# Benthos in Bear Creek, Mississippi: Effects of Habitat Variation and Agricultural Sediments

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ABSTRACT

The macroinvertebrate fauna of Bear Creek, a 83 km stream which flows through six oxbow lakes, and two off-stream lakes in the same watershed was studied for two years. Bear Creek, a tributary of the Yazoo River in the Delta region of Mississippi, drains 330 $km^2$ of intensively cultivated agricultural land and carries a continuing sediment concentration during the rainy season of up to 1300 mg $l^{-1}$. Benthic organisms were collected monthly from August, 1976 through August, 1978 at six stream stations and at 14 lake stations, across a variety of substrates, and at depths ranging from 0.5 to 6.5 m. In most lake and stream sections of the creek, Chaoborus (one species), Chironomidae (nineteen genera), and Oligochaeta (three species), dominated the benthos. Thirteen other genera of insects were represented as were Bryozoa (four genera), Mollusca (nine genera), Hirudinea (five genera), and Crustacea (three genera). There was continuous stress from high rates of sedimentation (up to seven cm $yr^{-1}$) as indicated by low taxa richness(s) and diversity ($\bar{d}$) at a majority of stations sampled. Most creek stations were subject not only to annual sedimentation and flushing but also to fluctuations in water level and drying. Secondary productivity varied greatly (one to 31 g dry wt $m^{-2}yr^{-1}$) and was almost totally dependent on three taxa of pollution tolerant organisms except in unstressed stream reaches. Low productivity in riverine lakes, when compared to stream sections was partially due to differences in species distribution in lotic and lentic habitats. The mayfly Hexagenia bilineata, the clam Sphaerium rhomboideum, and the bryozoan Pectinatella magnifica, responded negatively to environmental stresses induced by seasonally high concentrations of suspended sediments.

## INTRODUCTION

The effects of massive amounts of suspended and deposited sediments on various components of aquatic ecosystems have been documented in assessing the processes governing natural systems and man-induced system changes (Farnworth et al. 1979). Individual species of benthos exhibit specific levels of sensitivity or tolerance to such environmental stresses, making them useful in ecosystem analysis. In addition, the mobility of benthos assures seasonal redistribution into marginal habitats. Several investigations on benthos have been made, with widely varying results, on the catastrophic effects of large quantities of sediment from logging, mining and highway construction sites (Tebo 1955; Reed 1977, Lenat et al. 1981, Duchrow 1982, Cline et al. 1982). Generally, research has dealt with the effect of a specific disturbance and recovery following cessation of that event. Stream recovery, as measured by re-establishment of macroinvertebrates, may begin within a few weeks following a disturbance depending on how efficiently a stream flushes out the sediments deposited during perturbation.

Results of long-term deposition of sediments on an annual basis are more subtle. Benthos studies in the flatland streams and lakes of the Mississippi River alluvial plain where this type of sedimentation is a problem are almost non-existent. The Mississippi Department of Wildlife Conservation conducted cursory investigations of benthos (Bingham 1969) in several of their fisheries investigations in sediment stressed ecosystems, but no detailed taxonomic or ecological evaluations are available for these highly impacted ecosystems.

The objectives of this study were (1) to identify the macrobenthic components of a typical alluvial stream system and (2) to determine what limits are imposed on benthic macroinvertebrates by sediment deposition.

## STUDY AREA AND METHODOLOGY

Bear Creek, in Humphreys, Sunflower, and Leflore counties, Mississippi (Fig. 1) is a tributary of the Yazoo River in the intensively cultivated alluvial delta of the Mississippi River. The creek system (83.2 km long) can be divided into two reaches. The first reach is a sluggishly flowing stream that begins at Blue lake (Sites 1A and B) and meanders for 41 km (Sites 2-5A). Flow in the upper one-fourth of the stream is intermittent (No data are reported for site 3 because of annual dry periods caused from water withdrawal by irrigation). The second reach of 43 km consists of five riverine oxbow lakes (Sites 8, 11, 12) connected by short stream segments (Sites 9 and 10). The creek channel increases from one m deep and five m wide at its origin to five m deep and 10 m wide at maximum in-bank flow at its confluence with the Yazoo River. Flow varies with site and rainfall cycle. The six instream lakes vary in surface area from three to 142 ha. The 330 $km^2$ watershed also contains numerous off-stream lakes (Sites 6 and 7) and old channel scars, many of which are in advanced stages of ecological succession and are partially filled with floating herbaceous vegetation or emergent woody vegetation.

Bottom substrate (0.28 $m^2$) was collected monthly for two years, beginning in August 1976, at six stream sites and 14 lake sites (Fig. 1). Twelve Ekman grabs were pooled for each site for each of the 24 months of the project. Sampling was conducted on selected strata (stratified random sampling) since the characteristics of macroinvertebrate communities are closely related to physical site parameters. After sieving (0.589 $mm^2$), samples were preserved, sorted and counted. Exclusive of Mollusca, organisms not permanently fixed for identification were sorted to species level and divided into one-mm length size classes when necessary before being dried and weighed. Size-classes and life history information were used to separate generations or cohorts. Mollusca, including shell, were treated only where they formed a significant numerical benthic component. Production was estimated by the removal-summation method (Waters 1971) where the sum of mortality between successive samples for each cohort is calculated in terms of weight changes. Thus, annual production was based on the total loss calculated per year. Estimated weight per organism was based on the mean between two successive monthly sampling values to minimize error. Estimated weights from these means were used for calculations when species representation was too low to produce a reliable weight.

