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Abstract

The objective of this study was to assess the water quality of the Big Creek watershed during the winter and spring of 2002 by analyzing water physical, chemical variables, aquatic macro-invertebrates, and habitat. The Big Creek watershed, arising on Crowley's Ridge in northeast Arkansas, is a small deltaic watershed and is an area of intense cultivation. Four stations, Big Creek Upper (BCU), Mud Creek (MC), Lost Creek (LC), and Big Creek Lower (BCL) were established for this study from Big Creek, Mud Creek and Lost Creek. Water samples were collected on a weekly basis for 10 weeks from January 2002 through March 2002. We analyzed these streams for temperature, pH, D.O., conductivity, TSS, chlorophyll-*a*, DOC, total N and P, total dissolved N and P, nitrate, ammonium, and soluble reactive phosphorus. During this time period, we also sampled aquatic macroinvertebrates and assessed stream habitat according to USEPA rapid bioassessment protocols. Overall, nutrients and TSS were high, pH fluctuated from 5.8 to 7.8, and D.O. was moderate to high, ranging from 6.75 to 13.24 mg/L. Generally, physical and chemical water variables were correlated with changes in stream discharge. For a 20-jab dip-net sample, macroinvertebrate species richness ranged from 9 to 23 taxa, while abundance ranged from 38 to 209 individuals per station. Physical habitat index scores ranged from 75 to 104 (maximum of 200) indicating marginal physical habitat. We report that this watershed has high concentrations of nutrients and suspended solids during the winter and spring wet season and that the macroinvertebrate communities are influenced by stream conditions, including marginal physical habitat.

Introduction

Aquatic macroinvertebrate and fish faunal groups have been studied historically and used as indicators of water quality in the Big Creek watershed (Beadles, 1970; Jenkins and Harp, 1971; Cather and Harp, 1975; Arkansas Pollution Control and Ecology Commission, 1998). Cather and Harp (1975) reported lower macroinvertebrate taxa richness and species diversity at two stations on Big Creek in comparison to a high quality Ozark stream. In 1998 the Arkansas Department of Pollution Control and Ecology reported 9 to 20 aquatic macroinvertebrate taxa from three stations on Big Creek Ditch and 1 station on Lost Creek Ditch (Arkansas Pollution Control and Ecology Commission, 1998). Beadles (1970) observed only eight species of fish, several of which are considered tolerant to moderate amounts of domestic effluents, at 5 sampling stations on Lost Creek, a tributary of Big Creek. Jenkins and Harp (1971) reported low (11) to moderate (17) fish richness from Big Creek and its two major tributaries, Mud and Lost creeks, with several species that are known to withstand high turbidity. More recently, the Arkansas Department of Pollution Control and Ecology reported 6 to 20 taxa at four stations in the watershed (Arkansas Pollution Control and Ecology Commission, 1998).

Because habitat provides the template for the distribution of organisms, assessment of habitat quality is important in determining if habitat degradation is a factor influencing aquatic organism composition (Resh et al., 1996; Barbour et al., 1999). High nutrient concentrations also have been shown to influence fish and aquatic macroinvertebrates. For instance, Miltner and Rankin (1998) have shown that there is high negative correlation between biotic integrity and nutrient concentrations. One land use type that has been shown to be a source of high nutrient fluxes is the agriculture dominated watershed, which has been shown to be orders of magnitude higher in nutrient fluxes than the undisturbed forest watershed (Beaulac and Reckhow, 1982; Vanni et al., 2001).

Big Creek and its tributaries originate on Crowley's Ridge in southcentral Greene County and northeast Craighead County. It is 36.8 km long, has an average gradient of 1.6 m/km, and ultimately becomes Bayou DeView Ditch 8 km east of Cache, Craighead County, Arkansas (Jenkins and Harp, 1971; Cather and Harp, 1975). Big Creek is impounded by Lake Frierson before flowing into Craighead County. Lost Creek and Mud Creek are major tributaries of Big Creek, and like Big Creek, are channelized for most of their length (Jenkins and Harp, 1971). Mud Creek enters into Big Creek 4.2 km north of Jonesboro, Craighead County, Arkansas, has a total length of 12 km, and has an average gradient of 1.5 m/km (Jenkins and Harp, 1971). Lost Creek enters Big Creek 3.2 km west-southwest of Jonesboro, has a total length of 14 km, and an average gradient of 1.7 m/km. Between the confluences of Mud and Lost creeks with Big Creek, Jonesboro West Wastewater Treatment Facility (WWTF) discharges effluent into an unnamed tributary which then enters into Big Creek. The predominant soils of the watershed are Falaya-Collins association washed from loess, which are deep, poorly to moderately well drained, moderately permeable, and silty bottomed (Jenkins and Harp 1971). Land use in the watershed is mostly agriculture with rice, soybeans, and cotton crops. Streams in the Big Creek watershed have been extensively channelized and have been classified by the Arkansas Department of Pollution Control and Ecology as a channel-altered Delta Ecoregion fishery with designated beneficial uses for: primary and secondary contact recreation; and as domestic, industrial, and agricultural water supplies (Arkansas Pollution Control and Ecology Commission, 1998). National pollution discharge elimination system permit holders in the watershed include Jonesboro-West WWTF, Northern Mobile Home Park, and Olivetan Benedictine Sisters (Arkansas Department of Pollution Control and Ecology, 1998).

