

# Species Composition and Diversity of Benthic Macroinvertebrates in Greasy Creek, Red Rock Creek and the Arkansas River

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**ABSTRACT:** One hundred taxa of benthic macroinvertebrates were collected on artificial substrate samplers at seven stations in three streams between March 1975 and January 1976. Two-thirds of the taxa were Diptera, Ephemeroptera and Trichoptera. Sixty-two were collected in Greasy Creek, 64 in Red Rock Creek and 63 in the Arkansas River. Numbers of taxa and density were generally low in late autumn and winter, probably reflecting the low temperatures. Maximum density occurred at most stations in early autumn, resulting in low values of species diversity. Numbers of taxa and species diversity did not reflect high conductivity or low oxygen concentration in Greasy Creek. Although numbers of taxa and values of diversity were generally similar in the creeks and the river, density was considerably greater in the river.

## INTRODUCTION

Benthic macroinvertebrates have been studied extensively for many years because they are important in aquatic food chains and are useful as indicators of the degree and severity of organic pollution. Because of their importance in aquatic ecosystems, macroinvertebrates are usually included in environmental assessments and impact statements. Little data exist on the distribution and diversity of these organisms in the Arkansas River and its tributaries. It is the purpose of this study to describe the seasonal and spatial variation in species composition and diversity of benthic macroinvertebrates in three N-central Oklahoma streams: Greasy Creek, Red Rock Creek and in the Arkansas River near the confluence of the two creeks.

## SAMPLING SITES

Greasy Creek originates ca. 10 km SW of the intersection of U.S. Hwy. 177 and Oklahoma Hwy. 15, flows northwesterly for over 30 km, and empties into the Arkansas River (Fig. 1). Two stations were established, GU and GD (GU = Greasy Creek, upstream station; GD = downstream station). Station GU was located at the intersection of the two highways. Water level fluctuated considerably during the study in the intermittent Greasy Creek as in the other two streams, ranging from high levels in the spring to low levels in late summer and autumn. Mean width at station GU was ca. 3 m and average depth less than 1 m. Station GD was located ca. 10 km downstream from Station GU. Average width and depth were ca. 5 and 1 m, respectively. The substrate at both stations was fine silt, while

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mean flow in the creek ranged from 0 - 0.20 m<sup>3</sup>/sec.

Red Rock Creek originates ca. 1.0 km NW of Enid, Oklahoma, flows easterly for ca. 100 km, and empties into the Arkansas River ca. 15 km SE of Ponca City, Oklahoma. Two stations were established, RD ca. 3.5 km upstream from the mouth and Station RU ca. 9 km upstream from RD. Average width and depth were ca. 6 and 2 m, respectively, at the upstream station and ca. 7 and 4 m at the downstream station. The substrate of Red Rock Creek was fine silt and flow in the creek ranged from 0 - 0.37 m<sup>3</sup>/sec.

Three stations were established on the Arkansas River. Station AU was ca. 1.5 km upstream from the confluence of Red Rock Creek and the river, while Station AM (AM = middle station) was immediately downstream. Station AD was ca. 5 km downstream from AM and ca. 0.5 km downstream from the confluence of the river and Greasy Creek. The river ranged from 30 - 900 m in width, while flow varied from 32.0 - 151.78 m<sup>3</sup>/sec. Unlike the creeks, the substrate of the Arkansas River was primarily sand.

#### METHODS

Water temperature was measured with a mercury thermometer.