As part of the comprehensive study on Bear Creek, numerous physical, chemical and biological parameters were measured that are referred to but not discussed in detail in this article. These included temperature, conductivity, dissolved oxygen, pH, nutrients, BOD, residual pesticides, total solids, suspended sediments, and sediment deposition rates (Cooper et al. 1982, Cooper and Burris 1984, Cooper et al. 1987, Dendy et al. 1984, Ritchie et al. 1979).

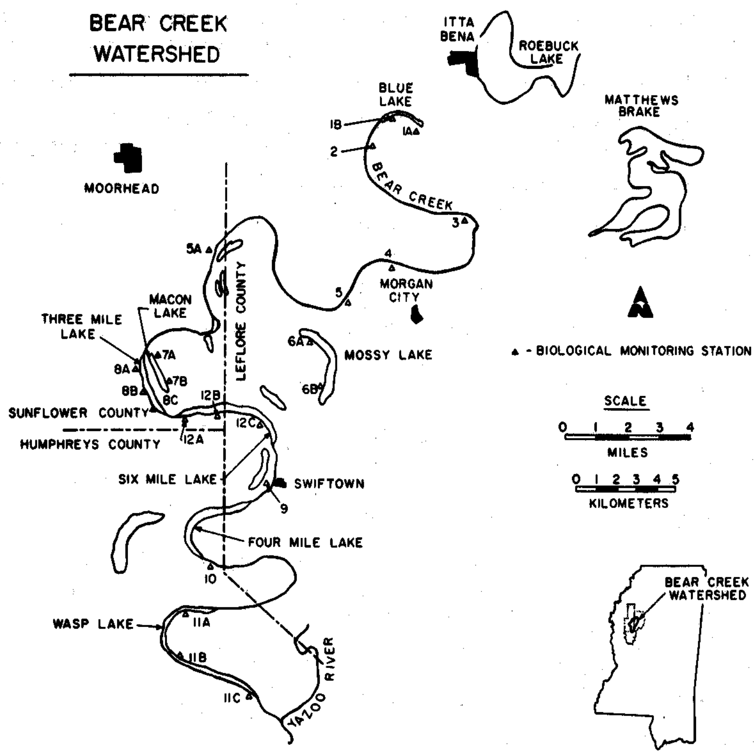


Figure 1. Map of Bear Creek, including sampling sites.

# RESULTS AND DISCUSSION

## Water Quality Results

Of the physical and chemical parameters examined (Table 1), turbidity and sediment accumulation were the most evident problems. Suspended sediment concentrations commonly ranged from 100 to >400 mg $L^{-1}$ during the rainy season. Suspended sediment concentrations of up to 1300 mg $L^{-1}$ were measured during rainfall events when runoff from cultivated fields reached levels of 2750 mg $L^{-1}$ (Dendy et al. 1984). Riverine lakes have accumulated sediments at rates which averaged from 1.4 to over 5.6 cm $yr^{-1}$ during the last 23 years (Ritchie et al. 1979).

## Taxonomic Results

Representatives of 69 species of invertebrates were collected from Bear Creek (Table 2). Of these, Chironomidae (19 genera), *Chaoborus punctipennis* (Say) and Oligochaeta (three species) composed the majority of the benthos. Aquatic insects other than *Chaoborus* and Chironomidae included Ephemeroptera (four species), Odonata (six species), Trichoptera (one species), Coleoptera (three species), Megaloptera (one species), Hemiptera (one species) and other Diptera (two species). In addition, Bryozoa (four species), Mollusca (nine species), Hirudinea (five species) and Crustacea (three species) were collected.

Table 1. Quarterly water quality values (1976-1978) from selected sites in Bear Creek, Mississippi, representing seasonal and site to site variation.