The objective of this study was to assess the water quality of the Big Creek watershed during the winter and spring of 2002 by analyzing select physical-chemical variables, aquatic macroinvertebrates, and habitat. We expect that the aquatic macroinvertebrate fauna will be impaired due to loss of habitat through channelization and due to high nutrient concentrations typically associated with agriculturally dominated watersheds.

Materials and Methods

Four stations were used in this study. The Big Creek upper (BCU) station is located in SE 1/4, SW1/4, Sec. 13, T 15 N, R 3 E, Craighead County, Arkansas [GPS: N 35" 54.064'; W 90" 43.063'], and has an elevation of 97.5 m. The Big Creek lower (BCL) station is located in NE1/4 NW1/4, Sec. 25, T 14 N, R 2 E, Craighead County, Arkansas [GPS: N 35" 49.277'; W 90" 50.045"], and has an elevation of 77.4 m. The Lost Creek (LC) station is located in NW1/4, NW1/4, Sec. 13, T 14 N, R 3 E, Craighead County, Arkansas [GPS: N 35" 50.915' W 90" 43.819'], and has an elevation of 91.4 m. The Mud Creek (MC) station is located in SW1/4, SW1/4, Sec. 18, T 15 N, R 4 E, Craighead County, Arkansas [GPS: N 35" 54.058; W 90" 42.779'], and has an elevation of 97.5 m.

The four stations were sampled on a weekly basis from 26 January to 30 March 2002. Stream stage and depth of water column, at a standard center stream location, also was determined weekly by using a weighted steel cable and subtracting the distance from the top of the bridge to the bottom of the stream from the distance from the top of the bridge to the water surface. Water samples were collected at 3 locations along a transect at the 25, 50, and 75% stream width, and transported back to the lab for particulate and dissolved nutrient analyses. At the same time, dissolved oxygen (D.O.), temperature, pH, and conductivity were determined in the field for each sample using a Hach sensION™ 156 Portable Multiparameter meter. Rainfall gauges were established streamside the first week of the study, and rainfall data were recorded on a weekly basis thereafter.

For particulate variable analyses, known volumes (between 100 and 500 ml) of sample water were filtered through pre-weighed combusted 22 or 47 mm Gelman A/E glass fiber filters (nominal pore size = 1.0 μm). Total suspended solids (TSS) dry mass for each sample was obtained by drying the 47-mm filters at 60°C for 48 hours or longer until dry mass stabilized. Ash-free dry mass for each water sample was obtained by drying 47-mm glass fiber filters at 60°C for 48 hours or until dry mass stabilized, recording a mass, cooking these filters in a muffle furnace at 550°C for 4 hours, and then recording a final mass (Clesceri et al., 1998).

For chlorophyll-*a* concentrations, a known volume of water was filtered onto a 47-mm glass fiber filter (Pall Corporation, Type A/E). Filters were subsequently wrapped, labeled, and frozen until analysis was performed. For analysis, filters were placed in test tubes and frozen for at least 24 hours. Chlorophyll-*a* was extracted in 5 mL of 90% acetone in the refrigerator for 2 to 24 hours prior to analysis. Chlorophyll-*a* concentrations were determined on extracted chlorophyll samples using absorbance at 663 nm (Clesceri et al., 1998).

Dissolved nutrient concentration determinations, including total phosphorus (TP), soluble reactive phosphorus (SRP), total nitrogen (TN), nitrate, and ammonium, were conducted on the filtrate of samples filtered for fine particulate organic matter (FPOM). Filtrate was stored in 250-ml, acid-washed Nalgene bottles and preserved using a 1.5 ml/L concentration of concentrated H_2SO_4. Ammonium and SRP were determined by the Solorzano Colorimetric technique (Soloranzo, 1969) and the acid molybdate method (Stainton et al., 1974) respectively, and are reported as μg NH_4-N/L and μg PO_4-P/L, respectively. Nitrate concentrations were determined using second derivative spectroscopy methodology (Crumpton et al., 1992) and are reported as μg NO_4-N/L. Total phosphorus was determined on a whole water sample by digesting the samples with potassium persulfate and

