	2	27
Procladius		1		1						
Psectrocladius sp. A	20				1	1				
Psectrocladius sp. B	12									
Pseudochironomus	1							1		
Rheotanytarsus		3								
Simuliidae									20	1
Simulium pupae										11
Stenonema sp. A										9
Stilobezzia	8			1					2	
Tanypodinae pupae	3					1		4		
Tanypus	1									
Tanytarsus	22	10			1	3	1	4		26
Thienemanniella	132			1		5			1	1
Tribelos		1								2
Trissocladius	4			2	2	3	3	10	4	
Zavrelimyia		1						1		
Unidentified B1				9						
Unidentified B2				1						
Unidentified D	1							1		
Immature tubificid without hair setae	22	9		1	1	4	2		4	
Immature tubificid with hair setae	39	7				2				

*Density is numbers/station, $0.52 m^2$ total area.

TABLE VII

DENSITY OF BENTHIC MACROINVERTEBRATES IN QUAPAW CREEK BASIN ON CLAY SOIL IN WINTER*

Taxa	Station 11	12	13	14	15	16	17	18	19	20
Ablabesmyia	1	5						4	1	
Agabus								1		1
Agrion		3								
Argia			1					4	1	3
Asellidae								10	1	3
Astacidae	1									
Berosus			1							
Caenis		34	9		26		4	75	23	30
Cheumatopsyche		1				1			1	
Chironominae pupae	1	1			1			1	1	4
Chrysops	2									
Cladotanytarsus								1		
Conchapelopia		9	1					14	19	11
Cricotopus	2	3	19			10		54	53	19
Dero digitata		37								
Dicrotendipes	2	33	1			3		15	37	20
Diplocladius	2	5	1			2				2
Empididae										1
Gomphus										1
Hexagenia		3								5
Hydra		277								
Hydrophilidae			1							
Hydroporinae					3		1		5	1
Lirceus	80				32	3			14	
Limnodrilus hoffmeisteri	6	38								
Micropsectra		4	2		1			13		1
Nais elinguis		14					10			
Nais variabilis		4								
Orthocladinae pupae	11		8		2	10	4	6	21	7
Orthocladius	4	38	3		2	13	2	19	49	5
Pentaneura								3		2
Perlesta placida									5	9
Physa anatina	23	19							1	
Podura			1							
Polypedilum	1	10	1			1		4	23	13
Procladius		1								
Psectrocladius sp. A	1	11						6	8	3
Rheotanytarsus	1	2	1					2	8	1
Rhizelmis										1
Simuliidae		1				1				
Simulium pupae	35		6				2		3	
Stenonema sp. A							1	53	41	65
Stenonema sp. B										2
Stilobezzia					1					
Tanypodinae pupae		5				1	2	2	3	
Tanytarsus	1	26	2					22	8	11
Thienemanniella		19			1			3	6	3
Tipula		1								
Tribelos	1	3						2		
Trissocladius	3	5	6		1	6	8	12	17	2
Immature tubificid with hair setae		4								

*Density is numbers/station, 0.52 m^2 total area.

TABLE VIII

DENSITY OF BENTHIC MACROINVERTEBRATES IN QUAPAW CREEK BASIN ON SAND SOIL IN SUMMER*

Taxa	Station									
	1	2	3	4	5	6	7	8	9	10
Ablabesmyia	3	11		9		3		2		1
Argia	1	6	2	1						2
Astacidae				1						
Berosus	2	1	2							
Caenis	43			3		6		1		6
Cheumatopsyche	5	5						14		
Chironominae pupae	8	9	1			2		1		16
Conchapelopia		6		1				2		2
Cricotopus	2	2	2					21		
Cryptochironomus		1								
Dicrotendipes	1	9				2				1
Empididae								3		
Eukiefferiella								2		
Gomphus			2							
Helisoma					1	1				
Hyalella azteca	1		1	12		2				
Limnodrilus hoffmeisteri				10						
Nais elinguis							8			
Orthocladinae pupae	1	3						1		
Parachironomus		9								
Physa anatina	2	8	13				5	1		
Polypedilum	32	86		4			2	22		163
Psectrocladius sp. A	12									
Rheotanytarsus		3								
Simuliidae		1						8		
Simulium pupae		7						7		
Stenonema sp. A		1				2				18
Stilobezzia		10						2		
Tanypodinae pupae		3		1				1		
Tanytarsus		3	1							
Thienemanniella				2						
Tribelos		2								1
Immature tubificid without hair seate				2						
Immature tubificid with hair setae					2		3			

*Density is numbers/station, 0.52 m^2 total area.