| Date Station Unit | Temp. C | Dissolved Oxygen $mg/L^{-1}$ | pH | $N-NO^3$ $mg/L^{-1}$ | Phosphorus Ortho $mg/L^{-1}$ | Total Sediments $mg/L^{-1}$ | Suspended Sediments $mg/L^{-1}$ |
|---|---|---|---|---|---|---|---|
| 11-17-76 | | | | | | | |
| 1A(0 m) | 8.9 | 3.4 | 6.9 | 0.09 | 0.03 | 119 | 19 |
| (2 m) | 8.8 | 3.2 | 6.8 | 0.08 | 0.09 | 112 | 11 |
| 2 | 6.5 | 9.8 | 6.8 | 0.07 | 0.11 | 109 | 9 |
| 5 | 7.0 | 11.5 | 6.8 | 0.72 | 0.19 | 146 | 66 |
| 5A | 7.7 | 0.5 | 7.2 | 0.07 | 0.49 | 207 | 44 |
| 12B(0 m) | 9.3 | 5.4 | 6.8 | 0.06 | 0.09 | 164 | 32 |
| (5 m) | 9.4 | 7.9 | 6.9 | 0.04 | 0.09 | 170 | 40 |
| 10 | 8.0 | 12.2 | 7.2 | 0.49 | 0.08 | 183 | 51 |
| 11C(0 m) | 8.1 | 7.9 | 6.8 | 0.05 | 0.09 | 135 | 54 |
| (1 m) | 8.0 | 8.5 | 6.8 | 0.04 | 0.07 | 137 | 50 |
| 3-23-77 | | | | | | | |
| 1A(0 m) | 18.6 | 6.9 | 6.3 | 0.03 | 0.29 | 177 | 108 |
| (3 m) | 15.1 | 1.2 | 6.3 | 0.03 | 0.26 | 179 | 115 |
| 2 | 14.2 | 11.2 | 6.6 | 0.03 | 0.23 | 152 | 80 |
| 5 | 12.7 | 11.7 | 6.8 | 0.05 | 0.24 | 313 | 243 |
| 5A | 12.2 | 12.5 | 7.2 | 0.06 | 0.22 | 420 | 348 |
| 12B(0 m) | 19.7 | 8.5 | 6.7 | 0.05 | 0.24 | 351 | 299 |
| (5 m) | 14.5 | 7.5 | 6.4 | 0.05 | 0.25 | 342 | 305 |
| 10 | 15.6 | 10.8 | 6.9 | 0.06 | 0.26 | 434 | 382 |
| 11C(0 m) | 19.0 | 11.2 | 6.0 | 0.13 | 0.27 | 456 | 405 |
| (3 m) | 14.1 | 8.3 | 6.1 | 0.11 | 0.21 | 449 | 392 |
| 5-17-77 | | | | | | | |
| 1A(0 m) | 23.5 | 5.5 | 6.8 | 0.25 | 0.19 | 77 | 22 |
| (3 m) | 17.5 | 6.9 | 6.6 | 0.21 | 0.23 | 70 | 16 |
| 2 | 24.1 | 8.3 | 6.5 | 0.11 | 0.22 | 86 | 34 |
| 5 | 23.6 | 7.1 | 6.9 | 0.06 | 0.32 | 197 | 117 |
| 5A | 23.6 | 7.1 | 6.9 | 0.21 | 0.29 | 135 | 111 |
| 12B(0 m) | 24.5 | 5.9 | 7.1 | 0.19 | 0.31 | 217 | 128 |
| (5 m) | 17.5 | 9.0 | 7.0 | 0.21 | 0.30 | 203 | 121 |
| 10 | 24.4 | 6.9 | 7.0 | 0.29 | 0.27 | 214 | 155 |
| 11C(0 m) | 25.5 | 5.4 | 7.1 | 0.31 | 0.29 | 232 | 160 |
| (2 m) | 22.8 | 6.3 | 6.9 | 0.33 | 0.32 | 247 | 183 |
| 7-26-77 | | | | | | | |
| 1A(0 m) | 30.2 | 3.1 | 6.2 | 0.37 | 0.04 | 68 | 5 |
| (3 m) | 28.7 | 1.3 | 6.0 | 0.39 | 0.09 | 75 | 9 |
| 2 | 26.3 | 4.4 | 6.1 | 0.31 | 0.13 | 109 | 28 |
| 5 | 27.4 | 3.0 | 6.3 | 0.51 | 0.26 | 205 | 110 |
| 5A | 27.4 | 8.6 | 6.5 | 0.12 | 0.21 | 195 | 71 |
| 12B(0 m) | 31.1 | 8.9 | 6.5 | 0.31 | 0.11 | 193 | 90 |
| (5 m) | 24.0 | 2.4 | 6.2 | 0.26 | 0.14 | 180 | 79 |
| 10 | 29.4 | 4.4 | 6.8 | 0.45 | 0.05 | 236 | 91 |
| 11C(0 m) | 34.8 | 8.9 | 8.0 | 0.42 | 0.06 | 207 | 95 |
| (3 m) | Too shallow for depth sample. | | | | | | |

Table 1 (Continued)

