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EXECUTIVE SUMMARY

The West Fork-White River has been and continues to be an important water resource for northwest Arkansas. It is used recreationally for fishing and swimming, agriculturally as a source of water for livestock and irrigation of crops, it is mined for gravel, used as a receiving stream for municipal wastewater effluent, and contributes to Beaver Lake which provides water for treatment and distribution to most of northwest Arkansas. While these uses have benefited a large segment of the Arkansas population, they have also contributed to the decline in environmental quality of the river. To facilitate the development of appropriate management protocols and assess restoration potential, we provided a biological assessment of the West Fork-White River to complement studies of its physical and chemical properties. This holistic evaluation can be used presently, and to track changes in the environmental quality of the river in the future.

We compared the fish assemblages that we described at eight West Fork-White River sites to historical information dating back to 1894 and to current conditions in other Boston Mountain streams that are less disturbed. We identified 39 fish species in our survey, compared to 63 species from historical records. Nine of the fish species missing in our survey are of particular concern because these species appear consistently in historical records of the West Fork-White River, have been commonly reported in Boston Mountain streams, and two (checkered madtom and yoke darter) are endemic to the White River basin. We noted an increase in abundance of tolerant species and decline of sensitive species, which indicates that environmental stress is influencing the composition of the fish assemblages. The paucity of desirable sportfish and sunfish (e.g. bass, crappie, catfish) also suggests that restoration is needed. However, it is encouraging to note that a headwater site that we intensively sampled compared favorably with least-disturbed streams in the Boston Mountain ecoregion in some measures of environmental health including fish density, biomass, and species richness.

The assessment of environmental quality based on macroinvertebrate assemblages is consonant with the assessment based on fishes. Tolerant species again predominated, and the species richness was lower than what would be expected for less disturbed streams in this ecoregion. Meiofauna, a group of stream invertebrates smaller than macroinvertebrates, are of increasing interest to stream ecologists and may become important tools for future bioassessment. While little is known about the influence of anthropogenic disturbance on

meiofauna, we noted that the West Fork-White River assemblage was also dominated by tolerant taxa. We provided a baseline of information on this group of organisms at this time for subsequent evaluations.

Riparian corridors were in good condition in some upstream reaches, but bank erosion was apparent where buffers were narrow or absent. Further downstream, extensive bank erosion has occurred contributing to open canopies, gravel substrate embedded with fine sediments, and excessive turbidity. The site downstream from the community of West Fork municipal wastewater outfall was in very poor condition and was dominated by tolerant fish and macroinvertebrate species.

Our overall assessment is that the biological community has been affected by the cumulative effect of disturbance over time, but that species richness remains moderately high over the course of the river, and headwater reaches have maintained sufficient biological integrity to suggest that restoration efforts at this time could be effective. Attention to the cumulative effects of physical and chemical disturbances on the biological community can provide information for setting benchmarks to evaluate the success of improved management protocols and restoration efforts.

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INTRODUCTION

The West Fork-White River is a Boston Mountain stream originating in Winslow, Arkansas, flowing north through the community of West Fork into Fayetteville, and emptying into the main channel of the White River downstream from Lake Sequoyah. Identified problems within the West Fork-White River watershed include point source discharges (principally municipal wastewater) as well as nonpoint sources from agricultural activity (conversion of forest to pasture and proliferation of confined animal operations), and road construction and maintenance. We performed a thorough biological assessment of the West Fork-White River in conjunction with the physicochemical and geomorphological survey by the Environmental Preservation Division of the Arkansas Department of Environmental Quality (ADEQ). The goal of this collaborative effort was to determine baseline biological, chemical, and physical conditions of the West Fork-White River and assess the need for restoration.

Our primary objective was to provide biological data that described fishes, macroinvertebrates, and meiofauna of the West Fork-White River in 2002 that can be used for comparative purposes. We paid particular attention to providing detailed information on the methods employed, the precise location of sampling, the time of the year, and the recording and analysis of data in order to facilitate comparison to past, present, and future data.

We surveyed eight sites representing the headwaters to the mouth of the river to provide a database on the status of biota at sites representing different watershed sizes (watershed size measured as the area from sampling site upstream to the headwaters). Because physical and chemical conditions of rivers change from headwaters to mouth, there are natural differences in the biological community along a longitudinal gradient (Vannote et al. 1980). While these changes are not as great for Ozark Plateau streams compared to many others, (Brussock and Brown 1991, Brown and Brussock1991), comparison among sites of different watershed sizes should not be used to assess environmental quality because natural differences become confounded with those that are the result of anthropogenic disturbances. The following comparisons avoid those confounding effects: (1) comparison of biological conditions over the full course of the West Fork-White River from headwaters to mouth to historical conditions for the full course of the River, (2) comparison of a West Fork-White River site of a specific watershed size to other Boston Mountain streams sites with approximately the same watershed size, (3) comparison of 2002 conditions at a particular West Fork-White River site to that found in the past for that particular site, and (4) comparison of 2002 conditions at a particular West-Fork-White river site to those found in the future for that particular site.

Specific comparisons made in this survey included a comparison of species richness of fishes of the West Fork-White River to historical records dating back to 1894 (Meeks 1894, Cloutman and Olmsted 1976), a comparison of fish and macroinvertebrate assemblages found in 2002 at a particular West Fork-White River site to assemblages described at or near that site in 1963 and 1993 (ADPCE 1995), and a comparison of the fish assemblage of a West Fork-White River site to other Boston Mountain sites in the 5000 to 10,000 ha watershed range (Rambo 1998, Radwell 2000).

While we were interested in employing methods for comparative purposes, we were also interested in establishing appropriate methods for future bioassessment. Information from previous work in Boston Mountain streams along with information on the West Fork-White River represent a database for further development of biocriteria that could be used for monitoring of the West Fork-White River in the future. It is anticipated that another biological assessment using the same methods would be done if restoration work is deemed necessary and completed. Data collected for the current project could serve as a baseline for determining the level of success of restoration efforts. If restoration work is not performed, our results will be useful to future investigators in assessing trends in biological conditions of the West Fork-White River, and will increase the database of objective, quantitative information to establish reference conditions for bioassessment of Boston Mountain ecoregion rivers. We end our report with a list of recommendations for appropriate bioassessment protocols for the West Fork-White River as well as other Boston Mountain ecoregion rivers based on our observations and examination of the state-of-the-art of bioassessment at this time.

STUDY SITES

The West Fork-White River is 50 km (31 mi.) long from headwater to mouth. Seven study sites, designated Sites 1 – 7, were selected by the Environmental Preservation Division of the ADEQ (Figure 4). Sites 1 and 2 represented headwater conditions, and Site 3 was on Winn Creek, a major tributary of the West Fork-White River. We added Site 3P-INT, between Sites 2 and 4, for a more intensive study of fishes than the other sites using a three-pass depletion technique comparable to that done at 10 other Boston Mountain ecoregion stream reaches studied in 1996 and 1998 (Rambo 1996, Radwell 2000). Site 4 was south of the community of West Fork, and Site 5 was downstream in West Fork. Site 6 was southeast of Hwy 156 near the low-water bridge known to local residents as the Tilly-Willy Bridge. Site 7 was west of the Dead Horse Mountain Road crossing over the West Fork-White River in Fayetteville. Precise sampling locations for all sites are shown in Table 1 to facilitate future comparisons.

Figure 1. *Site 1 – Wooded riparian corridor*

The riparian corridors of Sites 1 – 4 were more wooded than downstream sites, with some reaches having dense canopies of oak, hickory and sycamore trees (Figure 1). However, along reaches where riparian corridors were absent or narrow, bank erosion was evident. Highway 71 was in close proximity to Sites 1, 2, 3P-INT, and 4, with drainage structures directing storm water from the highway into the river. Site 3, on Winn Creek, was selected due to concerns about the impact of sediment deposition associated with construction of Interstate 540 (Figure 2). Trash dumping was apparent at this site.

Sites 5-7 had bank destabilization and siltation associated with the absence of riparian buffers (Figure 3). Turbidity and substrate embeddedness increased progressively downstream. Site 5 was located immediately downstream from the West Fork municipal wastewater outfall, and upstream from an active gravel mining operation. Bank erosion was severe above and below the site, and the river was wide and shallow. Cattle had access to the river at Site 6, where bank breakdown and high sediment load were evident. Trash dumping was also apparent at this site. Site 7 was characterized by extensive bank erosion, substrate embeddedness, and high turbidity, reflecting the accumulation of upstream disturbances.