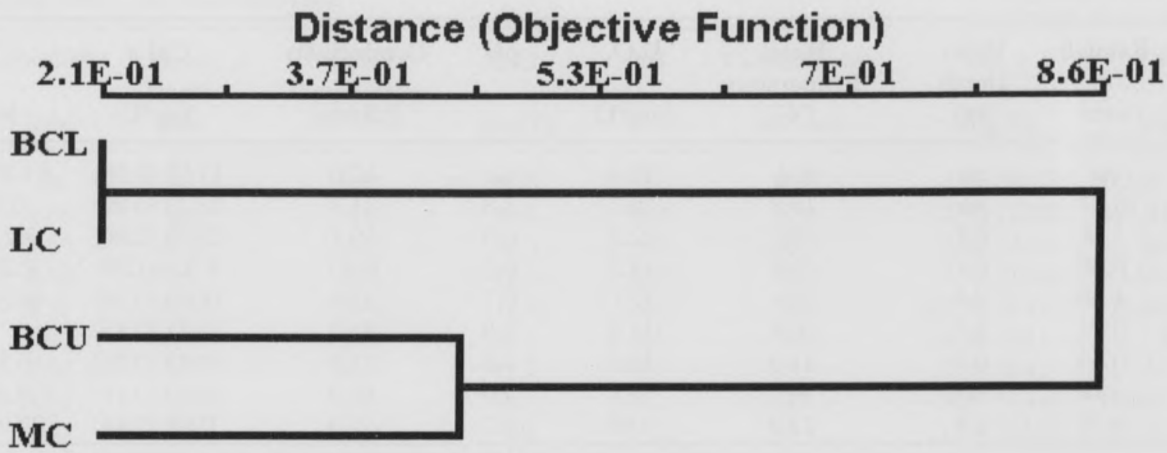

Fig. 1. A cluster dendogram based on Sorensen's distance of the aquatic macroinvertebrate fauna collected on 22 January 2002 at the Big Creek Lower (BCL), Big Creek upper (BCU), Lost Creek (LC), and Mud Creek (MC) stations.

analyzing the resulting orthophosphate using the acid molybdate method mentioned above (Stainton et al., 1974). Total nitrogen concentration of the filtrate was determined by digesting with low N potassium persulfate, followed by nitrate determination using second-derivative spectroscopy (Crumpton et al., 1992). Total dissolved carbon (TDC), total dissolved organic carbon (TDOC), and total dissolved inorganic carbon (TDIC) also were determined for each station on each sampling date using standardized methods (Clesceri et al., 1998).

We used the US Environmental Protection Agency (USEPA) rapid bioassessment protocol to qualitatively assess habitat on 26 January 2002 at each of four stations (Barbour et al., 1999). These habitat assessments were conducted along a 200 m stretch at each station. This qualitative assessment incorporates 10 metrics, each with a maximum score of 20 for a possible total of 200 points. Scores ranging from 200-160 represent optimal habitat conditions, 159-110 represent sub-optimal habitat conditions, 109-60 represent marginal habitat conditions, and scores below 60 represent poor habitat conditions.

We used the USEPA rapid bioassessment protocol to assess the macroinvertebrate community on 26 January 2002 at each of four stations (Resh et al., 1996; Barbour et al., 1999). This protocol calls for a composite 20-jab sample over a variety of microhabitats present along the 200-m

Table 1. Physical, chemical, and biological variables (± 1 SD, if applicable) of the Big Creek Lower station across ten weeks in winter and early spring 2002. na = not analyzed

Date	Rainfall (cm)	Water Depth (m)	Water Temperature (°C)	D.O. (mg/L)	pH	Conductivity (µS/cm)	Chl *a* (mg/L)	TSS (mg/L)
26 Jan.	na	na	na	na	na	na	9.46 (4.39)	43.00 (9.93)
01 Feb.	3.43	0.6	9.3	9.7	7.5	59.7	7.99 (0.90)	na
08 Feb.	1.24	0.6	8.5	9.1	7.8	104.5	4.36 (0.63)	2.23 (1.32)
16 Feb.	0.00	0.6	7.5	11.8	6.6	152.2	31.37 (25.02)	1.93(0.65)
22 Feb.	na	0.6	9.0	8.9	6.8	100.4	11.76 (1.19)	na
01 March	0.64	0.5	9.2	10.0	6.5	79.9	6.08 (0.28)	67.18 (22.10)
08 March	0.64	0.5	9.4	11.0	6.7	104.0	10.37 (1.71)	39.02 (12.13)
22 March	8.13	0.5	9.0	9.8	6.6	108.0	11.23 (0.23)	30.33 (1.93)
29 March	5.00	0.4	9.3	9.5	6.8	110.0	4.65 (1.27)	87.78 (9.40)

Table 2. Physical, chemical, and biological variables (± 1 SD, if applicable) of the Big Creek Upper station across 10 weeks in winter and early spring 2002. na = not analyzed

Date	Rainfall (cm)	Water Depth (m)	Water Temperature (°C)	D.O. (mg/L)	pH	Conductivity (µS/cm)	Chl *a* (mg/L)	TSS (mg/L)
26 Jan.	na	na	6.4	12.4	na	40.0	11.67 (0.58)	65.70 (23.33)
01 Feb.	3.87	na	10.9	10.7	5.8	41.7	13.13 (0.19)	77.60 (na)
08 Feb.	1.14	0.7	7.1	12.2	6.3	59.1	13.70 (2.06)	3.22 (1.03)
16 Feb.	0.00	0.7	5.3	12.5	6.7	103.1	8.22 (0.39)	2.21 (1.69)
22 Feb.	4.39	0.8	7.9	12.1	6.7	47.0	18.90 (0.56)	48.36 (8.04)
01 March	0.71	0.5	4.7	13.2	6.9	81.0	10.74 (0.45)	na
08 March	0.63	0.5	14.9	12.6	7.8	31.2	10.46 (0.35)	16.36 (4.90)
22 March	7.48	0.8	8.5	11.1	7.0	46.9	16.54 (1.11)	118.56 (41.41)
29 March	4.52	0.8	12.3	8.66	6.7	52.0	17.68 (0.44)	22.29 (5.66)