| Date Station Unit | Temp. C | Dissolved Oxygen mg/L$^{-1}$ | pH | N-NO$^3$ mg/L$^{-1}$ | Phosphorus Ortho mg/L$^{-1}$ | Total Sediments mg/L$^{-1}$ | Suspended Sediments mg/L$^{-1}$ |
|---|---|---|---|---|---|---|---|
| 2-8-78 | | | | | | | |
| 1A(0 m) | 2.6 | 12.6 | 6.3 | 0.08 | 0.29 | 109 | 49 |
| (4 m) | 2.5 | 16.3 | 6.2 | 0.10 | 0.21 | 107 | 42 |
| 2 | 2.3 | 13.21 | 6.2 | 0.22 | 0.32 | 103 | 33 |
| 5 | 1.2 | 11.5 | 6.5 | 0.49 | 0.31 | 125 | 56 |
| 5A | 1.0 | 12.9 | 6.8 | 0.24 | 0.27 | 182 | 126 |
| 12B(0 m) | 2.1 | 11.4 | 6.5 | 0.20 | 0.15 | 247 | 188 |
| (5 m) | 2.0 | 12.0 | 6.9 | 0.21 | 0.19 | 241 | 174 |
| 10 | 1.6 | 10.4 | 6.4 | 0.30 | 0.24 | 305 | 254 |
| 11C(0 m) | 1.8 | 10.8 | 6.5 | 0.28 | 0.20 | 267 | 209 |
| (3 m) | 1.7 | 15.0 | 6.5 | 0.31 | 0.21 | 258 | 211 |
| 10-18-77 | | | | | | | |
| 1A(0 m) | 18.0 | 7.3 | 7.6 | 0.03 | 0.09 | 92 | 7 |
| (3 m) | 17.3 | 8.2 | 6.5 | 0.05 | 0.08 | 97 | 8 |
| 2 | 17.5 | 5.9 | 6.5 | 0.09 | 0.09 | 102 | 13 |
| 5 | 14.6 | 7.2 | 6.5 | 0.39 | 0.12 | 186 | 116 |
| 5A | 15.5 | 6.9 | 6.7 | 0.31 | 0.14 | 181 | 113 |
| 12B(0 m) | 19.9 | 6.9 | 7.3 | 0.09 | 0.16 | 158 | 88 |
| (5 m) | 16.0 | 10.1 | 6.6 | 0.08 | 0.14 | 156 | 84 |
| 10 | 19.2 | 6.9 | 6.5 | 0.29 | 0.15 | 172 | 86 |
| 11C(0 m) | 18.9 | 7.5 | 7.4 | 0.08 | 0.04 | 147 | 33 |
| (2 m) | 18.7 | 8.4 | 7.1 | 0.07 | 0.03 | 148 | 34 |
| 4-5-78 | | | | | | | |
| 1A(0 m) | 25.4 | 6.5 | 6.7 | 0.23 | 0.27 | 83 | 8 |
| (4 m) | 11.2 | 12.3 | 6.3 | 0.18 | 0.21 | 79 | 7 |
| 2 | 21.8 | 8.1 | 6.2 | 0.07 | 1.30 | 88 | 1 |
| 5 | 24.2 | 6.7 | 6.2 | 0.41 | 0.58 | 178 | 89 |
| 5A | 23.9 | 8.6 | 6.6 | 0.21 | 0.16 | 268 | 180 |
| 12B(0 m) | 25.4 | 6.9 | 7.3 | 0.38 | 0.35 | 246 | 185 |
| (5 m) | 10.6 | 9.2 | 6.9 | 0.29 | 0.30 | 229 | 170 |
| 10 | 21.4 | 5.9 | 6.0 | 0.32 | 0.24 | 352 | 271 |
| 11C(0 m) | 23.9 | 6.8 | 6.6 | 0.80 | 0.23 | 255 | 193 |
| (3 m) | 18.7 | 9.2 | 6.8 | 0.63 | 0.19 | 240 | 182 |
| 8-9-78 | | | | | | | |
| 1A(0 m) | 29.0 | 5.6 | 6.6 | 0.31 | 0.10 | 111 | 15 |
| (4 m) | 21.7 | 6.6 | 6.1 | 0.35 | 0.12 | 102 | 10 |
| 2 | 254 | 5.9 | 7.0 | 0.15 | 0.09 | 224 | 18 |
| 5 | 26.8 | 6.7 | 6.1 | 0.48 | 0.14 | 146 | 59 |
| 5A | 26.8 | 5.2 | 7.4 | 0.13 | 0.07 | 261 | 49 |
| 12B(0 m) | 28.2 | 5.3 | 6.9 | 0.29 | 0.07 | 169 | 70 |
| (5 m) | 19.6 | 2.3 | 6.5 | 0.19 | 0.05 | 152 | 60 |
| 10 | 29.0 | 5.8 | 6.6 | 0.48 | 0.12 | 142 | 67 |
| 11C(0 m) | 29.1 | 6.7 | 6.6 | 0.51 | 0.13 | 164 | 100 |
| (3 m) | 20.8 | 6.6 | 6.3 | 0.46 | 0.09 | 138 | 92 |

Table 2. List of species of macrobenthos collected from Bear Creek, Mississippi (1976-1978).

Bryozoa
- Fredericella sultana (Blumenbach)
- Lophopus crystallinas (Pallas)
- Pectinatella magnifica (Leidy)
- Plumatella fruticosa (Allman)

Annelida
- Tubifex tubifex (O. F. Müller)
- Branchiura sowerbyi Beddard
- Limnodrilus hoffmeisteri Claparède
- Helobdella stagnalis (Linnaeus)
- H. elongata (Castle)
- Placobdella montifera Moore
- Illinobdella moorei Meyer
- Moorebdella microstoma (Moore)

Mollusca
- Helisoma sp.
- Physa sp.
- Stagnicola sp.
- Corbicula manilensis (Philippi)
- Musculum sp. (Say)
- Sphaerium rhomboideum
- Anodonta sp.
- Carunculina parva (Barnes)
- Amblema costata Rafinesque

Ephemeroptera
- Baetis sp.
- Caenis sp.
- Hexagenia bilineata (Say)
- Ephemerella sp.

Odonata
- Libellula sp.
- Perithemus tenera (Say)
- Argia sp.
- Ischnura posita (Hagen)
- Dromogomphus spinosus Selys
- Tauriphila sp.

Trichoptera
- Cyrnellus fraternus (Banks)

Coleoptera
- Berosus sp.
- Dubiraphia sp.
- Hydrocanthus sp.

Megaloptera
- Neohermes sp.

Hemiptera
- Notonecta sp.

Diptera
- Chironomus riparius Meigen
- Leptochironomus sp.
- Cryptochironomus digitatus Townes
- Dicrotendipes sp.
- Endochironomus sp.
- Coelotanypus concinnus (Coquillett)
- C. scapularis (Loew)
- C. tricolor (Loew)
- Kiefferulus sp.
- Goeldichironomus sp.
- Pentaneura monilis (Linnaeus)
- Tanypus carinatus Sublette
- T. stellatus Conquillett
- Tanytarsus sp.
- Ablabesmyia sp.
- A. annulata (Say)
- A mallochi (Walley)
- A. ornata
- Polypedilum sp.
- P. halterale (Coquillett)
- Glyptotendipes senilis (Joh.)
- Harnischia sp.
- Einfeldia natchitocheae Sublette
- Hydrobrobaeuus pilipes (Say)
- Procladius culiciformes Roback
- Parachironomus sp.
- Chaoborus punctipennis (Say)
- Chrysops sp.
- Ceratopogonidae

Crustacea
- Hyalella azteca (Saussure)
- Procambricus sp.
- Palaemonetes kadiakensis Rathbun