Figure 2. *Site 3 – Interstate 540 support structures near Winn Creek*

Figure 3. Site 5 – *Bank destabilization and erosion*

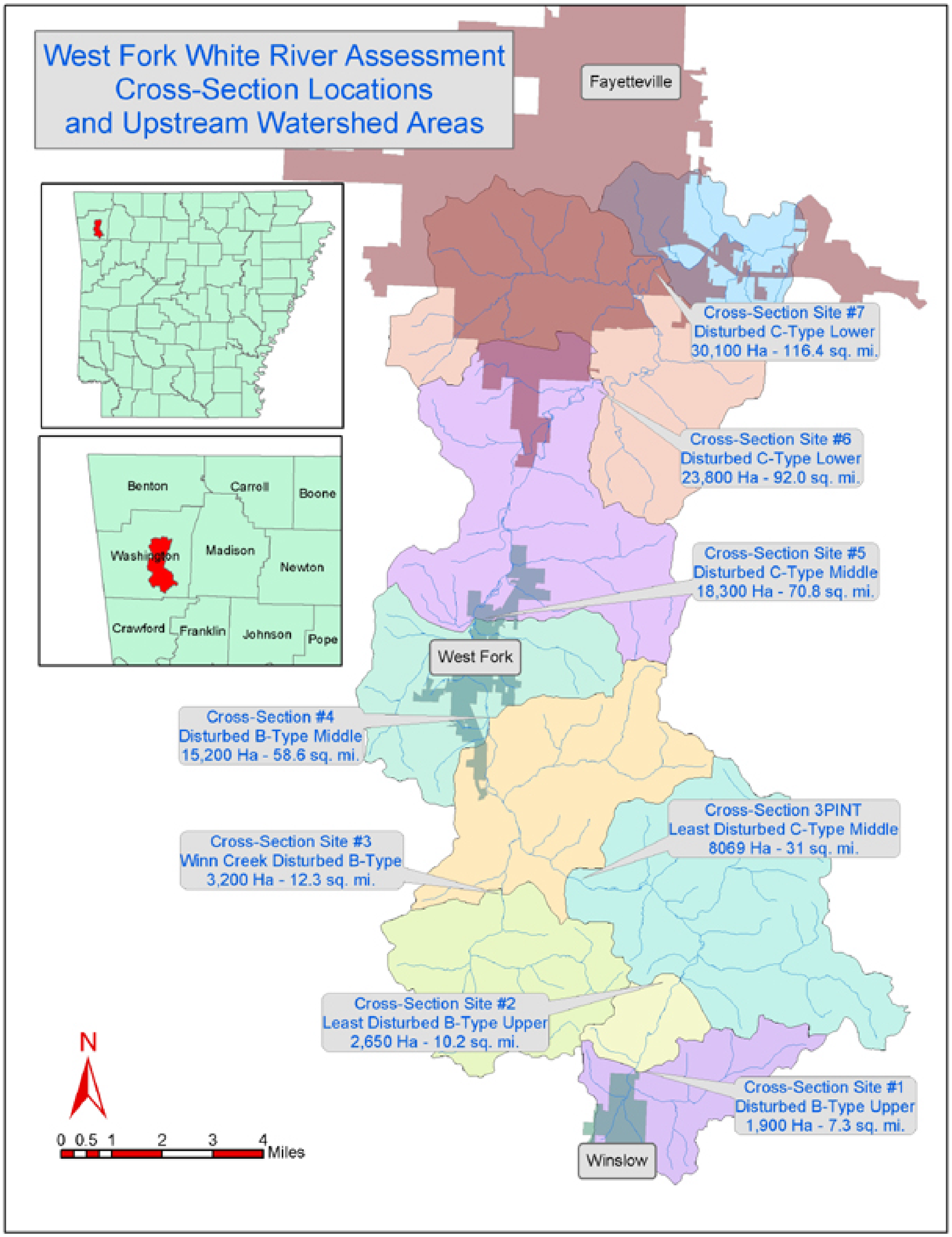


Figure 4. 2002 West Fork-White River study sites.

Table 1. West Fork-White River sampling sites for 2002 bioassessment surveys.

Site	Status and Classification*	Location	Watershed size	GPS Coordinates Zone 15S Datum: WGS 84	Latitude/Longitude	Altitude
1	Disturbed B-Type	Upper	1900 ha - 7.3 sq. mi.	398237E 3964377N	N 35° 49.099' W 94° 07.587'	507 m.
2	Least Disturbed B-Type	Upper	2650 ha - 10.2 sq. mi.	399303E 3966735N	N 35° 50.378' W 94° 06.899'	472 m.
3	Disturbed B-Type	Tributary	3200 ha - 12.3 sq. mi.	393961E 3969612N	N 35° 51.900' W 94° 10.471'	450 m.
4	Disturbed B-Type	Middle	15,200 ha - 58.6 sq. mi.	393532E 3974998N	N 35° 54.810' W 94°10.800'	498 m.
5	Disturbed C-Type	Middle	18,300 ha - 70.8 sq. mi.	393062E 3978558N	N 35° 56.733' W 94° 11.141'	399 m.
6	Disturbed C-Type	Lower	23,8000 ha - 92.0 sq. mi.	397060E 3986218N	N 36° 00.901' W 94° 08.541'	375 m.
7	Disturbed C-Type	Lower	30,100 ha - 116.4 sq. mi.	398757E 3990152N	N 36° 03.040' W 94° 07.461'	368 m.
3P-INT**	Least Disturbed C-Type	Middle	8069 ha - 31 sq. mi.	396480E 3970282N	N 35° 52.279' W 94° 08.804'	434 m.

* Stream classification based on Rosgen (1996).

** Sites 1 through 7 are located downstream of one another. Site 3P-INT was selected later for comparison to other Boston Mountain ecoregion stream sites in the 5000 to 10,000 ha watershed size range.

FISHES

INTRODUCTION

Arkansas has a rich diversity of fishes, with the first records of Arkansas fishes made by Hernando De Soto in the earliest European exploration of Arkansas in 1541. Fishes of the midwestern U.S. have been one of the most studied groups of aquatic organisms since the late 18th century. The most significant contributor to knowledge of Arkansas fishes before 1900 was Seth E. Meek, Professor of Biology and Geology at the Arkansas Industrial University (University of Arkansas) who explored fishes of the state from 1889 to 1893 (Meek 1894). Robison and Buchanan (1988) compiled the most comprehensive survey of fishes of Arkansas, reporting 217 species (including 17 introduced species) in the state.

The usefulness of fish assemblages as indicators of biological quality has been recognized since the early 1900s (Forbes and Richardson (1913). Characteristics of fish assemblages have been and remain a major part of aquatic study designed to evaluate the condition of water resources. Fish assemblages are a highly visible aquatic component, and their economic and aesthetic values are widely recognized. The availability of historical information enhances their usefulness for tracking changes in environmental quality over time. The rationale for their use in bioassessment is based on the notion that problems that first occur in lower trophic groups will eventually be revealed in higher trophic groups if they are indeed of ecological consequence.

METHODS

The eight study sites were sampled for fishes from 25 July to 22 August 2002. A representative pool-riffle sequence including all microhabitats was sampled at Sites 1-7 using a Smith Root battery-powered backpack electrofishing unit. For Sites 6 and 7, backpack sampling was supplemented with a boat-mounted pulsed DC electrofisher for pools that were not wadeable. Fish from each pass were held in oxygenated buckets; those that could be identified streamside were measured for length (TL ± 1mm) and weight (± 0.1g) and released. Small or unidentified fish were preserved in 10% buffered formalin, returned to the laboratory where they were rinsed, transferred to 70% ethanol, identified, and measured for length and weight. All fishes collected were identified to species (Robison and Buchanan 1988).

Site 3P-INT was chosen for a three-pass removal sampling described by Bohlin et al. (1989) to estimate fish populations. A representative pool-riffle sequence was electrofished for 60 minutes three times with a 45-minute interval between samplings. Fish were handled in the same way as those from Sites 1 to 7, except fish were returned downstream of the sampling area, and separate information was generated from each pass. Estimates of density and biomass were computed from catch, length, and weight for each species from Site 3P-INT using the three-pass removal, maximum likelihood method computed with Pop/Pro software (Seber 1982, Bohlin et al. 1989, Kwak 1992) with 2-cm size classes for each species.

2002 FISH SURVEY

A total of 4229 fishes representing 39 species were sampled at the eight study sites (Table 2). It should be noted that Site 3P-INT was more intensively sampled than the other sites, and the data is presented as the sum of the three passes in contrast to a single pass for Sites 1-7. Estimates computed from Pop-Pro software (Kwak 1992) for each species and total density and biomass at Site 3P-INT are shown in Table 3. Species identification of fishes in the genera *Campostoma* is difficult in the field, and we chose not to sacrifice the 1698 individuals to return them to the laboratory for definitive identification. Since *Campostoma anomalum* (central stonerollers) and *Campostoma oligolepis* (largescale stonerollers) have been reported in the West Fork-White River, we reported them as two species at all eight sites. We had a similar situation with fishes of the genera *Moxostoma* at Sites 6 and 7 and chose not to sacrifice them for definitive identification, reporting *Moxostoma spp* (black and golden redhorses) as two species representing *Moxostoma duquesnei* and *Moxostoma erythrurum*.

The relative proportion of major fish taxa and their biomass differed among the eight sites (Figures 5 and 6). Such differences are expected since each collection represents the biological assemblage that is characteristic of a particular watershed size, and each is influenced by a different set of anthropogenic disturbances. Data are not intended for

Table 2. Fish collected at eight sites during July and August, 2002 in the West Fork-White River. See text for a description of methods used.

		2002 SITES								
		1	2	3	4	5	6	7	3P-INT	Total
Lepisosteidae	Gars									
Lepisosteus osseus	Longnose Gar	0	0	0	0	0	0	1	0	1
Clupeidae	Herrings									
Dorosoma cepedianum	Gizzard shad	0	0	0	0	0	0	8	0	8
Cyprinidae	Minnows									
*Campostoma spp.**	Central and largescale stonerollers*	67	257	167	218	505	15	104	365	1698
Cyprinella whipplei	Steelcolor shiner	0	0	0	0	3	6	22	0	31
Luxilus pilsbryi	Duskystripe shiner	8	0	0	80	164	0	0	204	456
Notropis boops	Bigeye shiner	0	0	8	13	30	38	28	0	117
Notropis nubilus	Ozark minnow	0	3	0	2	0	6	9	0	20
Notropis rubellus	Rosyface shiner	0	0	0	0	0	2	6	0	8
Pimephales notatus	Bluntnose minnow	0	0	4	1	1	16	2	0	24
Semotilus atromaculatus	Creek chub	35	28	21	2	0	0	10	31	127
Catostomidae	Suckers									
Hypentelium nigricans	Northern hogsucker	1	1	7	3	4	3	11	4	34
*Moxostoma spp.***	Black and golden redhorses**	0	0	0	0	0	69	17	0	86
Ictaluridae	Freshwater catfishes									

(Continued on next page)

		2002 SITES								
		1	2	3	4	5	6	7	3P-INT	Total
Ictalurus melas	Black bullhead	1	0	3	0	1	0	0	0	5
Ictalurus natalis	Yellow bullhead	1	0	7	0	0	1	0	1	10
Noturus albater	Ozark madtom	0	0	0	3	0	0	6	0	9
Noturus exilis	Slender madtom	1	37	2	46	12	1	1	25	125
Cyprinodontidae	Killifishes									
Fundulus olivaceus	Blackspotted topminnow	7	0	1	1	0	3	1	4	17
Atherinidae	Silversides									
Labidesthes sicculus	Brook silversides	0	0	0	0	0	0	8	0	8
Centrarchidae	Sunfishes									
Ambloplites ariommus	Shadow bass	0	0	0	0	1	0	0	2	3
Ambloplites constellatus	Ozark bass	0	0	0	0	0	11	1	0	12
Ambloplites rupestris	Rock Bass	0	0	0	0	3	0	0	6	9
Lepomis cyanellus	Green sunfish	19	1	28	2	15	6	10	11	92
Lepomis gulosus	Warmouth	0	0	0	0	0	0	1	1	2
Lepomis macrochirus	Bluegill	4	0	4	3	1	19	39	1	71
Lepomis megalotis	Longear sunfish	0	2	20	51	84	59	6	63	285
Lepomis sp.	Hybrid Green sunfish/Bluegill	0	0	0	0	2	21	13	0	36
Micropterus dolomieui	Smallmouth bass	0	0	0	1	1	0	0	4	6

(Continued on next page)