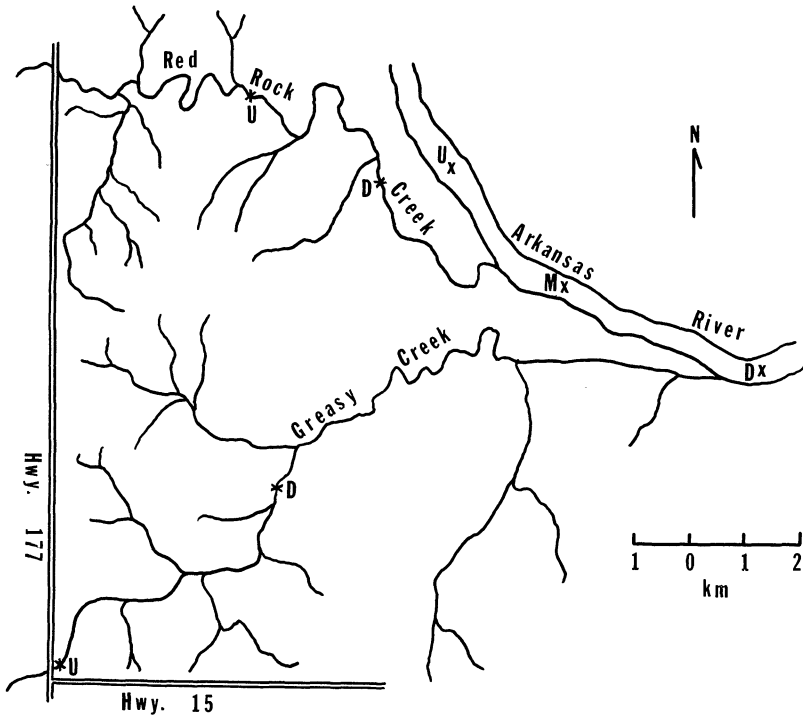


Fig. 1.—Map showing streams and collecting stations (X). U = Upstream station, M = Middle, D = Downstream station

Dissolved oxygen concentration, conductivity and  $pH$  were measured with a YSI model 54 oxygen meter, a Barstead PM — 70 CB conductivity meter and an IBC Trophy  $pH$  meter, respectively. Turbidity was analyzed with a Hach direct-reading colorimeter. Discharge in the creeks was estimated by timing the velocity of a float over a distance of 15.2 m and multiplying the velocity by the cross-sectional area of the water passing the reference point.

Macroinvertebrates were collected on modified Hester-Dendy artificial substrate samplers exposed for ca. 6 weeks during the following six periods in 1975-76:

Early spring	17 Mar. - 28 Apr. (4 Apr. - 19 May at RU)
Early spring	12 June - 16 July (22 May - 2 July at GU)
Summer	22 July - 2 Sept.
Early autumn	22 Sept. - 3 Nov.
Late autumn	10 Nov. - 22 Dec.
Winter	29 Dec. - 9 Feb.

Two samplers each were attached to three buoys anchored at each of the seven stations. The total surface area of each sampler was 0.15 m<sup>2</sup>. At the time of collection, a plankton net was placed below the sampler to catch dislodged organisms and the sampler was placed in a plastic bag. In the laboratory, the samplers and the contents of the plastic bag were placed in a No. 30 mesh sieve. Samplers were disassembled and material adhering to the plates was brushed into the sieve. Organisms were washed into an enamel pan, sorted and placed in a sample bottle containing 8% formalin. Organisms were identified on four of the six samplers from each station to the lowest taxonomic group possible, while the remaining two were held in reserve in the event of loss. Species diversity ( $\bar{d}$ ) was determined by the Shannon-Weaver (1963) information theory expression.

## RESULTS

Mean physicochemical conditions of the two stations each on Greasy and Red Rock creeks and the three stations in the Arkansas River are given in Table 1. Surface water temperature varied from 2 to 30 C. Dissolved oxygen concentration exceeded 5 mg/liter in all streams except in summer and early autumn in Greasy Creek. Maximum oxygen was recorded in winter in all streams. Specific conductance was considerably higher in Greasy Creek in spring and summer than in the other streams, reflecting the high runoff during these seasons over abandoned oil fields. During autumn and winter, when runoff was low, values of conductivity were highest in the Arkansas River but did not approach the magnitude of the values in spring and summer in Greasy Creek. Maximum turbidity was 174 JTU in early autumn in Greasy Creek. Minimum turbidity was measured in winter in Red Rock Creek and in the river.