Table 3. Physical, chemical, and biological variables (± 1 SD, if applicable) of the Lost Creek station across 10 weeks in winter and early spring 2002. na = not analyzed

Date	Rainfall (cm)	Water Depth (m)	Water Temperature (°C)	D.O. (mg/L)	pH	Conductivity (µS/cm)	Chl *a* (mg/L)	TSS (mg/L)
26 Jan.	na	0.0	6.4	12.4	na	42.5	36.95 (50.36)	70.56 (0.33)
01 Feb.	3.30	0.3	9.6	7.6	6.9	53.4	5.04 (0.26)	81.91 (65.72)
08 Feb.	1.02	0.3	8.1	6.8	7.0	62.5	1.78 (0.17)	4.82 (4.50)
16 Feb.	0.00	0.2	6.6	11.9	6.8	61.1	14.69 (20.47)	2.48 (0.87)
22 Feb.	7.87	0.2	8.4	10.0	6.8	60.0	6.66 (0.38)	18.69 (20.34)
01 March	1.14	0.2	8.6	11.0	6.7	64.0	8.19 (0.17)	11.73 (6.17)
08 March	0.51	0.1	9.8	10.5	6.8	71.1	9.04 (0.49)	18.93 (3.47)
22 March	8.38	0.1	9.9	10.1	7.3	68.0	8.28 (0.35)	18.96 (3.33)
29 March	5.00	0.3	10.1	9.8	7.1	65.0	7.49 (1.73)	70.62 (6.16)

stretch at each station. Taxa richness, total abundance, % Ephemeroptera, Plecoptera, and Trichoptera (EPT), % Diptera, % Chironomidae, functional feeding groups (i.e. % Shredders, % Collectors, % Filterers, % Scrapers, % Predators), and Family Level Tolerance Values (Hilsenhoff, 1988; Resh et al., 1996) were determined on the entire jab sample at each station. Sorensen community similarity distances were also calculated on the four assemblages using the software program PC-Ord (McCune and Mefford, 1999).

Results

Rainfall for the 10 week period ranged from 0.0 to 9.2 cm across all stations and water column depth ranged from 0.03 to 1.0 m (Tables 1-4). Water temperatures ranged from 5.0 to 14.9 °C across all stations over the 10-week period (Tables 1-4). Dissolved oxygen concentrations ranged from 6.8 to 13.2 mg/L and generally were lowest at BCL (Tables 1-4). The pH at the four stations ranged from 5.8 to 7.8 and generally was below 7.0 (Tables 1-4). Conductivity ranged from 31.2 to 152.0 µS/cm and generally was highest at BCL (Tables 1-4). Chlorophyll *a* concentrations ranged from 1.75 to 36.95 mg / L and was consistently above 10 mg/L at BCU (Tables 1-4). Total suspended solids ranged from 1.18 to 144.91 mg/L across all sampling stations (Tables 1-4).

Total dissolved organic carbon concentrations ranged from a low of 2.0 mg TDOC-C/L at BCL to a high of 8.6 mg TDOC-C/L at BCU (Tables 5-8). Total dissolved inorganic carbon concentrations ranged from a low of 0.7 mg TDOC-C/L at BCL to a high of 4.9 mg TDIC-C/L at BCU (Tables 5-8). Ammonium concentrations ranged from a low of 34.6 µg NH_4-N/L at LC to a high of 269.8 µg NH_4-N/L at BCL (Tables 5-8). Nitrate concentrations ranged from a low of 3.5 µg NO_3-N/L at BCL and BCU to a high of 1,294.3 µg NO_3-N/L at LC (Tables 5-8). Total nitrogen concentrations ranged from a low of 381.8 µg TN-N/L at

Table 4. Physical, chemical, and biological variables (± 1 SD, if applicable) of the Mud Creek station across 10 weeks in winter and early spring 2002. na = not analyzed

