Downstream Drift of Aquatic Insects in the Blue River of South-Central Oklahoma

Margaret H. Matzinger and David Bass

Biology Department, University of Central Oklahoma, Edmond, OK 73034-0177

Received: 1994 Aug 24; Revised: 1995 Feb 28

Drift of aquatic insects in the Blue River of south-central Oklahoma was studied from March 1990 through January 1991. Samples were collected every 3 h during one 24 h period in each of alternate months. Density and species richness of aquatic insects in the drift displayed a diel periodicity whereas density and species diversity exhibited a seasonal periodicity. Density was positively correlated with temperature, but negatively correlated with discharge. Conversely, species diversity was positively correlated with discharge and negatively correlated with water temperature. Species richness showed a slight positive correlation with discharge, but no significant correlation with water temperature. Some 43,619 individuals representing 10 orders and 174 species were collected, 51 of which were new for Oklahoma.

INTRODUCTION

Drift, the downstream transport of aquatic organisms in the current, was first observed in the early part of the twentieth century. Brittain and Eikeland (*1*) report that drift did not gain much attention, however, until Mueller's 1954 study of streams in Sweden. Since then, many studies have documented invertebrate drift (*2*-*8*).

This project studied drift in the Blue River of south-central Oklahoma. There are only two published studies involving drift in Oklahoma. Ernst and Stewart (*9*) examined nine stonefly species in an Oklahoma Ozark stream, and Reisen (*10*) measured stream productivity. Two published aquatic invertebrate studies have been conducted at the Blue River. Hornuff (*11*) and Wilhm et al. (*12*) made nonquantitative benthic collections.

This study investigated: 1) the composition and density of insects occurring in the drift, 2) their seasonal and diel variations in the drift, 3) the discharge (m^3/s), temperature, and drift density, and 4) other published stream drift studies.

MATERIALS AND METHODS

The Blue River originates NW of Connerville in Pontotoc County, Oklahoma, and flows SE approximately 177 km, draining approximately 2072 km^2 (*11*). Drift samples were collected near Camp Site Two of the Blue River Public Hunting and Fishing Area in a portion of the river characterized by small falls and riffles that flow into pools. The substrate was primarily bedrock interspersed with boulders, cobble, and gravel.

Drift samples were collected every 3 h during a 24 h period in each of alternate months from March 1990 through January 1991. Replicate samples were collected using Wildco drift nets with a mouth opening 0.31 m high and 0.45 m wide, and a mesh size of 0.363 mm. The bottom edge of the net was placed in a frame against the substrate with the top edge extending above the water's surface. The drift nets were emptied at the established collection times: 1500, 1800, 2100, 2400, 0300, 0600, 0900, and 1200 hours. The contents were washed through a number 60 (0.250 mm) US standard sieve bucket, transferred to a jar, and preserved in a mixture of formaldehyde and Rose Bengal dye (*13*). In the laboratory, the organisms were washed through a number 60 (0.250 mm) US standard soil sieve, sorted, and stored in 70% ethanol until they were identified and counted. Temperature readings were taken at each collection time on each collecting date. Flow through the net for each 24 h period was estimated by using a General Oceanic Flow Meter Model 2030R. An average of triplicate measures of flow was calculated at the beginning and end of each 24 h collection. Water velocity was then estimated in m/s using a calibration curve. Then discharge was calculated from the product of cross sectional area of the net opening and velocity.

Density, relative density, frequency, relative frequency, species richness, and species diversity were determined. A Jaccard coefficient, which is based on presence-absence data for taxa, was used to measure similarity. A nonparametric procedure (*14*) in which ranks are analyzed was used to compare density and species richness values of 3 h day samples with density values of the 3 h night samples for each 24 h collection. To analyze diel or seasonal effects on density, frequency, species composition, and species diversity, a nonparametric two-factor ANOVA was used. The first factor considered was daylight or darkness, and the second factor was season. Twenty-four-hour collections were divided into groups and classified as spring (March and May), summer (July and September), and winter (November and January). A separate test was run for each variable: density, frequency, species composition, and species diversity. Since the numbers of 3 h samples for daylight and darkness were not equal, a random numbers table was used to eliminate the number of 3 h samples needed to provide a balanced experimental design. A Spearman rank correlation test was used to determine if density, frequency, species composition, or species diversity varied with temperature or discharge.

RESULTS

Mean water temperatures during 24 h collections varied from a low of 6.1 °C in January 1991 to 25.9 °C in September 1990 (Fig. 1).