TABLE 1.—Mean physicochemical conditions\* in the three streams in 1975 - 76

Stream	Parameter	Early spring		Late spring		Summer		Early autumn		Late autumn		Winter
		spring	spring	spring	spring	Summer	Summer	Early autumn	Early autumn	Late autumn	Late autumn	
Greasy Creek	Temp (°C)	22	30	26	16	8						
	DO (mg/l)	8.8	7.0	4.6	3.8	11.5	16.3					
	Cond. ( $\mu$ mhos/cm)	4818	3009	4498	1648	844	1635					
	pH	8.0	7.9	7.8	7.4	8.2	8.2					
	Turbidity (JTU)	22	35	45	174	81	30					
	Discharge (m <sup>3</sup> /sec)	0.10	0.20	0	0	0	NM					
Red Rock Creek	Temp (°C)	NM	28	28	16	2	7					
	DO (mg/l)	NM	7.8	7.1	5.0	8.8	13.5					
	Cond. ( $\mu$ mhos/cm)	NM	1006	1086	583	868	1278					
	pH	NM	7.8	8.1	7.2	7.4	8.2					
	Turbidity (JTU)	NM	120	84	109	70	36					
	Discharge (m <sup>3</sup> /sec)	NM	0.37	0	0	0	NM					
Arkansas River	Temp (°C)	22	26	30	16	2	6					
	DO (mg/l)	10.8	7.9	6.8	10.7	11.5	14.2					
	Cond. ( $\mu$ mhos/cm)	1905	1500	1655	1868	2394	2458					
	pH	8.4	7.9	8.4	8.0	8.3	8.6					
	Turbidity (JTU)	65	108	96	90	84	26					
	Discharge (m <sup>3</sup> /sec)**	151.78	132.52	44.46	32.00	34.93	NM					

\* Means of values measured at two stations each in the creeks and three stations in the river

\*\* Source: U.S.G.S., Ralston Gauge

NM = Not measured

One hundred taxa of benthic macroinvertebrates were collected on the artificial samplers at the seven stations in the three streams (Table 2). Two-thirds of the taxa were Diptera (43 taxa), Ephemeroptera (13) or Trichoptera (9). Sixty-two taxa were collected in Greasy Creek, 64 in Red Rock Creek and 63 in the Arkansas River.

The number of taxa taken from any one station varied from four to 30 (Table 3). Variation among streams was less than seasonal variation within streams. Numbers of taxa were generally less in late autumn and winter than during the other seasons. Richness was especially low in late autumn and winter in Red Rock Creek.

Density of benthic macroinvertebrates in Greasy Creek varied from 108-3185 individuals/m<sup>2</sup> (Table 3). In Red Rock Creek, density reached 8856 individuals/m<sup>2</sup> in early autumn. Density was considerably greater at the riverine stations than in the creeks, reaching 30,456 individuals/m<sup>2</sup> in early autumn at the upstream station and 21,895 in summer at the middle station. Maximum density was measured in early autumn at five of the seven stations, while density was generally low in early spring and in winter.

In Greasy Creek several kinds of mayflies and midges were occasionally numerous. *Caenis* sp. was abundant at Station GU, the upstream station, from late spring through early autumn; in late spring *Stenonema frontale* and *Hyalella azteca* were relatively common. Large numbers of *Stenonema frontale* were also taken from Station GD in late spring and summer, while *Argia* sp. was common at both stations in summer. Midges generally were most abundant in early autumn. *Glyptotendipes* sp. was the most abundant organism collected at both stations. *Chironomus (Dicrotendipes)* sp. was numerous in Greasy Creek in summer and early autumn.