Habitat Preference

Over 50 percent of the species in this study were found at only one or two sites; 14 species occurred only at Site 5A, 11 species occurred only at Site 10 and eight species occurred only at Site 2. Nonparametric statistics were used to test for significant differences between sites for each species represented because the benthos was not normally distributed [0.01 level, as determined by Lilliefors' test (Conover 1971)]. The Kolmogorov-Smirnov two-sample test statistic ($T_1$) as described by Conover (1971) was used to test the null hypothesis that the frequency of distribution of any specific organism at sites x and y did not differ significantly during the two year study). $T_1$ was the greatest vertical distance between two empirical cumulative distribution functions. Distribution functions for 25 species found at 5A differed significantly ($P<0.1$) from all other sites. The relative abundance of numerous species at sites 2 and 10 (Table 3) was also significantly different ($P<0.1$) from other sites. Substrate type and current were the major differences between these three sites (2, 5A, 10) and the other habitats sampled in Bear Creek. Because of high stream gradient, there was consistently enough flow at Sites 2, 5A, and 10 to prevent sediment accumulation and to allow organisms that require current in food gathering activities to function. Site 5A had an additional substrate variation. The collection site was 20 m downstream from a clay-gravel covered road bridge. Gravel, which does not occur naturally in Bear Creek, had gradually accumulated downstream from the bridge and created an artificial substrate unlike any other in the watershed. Statistical analysis showed that the four sites in Bear Creek watershed with <one cm $yr^{-1}$ of sediment accumulation (Sites 2, 5A, 7B and 10) had a significantly ($P<0.05$) greater diversity ($\bar{d}$) and taxa richness than all other sites during the two years of the study. Other stream sites (4, 5, 9) had a lower gradient and accumulated sediments seasonally. Lake sites normally had no visible flow and accumulated sediments at rates that varied from <one cm $yr^{-1}$ (7B) to over seven cm $yr^{-1}$ (11 B) (Ritchie et al. 1979). The number of commonly-occurring species in sluggish water in riverine habitats compared favorably with lacustrine habitats in the mid-south region of the U.S. (Cooper and Knight 1985).

Diversity

Diversity indices are used to measure the effect of stress on the structure of macroinvertebrate communities and, thus, measure the quality of the environment. Wilhm (1970) found unpolluted waters generally have a diversity of between three and four and polluted waters to be less than one, but many biologists have found naturally-stressed waters to also have low diversity and poor sensitivity to change (EPA 1973). Shannon-Weaver diversity ($\bar{d}$) as presented by Lloyd et al. (1968) was calculated for each month and an annual mean diversity ($\bar{d}$) was derived for each site (Fig. 2). These calculations indicated stress at all sites. It is noteworthy that there was, without exception, more stress in the areas subject to measurable sediment accumulation. While $\bar{d}$ was no more sensitive to site quality than was taxa richness (number of species) (Table 2), both indices indicated the three stream sites with no sediment accumulation to be significantly less stressed ($P<0.05$) than other stream sites or lake sites.

Secondary Productivity

Stream sites with the greatest taxa richness (2, 5A, 10) had much higher productivity (Fig. 3) than other habitats. All stream sites were generally quite productive in spite of water level fluctuations and seasonally high levels of suspended sediments. In addition, qualitative sampling of snag and emergent vegetation indicated that it provided substrate for additional secondary productivity in most stream sections. Estimates commonly revealed 500-1000 organisms $m^{-2}$ of snag surface in stream reaches which had a stable water level. Declines in standing crop of sediment-sensitive organisms reduced stream productivity in several instances [i.e., Site 5A in 1977-1978 (Fig. 3) when high sediment loads and flooding resulted in no flow conditions and the bottom substrate was temporarily covered with one + cm of silt.] Lake benthic productivity ranged from 1.5 g dry wt. $m^{-2}$ $yr^{-1}$ to 9.3 g $m^{-2}$ $yr^{-1}$ (Fig. 3). This range of productivity was more variable than stressed littoral zones in flood control reservoirs in the nearby Yazoo basin foothills. For comparison, productivity in stressed drawdown zones in hill land flood control reservoirs in Mississippi may vary from <one g $m^{-2}$ $yr^{-1}$ to two g $m^{-2}$ $yr^{-1}$ (Cooper and Knight 1985). Lakes in the nearby foothills with stable water levels may have littoral zone productivity of four to five g $m^{-2}$ $yr^{-1}$. Lakes in Bear Creek watershed had fewer species and lower density than stream sections and, thus, were generally less productive (Fig. 3). Reduced productivity in the riverine lakes was at least partially caused by the habitat differences in lentic and lotic environments. This was attested to by the productivity of two isolated lakes in the Bear Creek watershed. Mossy Lake (Site 6) received and deposited sediments much like the riverine lakes of Bear Creek; Macon Lake (Site 7) received little surface runoff and had substantially less sediment deposition. Site 7B had a sedimentation rate of 0.4 cm $yr^{-1}$ during the period 1966-1977, the smallest deposition of any lake site. Yet neither lake differed markedly in benthic secondary productivity (Fig. 3) from the flow-through lakes in the creek system.

Larval dipterans played an important role in secondary productivity at all sites (Fig. 3). Pollution tolerant oligochaetes dominated the productivity at several sluggish water or lacustrine sites that were organically enriched (e.g. Sites 4 and 5 were in close proximity to cattle crossings and watering areas). Other species only had isolated influence since they were not able to permanently occupy many sites (Fig. 3).