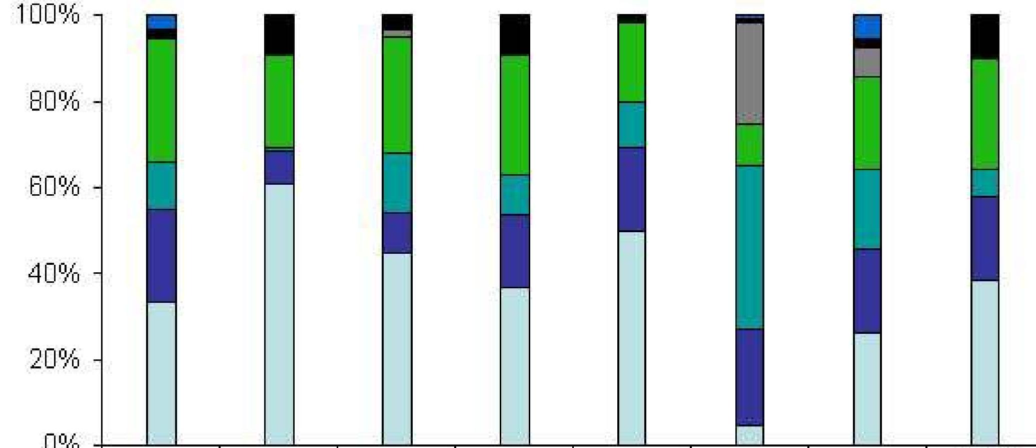
		2002 SITES								
		1	2	3	4	5	6	7	3P-INT	Total
Micropterus punctulatus	Spotted bass	0	0	0	0	1	2	3	0	6
Micropterus salmoides	Largemouth bass	0	0	0	0	0	0	2	0	2
Percidae	Perches									
Etheostoma blennioides	Greenside darter	0	0	1	20	50	11	13	18	113
Etheostoma caeruleum	Rainbow darter	9	14	12	37	84	8	34	67	265
Etheostoma punctulatum	Stippled darter	2	0	24	25	14	1	4	24	94
Etheostoma spectabile	Orangethroat darter	33	76	44	70	37	4	17	86	367
Etheostoma zonale	Banded darter	13	2	18	14	0	2	4	12	65
Percina caprodes	Logperch	0	0	0	0	0	0	12	0	12
Poeciliidae	Livebearers									
Gambusia affinis	Mosquitofish	0	0	0	0	0	0	3	0	3
Moronidae	Temperate basses									
Morone saxatilis	Striped Bass	0	0	0	0	0	0	1	0	1
Cottidae	Sculpins									
Cottus carolinae	Banded Sculpin	0	0	0	1	0	0	0	0	1
Total Individuals		202	423	374	597	1018	310	404	929	4229
Species Count		15	11	18	21	21	24	33	20	

* *Campostoma anomalum* and *Campostoma oligolepis* were not differentiated and were included as two species in the species count.
** *Moxostoma Duquesnei* and *Moxostoma erythrurum* were not differentiated and were included as two species in the species count.

Table 3. Density and biomass estimates for fishes sampled at West Fork-White River Site 3P-INT 1 August 2002. Values in parentheses are ± 2 SE.

Species	Density (fish/ha)	Biomass (kg/ha)
Campostoma spp. Central (and large scale) stoneroller	10,357 (± 2824)	56.56 (± 16.03)
Luxilus pilsbryi Duskystripe shiner	4595 (± 848)	4.80 (± 0.69)
Semotilus atromaculatus Creek chub	539*	0.90*
Hypentelium nigricans Northern hogsucker	70 (± 9)	4.45 (± 4.82)
Ictalurus natalis Yellow bullhead	17*	1.35*
Noturus exilis Slender madtom	2638 (± 19,688)	10.71(± 79.97)
Fundulus olivaceus Blackspotted topminnow	70 (± 9)	0.17 (± 0.13)
Ambloplites ariommus Shadow bass	35*	3.32*
Ambloplites constellatus Rock bass	196 (± 539)	20.40 (± 56.65)
Lepomis cyanellus Green sunfish	322 (± 1122)	11.98 (± 41.95)
Lepomis gulosus Warmouth	17*	1.83*
Lepomis macrochirus Bluegill	17*	0.06*
Lepomis megalotis Longear sunfish	1014 (± 123)	12.97 (± 2.36)
Micropterus dolomieui Smallmouth bass	76 (± 36)	0.59 (± 0.55)
Etheostoma blennioides Greenside darter	629 (± 344)	2.07 (± 1.50)
Etheostoma caeruleum Rainbow darter	1455 (± 387)	1.46 (± 0.46)
Etheostoma punctulatum Stippled darter	571 (± 366)	2.25 (± 1.51)
Etheostoma spectabile Orangethroat darter	3956 (± 5769)	3.73 (± 4.59)
Etheostoma zonale Banded darter	214 (± 25)	0.21 (± 0.14)
Total	26,788 (± 20,774)	139.81 (± 108.06)

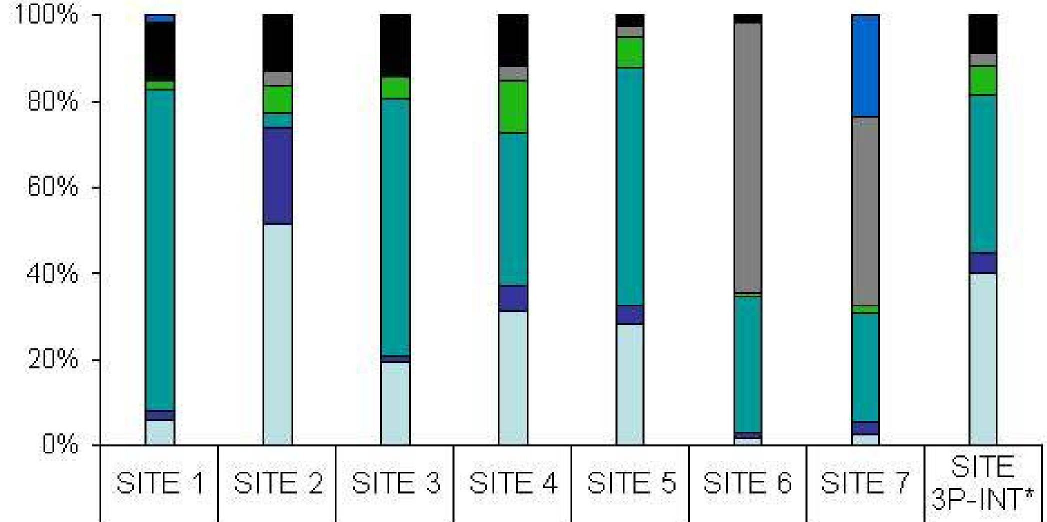
* population not depleted; minimum summing 3 passes



	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 7	SITE 3P-INT*
Other	3.5	0	0.3	0.3	0	1	5.5	0
Ictaluridae	1.5	8.8	3.2	8.3	1.3	0.7	1.8	9.9
Catostomidae	0.5	0.2	1.9	0.5	0.4	23.5	7.1	0
Percidae	28.4	21.9	26.7	28.1	18.3	9.4	21.2	25.6
Centrarchidae	11.4	0.7	14	9.6	10.7	38.4	18.9	6.3
Other Cyprinidae	21.4	7.4	8.9	16.6	19.5	22.1	19.4	19.2
Campostoma	33.3	61	45	36.9	49.9	4.9	26.2	38.6

Figure 5. Relative proportion of major fish taxonomic groups shown as a percentage of the total individuals. These data are intended for comparison to data from other Boston Mountain ecoregion stream sites of comparable watershed size or to data collected at the same site in the future. They are not intended for comparison among sites (i.e. to each other).

* Data for Site 3P-INT based on estimates using three-pass removal, maximum likelihood method computed with Pop/Pro software (Kwak, 1992).



	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 7	SITE 3P-INT*
Other	1.8	0	0.1	0.4	0	0.1	23.3	0
Ictaluridae	13.4	13.2	14.4	11.2	2.8	1.6	0	8.7
Catostomidae	0	3.2	0	3.5	2.5	62.7	43.9	3.2
Percidae	2	6.2	5	12.1	6.8	0.9	1.7	6.9
Centrarchidae	74.7	3.4	59.7	35.5	55.3	31.6	25.5	36.5
Other Cyprinidae	2.2	22.5	1.2	5.8	4.5	1.5	2.9	4.8
Campostoma	5.9	51.6	19.5	31.5	28.1	1.6	2.6	40.4

Figure 6. Relative proportion of biomass of major fish taxonomic groups shown as a percentage of the total biomass. These data are intended for comparison to data from other Boston Mountain stream sites of comparable watershed size or to data collected at the same site in the future. They are not intended for comparison among sites (i.e. to each other).

*Data for Site 3P-INT based on estimates using three-pass removal, maximum likelihood method computed with Pop/Pro software (Kwak, 1992).

comparison among sites, but rather to other Boston Mountain ecoregion sites of comparable watershed size or to data collected at the same site in the future.

The major fish taxa represented in Figures 5 and 6 respond to the natural environment and anthropogenic disturbance in different ways. *Campostoma* (stonerollers) and some species of Catostomidae (suckers) are tolerant of disturbance, and may out-compete other species under adverse conditions. Centrarchidae (sunfishes including bass) represent the top predators of stream ecosystems. Some are very tolerant of disturbance (e.g., green sunfishes), and others are highly sensitive (e.g., smallmouth bass). Most fishes in the Percidae family (darters) are sensitive to disturbance, with the exception of the orangethroat darter.

Campostoma (stonerollers) thrive in reaches with open canopies. The geomorphology of Site 2 was dominated by bedrock with shallow water open to the sunlight, and *Campostoma* were abundant. The relative proportion of *Campostoma* often increases when riparian vegetation is reduced and sunlight and algal growth increases during conversion of woodland to pasture. Petersen (1998) reported higher relative proportions of *Campostoma* in agricultural watersheds and downstream from wastewater-treatment plants. Site 5, an agricultural site, had no canopy cover and was located immediately below the West Fork wastewater outfall. Severe bank destabilization had reduced pool and riffle habitat in favor of a shallow run with high embeddedness from erosion. Such conditions favored the *Campostoma* population, which comprised nearly 50% of the individuals present at that site.

The relative biomass of major fish taxonomic groups (Figure 6) was provided as baseline data. It should be noted that high biomass at a site is not necessarily indicative of good environmental quality because poor conditions can favor the proliferation of tolerant species. The relative proportion of biomass is a more meaningful measure of environmental conditions at a site than total biomass.