Date	Rainfall (cm)	Water Depth (m)	Water Temperature (°C)	D.O. (mg/L)	pH	Conductivity (μS/cm)	Chl *a* (mg/L)	TSS (mg/L)
26 Jan.	na	na	6.1	12.3	na	46.8	5.05 (0.15)	62.47 (21.31)
01 Feb.	4.06	na	10.3	10.3	6.3	57.4	4.83 (1.82)	144.91 (13.15)
08 Feb.	1.63	0.7	6.0	12.9	5.8	56.0	2.24 (0.56)	1.38 (0.47)
16 Feb.	0.00	0.9	5.0	12.3	6.7	78.4	1.75 (0.36)	1.18 (0.53)
22 Feb.	6.77	0.8	8.4	11.4	6.6	50.4	10.73 (0.32)	16.00 (4.22)
01 March	2.03	0.7	5.0	12.2	7.4	70.0	4.46 (0.11)	na
08 March	0.86	0.7	13.4	12.7	7.2	83.1	7.56 (0.42)	11.31 (0.54)
22 March	9.20	1.0	7.8	12.2	6.3	47.8	8.07 (0.44)	66.92 (17.84)
29 March	4.52	1.0	12.2	7.9	6.5	53.1	11.69 (0.56)	32.38 (2.16)

Table 5. Mean (± 1 SD) nutrient concentrations for the Big Creek Lower station across 10 weeks in winter and early spring 2002. na = not analyzed

Date	TDOC-C (mg/L)	TDIC-C (mg/L)	NH_4-N (μg/L)	NO_3-N (μg/L)	TN-N (μg/L)	PO_4-P (μg/L)	TP-P (μg/L)
26 Jan.	4.38 (0.09)	1.60 (0.08)	47.11 (5.80)	na	9868.32 (7887.29)	1993.49 (282.68)	3121.62 (746.07)
01 Feb.	2.08 (0.05)	2.34 (0.03)	50.07 (14.56)	221.08 (8.19)	618.83 (536.64)	1694.58 (164.51)	2866.03 (24.25)
08 Feb.	6.77 (0.05)	1.56 (0.08)	53.22 (8.17)	444.95 (27.31)	1451.96 (350.36)	9333.40 (694.51)	5372.77 (167.90)
16 Feb.	6.51 (0.36)	4.58 (0.34)	165.80 (95.13)	681.43 (23.33)	1333.08 (73.36)	13,961.86 (410.83)	8946.07 (115.21)
22 Feb.	2.03 (0.03)	4.81 (0.11)	120.29 (4.84)	355.09 (17.91)	998.96 (79.94)	3267.90 (132.71)	5411.97 (139.81)
01 March	7.33 (0.10)	3.64 (0.08)	84.27 (20.70)	921.06 (20.62)	2015.46 (259.61)	15,229.45 (414.41)	14,968.05 (349.85)
08 March	8.40 (0.06)	0.68 (002)	269.83 (29.24)	832.78 (10.92)	1624.72 (147.30)	4229.82 (87.85)	5295.22 (1038.15)
22 March	5.40 (0.05)	2.85 (0.08)	73.09 (6.97)	233.42 (18.82)	729.35 (14.82)	2213.59 (105.39)	2573.38 (36.80)
29 March	5.63 (0.17)	2.85 (0.10)	149.29 (19.01)	256.64 (5.36)	na	2767.92 (136.04)	na

BCU to a high of 9,868.3 μg TN-N/L at BCL (Tables 5-8). SRP concentrations ranged from a low of 272.5 μg PO_4-P/L at MC to a high of 15,229.5 μg PO_4-P/L at BCL (Tables 5-8). Total phosphorus concentrations ranged from a low of 717.2 μg TP-P/L to a high of 14,968.1 μg TP-P/L at BCL (Tables 5-8).

Habitat assessment total scores ranged from a low of 75 at LC to a high of 104 at BCL (Table 9). These total scores fall into the range of "Marginal" habitat quality. Habitat metrics that reflect variables that limit aquatic macroinvertebrates such as epifaunal substrate / available cover, pool substrate, and substrate deposition generally were low (i.e. marginal)(Table 9).

Macroinvertebrate taxa richness ranged from a low of 9 to a high of 23 at BCL and MC, respectively (Tables 10-11). Total abundance per station ranged from 38 to 207 (Table 10). Family Biotic Index scores for all stations ranged from 4.8 (i.e. good water quality) at MC to 6.2 (i.e. fairly poor water quality) at LC (Table 11). Evenness, Shannon's Diversity, and Simpson's Diversity were lowest at BCU and higher and variable at the other sites (Table 11). The % of EPT was lowest at LC and highest at BCL, whereas % Diptera was highest at the BCU. Chironomidae composition, a component of % Diptera, was lowest at BCU and highest at BCL (Table 11). Collectors comprised the highest % and shredders comprised the lowest % of macroinvertebrates at all stations with all stations being similar in % composition for all 5 functional feeding groups (Table 11). Sorensen's distance analysis reveled that BW and MC macroinvertebrate assemblages were 0.395 dissimilar, whereas the BCL and LC macroinvertebrate assemblages were 0.210 dissimilar (Fig. 1). The clusters of BCU and MC were 0.830 dissimilar to the BCL and LC group (Fig. 1).