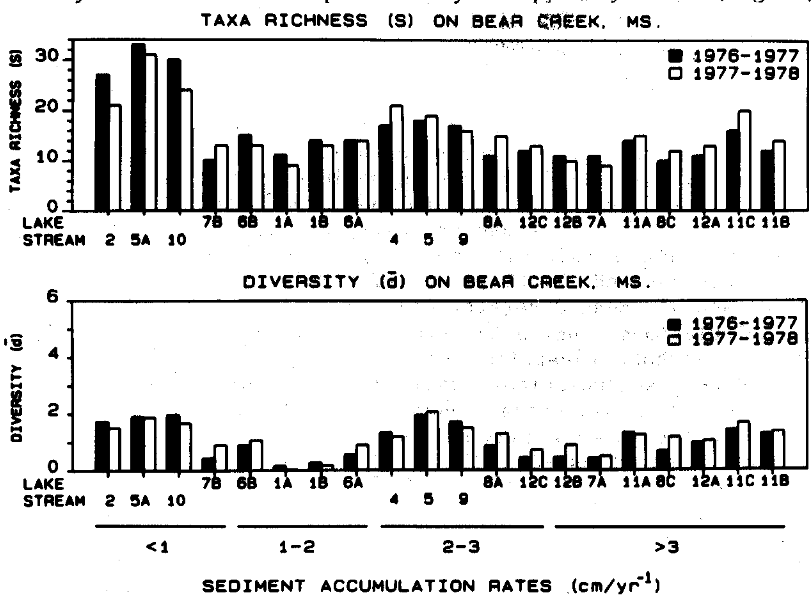


Figure 2. Mean annual Taxa richness(s) and diversity ($\bar{d}$) for Bear Creek.

Table 3. Mean density (organisms/$m^{-2}$) of abundant benthic macroinvertebrates from the lakes and stream sections of Bear Creek, Mississippi (August 1976–July 1977) (N=12).

| | Site # | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1A | 1B | 2 | 4 | 5 | 5A | 8A | 8C | 12A | 12B | 12C | 9 | 10 | 11A | 11B | 11C | 6A | 6B | 7A | 7B |
| **Annelida** | | | | | | | | | | | | | | | | | | | | |
| Tubifex tubifex | * | 1 | 54 | – | 48 | 16 | 26 | 12 | 5 | – | 1 | 31 | 11 | 5 | 5 | 5 | – | 1 | 1 | – |
| Branchiura sowerbyi | – | 1 | 14 | 10 | 77 | 329 | 1 | – | – | – | – | 2 | – | 2 | 16 | 31 | 2 | 4 | 8 | – |
| Limnodrilus hoffmeisteri | 1 | 16 | 358 | 1114 | 234 | 551 | 175 | 73 | 125 | 638 | 58 | 137 | 57 | 116 | 138 | 274 | 22 | 26 | 76 | 5 |
| **Mollusca** | | | | | | | | | | | | | | | | | | | | |
| Sphaerium rhomboideum | – | – | 4 | 5 | 2 | 583 | – | – | – | – | – | – | 2 | – | – | – | 55 | – | – | – |
| **Ephemeroptera** | | | | | | | | | | | | | | | | | | | | |
| Hexagenia bilineata | – | – | – | 2 | – | 16 | – | – | – | – | – | – | 1 | – | – | 2 | 1 | – | – | – |
| **Diptera** | | | | | | | | | | | | | | | | | | | | |
| Chironomus riparius | 49 | 55 | 147 | 96 | 82 | 639 | 16 | 34 | 72 | 10 | 37 | 25 | 21 | 22 | 13 | 4 | 15 | 10 | 3 | 9 |
| Leptochironomus sp. | – | 1 | 1 | – | – | – | – | – | – | – | 1 | 1 | 1 | – | – | 4 | – | – | – | – |
| Cryptochironomus digitatus | – | – | 10 | 19 | 25 | 34 | 21 | 10 | 11 | – | 7 | 36 | 75 | 2 | 18 | 28 | 3 | 10 | 2 | 7 |
| Coelotanypus tricolor | – | – | 10 | – | 37 | 1 | 1 | 2 | – | – | 7 | 10 | 2 | 5 | 10 | 7 | – | 9 | – | 2 |
| Tanypus stellatus | 3 | 3 | 132 | 151 | 177 | 247 | 34 | 42 | 94 | 6 | 101 | 212 | 55 | 176 | 73 | 69 | 306 | 583 | 33 | 272 |
| Glyptotendipes senilis | 1 | 11 | 1 | – | – | 1 | – | – | – | 1 | – | – | 54 | 1 | – | – | – | 1 | 1 | – |
| Procladius culiciformes | – | 2 | 33 | 19 | 52 | 23 | 9 | 13 | 17 | 2 | 16 | 111 | 26 | 46 | 16 | 25 | 16 | 78 | 9 | 35 |
| Chaoborus punctipennis | 2801 | 2796 | 336 | 793 | 623 | 229 | 1476 | 2020 | 1458 | 3844 | 2628 | 888 | 207 | 854 | 654 | 411 | 2404 | 2636 | 2404 | 2937 |
| Ceratopogonidae | – | – | 2 | 8 | 2 | 44 | – | – | – | – | – | 1 | 1 | – | – | – | – | 1 | – | – |
| **Density (N)** | 2855 | 2887 | 1120 | 2221 | 1367 | 2725 | 1759 | 2206 | 1783 | 4505 | 2857 | 1459 | 538 | 1231 | 944 | 862 | 2825 | 3363 | 2537 | 3268 |
| **Taxa Richness (S)** | 11 | 14 | 27 | 17 | 18 | 33 | 11 | 10 | 11 | 11 | 12 | 17 | 30 | 14 | 12 | 16 | 14 | 15 | 11 | 10 |
| **Diversity ($\bar{d}$)** | 0.16 | 0.27 | 1.74 | 1.34 | 1.96 | 1.92 | 0.86 | 0.67 | 0.97 | 0.46 | 0.44 | 1.72 | 1.99 | 1.33 | 1.29 | 1.43 | 0.56 | 0.90 | 0.42 | 0.44 |
| **Sediment accumulation rates (1965–78)(cm/yr$^{-1}$)** | 1.9 | 1.9 | <1 | 2.0 | 2.0 | <1 | 2.7 | 5.0 | 5.0 | 3.8 | 2.7 | 2.1 | <1 | 4.2 | >7.7 | 5.0 | 1.9 | 1.2 | 4.0 | 0.4 |

* Not found in reoccurring frequency.