HISTORICAL CHANGES IN FISH SPECIES RICHNESS

Species richness is an important assemblage characteristic that is included in all bioassessment protocols that examine fish assemblages. The White River basin is recognized for its high fish diversity, and various accounts of fishes in the West Fork-White River have been reported. Historical records often lack information (or the information has been lost over time) on exactly where, how, and when the species were collected, and quantitative information is frequently lacking. However, these records provide important information about species richness that is useful for assessing changes over time.

We created an inventory of fish species historically reported in the West Fork-White River using the following sources: (1) a compilation of fish species reported in streams and rivers in Washington County, Arkansas dating back to Meek's report of 1894 (Cloutman and Olmsted 1976), (2) fish species reported in the West Fork-White River in 1963 and 1993 (ADPCE 1995), (3) fish species presence pre-1960 and from 1960 to 1987 (Robison and Buchanan 1988), and (4) the current survey of West Fork-White River fishes sampled in 2002. These sources generated an historical list of 63 West Fork-White River fish species (Table 4).

In contrast to the historic list of 63, our 2002 survey of eight sites generated a list of 39 West Fork-White River species (Table 2). Our survey contributed three species to the list of 63 that were not reported previously in the historical sources we used: striped bass, warmouth, and a hybrid of green sunfish and bluegill. Striped bass is an introduced species found commonly in reservoirs, and our finding is likely an introduced refugee. Warmouth are reported in Ozark streams, and the two individuals we found may have been introduced from elsewhere, or the species has been present historically but not reported. Hybridization between *Lepomis* species has been reported previously in Arkansas (Robison and Buchanan 1988), but the specific hybrid we found was not reported in the West Fork-White River in the historical sources we used.

The hybrid of green sunfish and bluegill comprised 20 percent of the fish in the family Centrarchidae sampled at Site 6 and 19 percent at Site 7. Karr (1986) had initially included hybridization in the Index of Biotic Integrity as an indication of water quality degradation. Subsequently, there were reports of hybrids at both disturbed and undisturbed sites, and the reliability of hybridization as an environmental indicator was called into question (Hughes and Oberdorff 1999, Simon and Lyons 1995). However, Sites 6 and 7 were the most disturbed reaches of the West Fork-White River in our survey, and

Table 4. Fish species historically reported in West Fork-White River from Cloutman and Olmsted (1976), Robison and Buchanan (1988), ADPCE (1995), and the 2002 survey.

Lepisosteidae	Gars
Lepisosteus osseus	Longnose gar
Clupeidae	Herrings
Dorosoma cepedianum	Gizzard shad
Cyprinidae	Minnows
Campostoma anomalum	Central stoneroller
Campostoma oligolepis	Largescale stoneroller
Cyprinella whipplei	Steelcolor shiner
Cyprinus carpio	Common carp
Hybopsis amblops	Bigeye chub
Luxilus chrysocephalus	Striped shiner
Luxilus pilsbryi	Duskystripe shiner
Nocomis biguttatus	Hornyhead chub
Notropis boops	Bigeye shiner
Notemigonus crysoleucas	Golden shiner
Notropis nubilus	Ozark minnow
Notropis rubellus	Rosyface shiner
Notropis telescopus	Telescope shiner
Pimephales notatus	Bluntnose minnow
Pimephales promelas	Fathead minnow
Pimephales tenellus	Slim minnow
Semotilus atromaculatus	Creek chub
Catostomidae	Suckers
Catostomus commersoni	White sucker
Hypentelium nigricans	Northern hogsucker
Moxostoma carinatum	River red horse
Moxostoma duquesnei	Black redhorse
Moxostoma erythrurum	Golden redhorse
Minytrema melanops	Spotted sucker
Ictaluridae	Freshwater catfishes
Ictalurus melas	Black bullhead
Ictalurus natalis	Yellow bullhead
Ictalurus punctatus	Channel catfish
Noturus albater	Ozark madtom
Noturus exilis	Slender madtom
Noturus flavater	Checkered madtom
Pylodictis olivaris	Flathead catfish

(Continued on next page)

Table 4. Continued.

Cyprinodontidae	Killifishes
Fundulus catenatus	Northern studfish
Fundulus olivaceus	Blackspotted topminnow
Atherinidae	Silversides
Labidesthes sicculus	Brook silverside
Centrarchidae	Sunfishes
Ambloplites ariommus	Shadow bass
Ambloplites constellatus	Ozark bass
Ambloplites rupestris	Rock bass
Lepomis cyanellus	Green sunfish
Lepomis gulosus	Warmouth
Lepomis macrochirus	Bluegill
Lepomis megalotis	Longear sunfish
Lepomis sp.	Hybrid Green sunfish/Bluegill
Micropterus dolomieui	Smallmouth bass
Micropterus punctulatus	Spotted bass
Micropterus salmoides	Largemouth bass
Pomoxis annularis	White crappie
Percidae	Perches
Etheostoma blennioides	Greenside darter
Etheostoma caeruleum	Rainbow darter
Etheostoma juliae	Yoke darter
Etheostoma punctulatum	Stippled darter
Etheostoma spectabile	Orangethroat darter
Etheostoma stigmaeum	Speckled darter
Etheostoma zonale	Banded darter
Percina caprodes	Logperch
Stizostedion vitreum	Walleye
Poeciliidae	Livebearers
Gambusia affinis	Mosquito fish
Moronidae	Temperate Basses
Morone chrysops	White bass
Morone saxatilis	Striped bass
Cottidae	Sculpins
Cottus carolinae	Banded sculpin
Petromyzontidae	Lampreys
Ichthyomyzon castaneus	Chestnut lamprey
Ichthyomyzon gagei	Southern brook lamprey
Anguillidae	Freshwater eels
Anguilla rostrata	American eel

hybridization may represent reproductive dysfunction induced by environmental conditions in this particular situation.

Twenty-two fish species reported historically in the West Fork-White River were not found in 2002 (Table 5). Some of the missing species (e.g., chestnut and southern brook lamprey, and American eel) may still be present, but electrofishing may have been ineffective in capturing them or their seasonal migratory patterns may have precluded our capture at the particular time of sampling. Other missing species (e.g., common carp and fathead minnow) are introduced species, and their absence cannot be construed as a significant loss in species richness.

Nine species (shown with an asterisk in Table 5) of the 22 species reported historically that were missing in 2002 are of concern because they appear in historical records of the West Fork-White River, have been commonly reported in Boston Mountain ecoregion streams, and two are endemic to the White River basin. Cloutman and Olmsted (1976) report the presence of bigeye chub at five West Fork sites (specific dates were not given), and Robison and Buchanan (1988) report it as widely distributed throughout clear streams of the upper White River system including the West Fork. It was not collected in the ADPCE survey of the West Fork-White River (1995) in either 1963 or 1993. Striped shiner, hornyhead chub, golden shiner, telescope shiner, speckled darter, and yoke darter, were reported in the West Fork in either 1963 or 1993 (ADPCE 1995) at Site 6, but they were not found at any of the sites we sampled in 2002. Checkered madtoms have been reported in the West Fork historically, but the species has not been reported in recent times.

Because checkered madtoms and yoke darters are endemic to the White River basin, their possible extirpation from the West Fork is worthy of attention. The Missouri Department of Conservation lists the checkered madtom as a species of concern with a state ranking of S3, which designates the species as rare and uncommon in the state. Petersen (1998) reported checkered madtoms and yoke darters in Ozark plateau streams, but both species have been extirpated from the reach downstream of Beaver Dam (Quinn and Kwak 2003), where yoke darters comprised 34% of the fishes sampled prior to closure of the dam. Yoke darters comprised 24% of the fish sampled in the White River near Durham in 1963,

Table 5. Fish species present historically in the West Fork-White River but not found in the 2002 survey.

Cyprinidae		Minnows	
	Cyprinus carpio		Common carp
	Hybopsis amblops		Bigeye chub*
	Luxilus chrysocephalus		Striped shiner*
	Nocomis biguttatus		Hornyhead chub*
	Notemigonus crysoleucas		Golden shiner*
	Notropis telescopus		Telescope shiner*
	Pimephales promelas		Fathead minnow
	Pimephales tenellus		Slim minnow
Catostomidae		Suckers	
	Catostomus commersoni		White sucker
	Moxostoma carinatum		River red horse
	Minytrema melanops		Spotted sucker
Ictaluridae		Freshwater catfishes	
	Ictalurus punctatus		Channel catfish
	Noturus flavater		Checkered madtom*
	Pylodictis olivaris		Flathead catfish
Cyprinodontidae		Killifishes	
	Fundulus catenatus		Northern studfish*
Centrarchidae		Sunfishes	
	Pomoxis annularis		White crappie
Percidae		Perches	
	Etheostoma juliae		Yoke darter*
	Etheostoma stigmaeum		Speckled darter*
	Stizostedion vitreum		Walleye
Moronidae		Temperate basses	
	Morone chrysops		White bass
Petromyzontidae		Lampreys	
	Ichthyomyzon castaneus		Chestnut lamprey
	Ichthyomyzon gagei		Southern brook lamprey
Anguillidae		Freshwater eel	
	Anguilla rostrata		American eel

* missing species of concern

but only 6% in 1993 (ADPCE 1995). Two yoke darters (<1% of the fishes sampled) were reported in the White River near St. Paul in 1998 (Radwell 2000).

SITE 6 COMPARISON OF SPECIES RICHNESS, RELATIVE ABUNDANCE

The ADPCE (1995) study of the upper White River watershed includes information on species richness and relative abundances of fish species in the West Fork-White River at a site in the vicinity of Site 6 of our 2002 survey. Fish assemblages were sampled in 1963 and 1993, but ADPCE personnel involved in that study indicate that they were unable to sample the same site due to changes that occurred in the intervening 30 years. They were, however, sampling in reaches with comparable watershed size to suggest that comparison of fish assemblages over time is justified. Our Site 6 sampling, which we believe to be close to the sites surveyed in 1963 and 1993 is compared to the earlier work in Table 6.

Changes in species richness, relative abundance, and diversity have occurred at Site 6 from 1963 to 2002. Species richness declined from 35 to 26 between 1963 and 1993. While 26 species were still found in 2002, the species differed from those present in 1993. Striped shiner, duskystripe shiner, Ozark madtom, smallmouth bass, and largemouth bass were found in 1993, but not in 2002. Those five species were replaced by rosyface shiner, yellow bullhead, Ozark bass, hybrid green sunfish/bluegill, and stippled darter in the 2002 survey, resulting in no change in species richness. The total fish sampled at this site was considerably less in 2002 (308 vs. 1088). However, no significance should be attached to that fact since comparability of sampling time and effort cannot be verified. We employed both backpack and boat electrofishing methods to maximize catchability, but high turbidity was a significant deterrent to our efforts and may account in part for the lower catch in 2002. Our sample was dominated by *Moxostoma spp.*

The Shannon-Wiener dominance diversity index using a log to base 2 was used to report species diversity in 1963 and 1993, and we reported it for the 2002 survey for comparative purposes (Table 6). Diversity declined from 3.66 to 3.34 from 1993 to 1963, but rose to 3.54 in 2002. The range of diversity values for the three surveys is small, and all three values may be described as moderate.