Mean discharge ranged from 0.03 m³/s in November 1990 to 0.15 m³/s in January 1991 (Fig. 1). Highest water levels in the river occurred during the May collection, the result of heavy rainfall in the south-central area of Oklahoma.

During the entire study period, a total of 43,619 individual aquatic insects were collected, representing 10 orders and 174 species. Fifty-one of these taxa have not been reported from Oklahoma previously. The dominant groups were Ephemeroptera (61.95%), Diptera (23.64%), of which 93.8% were Chironomidae, and Coleoptera (8.38%) (Fig. 2). These were found in all 3 h sampling periods, which made them the most frequently occurring aquatic insects in this study.

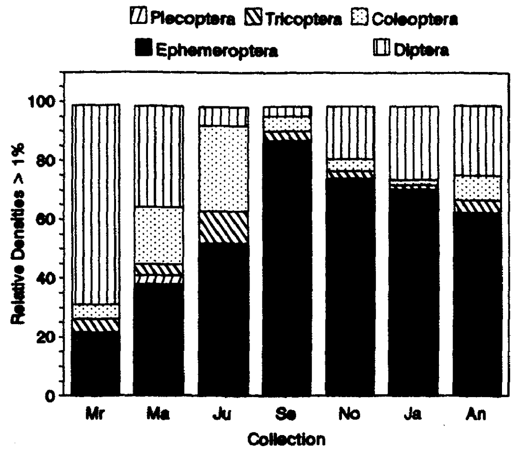

Figure 2. Total relative densities for orders with values over 1.0% for each 24 h collection and an annual value (ANN) for all collections combined.

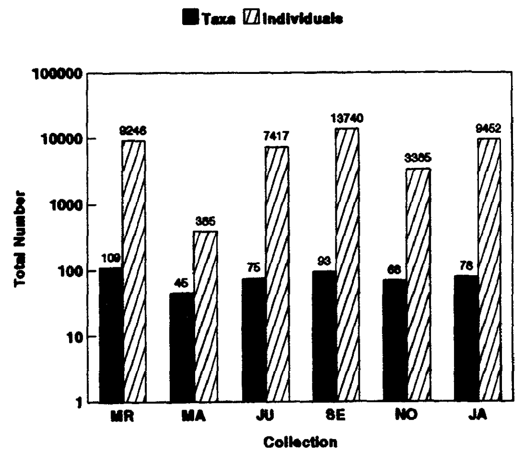

Figure 3. Total numbers of taxa and individuals in each 24 h collection from March 1990 through January 1991.

Figure 1. Mean discharge and mean temperature for each 24 h collection taken at the Blue River from March 1990 through January 1991.

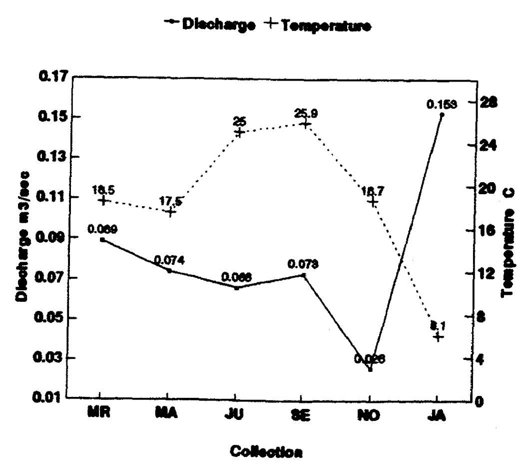

TABLE 1. Jaccard coefficients of similarity based on presence-absence data among pairs of the six 24 h collections made between March 1990 and January 1991.

Col-	1990					1991
lection	Mar	May	Jun	Sep	Nov	Jan
Mar						
May	0.343					
Jun	0.407	0.376				
Sep	0.396	0.348	0.563			
Nov	0.459	0.441	0.445	0.423		
Jan	0.464	0.426	0.424	0.415	0.489	

TABLE 3. Results of the nonparametric two-factor ANOVA of diel and seasonal effects on density, taxa, species diversity, and frequency using a Kruskal-Wallis H statistic which closely approximates X^2.

	Density	Taxa	Diversity	Frequency
Factor A (day/night)	14.7[a]	18.4[a]	3.0	3.3
Factor B (season)	13.4[a]	4.3	18.8[a]	1.7
Factor A X B	4.2	4.1	2.5	0.1

a Significant difference (P<0.05)

TABLE 2. Results of the analysis of the Mann-Whitney U and U′ for comparison of the density (D) and species richness (SR) values of day and night samples for each 24 h collection from March 1990 through January 1991.