Table 3. (Continued.) Mean density (organisms/$m^{-2}$) of abundant benthic macroinvertebrates from the lakes and stream sections of Bear Creek, Mississippi (August 1977 – July 1978) (N=12).

| | Site # | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1A | 1B | 2 | 4 | 5 | 5A | 8A | 8C | 12A | 12B | 12C | 9 | 10 | 11A | 11B | 11C | 6A | 6B | 7A | 7B |
| Annelida | | | | | | | | | | | | | | | | | | | | |
| Tubifex tubifex | – | – | 99 | – | 5 | 2 | 4 | 1 | – | – | – | – | – | – | – | 1 | – | – | – | – |
| Branchiura sowerbyi | – | – | – | – | 43 | 28 | 46 | 29 | 21 | 38 | 6 | 12 | 11 | 19 | 14 | 23 | 2 | 1 | – | 2 |
| Limnodrilus hoffmeisteri | 1 | 5 | 205 | 412 | 311 | 312 | 246 | 88 | 111 | 200 | 24 | 110 | 67 | 165 | 135 | 401 | 19 | 29 | 52 | 39 |
| Mollusca | | | | | | | | | | | | | | | | | | | | |
| Musculum sp. | – | – | – | 1 | – | 10 | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – |
| Sphaerium rhomboideum | – | – | – | 3 | 1 | 87 | – | – | – | – | – | – | 1 | – | – | – | 10 | 7 | – | – |
| Ephemeroptera | | | | | | | | | | | | | | | | | | | | |
| Hexagenia bilineata | – | – | – | – | – | – | – | – | – | – | – | 2 | – | – | – | 10 | – | – | – | – |
| Diptera | | | | | | | | | | | | | | | | | | | | |
| Chironomus riparius | 1 | 1 | 67 | 391 | 12 | 46 | 11 | 13 | 12 | 7 | 6 | 14 | 14 | 11 | 3 | 19 | 1 | 4 | 2 | 4 |
| Cryptochironomus digitatus | 1 | 1 | – | 391 | 12 | 46 | 11 | 13 | 12 | 7 | 6 | 14 | 14 | 11 | 3 | 19 | 17 | 17 | 13 | 10 |
| Coelotanypus tricolor | – | – | – | 1 | 27 | 2 | 1 | 2 | 3 | – | – | 29 | – | 10 | 48 | 4 | 11 | 39 | 1 | 11 |
| Tanypus stellatus | 1 | 2 | 30 | 16 | 226 | 67 | 273 | 368 | 770 | 229 | 536 | 597 | 136 | 618 | 317 | 372 | 351 | 642 | 266 | 629 |
| Ablabesmyia ornata | – | – | 1 | – | 1 | 10 | – | – | – | – | – | 2 | – | – | – | – | – | – | – | – |
| Polypedium halterale | – | – | 9 | 1 | – | – | – | – | – | – | – | – | 11 | 1 | 1 | 4 | – | – | – | – |
| Glyptotendipes senilis | – | – | 8 | 2 | 2 | 1 | – | – | 8 | 3 | 4 | 2 | 19 | 2 | 5 | 6 | – | – | – | 1 |
| Harnischia sp. | – | – | 6 | 4 | 1 | 4 | 1 | 1 | – | – | 1 | 3 | – | 1 | – | – | 1 | – | – | – |
| Procladius culiciformes | – | 1 | 9 | 7 | 50 | 10 | 16 | 35 | 60 | 24 | 24 | 49 | 16 | 65 | 31 | 19 | 35 | 32 | 19 | 34 |
| Chaoborus punctipennis | 2968 | 3204 | 333 | 1526 | 315 | 262 | 956 | 1263 | 1451 | 1624 | 2151 | 1568 | 190 | 1917 | 1239 | 408 | 1979 | 2267 | 4108 | 2595 |
| Ceratopogonidae | – | 1 | 2 | – | 4 | 19 | 1 | – | – | – | 1 | 3 | 2 | 1 | 1 | 7 | – | 1 | – | – |
| Density (N) | 2972 | 3215 | 781 | 2766 | 1011 | 918 | 1566 | 1813 | 2449 | 2132 | 2755 | 2406 | 491 | 2828 | 1798 | 1297 | 2427 | 3040 | 4461 | 3326 |
| Taxa Richness (S) | 9 | 13 | 21 | 21 | 19 | 31 | 15 | 12 | 13 | 10 | 13 | 16 | 24 | 15 | 14 | 20 | 14 | 13 | 9 | 13 |
| Diversity ($\bar{d}$) | 0.03 | 0.17 | 1.51 | 1.20 | 2.08 | 1.89 | 1.31 | 1.18 | 1.05 | 0.90 | 0.73 | 1.51 | 1.68 | 1.26 | 1.37 | 1.69 | 0.90 | 1.07 | 0.50 | 0.90 |