Table 6. Comparison of fishes collected from the West Fork-White River at Site 6 in 1963, 1993, and 2002.

		2002		1993		1963	
		No.	%	No.	%	No.	%
Lepisosteidae	Gars						
Lepisosteus osseus	Longnose gar	1	0.3	2	0.2		
Clupeidae	Herrings						
Dorosoma cepedianum	Gizzard shad					15	0.7
Cyprinidae	Minnows						
*Campostoma spp.**	Central and largescale stonerollers*	15	4.9	422	38.8	313	14.7
Cyprinella whipplei	Steelcolor shiner	6	2	96	8.8	2	0.1
Luxilus chrysocephalus	Striped shiner			1	0.1	24	1.1
Luxilus pilsbryi	Duskystripe shiner			137	12.6	171	8
Nocomis biguttatus	Hornyhead chub					26	1.2
Notropis boops	Bigeye shiner	38	12.4	34	3.1	11	0.5
Notemigonus crysoleucas	Golden shiner					1	0
Notropis nubilus	Ozark minnow	6	2	23	2.1	48	2.2
Notropis rubellus	Rosyface shiner	2	0.7				
Notropis telescopus	Telescope shiner					35	1.6
Pimephales notatus	Bluntnose minnow	16	5.2	12	1.1	18	0.8
Semotilus atromaculatus	Creek chub					3	0.1
Catostomidae	Suckers						
Hypentelium nigricans	Northern hogsucker	3	1	16	1.5	18	0.8
Moxostoma carinatum	River red horse					2	0.1
Moxostoma duquesnei	Black redhorse			30	2.8	16	1.7
Moxostoma erythrurum	Golden redhorse			62	5.7	7	0.3
*Moxostoma spp.***	Black and golden redhorses**	69	22.5				
Ictaluridae	Freshwater catfishes						
Ictalurus natalis	Yellow bullhead	1	0.3				
Noturus albater	Ozark madtom			27	2.5	201	9.4

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Table 6. Continued.

		2002		1993		1963	
		No.	%	No.	%	No.	%
Noturus exilis	Slender madtom	1	0.3	15	1.4	150	7
Cyprinodonidae	Killifishes						
Fundulus catenatus	Northern studfish					5	0.2
Fundulus olivaceus	Blackspotted topminnow	3	1	3	0.3	17	0.8
Centrarchidae	Sunfishes						
Ambloplites constellatus	Ozark bass	11	3.6			4	0.2
Lepomis cyanellus	Green sunfish	6	2	17	1.6	22	1
Lepomis macrochirus	Bluegill	19	6.2	11	1		
Lepomis megalotis	Longear sunfish	59	19.2	41	3.8	93	4.4
Lepomis sp.	Hybrid Green sunfish/Bluegill	21	6.8				
Micropterus dolomieui	Smallmouth bass			3	0.3	5	0.2
Micropterus punctulatus	Spotted bass	2	0.7	27	2.5	35	1.6
Micropterus salmoides	Largemouth bass			3	0.3		
Percidae	Perches						
Etheostoma blennioides	Greenside darter	11	3.6	20	1.8	69	3.2
Etheostoma caeruleum	Rainbow darter	8	2.6	49	4.5	591	27.7
Etheostoma juliae	Yoke darter					13	0.6
Etheostoma punctulatum	Stippled darter	1	0.3			9	0.4
Etheostoma spectabile	Orangethroat darter	4	1.3	9	0.8	126	5.9
Etheostoma stigmaeum	Speckled darter					1	0
Etheostoma zonale	Banded darter	2	0.7	23	2.1	75	3.5
Percina caprodes	Logperch	3	1	1	0.1	3	0.1
Stizostedion vitreum	Walleye					1	0

(Continued on next page)

Table 6. Continued.

		2002		1993		1963	
		No.	%	No.	%	No.	%
Cottidae	Sculpins						
Cottus carolinae	Banded Sculpin					5	0.2
Petromyzontidae	Lampreys						
Ichthyomyzon sp.	Lamprey species			4	0.4		
Species Count		26		26		35	
Fish Count		308		1088		2135	
Diversity Index		3.57		3.34		3.66	
Similarity Index		2002 vs. 1993 = 0.86				1993 vs. 1963 = 0.65	

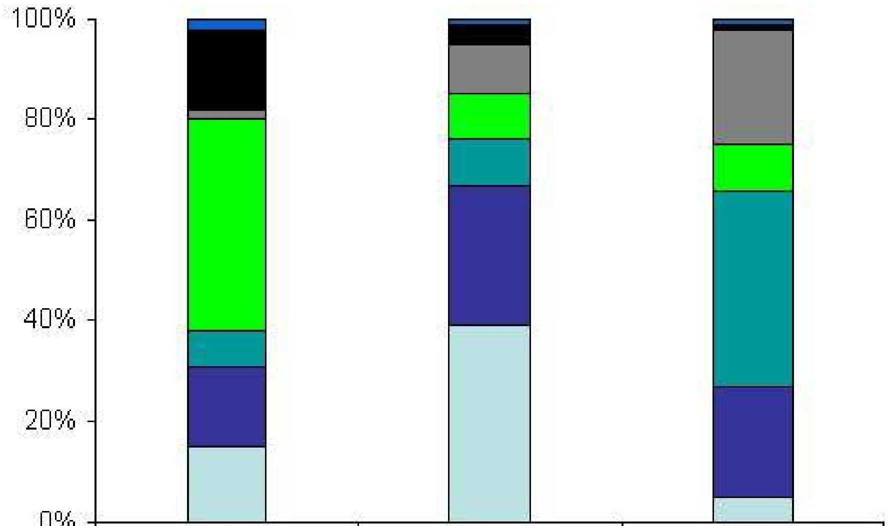
* *Compostoma anomalum* and *Campostoma oligolepis* were not differentiated and were included as two species in the species count.
** *Moxostoma duquesnei and Moxostoma erythrurum* were not differentiated and were included as two species in the species count.

ADPCE (1995) used a modification of Odum's index of similarity (Appendix A) to compare the number of species between the 1963 and 1993 samples. We employed the same method to compare our 2002 sample to the 1993 sample (Table 6). ADPCE concluded that the 0.65 similarity value between the 1963 and 1993 assemblages represented a difference in the two assemblages. We found a much higher similarity value (0.86) between the 1993 and 2002 assemblages, suggesting that the fish assemblage has remained more similar in recent years. However, a comparison of the relative proportion of major fish taxonomic groups (Figure 7) suggests a different conclusion. From 1993 to 2002, the percent of *Campostoma* dropped from 39% to 5%, and the percent of Catostomidae (represented primarily by *Moxostoma sp*.) increased from 10% to 23%. The highly turbid conditions at Site 6 may account for the decline of *Campostoma* since they thrive where algae can proliferate. We may be seeing the replacement of *Campostoma* by another tolerant species better adapted to the currently turbid conditions.

COMPARISON OF SITE 3P-INT TO OTHER BOSTON MOUNTAIN RIVERS

Fishes were sampled from 10 Boston Mountain ecoregion rivers with watersheds from 5000 to 10,000 ha by Rambo (1998) and Radwell (2000). For comparison to these rivers, West Fork-White River Site 3P-INT, with a watershed size of 8069 ha, was selected for a three-pass depletion of fishes, and densities and biomass were estimated (Table 3). These data were compared to the North and Middle Forks of the Illinois Bayou and the means and range of values from the 10 Boston Mountain ecoregion rivers (Table 7). The Illinois Bayou study sites were chosen for comparison because they ranked highest in ecological integrity of the 10 rivers based on 34 variables representing fish and macroinvertebrate assemblage characteristics, instream habitat, riparian vegetation, water quality, and watershed attributes (Radwell 2000).

Boston Mountain ecoregion streams are nutrient poor, and total fish density, biomass, and production estimates from these streams have been shown to be low compared to other areas (Rambo (1998). Steedman (1988) found fish abundance to be higher at moderate levels of degradation (i.e. nutrient enrichment), and Yoder and Smith (1999) reported a pattern of increased fish density and biomass with moderate species richness in disturbed streams.



	1963	1993	2002
Other	2	1	1
Ictaluridae	16	4	1
Catostomidae	2	10	23
Percidae	42	9	9
Centrarchidae	7	9	39
Other Cyprinidae	16	28	22
Campostoma	15	39	5

Figure 7. Comparison of fish assemblages by percentage from West Fork-White River at Site 6 sampled in 1963, 1993, and 2002.

Table 7. Comparison of fish assemblage characteristics of West Fork-White River Site 3P-INT to other Boston Mountain river reaches with comparable watershed size.

	Total Density (fish/ha)	Total Biomass (g/ha)	Species Richness	% *Campostoma*	% Other Cyprinidae	% Centrarchidae	% Percidae	% *Lepomis cyanellus*
West Fork-White River Site 3P-INT	26,788	139.81	19	38.6	19.2	6.3	25.6	1.20
North Fork-Illinois Bayou	18,140	89.93	15	7.3	13.9	40.4	32.8	0.26
Middle Fork-Illinois Bayou	17,965	154.77	17	4.2	10.1	53.1	25.2	0.67
10 Boston Mountain Rivers Mean*	22,328	117.87	14.90	22.1	15.9	22.8	30.7	2.13
10 Boston Mountain Rivers Range*	8676 - 46,150	26.82 - 202.85	10 - 19	0 – 42.1	5.7 – 34.1	0.1 – 53.1	10.0 – 61.5	0 – 5.75

* Big Piney Creek, Hurricane Creek, Kings River, Middle Fork-Illinois Bayou, Mulberry River, North Fork-Illinois Bayou, Richland Creek, War Eagle Creek, White River, Upper Buffalo River. For specific location of sampling sites and watershed size, see Rambo (1998) and Radwell (2000).