	1990										1991	
	Mar		May		Jun		Sep		Nov		Jan	
	D[a]	SR[a]	D	SR	D	SR	D	SR	D	SR	D	SR
U	64.0[b]	64.0[b]	39.5	42.5	40.0[b]	40.0[b]	54.0[b]	56.5[b]	54.0[b]	57.5[b]	26.0	61.5[b]
U′	0.0	0.0	20.5	17.5	0.0	0.0	6.0	3.5	10.0	6.5	38.0	2.5

a D=Density, SR=Species richness
b Significant difference (P<0.05).

The greatest number of individuals (13,740) occurring in a single 24 h collection were found in September. The least number of individuals (385) in a single 24 h collection occurred during May. The greatest number of taxa (109) found in a single 24 h collection occurred during March, whereas the smallest number of taxa (45) occurring in a single 24 h collection was in the May collection (Fig. 3).

During March, the dipterans were the dominant order with a relative density of 67.76% (Fig. 2). Most of these dipterans were Chironomidae.

Ephemeroptera had the greatest relative densities for the remaining 24 h collections from May through January, forming 37.92%, 51.71%, 86.80%, 73.91%, and 70.08% of the individuals present (Fig. 2).

Ephemeroptera and Diptera were the two most abundant orders during March, May, November, and January. However, in July and September, Coleoptera became the second most abundant order after Ephemeroptera. The relative density of coleopterans was 29.01% in July, but it was reduced to 4.96% in September.

Species diversity ranged from 0.76 in September to 1.28 in May.

Jaccard coefficients of similarity ranged from 0.343 for March and May to 0.563 for July and September (Table 1).

A comparison of densities between 3 h day and 3 h night samples using a Mann-Whitney test (*14*) revealed a statistically significant difference in March, July, September, and November, but not collections in May and January. When the number of taxa present in 3 h day and 3 h night samples were analyzed for a difference, all 24 h collections showed a statistically significant difference except May (Table 2).

ANOVA analysis revealed the time of day had a statistically significant effect on density and species richness, but no effect on frequency or species diversity. There was a significant difference in density and species diversity among seasons, but no difference in species richness or frequency among seasons. There was no significant interaction between time of day and season on any variable tested (Table 3).

Five correlation measurements produced statistically significant results. Total density showed a positive correlation with temperature, but a negative correlation with discharge. Total species diversity had opposite results, a positive correlation with discharge, and a negative correlation with temperature. Total taxa showed a slightly positive correlation with discharge, but no significant correlation with temperature. Correlation of frequency with discharge, and frequency with temperature, were not

TABLE 4. Results of Spearman rank correlation analysis between density, frequency, species composition, or species diversity and temperature or discharge.

	Discharge	Temperature
Density	–0.303[a]	0.432[a]
Taxa	0.225[a]	0.125
Diversity	0.484[a]	–0.388[a]
Frequency	0.019	0.069

a Significant correlation ($P<0.05$).

significant (Table 4).

DISCUSSION

Water temperatures were highest in September 1990. It was also during this time that the greatest density of individuals for a single 24 h collection occurred. A non-parametric correlation analysis indicated water temperature and density had a significant positive correlation (Table 4). Neves (*16*) and Pearson and Franklin (*15*) suggested that drift rates may have increased in response to an increase in temperature.

Increased temperatures are often associated with increased growth and activity in immature aquatic insects (*17*). It has been suggested that as an insect increases in size with higher temperatures, it will spend more time actively searching for food (*18*). As the immature insects become more active, they may also become more vulnerable to being swept into the current. Additionally, as the immature ones increase in size, competition for space may become more intense, inducing behavioral drift (*5*). If increased temperatures in September contributed to increased activity and growth, they may also have contributed to the high numbers of individuals present in the drift during September.

Discharge was maximum in January 1991 when densities were high. During November 1990, when discharge was minimum, the second smallest number of individuals in a 24 h collection occurred. The lowest number of individuals occurred during May when water levels were fluctuating after several weeks of flooding in the Blue River. Studies have shown that an increase *(6, 19)* or a decrease *(20, 21)* in discharge can lead to an increase in density. Results from this study revealed that discharge and density had a slightly negative correlation.