In Red Rock Creek, *Stenonema frontale* was generally common at both stations through early autumn. *Tricorythodes* sp. and *Cheumatopsyche* sp. were common in spring. *Argia* sp. also was common in summer, as in Greasy Creek. Several midges were numerous in Red Rock Creek. *Glyptotendipes* sp., the most common organism at the downstream station (8343 individuals/m<sup>2</sup> in early autumn) in Red Rock Creek, was rare at Station RU. *Chironomus (Dicrotendipes)* sp. was common in summer at both stations, as in Greasy Creek. *Rheotanytarsus* sp. was abundant in early spring at Station RU, while *Larsia* sp. and *Chironomus (Tribelos)* sp. were common in summer at the downstream station.

In the Arkansas River, many taxa were abundant including *Caenis* sp. and *Stenonema ares* in late spring, *Cheumatopsyche* sp. and *Hydropsyche orris* from summer through late autumn, and *Simulium* sp. in late autumn and winter. Two midges were abundant at all riverine stations, *Polypedilum* sp. in summer and *Rheotanytarsus* sp. from late spring through early autumn. A number of other species were common at one or two stations. Several species attained densities exceeding 2000 individuals/m<sup>2</sup> during at least one sampling period—*Caenis* sp., *Cheumatopsyche* sp., *Hydropsyche orris*, *Polypedilum* sp. and *Rheo-*

TABLE 2.—Benthic macroinvertebrates collected from Greasy Creek, Red Rock Creek and the Arkansas River

Clavidae	<i>Cordylophora lacustris</i> Allman (R/EF) *
Planariidae	<i>Dugesia tigrina</i> (Girard) (R/S)
Endoprocta	<i>Urnatella gracilis</i> Leidy (G, A/S)
Glossiphoniidae — unidentifiable organisms (R/LS)	
Naididae	<i>Dero digitata</i> (O. F. Muller) (G, R, A/LS, S, EF, LF, W); <i>Nais variabilis</i> Pignet (G, R, A/ES, LS, EF, LF, W); <i>Pristina</i> sp. (R/S, EF)
Enchytraeidae — Unidentifiable organisms (G/ES)	
Tubificidae	<i>Aulodrilus pigueti</i> Kowalewski (G/LF, W); <i>Branchiura sowerbyi</i> Beddard (R/LS); Unidentifiable tubificid with capilliform chaetae (G/EF); Unidentifiable tubificid without capilliform chaetae (A/LF)
Astacidae — unidentifiable organisms (G/ES)	
Talitridae	<i>Hyalella azteca</i> (Saussure) (G, R/ES, LS, S, EF, LF, W)
Nemouridae	<i>Taeniopteryx maura</i> Pictet (A/LF, W)
Perlodidae	<i>Isogetis</i> sp. (A/W); <i>Isoperla</i> sp. (A/LF)
Perlidae	<i>Neoperla clymene</i> (Newman) (A/S, LF); <i>Perlesta placida</i> (Hagen) (R, A/ES)
Ephemeroidea	<i>Hexagenia limbata</i> (Serville) (G/S, EF)
Baetidae	<i>Caenis</i> sp. (G, R, A/ES, LS, S, EF, LF); <i>Campsurus</i> sp. (A/LS); <i>Choroterpes</i> sp. (G, R, A/ES, LS, EF, LF, W); <i>Isonychia</i> sp. (R, A/ES, LS, EF); <i>Pseudocloeon</i> sp. (R, A/ES, LS, S, LF); <i>Tricorythodes</i> sp. (G, R, A/LS, S, EF); Unidentifiable organisms (R/LS)
Heptageniidae	<i>Heptagenia diabasia</i> Burks (R/ES); <i>Heptagenia maculipennis</i> Walch (R, A/ES, EF, LF, W); <i>Stenonema ares</i> Burks (R, A/ES, LS, S, EF, LF, W); <i>Stenonema birdi</i> Needham (G, R, A/ES, LS, S, EF); <i>Stenonema frontale</i> (Banks) (G, R, A/ES, LS, S, EF, LF, W)
Gomphidae	<i>Gomphus</i> sp. (R, A/LS, S, W)
Coenagrionidae	<i>Argia</i> sp. (G, R, A/ES, LS, S, EF, LF, W); <i>Ischnura</i> sp. (G/LS); Unidentifiable organisms (G, R/ES, LS)
Corixidae — Unidentifiable organisms (R/ES)	
Corydalidae	<i>Corydalus cornutus</i> L. (G, A/LS, S, EF, LF)
Sialidae	<i>Sialis</i> sp. (G, A/LS, EF)
Leptoceridae	<i>Leptocella</i> sp. (R, A/LS, S, EF)
Hydroptilidae	<i>Mayatrichia</i> sp. (A/LS, S)
Hydropsychoidea	<i>Cheumatopsyche</i> sp. (G, R, A/ES, LS, S, EF, LF, W); <i>Hydropsyche orris</i> Ross (G, R, A/ES, LS, S, EF, LF, W); <i>Hydropsyche scularis</i> group (G, R, A/ES, LS, S, EF, LF, W); <i>Hydropsyche pupae</i> (A/S, EF); Unidentifiable organisms (R, A/LS, S, EF, LF, W)