While total fish density and biomass of Site 3P-INT are higher than the Illinois Bayou sites and the mean for the 10 rivers, they are moderate and compare favorably from an environmental quality perspective. The species richness of 19 reported at Site 3P-INT matched the highest found among the 10 streams, a very favorable comparison. However, the percentage of *Campostoma*, a very tolerant species, was high, and the percentage of Centrarchidae that includes top predators was low relative to the other rivers. This relationship suggests a possible trophic imbalance at Site 3P-INT where predatory species may be not keeping the *Campostoma* population in check. Cyprinids other than Campostoma include insectivorous minnows, the presence of which indicates a healthy macroinvertebrate population. The percentage of Percidae (darters) is also a positive indicator. Site 3P-INT compared favorably in percentage of Cyprinidae and Percidae to the Illinois Bayou sites, but was moderate compared to the range found among the 10 rivers. Finally, *Lepomis cyanellus*, green sunfish, are a very tolerant species known to increase in abundance under degraded environmental conditions; the percentage at Site 3P-INT was small.

MACROINVERTEBRATES

INTRODUCTION

Macroinvertebrates are described as organisms that are retained by a number 30 U.S. Series screen (0.595 mm) (Lind 1985). Benthic macroinvertebrates are an important part of the food web in aquatic environments and recycle organic matter by converting it to a form that is used by other organisms. Within a forested stream, the majority of the organic input is from the surrounding terrestrial vegetation (Fisher and Likens 1973). Boling et al. (1975) reported that streams are significantly dependent on allochthonous detritus. Woodland streams are heterotrophic, deriving the bulk of their energy from the surrounding forest (Minshall 1967, Hynes 1976, Petersen and Cummins 1974, Minshall et al. 1983, Webster et al. 1990, Webster and Meyer 1997).

Cummins (1977) standardized assignment of benthic macroinvertebrates to functional feeding groups designating four general categories: shredders, collectors, scrapers, and predators. Merritt and Cummins (1996) defined six functional feeding groups: grazers, gatherers, miners, filterers, shredders, and predators. These groups are frequently used to characterize communities, and several classifications are often used within one genus to describe macroinvertebrate feeding habits (Merritt and Cummins 1996). Vannote et al. (1980) examined the change in functional feeding groups from shredders to grazers as the energy sources within the stream changed from upstream to downstream.

Macroinvertebrates are commonly used as water quality indicators. Certain organisms are highly tolerant of low levels of dissolved oxygen, and their presence is often regarded as indicative of pollution. Other organisms require high levels of dissolved oxygen (9-12 mg/L) and are considered indicators of good water quality. Members of the orders Ephemeroptera, Plecoptera and Trichoptera (EPT) are generally considered intolerant of organic enrichment. The presence of tolerant organisms cannot be used to justify an argument that the environment is degraded according to Wurtz (1955). The absence of intolerant (i.e., sensitive) organisms is of primary concern. Goodnight (1973) prepared a rigorous examination of the history of macroinvertebrates as indicator species in which he stated that macroinvertebrates are "large enough to be easily collected, show wide ranges of tolerance in their reactions to various degrees of pollution, are not mobile enough to leave an area of pollution rapidly, and are adaptable to laboratory study without a large amount of specialized equipment." For these reasons, and because they an important element of stream communities, macroinvertebrates have been adopted as tools for bioassessment of environmental quality of streams and their watersheds.

METHODS

Macroinvertebrates were collected twice at each of the eight sampling sites: 13-22 July 2002 and 6-7 January 2003. An additional sample was taken at Site 6 using the Rapid Bioassessment Protocol described by Platkin et al. (1989) for comparison to the sample taken by the ADPCE (1995). A Hess sampler was used to obtain quantitative samples to facilitate future comparisons. Three samples were collected at each site in the upper, middle, and lower area of riffles. The substrate was disturbed for five minutes, and samples were washed into a Wisconsin bucket with a 600-μm mesh by pouring water into the net until no organisms were observed on the netting. The organisms were then rinsed from the Wisconsin bucket into sample jars and preserved using 70% ethanol. Samples were returned to the laboratory for identification.

Organisms were identified by Robin Reese using a MEIJI model EMZ- TR compound light microscope and a Nikon Alphahot-2 YS2 transmitting light microscope. The number of each type of organism from the three samples for each site was pooled. All organisms were identified to genus when possible except Diptera:Chironomidae and Oligochaeta using appropriate keys (McCaffertyI981, Peckarsky et al. 1990, Stewart and Stark 1993, Merritt and Cummins 1996, Smith 2001, and Thorp and Covich 2001). Early instars were identified to family and classified as immature. Voucher specimens will be housed in the Department of Entomology Museum at the University of Arkansas.

FUNCTIONAL FEEDING GROUPS

Boston Mountain ecoregion streams present an opportunity to examine a system that has characteristics that are not found elsewhere. These streams are forested but do not retain leaf and woody debris long after leaf fall in autumn. Organic matter inputs in the fall are swept onto the banks or transported downstream with the onset of winter rains and cooler temperatures. Retention time of organic matter in this system may be much lower than other mountainous, forested headwater streams in the United States. Debris dams are not common and high percolation rates allow water to leave the system more rapidly than other forested streams. Previous studies have shown that shredders are not as important a component of the macroinvertebrate community in these streams as they are in other forested streams (Petty and Brown 1982, Brussock 1986, Burns 2001).

Because of the uniqueness of the Boston Mountain ecoregion macroinvertebrate community, all members of the Class Insecta were classified according to functional feeding groups assigned by Merritt and Cummins (1996) (Tables 8 and 9). Shredders-detritivores and collectors-detritivores were essentially absent from all sites. None were found in the samples from July (Figures 8 and 9). Proportions of functional feeding groups differed markedly between seasons (Figure 10). The large proportions of predators found in January at Sites 1 and 2 were *lsoperla sp.,* a predaceous plecopteran found in headwater streams. The group labeled 'varies by subfamily' in Figures 8 and 9 were the Chironomidae. At Sites 4, 5,6, and 7, they comprised over 40 percent of the insects found (Figures 8 and 9) indicating possible influence of the effluent from the West Fork municipal wastewater treatment plant which discharges just downstream of Site 4. A comparison of the average proportions of functional feeding groups between seasons (Figure 10) indicates that predators found in July were only half of the proportion found in January and collectors-gatherers followed the same pattern.

2002 AND 2003 MACROINVERTEBRATE SURVEY

Biological indices have been established for evaluating the relative health of aquatic ecosystems using benthic macroinvertebrates (Wilhm and Dorris 1968, Ransom and Dorris 1972, Goodnight 1973, Ransom and Prophet 1974, Godfrey 1978, Benear and Ransom 1981). The Shannon-Wiener diversity index (H`) is an attempt to reduce the community structure of the organisms to a single number for comparative purposes. Benear and Ransom (1981), Godfrey (1978) and Ransom and Prophet (1974) cautioned against making literal interpretations of index values. According to Godfrey (1978), comparison of community composition is also necessary when making judgments regarding stream health.

Table 8. Functional feeding groups of the insects collected from the West Fork-White River in July 2002.

Order	Family	Genus	Functional Feeding Group*
Ephemeroptera		*Leptophlebia*	
	Baetidae	*Baetis*	collectors-gatherers
	Caenidae	*Brachycercus*	collectors-gatherers
		Caenis	collectors-gatherers, scrapers
	Ephemeriidae	*Ephemera*	collectors-gatherers
	Isonychiidae	*Isonychia*	collectors-filterers
	Heptageniidae	*Cinygmula*	scrapers, collectors-gatherers
		Stenacron	collectors-gatherers
		Stenonema	scrapers, collectors-gatherers
	Leptophlebiidae	*Choroterpes*	collectors-gatherers, scrapers
		Leptophlebia	collectors-gatherers
		Neochorotorpes	collectors-gatherers, scrapers
		immature	
	Tricorythidae	*Tricorythodes*	collectors-gatherers
Plecoptera			
	Perlidae	*Acroneuria*	predator
		Neoperla	predator
	Taeniopoterygidae	*Strophopteryx*	scrapers, collectors-gatherers
Trichoptera			
	Glossosomatidae	*Agapetus sp.*	scrapers, collectors-gatherers
	Hydropsychidae	*Cheumatopsyche*	collectors-filterers
		Smicridea	collectors-filterers
	Leptoceridae	*Oecetis*	predators
	Philopotamidae	*Chimarra*	collectors-filterers
	Polycentropodidae	*Cernotina*	predators
		Neuroclipsis	collectors-filterers.shredders-herbivores, engulfers
	Ceratopogonidae		predators, collectors-gatherers
	Chironomidae		varies with subfamily

(Continued on next page)

Table 8. Continued.

Order	Family	Genus	Functional Feeding Group*
	Empididae		predators, collectors-gatherers
	Simuliidae	*Simulium*	collectors-filterers
		Prosimulium	collectors-filterers
	Tanyderidae		
	Tipulidae	*Hexatoma*	predators
		Tipula	shredders-detritovores and herbivores, collector-gatherers, possibly some scrapers, predators
Coleoptera			
	Elmidae	*Macronychus*	collectors-detritovores
		Stenelmis	scrapers-collector, gatherers
	Hydrophilidae	*Berosus*	piercers-herbivores, collectors-gathers, shredders
	Psephenidae	*Psephenus*	scrapers, collectors-gatherers
Hemiptera			
	Veliidae	*Rhagovelia*	predators
Megaloptera			
	Corydalidae	*Corydalus*	predators
		Nigronia	predators
	Sialidae	*Sialis*	predators
Odonata			
	Coenagrionidae	*Argia*	predators
	Gomphidae	*Gomphus*	predators
		Stylogomphus	predators

* All functional feeding groups as designated by Merritt and Cummins (1996)

Table 9. Functional feeding groups of the insects collected from the West Fork-White River in January 2003.

Order	Family	Genus	Functional Feeding Group*
Ephemeroptera			
	Baetidae	*Baetis*	collectors-gatherers
	Caenidae	*Brachycercus*	collectors-gatherers
		Caenis	collectors-gatherers, scrapers
	Ephemeriidae	*Ephemera*	collectors-gatherers
	Isonychiidae	*Isonychia*	collectors-filterers
	Heptageniidae	*Cinygmula*	scrapers, collectors-gatherers
		Eperorus	
		Stenacron	collectors-gatherers
		Stenonema	scrapers, collectors-gatherers
	Leptophlebiidae	*Choroterpes*	collectors-gatherers, scrapers
		Leptophlebia	collectors-gatherers
		Neochorotorpes	collectors-gatherers, scrapers
	Tricorythidae	*Tricorythodes*	collectors-gatherers
Plecoptera			
	Capniidae	*Allocapnia*	shredders-detritovore
		Isocapnia	
	Chloroperlidae	*Alloperla*	predators
	Perlidae	*Acroneuria*	predators
		Neoperla	predators
	Perlodidae	*Diploperla*	predators
		Diura	scrapers-predators
		Isoperla s	predators
		Hydroperla	predators
	Pteronarcyidae	*Immature*	
	Taeniopoterygidae	*Oemopteryx*	scrapers, collectors-gatherers

(Continued on next page)

Table 9. Continued.