It was expected that drift would be dominated by immature Ephemeroptera, Chironomidae, and Plecoptera (*22*) while the aquatic Coleoptera would also be prominent (*23*). In this study, Ephemeroptera, Chironomidae, and Coleoptera were the dominant groups; however, temperatures during summer in Oklahoma probably limited the plecopterans from becoming more abundant. Many aquatic insects, including plecopterans, estivate during warmer months (*22*).

Many factors were probably responsible for high diversity values in May and March. Increased discharge accompanied increased species diversity. High water levels during part of the May collecting probably dislodged many aquatic insects. Increased species diversity may have resulted from insects washed in from tributaries. Lewis and Harrel (*24*) found higher species diversity values during periods of high discharge, which was attributed to many taxa being carried into the main stream from tributaries, and that more substrates were made available by high water.

Another factor related to discharge is the amount of coarse particulate organic matter (CPOM) washed into the river from either runoff or increased water levels. In both March and May, there was an abundance of CPOM in the form of small pieces of leaves, wood, and juniper needles that would have provided habitat and nutrients.

The lowest species diversity occurred in September when temperature and density were maximum. A limited number of species are found at high temperatures (*17*). Also, there was very little plant and wood debris available. The water was clear with almost no suspended organic material. There were some macroalgae present in which many smaller immature insects were found. However, the environmental heterogeneity that enhances species richness (*25*) did not appear as pronounced during September as in March and May when diversity values were higher.

The species diversity of the fauna in the Blue River for each of the six 24 h collections of this study was not as great as one might expect with the wide range of microhabitats available and the plentiful food supply present during most of the year. Because the Blue River is subject to the scouring effects of periodic spates, the total species diversity may be lower than what would seem ecologically possible for such a varied habitat *(22).*

None of the 24 h collections were particularly similar on the basis of Jaccard's coefficient of similarity. Physical as well as biotic conditions within the water reflect seasonal changes, which can vary considerably from month to month. Many of the aquatic insect life cycles are adapted to seasonal changes in the environment, resulting in the low similarity index among the six 24 h collections of this study. However, the most similar were July and September collections. Higher temperatures, lower discharge, and lack of varied habitats occurring during these two 24 h collecting periods may have attributed to their overall similiarity.

The March and May collections were the two most diverse so one might expect them to be the most dissimilar. Probably the most important factor contributing to the dissimilarity of these two 24 h collections was the amount of change occurring within the environment as stated earlier. Many of the taxa present in March were no longer present in May, probably because of increased discharge and emergence of adults.

Many studies have detected a diel periodicity in drifting aquatic insects *(5-7, 26).* This has been attributed to aquatic insects avoiding drift during the day when they are more likely to be preyed upon by fish, which are visual predators. It was expected that the present study would have similar results.

The two exceptions, January and May, were probably the result of many factors. Discharge was highest in January, which may have dislodged many insects that normally would not have been found drifting during the day. Many of the specimens collected in January were found in clumps of filamentous macroalgae. These clumps were found in both day and night 3 h samples, which may have been prone to breaking loose because of the increased discharge. Macrovegetation offers a food source, cover from predation, and protection from water currents *(22).* Insects sheltering and feeding in the algae would have been found in the 3 h day drift samples even if they were not actively drifting.

A comparison was also made between species richness of the day and night samples. A significant difference was detected for all 24 h collections except in May. Flooding during May might have disrupted the normal drift patterns of many aquatic insects.

In May, flooding affected many aspects of the aquatic community in the Blue River. This also may have affected the day and night drift patterns of many immature insects. During the 24 h collecting period in May, water levels were fluctuating because of rain in the watershed of the Blue River. Scouring effects alone probably dislodged many insects that normally would not have drifted during the day. As the water levels rose, debris was picked up along the shoreline, the turbulence of the water eroded the bank, and runoff from surrounding land would have increased the turbidity of the water. As the water levels subsided, the turbidity remained high. Pearson and Franklin *(15)* found that a sudden increase in turbidity was immediately accompanied by a rise in the drift rate of *Baetis* nymphs. Many insects may have drifted to find more suitable habitat. In addition, many may have drifted earlier in the diel period than normal because the turbidity decreased light penetration. Also present were large amounts of macrovegetation and pieces of wood which would have provided an abundance of food and shelter for many different species.

Analysis of diel and seasonal effects on density, frequency, species composition, and species diversity revealed that daylight or darkness had a statistically significant effect on species richness and total density. As stated earlier, most studies have detected a diel periodicity in the drift of immature aquatic insects. However, there was no effect on frequency or species diversity in the present study.