*tanytarsus* sp. Several taxa of the order Plecoptera were taken in the Arkansas River, but were collected during only one sampling period in Red Rock Creek and were not taken from Greasy Creek.

Species diversity ( $\bar{d}$ ) in Greasy Creek ranged from 1.2 - 3.8 (Table 3). Maximum values occurred in early spring and minimum values in early autumn. Diversity was generally lower in Red Rock Creek than

TABLE 2.—(continued)

Psychomyiidae	<i>Polycentropus</i> sp. (R/ES); Psychomyiid genus A (Ross) (G, R, A/LS, S, EF, LF, W); Unidentifiable organisms (G, A/LS, S)
Dytiscidae	<i>Hydporus</i> sp. (G/ES, EF, W)
Gyrinidae	<i>Gyrinus</i> sp. (G, R/ES, LS, S, EF)
Dryopidae	<i>Helichus lithophilus</i> Germar (R, A/S)
Elmidae	<i>Dubiraphia</i> sp. (G/EF); <i>Stenelmis</i> sp. (G, R, A/ES, LS, S, EF, LF, W)
Hydrophilidae	<i>Berosus</i> sp. (G, R/LS, S, EF, LF)
Helodidae — unidentifiable organisms	(G/EF)
Simuliidae	<i>Simulium</i> sp. (G, R, A/ES, LS, EF, LF, W)
Chironomidae	<i>Ablabesmyia</i> sp. (G, R, A/ES, LS, S, EF, LF); <i>Chironomini</i> sp. A (Roback) (R/S); <i>Chironomus</i> ( <i>Chironomus</i> ) sp. (G, R, A/ES, LS, S, EF, LF, W); <i>Chironomus</i> ( <i>Dicrotendipes</i> ) sp. (G, R, A/ES, LS, S, EF, LF, W); <i>Chironomus</i> ( <i>Tribelos</i> ) sp. (G, R, A/ES, LS, S, EF, LF); <i>Cladotanytarsus</i> sp. (G/LF); <i>Coelotanypus</i> sp. (R/S); <i>Conchopelopia</i> sp. (R, A/EF, LF, W); <i>Corynoneura</i> sp. (G, R, A/ES, S); <i>Cricotopus</i> sp. 2 (G, A/ES, W); <i>Cricotopus</i> sp. 3 (G, R, A/ES); <i>Cryptochironomus</i> sp. (R/S); <i>Eukiefferiella</i> sp. (A/W); <i>Glyptotendipes</i> sp. (G, R, A/S, EF, LF, W); <i>Goeldichironomus</i> sp. (G, A/ES); <i>Guttipelopia</i> sp. (R/ES); <i>Harnischia</i> sp. (G/LS); <i>Labrundinia</i> sp. (G, R/LS, S, EF, LF); <i>Larsia</i> sp. (G, R, A/ES, LS, S, EF, LF, W); <i>Metriocnemus</i> sp. (A/ES); <i>Micropsectra</i> sp. (G, R, A/ES, LS, S, EF, LF, W); <i>Microtendipes</i> sp. (G/LS); <i>Orthocladus</i> sp. (G, R, A/EF, LF, W); <i>Parachironomus</i> sp. 1 (G, R/ES, S, LF); <i>Parachironomus</i> sp. 2 (G, R/ES, S); <i>Paralauterborniella</i> sp. (R, A/LS, S); <i>Pedionomus</i> sp. (G/S); <i>Pentaneura</i> sp. (R, A/ES, EF); <i>Phaenopsectra</i> sp. (G/LS); <i>Polypedilum</i> sp. (G, R, A/ES, LS, S, EF, LF, W); <i>Procladius</i> sp. (G, R/ES, S, EF, W); <i>Psectrocladius</i> sp. (G, R, A/ES, LS, S, EF, LF, W); <i>Pseudochironomus</i> sp. (G/S, EF); <i>Rheotanytarsus</i> sp. (G, R, A/ES, LS, S, EF, LF, W); <i>Stenochironomus</i> sp. (A/LS); <i>Tanypus</i> sp. (G/S); <i>Tanytarsus</i> sp. (G, A/ES, LS, S, EF); <i>Thienemanniella</i> sp. (A/ES, W); <i>Trichocladus</i> sp. (R, A/ES); <i>Trissocladius</i> sp. (G, R, A/EF, LF, W); Unidentified pupae (G, R, A/ES, LS, S, EF, LF, W)
Ceratopogonidae	(G, A/S, LF)
Empididae — unidentifiable organisms	(R, A/ES, LS, S, EF, LF)
Physidae	<i>Physa halei</i> Lea (G/S, EF, W)
Sphaeriidae	<i>Sphaerium</i> sp. (R/LS)