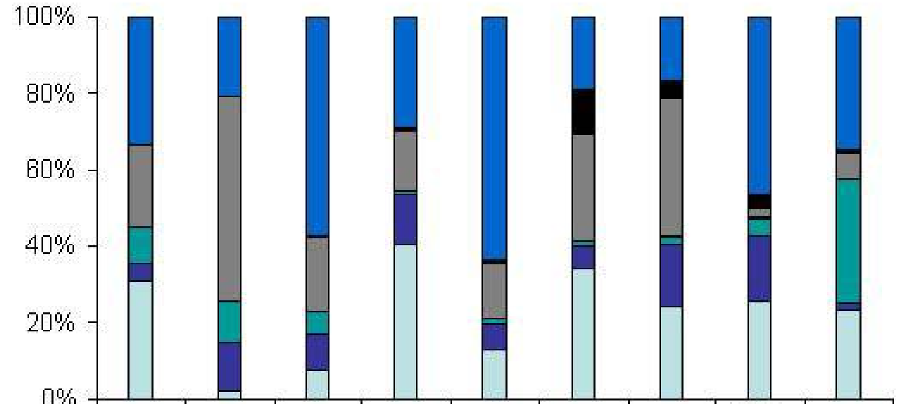
Order	Family	Genus	Functional Feeding Group*
		Strophopteryx	scrapers, collectors-gatherers
		Taeniopteryx	shredders-detritovores, facultative collectors-gatherers
	Leuctridae	*Zealeutra*	shredders-detritovore
Trichoptera			
	Glossosomatidae	*Agapetus*	scrapers, collectors-gatherers
	Hydropsychidae	*Cheumatopsychae*	collectors-filterers
		Smicridea	collectors-filterers
	Leptoceridae	*Oecetis*	predators, shredders-herbivores
	Philopotamidae	*Chimarra*	collectors-filterers
	Polycentropodidae	*Cernotina*	predators
		Neuroclipsis	collectors-filterers, shredders-herbivores, engulfers
Diptera			
	Ceratopogonidae	*Dashyelea*	collectors-gatherers, scrapers
	Chironomidae		varies by species
	Dixidae		collectors-gatherers
	Empididae	*Chelifera*	generally predators, some collectors-gatherers
	Simliidae	*Cnephia*	collector-filterers
		Prosimulium	collector-filterers
		Simulium	collector-filterers
	Tabanidae		generally predators
	Tanyderidae		
	Tipulidae	*Antocha*	collectors-gatherers
		Hexatoma	predators
		Tipula	shredders-detritivores, collectors-gatherers, predators
Coleoptera			
	Elmidae	*Ordobrevia*	

(Continued on next page)

Table 9. Continued.

Order	Family	Genus	Functional Feeding Group*
		Macronychus	collectors-detritovores
		Neoelmis	collectors-detritovores
		Stenelmis	
	Psephenidae	*Psephenus*	scrapers, collectors-gatherers
Megaloptera			
	Corydalidae	*Corydalus*	predators
	Sialidae	*Sialis*	predators
Odonata			
	Coenagrionidae	*Argia*	predators
	Gomphidae	*Gomphus*	predators
		Stylogomphus	predators

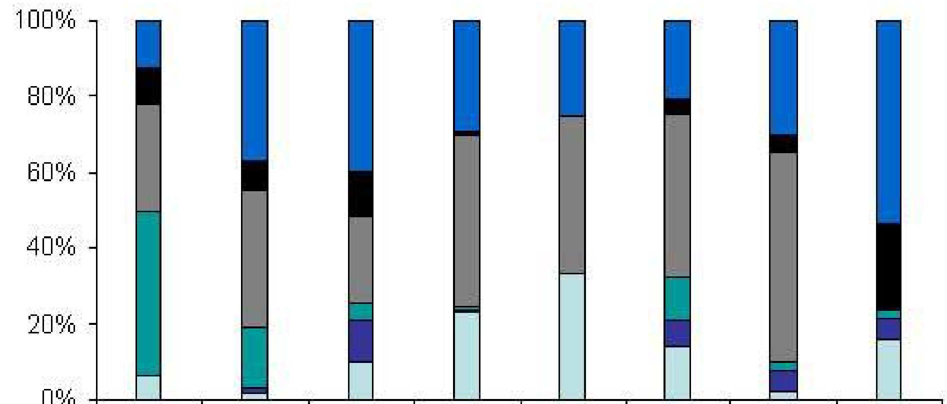
* All functional feeding groups as designated by Merritt and Cummins (1996)



	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 7	SITE 3P-INT*	RBA
multiple***	0.311	0.188	0.519	0.277	0.239	0.194	0.16	0.476	0.33
unknown**	0	0	0.006	0.007	0.003	0.115	0.045	0.038	0.005
varies by subfamily*	0.198	0.483	0.175	0.156	0.055	0.284	0.341	0.021	0.064
shredders-detritrivores	0	0	0	0	0	0	0.002	0.003	0
predators	0.093	0.099	0.052	0.008	0.005	0.015	0.018	0.047	0.303
collector-gatherers	0.035	0.11	0.086	0.123	0.024	0.062	0.157	0.177	0.018
collectors-filterers	0.291	0.023	0.069	0.39	0.049	0.344	0.229	0.263	0.22

Figure 8. Relative proportion of functional feeding groups July 2002. These data are intended for comparison to data from other Boston Mountain ecoregion streams sites of comparable watershed size or to data collected at the same site in the future. They are not intended for comparison among sites (i.e. to each other).

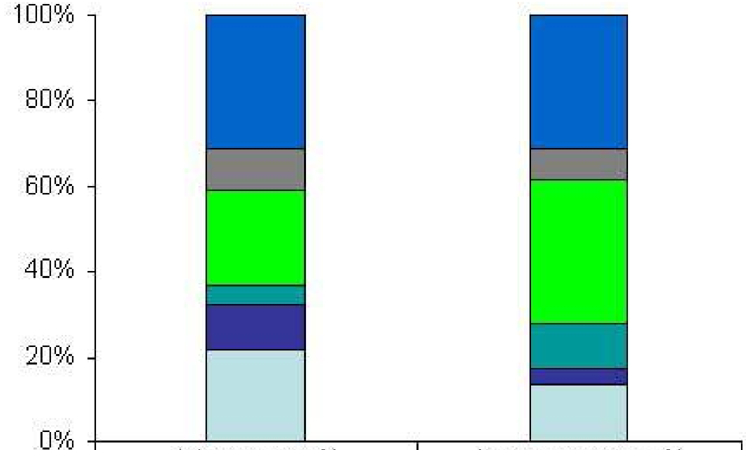
* Chironomidae.
** Not classified by Merritt and Cummins (1996).
*** Multiple functional feeding groups.



	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 7	SITE 3P-INT*
multiple***	0.121	0.369	0.376	0.279	0.242	0.208	0.255	0.534
unknown**	0.093	0.077	0.113	0.006	0	0.039	0.043	0.229
varies by subfamily*	0.29	0.361	0.22	0.43	0.403	0.429	0.468	0
shedders-detritivores	0.001	0	0	0	0	0.002	0	0
predators	0.43	0.156	0.043	0.011	0	0.117	0.021	0.025
collector-gatherers	0.002	0.016	0.106	0.006	0	0.065	0.043	0.051
collectors-filterers	0.06	0.018	0.092	0.218	0.323	0.143	0.021	0.161

Figure 9. Relative proportion of functional feeding groups January 2003. These data are intended for comparison to data from other Boston Mountain ecoregion stream sites of comparable watershed size or to data collected at the same site in the future. They are not intended for comparison among sites (i.e. to each other).

* Chironomidae.
** Not classified by Merritt and Cummins (1996).
*** Multiple functional feeding groups.



	July average %	January average %
shedders-detritivores	0	0.0005
multiple***	0.295	0.298
collectors-detritivores	0.001	0
unknown**	0.091	0.075
varies by subfamily*	0.214	0.325
predators	0.042	0.1
collectors-gatherers	0.097	0.036
collectors-filterers	0.207	0.13

Figure 10. Average percentage of functional feeding groups by season.

* Chironomidae
** Not classified in Merritt and Cummins (1996).
*** Multiple functional feeding groups.

Plafkin et al. (1989) adopted Hilsenhoff's Biotic Index (Hilsenhoff 1987) in a modified form for use as a rapid bioassessment technique. This technique uses a familial level of identification with assigned tolerance values along with seven other metrics to determine ecosystem health. The seven metrics recommended are taxa richness, percent contribution of dominant taxa, EPT index, community loss index, and the ratios of EPT to Chironomidae, scrapers to filterers, and shredders to total organisms. Hilsenhoff's Biotic Index was not used in this study because tolerance values have not been established for the Boston Mountain ecoregion. Taxa richness, EPT index, and percent Chironomidae were used since they are universally applicable to streams regardless of locale.

We were unable to find historical data on macroinvertebrates in the West Fork-White River that could be used for comparison to our results. Samples collected in October 2000 and June 2001 by the Water Division of the ADEQ were collected using a five-minute kick-net method with a d-shape net. Their findings indicate similar species composition, but the use of different methodology precludes any comparisons of biological indices between their results and what we found.