Because species diversity values for 3 h daylight samples varied little from the species diversity values for 3 h darkness samples, one would not expect an effect of daylight or darkness on species diversity. Although the total number of taxa and individuals were different for the daylight or darkness samples, the distribution of individuals among the various taxa remained static for daylight or darkness. Therefore, there was no detectable difference between the daylight or darkness samples.

Results of ANOVA analysis indicate that density and species diversity vary signif-

TABLE 5. Summary of information from prior drift studies (31), including the present study.

River (Country)	Study period	Width (m)	Depth (m)	Mesh (mm)	Drift density[a]
Blue River (U.S.A.)	3/90–1/91	12.0–20.0	0.10–3.00	0.36	105.2[b]
Dale Park Beck Stream (U.K.)	4/70–5/71	3.0–3.5	0.19	0.44	27.6[c]
Gombak River (Malaysia)	10/68–11/69	6.0	0.18	0.56	134.4[c]
Blackwater Crk (U.S A.)	12/71–12/72	8.0–10.0	0.25	0.47	16.0[c]
Widawka River (Poland)	3/83–3/84	24.0–29.0	0.85	0.12–10.0	234.0[c]
Satilla River (U.S.A.)	12/74–12/75	--	1.0–4.0	0.40	312.9[b,d] 218.6[b,e]
Danube River (Austria)	4/89–11/89	330.0	3.0–3.5	0.40	5.7[b]

a Drift density=number per 100 m^3.
b Aquatic insects only.
c All aquatic macroinvertebrates.
d Upper site
e Lower site.

icantly among seasons. Since most immature aquatic insects' life cycles are adapted to seasonal occurrences such as unfavorable physical conditions, food availability, and biotic interactions *(17)*, it was not unexpected that a difference in the variables examined among seasons would occur. However, there was no difference in frequency and species richness among seasons. Even though species richness did not vary among seasons, the Jaccard coefficient indicated that most collections were not similar. This would seem to indicate that although the number of taxa remained even, significant species turnover occurred seasonally.

The ANOVA analysis revealed that there was no interaction between the factors under consideration. This implies that the daylight or darkness effects were independent of season *(27)*.

A summary of drift densities (number per 100 m^3) for several drift studies, including the present study, is presented in Table 5. As these studies indicate, spatial variation in drift densities is extensive. Making detailed comparisons can be difficult because sampling methods and analyses vary considerably among studies. Density values for three of the studies include only the insects. The remaining studies include all groups of macroinvertebrates which will result in a larger value.

In most cases, the present study produced a greater number of taxa than previous studies in the Blue River, and a higher number per 100 m^3 than studies in other rivers and streams. The reasons for this include the ecological nature of the Blue River, more frequent collections, and the use of a smaller sieve mesh size (U.S. Standard Soil Sieve No. 60) as proposed by Bass (*30*).

ACKNOWLEDGMENTS

Permission for this study was granted from state authorities in charge of the Blue River Public Fishing and Hunting Area. We appreciate the suggestions of Dr. Terry P. Harrison and Dr. Jenna Hellack who read an earlier version of this manuscript. We also thank Marvin Matzinger for his help in the field. This paper is a result of a Master's Thesis submitted to the University of Central Oklahoma.

REFERENCES

1. Brittain, J.E., and Eikeland, T.J., Invertebrate drift-a review. *Hydrobiologia* **166**, 77-93 (1988).
2. Denham, S.C., A limnological investigation of the West Fork and Common Branch of White River. *Invest. Indiana Lakes Streams I*, 17-71 (1938).
3. Lewis, D.J., Observations on Chironomidae at Khartoum. *Bull. Entomol. Res.* **48**, 155-184 (1957).
4. Berner, L., Limnology of the lower Missouri river. *Ecology* **32**, 1-12 (1951).
5. Waters, T.F., Standing crop and drift of stream bottom organisms. *Ecology* **42**, 532-537 (1961).
6. Waters, T.F., A method to estimate the production rate of a stream bottom invertebrate. *Trans. Am. Fish. Soc.* **91**,