\*G — Greasy Creek, R — Red Rock Creek, A — Arkansas River  
 ES — Early spring S — Summer LF — Late fall  
 LS — Late spring EF — Early fall W — Winter

in Greasy Creek, varying from 0.4 to 3.3. Maximum values occurred in summer. The range in diversity in the Arkansas River was from 1.6 - 3.3. No trend was apparent at the riverine stations.

#### DISCUSSION

The number of taxa of benthic macroinvertebrates collected (62 in Greasy Creek, 64 in Red Rock Creek, 63 in the Arkansas River) is within the range reported for annual studies in other Oklahoma streams. Mathis (1965) used Ekman and Surber samples to collect 79 taxa in Black Bear Creek, which is located ca. 9 km S of Greasy Creek. Harrell and Dorris (1968) collected 111 taxa with an Ekman dredge in Otter Creek. Black Bear Creek and Otter Creek are relatively unpolluted except for oil-field brines. In Skeleton Creek, which receives domestic and oil refinery wastes, only 42 taxa were taken (Wilhm and Dorris, 1966).

TABLE 3.—Mean density ( $\bar{n}$ ) in numbers/m<sup>2</sup>, total numbers of taxa (s), and pooled species diversity ( $\bar{d}$ ) of benthic macroinvertebrates in four Ekman dredge hauls at each station for each season in 1975 - 76

Stream	Station	Early spring			Late spring			Summer		
		n	s	$\bar{d}$	n	s	$\bar{d}$	n	s	$\bar{d}$
Greasy Creek	GU	379	20	3.2	1078	20	2.8	2265	22	2.4
	GD	302	21	3.8	1285	20	2.2	708	16	2.9
Red Rock Creek	RU	929	26	2.8	1411	25	1.8	1025	26	3.0
	RD	NM	....	NM	1926	13	0.4	1163	23	3.3
Arkansas River	AU	NM	....	NM	21793	17	2.7	14515	19	2.0
	AM	1431	30	3.3	12053	20†	2.3	21895	18†	2.2
	AD	NM	....	NM	2802	25	2.4	11996	27	2.6

TABLE 3.—(continued)