TABLE IX

DENSITY OF BENTHIC MACROINVERTEBRATES IN QUAPAW CREEK BASIN ON CLAY SOIL IN SUMMER*

Taxa	Station									
	11	12	13	14	15	16	17	18	19	20
Ablabesmyia			12		4		8			
Astacidae					3					
Caenis	1	1	18		4		1			
Cheumatopsyche	7									
Chironomine pupae	2	1	4		7					
Chironomus			4							
Conchapelopia	2		2		1		3			
Cricotopus	1		2				2			
Dero digitata	7	3								
Dicrotendipes	1		4				7			
Hyalella azteca	1		2		2					
Hydra		1								
Hydroporinae					1		1			
Lirceus	136				7					
Limnodrilus hoffmeisteri	6						7			
Micropsectra					3					
Nais elinguis	25						1			
Orthocladinae pupae			1							
Orthocladius					2					
Physa anatina	19	9	4							
Polypedilum	65		14		2		13			
Rheotanytarsus							2			
Simulium pupae	23	1								
Stilobezzia							4			
Tanytarsus					1					
Immature tubificid without hair setae	4	6					8			

*Density is numbers/station, 0.52 m^2 total area.

TABLE X

DENSITY OF BENTHIC MACROINVERTEBRATES
IN ROBINSON CREEK BASIN IN WINTER*

	Station					
Taxa	21	22	23	24	25	26
Ablabesmyia	1	1		2		1
Astacidae			1			
Caenis		12	7	1		5
Chironomidae pupae	1			1		
Dero digitata				1		1
Dicrotendipes		1		1		
Hyalella azteca			1	3		
Hydroporinae	7	3	2	2		1
Limnodrilus hoffmeisteri	5	3				
Lirceus	7			11		3
Micropsectra	1	2		1		
Nais elinguis				27		5
Orthocladinae pupae		1				
Orthocladius						2
Psectrocladius sp. A				1		
Stenonema			1			2
Tanypodinae pupae				1		
Tanytarsus		1				
Thienemanniella						1
Tribelos		1	1	1		
Unidentified A			1			

*Numbers are in terms of benthic macroinvertebrates sampled by four multiple plate samplers, 0.52 m^2 total area, per station.

TABLE XI

DENSITY OF BENTHIC MACROINVERTEBRATES
IN ROBINSON CREEK BASIN IN SUMMER*

Taxa	Station 21	22	23	24	25	26
Ablabesmyia		4	4	5	1	3
Agabus		1				
Argia				4		
Caenis	9	22	25	19	9	4
Chironominae pupae		1		6		1
Conchapelopia		2	1		2	1
Cricotopus		1		2		
Cryptochironomus	1					
Dero digitata	5					
Dicrotendipes	3	4	1	4		
Hyalella azteca	4	2		31	5	
Hydroporinae	1	1	1			
Limnodrilus hoffmeisteri	7					
Lirceus	2					
Micropsectra	4	1	1	11	2	7
Microtendipes	7	1				
Nais elinguis			6			
Orthocladinae pupae	1		3	2		
Physa anatina	1	3		1		
Polypedilum		1	1	2		1
Rheotanytarsus	1					
Simulium pupae				1		
Stenonema	1		1	3	8	26
Stilobezzia	2			1		
Tanypodinae pupae			2			
Tanytarsus	3	1		1		1
Thienemanniella	1					
Tribelos						2
Trissocladius		2	1	1		
Unidentified C		11				
Immature tubificid with hair setae	4		3		2	

*Numbers are in terms of benthic macroinvertebrates sampled by four multiple plate samplers, 0.52 m^2 total area, per station.

VITA

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