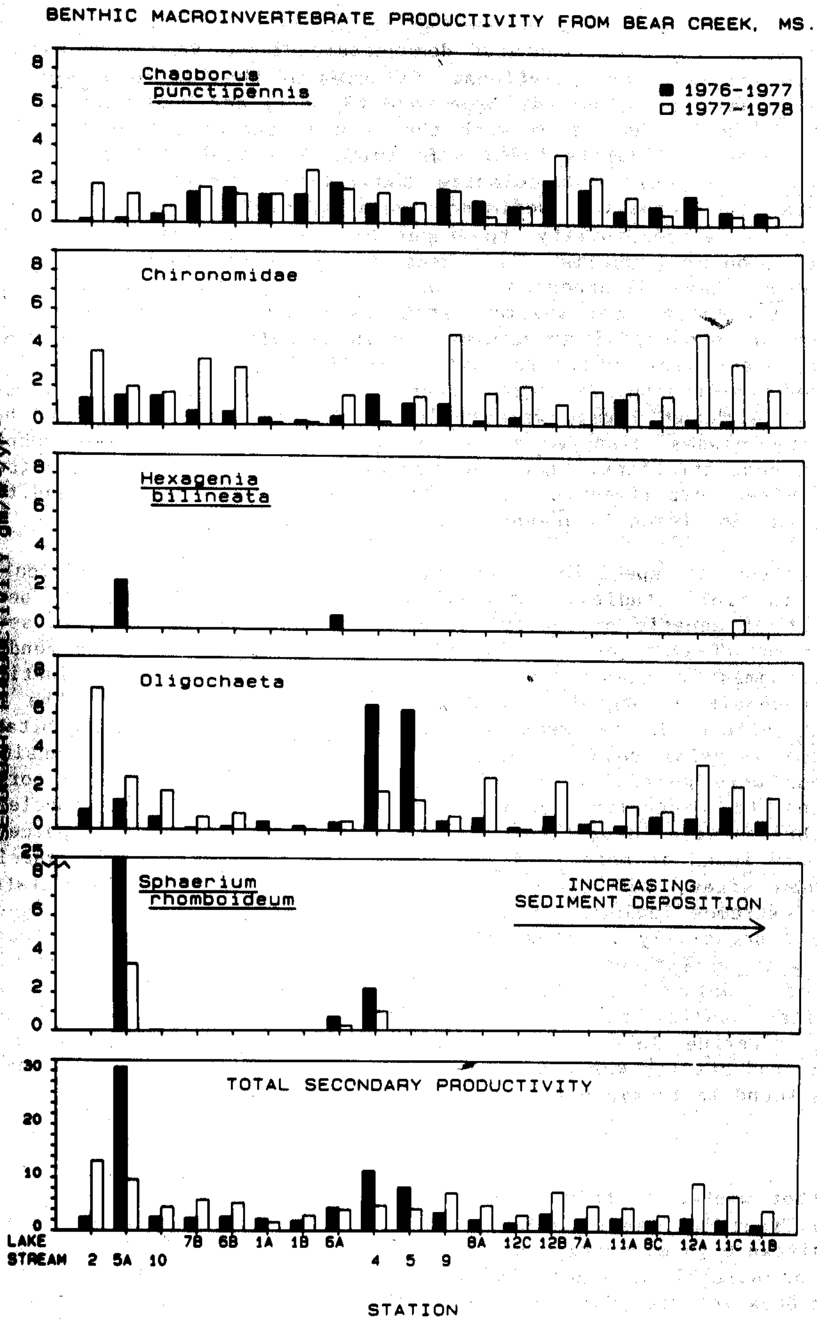


Fig. 3. Secondary productivity in Bear Creek for (1) major contributing taxa and (2) total benthic productivity (dry wt).

Indication of Stress

Several species of invertebrates demonstrated negative responses to high suspended sediment concentrations. Colonies of the bryozoan Pectinatella magnifica (Say) were found in Blue Lake (Site 1) and Mossy Lake (Site 6), the two lakes in the system with the lowest concentrations of suspended solids (Cooper and Burris 1984). In spite of suitable attachment sites, P. magnifica did not colonize downstream reaches where levels of suspended and deposited sediments were higher. Additional research indicated a susceptibility to ingestion or collection of suspended material (Cooper unpublished). Beds of the fingernail clam Sphaerium rhomboideum (Say) disappeared or were greatly reduced (Fig. 3) during periods of high sediment movement at Sites 5A and 10. Both Ephemeroptera and Odonata, whose gill structures are vulnerable to high concentrations of suspended sediments, responded similarly. Hexagenia bilineata attempted to repopulate some lakes each spring during reproductive periods. Although larvae were collected in the water column and bottom mud, they always disappeared after spring rains increased suspended sediment concentrations. Low concentrations of dissolved oxygen (<two mg $l^{-1}$) created hypolimnetic stress in summer, creating an additional detrimental condition in deeper sites in riverine lakes.

Documentation of specific cause and effect relations is difficult to acquire in field studies. Evidence obtained indicated that the benthic component of aquatic productivity in Bear Creek was affected in several ways by runoff-associated sediments. Direct effects included rendering the environment uninhabitable to sensitive larval forms and elimination of sediment-sensitive organisms during periods of deposition. The major indirect effect of sediment was a degradation of bottom habitat by deposited material so that both the number of taxa and the density of organisms were generally reduced when compared with areas not normally subjected to excessive sediment deposition. Sixty-nine species of invertebrates were identified from Bear Creek but less than 50 percent of those were found at more than two sites. Thus, productivity, especially at stream sites, was often limited by lack of suitable substrate or weather extremes including storm events and low flows. Several species responded negatively to seasonal sediment stress and their fluctuations caused wide variations in secondary productivity. The combination of number of organisms per unit area and taxa richness provided an indication of habitat quality and relative environmental stress. Comparisons of stream, riverine lake and isolated lake productivity revealed that benthic productivity was also limited by habitat type with fewer taxa and numbers found in lentic environments.

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