Discussion

Nutrient concentrations in this study were high and typical of agriculturally dominated watersheds (Beaulac and

Table 6. Mean (± 1 SD) nutrient concentrations for the Big Creek Upper station across 10 weeks in winter and early spring 2002. na = not analyzed

Date	TDOC-C (mg/L)	TDIC-C (mg/L)	NH_4-N (μg/L)	NO_3-N (μg/L)	TN-N (μg/L)	PO_4-P (μg/L)	TP-P (μg/L)
26 Jan.	8.56 (0.44)	4.90 (0.36)	43.18 (5.88)	na	556.21 (129.14)	971.78 (60.17)	1929.43 (196.16)
01 Feb.	2.71 (0.60)	3.75 (0.61)	42.45 (0.32)	69.73 (4.73)	697.65 (122.83)	880.30 (140.99)	4871.52 (2381.64)
08 Feb.	3.62 (0.05)	1.80 (0.11)	57.58 (4.36)	83.92 (0.00)	593.11 (12.30)	704.58 (109.45)	1688.54 (486.87)
16 Feb.	3.50 (0.02)	3.17 (0.12)	52.82 (4.07)	76.04 (2.73)	453.73 (69.93)	527.05 (49.14)	1346.40 (61.50)
22 Feb.	3.55 (0.06)	1.40 (1.40)	57.38 (1.35)	255.77 (5.46)	595.16 (87.04)	499.88 (74.76)	1520.33 (154.34)
01 March	2.42 (0.02)	1.06 (0.06)	35.60 (2.02)	14.56 (2.73)	513.36 (125.84)	677.41 (20.39)	1047.09 (211.53)
08 March	5.91 (0.09)	4.48 (0.47)	51.41 (0.82)	3.52 (0.00)	381.81 (39.22)	579.58 (141.52)	1135.71 (12.33)
22 March	4.14 (0.20)	2.91 (0.06)	41.04 (4.36)	60.12 (3.09)	542.82 (42.61)	961.82 (27.58)	1751.29 (107.74)
29 March	3.76 (0.06)	2.61 (0.08)	41.51 (3.64)	147.66 (74.33)	572.27 (18.00)	997.14 (36.56)	1524.20 (154.73)

Table 7. Mean (± 1 SD) nutrient concentrations for the Lost Creek station across 10 weeks in winter and early spring 2002. na = not analyzed

Date	TDOC-C (mg/L)	TDIC-C (mg/L)	NH_4-N (μg/L)	NO_3-N (μg/L)	TN-N (μg/L)	PO_4-P (μg/L)	TP-P (μg/L)
26 Jan.	3.08 (0.03)	1.88 (0.02)	34.62 (4.20)	na	716.10 (221.97)	949.14 (68.38)	1842.87 (428.27)
01 Feb.	6.07 (0.10)	1.98 (0.03)	70.17(14.05)	1294.39 (320.76)	778.71 (674.39)	894.79 (142.76)	2656.58 (337.78)
08 Feb.	2.77 (0.10)	3.27 (0.10)	60.24 (5.56)	1033.94 (40.38)	904.68 (103.14)	624.87 (205.49)	1949.84 (162.42)
16 Feb.	7.30 (0.19)	0.72 (0.27)	89.04 (45.87)	762.32 (19.60)	787.84 (193.71)	872.15 (71.27)	1650.16 (95.71)
22 Feb.	5.22 (0.06)	2.20 (0.12)	97.76 (21.35)	1015.33 (250.66)	1068.66 (381.32)	701.86 (46.86)	1944.94 (69.76)
01 March	5.06 (0.05)	4.71 (0.44)	174.80 (146.85)	898.26 (80.18)	996.39 (172.98)	1274.31 (327.65)	1884.21 (194.62)
08 March	4.62 (0.10)	2.02 (0.36)	124.18 (15.03)	789.70 (76.47)	770.58 (85.84)	1113.99 (63.90)	2120.79 (84.29)
22 March	4.88 (0.09)	2.32 (0.10)	56.72 (7.33)	873.56 (63.30)	752.91 (23.81)	1399.30 (57.56)	1609.66 (27.51)
29 March	4.15 (0.17)	4.14 (0.28)	74.71 (9.75)	933.47 (93.58)	622.37 (539.12)	1601.29 (19.09)	2061.09 (1835.38)

Reckhow, 1982; Vanni et al., 2001). Arkansas Department of Environmental Quality has not set any nutrient standards other than for total phosphorus (≤ 100 mg TP/L) in clear flowing streams and does not have any criteria established in streams with high natural silt loads or color (Arkansas Pollution Control and Ecology Commission, 2001). Since no nutrient criteria are established for these streams, we used literature values to determine if nutrient concentrations in the ranges we observed in this study have the potential to impair stream organisms. For example, Miltner and Rankin (1998) reported that fish communities in small streams begin to show deleterious effects of increasing nutrient concentrations when total inorganic nitrogen exceeds 0.61 mg N/L and total phosphorus exceeds 0.06 mg TP/L. Both of these concentrations were exceeded consistently during this study. Our results indicate high levels of nutrient and suspended solids fluxes during the winter and early spring rainy season in the Big Creek watershed, and this information may be important for future management decisions because of the development of total maximum daily load initiatives across the state and nation as part of the Clean Water Act.