Stream	Station*	Early autumn			Late autumn			Winter		
		n	s	$\bar{d}$	n	s	$\bar{d}$	n	s	$\bar{d}$
Greasy Creek	GU	3185	17	1.2	191	12	2.2	108	9	2.2
	GU	1733	19	1.8	964	21	2.6	166	14	3.1
Red Rock Creek	RU	467	22	2.8	49	9	2.6	150	5	0.6
	RD	8856	19	0.5	46	9	2.4	37	4	1.2
Arkansas River	AU	30456	21	2.1	3012	22	3.0	928	14	2.5
	AM	4268	27	2.8	1799	20	2.8	1811	12	1.9
	AD	13847	14	1.6	2520	18	2.6	1010	14	1.7

\*U — Upstream, D — Downstream, M — Middle station

† — Values based on two samples

NM — Not measured, samplers lost due to high water

A number of studies have demonstrated a reduction in numbers of species and diversity in stream areas receiving pollutants (Wilhm, 1970). In Black Bear Creek, 31 taxa were collected at a station below an input of oil-field brines, while 55 taxa were taken from the station farthest downstream (Mathis, 1965). In Skeleton Creek six taxa and a species diversity ( $\bar{d}$ ) of 0.8 were recorded at a station below an input of domestic and oil refinery effluents (Wilhm and Dorris, 1966). The values increased to 30 taxa and a diversity of 3.4 at a relatively clean water station. In the present study, diversity appeared to be more closely related to seasonal cycles than to effluents. Numbers of taxa and diversity did not appear to be limited by high conductivity in spring and summer in Greasy Creek or by the low dissolved oxygen concentration in summer. Low numbers of taxa occurred at most stations in late autumn and winter, probably reflecting the low temperatures in December and January. The low values of species diversity in early autumn at most stations reflected large densities. Consistent differences were not observed in numbers of taxa and diversity between the creeks and the river.

A high density has been associated with enriched environments in several studies. Density reached 3560 organisms/m<sup>2</sup> in Skeleton Creek at a station receiving domestic and oil refinery effluents (Wilhm and Dorris, 1966). However, Mathis (1965) found that the maximum density of 11,800 individuals/m<sup>2</sup> in Black Bear Creek occurred during the reproductive season of blackflies. In the present study maximum densities were recorded in early autumn at most stations during the reproductive cycle of several species of midges and mayflies. Density was relatively low in late autumn and winter. Considerably greater numbers of benthic macroinvertebrates were collected in the rivers than in the creeks.

Most of the taxa taken in the present study were Diptera, Ephemeroptera and Trichoptera. In a study of the Arkansas River from Tulsa to Muskogee (Federal Water Pollution Control Administration, 1966), most of the taxa belonged to the first two of these groups. Diptera, Coleoptera and Odonata were well represented in Otter Creek (Harrell and Dorris, 1968) and Black Bear Creek (Mathis, 1965). Beetles and odonates were not commonly collected on the multiplate samplers in the present study. In a study comparing artificial substrates, odonates were found in basket samplers but not on four different types of multiplate samplers (Mason *et al.*, 1973). Gaufin and Tarzwell (1956) reported that, in general, a benthic macroinvertebrate assemblage comprised of abundant gill-breathing mayflies, stone flies and caddis flies indicated a clean-water environment. Although a diverse group of mayflies and caddis flies were collected in the present study at all stations, stone flies were limited to the Arkansas River and to one collection in Red Rock Creek.

A diverse assemblage of benthic macroinvertebrates inhabited Greasy Creek, Red Rock Creek and the Arkansas River near the confluence of these two creeks. Numbers of taxa and density were general-

ly low in late autumn and winter, probably reflecting low temperatures. High densities occurred in early autumn during the reproductive cycle of several species of midges and mayflies. The large density resulted in low values of species diversity. Diversity did not reflect the high conductivity values in Greasy Creek in spring and summer or the low dissolved oxygen concentration in Greasy Creek. Numbers of taxa and values of diversity were generally similar in the creeks and the river. Density was considerably greater in the river.

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