243-250 (1962a).
7. Waters, T.F., Diurnal periodicity in the drift of stream invertebrates. *Ecology* **43**, 316-320 (1962b).
8. Waters, T.F., Interpretation of invertebrate drift in streams. *Ecology* **46**, 327-334 (1965).
9. Ernst, M.R., and Stewart, K.W., Growth and drift of nine stonefly species (Plecoptera) in an Oklahoma Ozark foothills stream, and conformation to regression models. *Ann. Entomol. Soc. Am.* **78**, 635-646 (1985).
10. Reisen, W.K., The ecology of Honey Creek, Oklahoma: spatial and temporal distributions of the macroinvertebrates. *Proc. Okla. Acad. Sci.* **55**, 25-31(1975).
11. Hornuff, L.E., A survey of four Oklahoma streams with reference to production. *Okla. Fish. Res. Lab. Rep.* 62, 1-22 (1957).
12. Wilhm, J.J., Cooper, J., and Burks, S., Species composition of algae and benthic macroninvertebrates in the Blue and Kiamichi Rivers. *Proc. Okla. Acad. Sci*. **59**, 85-88 (1979).
13. Mason, W.T., and Yevich, P.P. Jr., The use of phloxine B and rose bengal stains to facilitate sorting benthic samples. *Trans. Am. Microsc. Soc*. **86**, 221 (1967).
14. Mann, H.B., and Whitney, D.R., On a test of whether one of two random variables is stochastically larger than the other. *Ann. Math. Statist*. **18**, 50-60 (1947).
15. Pearson, W.D., and Franklin, D.R., Some factors affecting drift rates of *Baetis* and Simuliidae in a large river. *Ecology* **49**, 75-81 (1968).
16. Neves, R.J., Movements of larval and adult *Pycnopsyche guttifer* (Walker) (Trichoptera: Limnephilidae) along Factory Brook, Massachusetts. *Am. Midl. Nat*. **102**, 51-58 (1979).
17. Merritt, R.W. and Cummins, K.W., *An Introduction to the Aquatic Insects of North America*. 2nd ed., Kendall Hunt Publ. Co., Dubuque, Iowa (1984) 722 pp.
18. Corkum, L.D., Is benthic activity of stream invertebrates related to behavioral drift? *Can. J. Zool*. **56**, 2457-2459 (1978).
19. Hynes, H.B.N., Benthos of flowing water, pp. 66-80, in *A Manual on Methods for the Assessment of Secondary Productivity in Freshwaters* (Edmondson, W.T., and Winberg, G.G., Eds.). IBP Handbook 17, Blackwell, Oxford (1971) 358 pp.
20. Minshall, G.W., and Winger, P.V., The effect of reduction in stream flow on invertebrate drift. *Ecology* **49**, 580-582 (1968).
21. Gore, J.A., Reservoir manipulations and benthic macroinvertebrates in a prairie river. *Hydrobiologia* **55**, 113-123 (1977).
22. Hynes, H.B.N., *The Ecology of Running Waters*. 5th ed. Univ. Toronto Press, Toronto (1970) 555 pp.
23. Reisen, W.K., The ecology of Honey Creek, Oklahoma: the downstream drift of three species of aquatic dryopoid beetles (Coleoptera: Dryopoidea). *Entomol. News* **88**, 185-191 (1977).
24. Lewis, S.P., and Harrel, R.C., Physicochemical conditions and diversity of macrobenthos of Village Creek, Texas. *Southw. Nat*., **23**, 262-272 (1978).
25. Minshall, G.W., Petersen, Jr., R.C., and Nimz, C.F., Species richness in streams of different size from the same drainage basin. *Am. Nat*. **125**, 16-37 (1985).
26. Anderson, N.H., Depressant effect of moonlight on activity of aquatic insects. *Nature* **209**, 319-320 (1966).
27. Steel, R.G.D., and Torrie, J.H., *Principles and Procedures of Statistics*. McGraw Hill Book Co., New York (1980) 481 pp.
28. McKinley, R.E., Prins, R., and Jech, L.E., Currents and distribution of arthropods in Travertine Creek, Platt National Park, Murray County, Oklahoma. *Proc. Okla. Acad. Sci*. **52**, 49-52 (1972).
29. Bass, D., A survey of aquatic invertebrates from Wichita Mountain streams. *Proc. Okla. Acad. Sci*. **70**, 35-36 (1990).
30. Bass, D., Larval Chironomidae (Diptera) of the Big Thicket streams. *Hydrobiologia* **135**, 271-285 (1986).
31. Anderwald, P.H., Konar, M., and Humpesch, U.H., Continuous drift samples of macroinvertebrates in a large river, the Danube in Austria. *Freshw. Biology* **25**, 461-476 (1991).