Our low taxa richness (Barbour et al., 1999), moderate Shannon's Species Diversity (Wilhm and Dorris, 1968), low % EPT (Barbour et al., 1999), moderate Family Biotic Index (Hilsenhoff, 1988), and high % Diptera and % Chironomidae (Barbour et al., 1999) indicate an impaired aquatic macroinvertebrate fauna. The species diversity values for the macroinvertebrate fauna in this study were similar to or slightly lower than those of Cather and Harp (1975) at two stations on Big Creek. They reported species diversity values that ranged from a low of 1.882 to a high of 2.905 during the summer and fall. They attributed their relatively low aquatic macroinvertebrate diversity values to a lack of microhabitats and related loss of ecological niches for aquatic invertebrates as compared to the high microhabitat diversity Ozark stream, Janes Creek, in which they reported species diversity index values over 3.272

Table 8. Mean (± 1 SD) nutrient concentrations for the Mud Creek station across 10 weeks in winter and early spring 2002. na = not analyzed

Date	TDOC-C (mg/L)	TDIC-C (mg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	TN-N (µg/L)	PO_4-P (µg/L)	TP-P (µg/L)
26 Jan.	3.88 (0.11)	0.83 (0.21)	46.61 (17.73)	na	618.32 (188.39)	665.63 (82.91)	1830.62 (243.05)
01 Feb.	2.61 (0.49)	3.16 (2.03)	35.09 (6.45)	131.22 (4.73)	652.55 (52.30)	757.11 (68.00)	3037.51 (581.90)
08 Feb.	2.19 (0.03)	2.26 (0.17)	42.95 (13.30)	145.41 (0.00)	558.26 (110.23)	467.27 (60.70)	1240.25 (133.04)
16 Feb.	2.78 (0.13)	1.83 (0.13)	58.36 (13.15)	219.51 (7.22)	740.69 (117.32)	402.05 (86.40)	949.55 (66.88)
22 Feb.	3.63 (0.09)	0.88 (0.10)	40.00 (26.90)	251.04 (9.85)	562.36 (22.17)	272.53 (23.43)	1438.67 (87.83)
01 March	2.51 (0.02)	2.49 (0.01)	34.93 (6.58)	159.60 (9.46)	444.64 (10.20)	306.95 (80.47)	775.70 (27.52)
08 March	2.23 (0.03)	2.06 (0.02)	37.14 (9.61)	146.98 (2.73)	554.60 (212.17)	351.33 (48.94)	717.15 (422.77)
22 March	2.78 (0.06)	1.96 (0.07)	40.33 (11.32)	115.51 (8.19)	487.84 (63.53)	866.71 (24.91)	1173.69 (68.84)
29 March	2.66 (0.01)	2.12 (0.02)	43.92 (13.65)	144.09 (0.00)	758.80 (14.82)	751.68 (50.13)	1073.99 (98.24)

Table 9. Habitat assessment at the Big Creek Lower (BCL), Big Creek Upper (BCU), Lost Creek (LC), and Mud Creek (MC) stations sampled on 22 January 2002 in the Big Creek Watershed of northeast Arkansas.

Metric	Variable	BCL	BCU	LC	MC
1	Epifaunal Substrate / Available Cover	7	7	6	8
2	Pool Substrate	8	7	6	8
3	Pool Variability	13	13	3	16
4	Sediment Deposition	9	4	12	16
5	Channel Flow	11	7	8	7
6	Channel Alteration	14	18	13	16
7	Channel Sinuosity	10	13	3	13
8	Bank Stability	18	4	15	4
9	Vegetative Protection	14	8	9	8
10	Riparian Vegetative Zone	16	4	12	2
Total		104	81	75	96

(Cather and Harp, 1975). This anecdotal lack of micro- and macro-habitat in the Big Creek watershed discussed by Cather and Harp (1975) for macro-invertebrates and by Beadles (1970) and Jenkins and Harp (1971) for fishes was also observed in this study and quantified by the "marginal" designation of our habitat assessment. Big Creek and its tributaries lack riffle-run-pool development due to the extensive historical and current channelization for flood control. Substrates of Big Creek consist of hard clays, mud, and silt.

Our species richness was slightly lower than the 55 taxa reported from two stations across four summer and fall months (by Cather and Harp 1975). Their sampling consisted of 38 quantitative and 16 qualitative dip net samples in Big Creek; we however, sampled four stations in the watershed on one date in mid-winter using qualitative sampling dip-nets. Another explanation in the difference in taxa richness is that Cather and Harp (1975) identified many of their taxa to the species level, whereas we have only identified to the generic level. The higher degree of taxonomic resolution also could have been a reason for the higher diversity values reported by Cather and Harp (1975).

Our taxa richness (9 to 23 taxa) and Family Level Biotic Index values (4.8 to 6.2) were similar to those reported by the Arkansas Department of Pollution Control and Ecology (9 to 20 taxa; 4.3 to 6.4) using a similar 20 jab sampling technique (Arkansas Pollution Control and Ecology Commission, 1998). Our taxonomic composition is similar to theirs as well, with overlaps in ranges. They also reported similar relative percentages of functional feeding groups to ours, except that their % collectors ranged from 19.0 to 48.4%, whereas ours ranged from 66 to 89%. Overall, they

Table 10. Aquatic macroinvertebrate abundance collected on 22 January 2002 for the Big Creek Lower (BCL), Big Creek Upper (BCU), Lost Creek (LC) and Mud Creek (MC) stations.

Taxon			BCL	BCU	LC	MC
Oligochaeta		Oligochaeta	3	5	15	
Cladocera	Daphnidae	Daphnidae		1		
Isopoda	Asellidae	*Caecidotea*			1	
		Lirceus		1		1
Amphipoda	Talitridae	*Hyalella*				5
	Gammaridae	*Gammarus*			5	
	Crangonyctidae	*Synurella*				2
	Crangonyctidae	*Crangonyx*		1		1
Decapoda	Cambaridae	*Cambaridae*		1	2	
	Cambaridae	*Procambarus*				1
Ephemeroptera	Baetidae	Baetidae		1		1
	Heptageniidae	*Stenacron*		4		
	Heptageniidae	*Stenonema*				1
	Caenidae	*Caenis*	1	1		12
Odonata	Calopterygidae	*Calopteryx*				1
	Coenagrionidae	*Argia*				1
	Macromiidae	*Macromia*				1
	Corduliidae	*Epitheca*	1			
Plecoptera	Perlodidae	*Isoperla*			1	3
Hemiptera	Corixidae	*Trichocorixa*			4	
	Corixidae	*Ramphocorixa*		1		
	Notonectidae	*Notonecta*			1	
Trichoptera	Hydrophsychidae	*Cheumatopsyche*	5	2		
	Limnephilidae	*Ironoquia*				1
Coleoptera	Dytiscidae	*Brachyratus*			2	
	Carabidae	Carabidae			1	
	Hydrophilidae	*Tropisternus lateralis nimbatus*			1	2
	Elmidae	*Stenelmis*		1		1
Diptera	Tipulidae	*Tipula*			1	
	Simuliidae	*Cnephia*			9	
	Simuliidae	*Prosimulium*	5	74	6	19
	Simuliidae	*Simulium*		101		20
	Ceratopogonidae	*Mallochohelea*		1		
	Chironomidae	Tanypodinae	5	4		1
	Chironomidae	Orthocladiinae	16		53	
	Chironomidae	Chironomini		3		26
	Chironomidae	Tanytarsini	1			
	Tabanidae	Tabanidae		1		
	Stratiomyidae	*Allognosta*		1		
Mollusca	Lymnaeidae	*Pseudosuccinea columella*				1
	Ancylidae	Ancylidae				1
	Physidae	*Physa*			2	
	Corbiculidae	*Corbicula fluminea*		2		4
	Unionidae	*Toxolasma lividus*				1
	Sphaeridae	*Sphaerium*	1		2	

Table 11. Macroinvertebrate assemblage characteristics collected on 22 January 2002 at the Big Creek Lower (BCL), Big Creek Upper (BCU), Lost Creek (LC), and Mud Creek (MC)stations sampled in the Big Creek Watershed of northeast Arkansas.

Variable	BCL	BCU	LC	MC
Richness	9	19	16	23
Family Biotic Index	5.9	5.9	6.2	4.8
Evenness	0.796	0.474	0.659	0.745
Shannon's Diversity	1.748	1.397	1.827	2.336
Simpson's Diversity	0.762	0.629	0.714	0.856
% EPT	16.0	3.8	0.9	5.4
% Diptera	71.0	89.0	65.0	62.0
% Chironomidae	58.0	3.0	50.0	25.0
% Shredders	3.0	0.0	1.0	0.0
% Collectors	71.0	89.0	66.0	74.0
% Filterers	3.0	1.0	2.0	5.0
% Scrapers	0.0	2.0	0.0	4.0
% Predators	3.0	3.0	9.0	8.0

reported higher % EPT (8.9 to 39.1) than we did (0.9 to16). Based on samples collected using similar methods, we can say that our winter results overlap with their summer samples (Arkansas Pollution Control and Ecology Commission, 1998). The Arkansas Department of Pollution Control and Ecology stated that based on the biological assessment of Big Creek and Lost Creek ditches, that the fish and macroinvertebrate communities generally were below expectations for a channel-altered Delta fishery (Arkansas Pollution Control and Ecology Commission, 1998). They also noted the high concentrations of nutrients and TSS as potential impacts to the Big Creek Ditch system.

The aquatic macroinvertebrates of Big Creek and its tributaries are impacted by both physical and chemical variables. Nutrients and suspended solids are high and have the potential to impair macro-invertebrate communities. Furthermore, the lack of macro- and micro-habitat also limits the diversity of habitat that can be used by taxa compared to unaltered or less altered streams. Nevertheless, over the last 25 plus years, water quality based on the aquatic macroinvertebrate fauna of the Big Creek watershed does not appear to have changed.

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