Macroinvertebrates found in both seasons from the eight sampling sites are enumerated in Tables 10 and 11. Large proportions of short-lived Ephemeroptera *(Caenis spp., Tricorythodes spp.)* were found in July samples with *Caenis spp.* present in all samples. *Tricorythodes spp.* was dominant at Site 5, comprising 61% of the total sample. As mentioned previously, Site 5 is directly below the West Fork municipal wastewater treatment plant. *Cheumatopsyche spp.* and *Chimarra spp.* were the most common Trichopterans. *Cheumatopsyche spp.* is a tolerant species and can be found in all types of waters, even in severely degraded systems. Few long-lived species such as the Odonata were found at any of the sites in January or July. Even the extremely tolerant megalopterans, which are also long-lived, were found in low numbers. The absence of long-lived species and dominance of short-lived species indicates an unstable system incapable of sustaining longer-lived macroinvertebrate species. Although several species of plecopterans were found, only seven individuals were found below Site 3. The presence in the headwaters of *Isocapnia spp., Alloperla spp.,* and *Isoperla spp.* gives hope that recolonization of these groups could occur downstream if restoration were undertaken. Heptageniidae, *Stenacron spp.* and *Stenonema*

Table 10. Macroinvertebrates collected by Hess Sampler in the West Fork-White River in July 2002

			2002 Sites								
Order	Family	Genus	1	2	3	4	5	6	7	3-P INT	6 RBA
Ephemeroptera											
	Baetidae	*Baetis*	1	2	29	37	29	28	110	21	2
	Caenidae	*Brachycercus*	0	0	1	2	0	7	35	5	0
		Caenis	26	45	230	114	320	113	29	143	10
	Ephemeriidae	*Ephemera*	0	1	0	0	0	0	0	0	0
	Isonychiidae	*Isonychia*	22	0	1	4	24	55	15	105	5
	Heptageniidae	*Cinygmula*	0	0	7	4	0	6	0	1	0
		Stenacron	2	16	4	35	12	2	15	84	0
		Stenonema	2	2	4	38	57	15	48	123	15
	Leptophlebiidae	*Choroterpes*	0	0	6	37	38	5	17	5	0
		Leptophlebia	0	0	1	0	0	0	0	0	0
		Neochoroterpes	0	0	0	0	0	0	0	0	0
		Immature	0	0	1	0	0	0	0	0	0
	Tricorythidae	*Tricorythodes*	0	0	2	2	1036	27	39	3	0
Plecoptera											
	Perlidae	*Acroneuria*	0	1	0	0	0	0	0	0	0
		Neoperla	0	0	0	2	0	0	0	0	0
	Taeniopoterygidae	*Strophopteryx*	1	0	0	0	0	0	0	0	0
Trichoptera											
	Glossosomatidae	*Agapetus*	0	0	0	0	0	0	0	0	0
	Hydropsychidae	*Cheumatopsyche*	3	0	27	182	55	70	206	56	15
		Smicridea	0	0	0	0	1	0	0	0	0
	Leptoceridae	*Oecetis*	1	0	0	0	0	0	0	0	0
	Philopotamidae	*Chimarra*	0	4	0	46	3	81	12	3	4
	Polycentropodidae	*Cernotina*	1	0	8	2	0	0	0	10	0

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Table 10. Continued.

				2002 Sites							
Order	Family	Genus		1	2	3	4	5	6	7	3-P INT
		Neuroelipsis	1	0	0	0	1	2	0	0	0
Diptera											
	Ceratopogonidae		0	1	0	0	1	0	0	0	0
	Chironomidae		17	83	71	94	92	170	346	13	7
	Empididae		0	0	0	0	7	0	0	0	0
	Simuliidae	*Simulium*	0	0	0	3	0	0	0	0	0
		Prosimulium	0	0	0	0	0	0	0	0	0
	Tanyderidae		1	1	1	0	0	0	0	0	0
	Tipulidae	*Hexatoma*	1	5	3	1	0	0	12	2	4
		Tipula	2	0	0	0	0	4	0	0	6
	Diptera pupa		5	0	1	7	5	6	11	4	0
Coleoptera											
	Elmidae	*Macronychus*	0	0	0	0	0	0	2	2	0
		Stenelmis	0	0	0	0	0	1	123	1	0
	Hydrophilidae	*Berosus*	0	0	0	0	0	0	1	0	0
	Psephenidae	*Psephenus*	0	0	0	0	0	3	0	29	5
Hemiptera											
	Veliidae	*Rhagovelia*	0	0	2	0	0	0	0	1	10
Megaloptera											
	Corydalidae	*Corydalus*	5	1	2	0	9	5	2	5	7
		Nigronia	0	0	6	0	0	0	0	8	0
	Sialidae	*Sialis*	0	0	0	0	0	0	0	0	5
Odonata											
	Coenagrionidae	*Argia*	0	0	0	0	0	4	4	2	7
	Gomphidae	*Gomphus*	0	7	0	0	0	0	0	0	0
		Stylogomphus	0	3	0	0	0	0	0	1	0

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Table 10. Continued.

Order	Family	Genus	2002 Sites 1	2	3	4	5	6	7	3-P INT	Order
Decapoda											
	Cambaridae	*Orconectes*	0	1	4	0	0	0	0	1	0
		immature	0	0	0	0	0	0	0	1	0
Isopoda											
	Asellidae	*Lirceus*	0	0	0	0	0	0	0	0	0
Veneroida											
	Corbiculidae	*Corbicula fluminea*	0	0	0	0	0	0	12	0	8
Gastropoda											
	Hydrobiidae		0	0	0	2	4	0	0	0	0
Oligochaeta											
	Lumbricidae		8	37	6	4	0	0	1	0	3
Tricladida											
	Dendrocoelidae		0	0	0	0	3	0	0	0	0
Prostigmata											
	subcohort Hydrachnidia		0	0	0	0	0	1	2	3	0
		Totals	99	210	417	618	1697	605	1042	632	113

Table 11. Macroinvertebrates collected by Hess Sampler in the West Fork-White River in January 2003

			2003 Sites							
Order	Family	Genus	1	2	3	4	5	6	7	3P-INT
Ephemeroptera										
	Baetidae	*Baetis*	0	4	10	1	0	0	0	0
	Caenidae	*Brachycercus*	0	0	2	0	0	3	1	0
		Caenis	3	11	25	16	15	5	1	0
	Ephemeriidae	*Ephemera*	0	0	0	0	0	0	0	0
	Isonychiidae	*Isonychia*	1	6	0	1	0	0	0	2
	Heptageniidae	*Cyngymula*	0	0	0	0	0	2	0	0
		Eperorus	10	15	0	0	0	0	0	0
		Stenacron	1	4	2	0	0	2	0	6
		Stenonema	1	22	3	18	0	5	5	15
	Leptophlebiidae	*Choroterpes*	0	7	0	0	0	0	0	0
		Leptophlebia	0	0	0	0	0	0	0	0
		Neochoroterpes	0	0	0	0	0	0	0	0
	Tricorythidae	*Tricorythodes*	0	0	1	0	0	0	0	0
Plecoptera										
	Capniidae	*Allocapnia*	2	0	0	0	2	0	0	0
		Isocapnia	48	38	16	0	0	0	0	27
	Chloroperlidae	*Alloperla*	11	0	0	0	0	0	0	2
	Perlidae	*Acroneuria*	0	0	0	0	0	0	0	0
		Neoperla	0	0	0	0	0	0	0	0
	Perlodidae	*Diploperla*	0	0	0	0	0	0	0	0
		Diura	0	0	0	1	0	1	0	0
		Isoperla	201	32	1	0	0	0	0	0
		Hydroperla	0	0	0	0	0	0	0	0
	Taeniopoterygidae	*Oemopteryx*	3	0	0	1	0	0	0	0

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Table 11. Continued.

Order	Family	Genus	2003 Sites 1	2	3	4	5	6	7	3P-INT
		Strophopteryx	1	0	0	0	0	0	0	0
		Taeniopteryx	0	0	1	0	0	1	1	0
		immature	0	0	7	0	0	0	0	0
	Leuctridae	*Zealeutra*	0	0	0	9	0	0	0	0
Trichoptera										
	Glossosomatidae	*Agapetus*	33	105	22	0	0	0	0	48
	Hydropsychidae	*Cheumatopsyche*	16	3	8	13	18	10	1	10
		Smicridea	0	0	0	0	0	0	0	0
	Leptoceridae	*Oecetis*	0	0	0	0	0	0	0	0
	Philopotamidae	*Chimarra*	14	0	0	24	0	0	0	7
	Polycentropodidae	*Cernotina*	6	23	3	0	0	0	0	1
		Neureclipsis	0	0	0	0	0	0	0	0
Diptera										
	Ceratopogonidae	*Dashyelea*	0	0	0	3	0	0	0	0
	Chironomidae		149	178	31	77	25	33	22	0
	Dixidae		0	0	0	0	0	0	1	0
	Empididae	*Chelifera*	0	1	0	0	0	0	0	0
	Simuliidae	*Cnephia*	0	0	0	1	0	1	0	0
		Prosimulium	0	0	4	0	2	0	0	0
		Simulium	0	0	1	0	0	0	0	0
	Tabanidae		0	0	0	0	0	1	1	0
	Tanyderidae		0	0	0	1	0	0	0	0
	Tipulidae	*Antocha*	0	0	0	0	0	0	0	0
		Hexatoma	2	0	1	0	0	7	0	0
		Tipula	4	13	1	0	0	0	5	0
	Diptera pupa		0	1	0	0	0	0	6	0

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Table 11. Continued.

Order	Family	Genus	2003 Sites 1	2	3	4	5	6	7	3P-INT
Coleoptera	Elmidae	*Ordobrevia*	0	0	0	0	0	1	1	0
		Macronychus	0	0	0	0	0	2	0	0
		Neoelmis	0	0	0	0	0	2	1	0
		Stenelmis	2	0	0	0	0	0	0	0
	Psephenidae	*Psephenus*	5	8	1	11	0	0	0	0
Megaloptera										
	Corydalidae	*Corydalus*	0	0	0	0	0	1	0	0
	Sialidae	*Sialis*	0	0	0	0	0	0	0	0
Odonata										
	Coenagrionidae	*Argia*	1	9	0	2	0	0	0	0
	Gomphidae	*Gomhpus*	0	13	0	0	0	0	0	0
		Stylogomphus	0	0	1	0	0	0	0	0
Decapoda										
	Cambaridae		0	0	0	1	0	0	0	0
Isopoda			0	0	0	0	0	0	0	0
	Asellidae	*Lirceus*	0	0	0	12	0	0	0	0
Veneroida										
	Corbiculidae	*Corbicula fluminea*	0	0	0	3	0	0	1	0
Gastropoda										
	Hydrobiidae		0	0	0	0	1	0	0	0
Oligochaeta										
	Lumbricidae		13	22	2	5	2	0	17	0
Tricladida										
	Dendrocoelidae	*Procotyla*	0	0	0	0	4	0	0	0
Collembola			0	0	23	0	0	0	0	0
		Totals	527	515	166	200	69	77	65	118

spp. were found in all sites in July and at most sites in January but at lower numbers, which was the general trend for all macroinvertebrate species.

The total number of organisms decreased markedly in the January samples from 542 individuals at Site 1 to only 72 at Site 7, the opposite of what would be expected in a healthy watershed. The EPT index indicated the same pattern in January with proportions decreasing from 40% to only 13% from Sites 1 to 7. Forty-six taxa were found in July, and 51 in January. Taxa richness dropped to only eight at Site 5 in January, but showed some recovery with 16 and 15 species at Sites 6 and 7 respectively. Taxa richness was relatively consistent in July with a range of 17 to 25. The absence of tolerant organisms in the summer months during higher water temperatures may explain this consistency. In July, total organisms increased downstream as would be expected in a healthy riverine system, but these were the short-lived macroinvertebrates previously mentioned. The Shannon-Weiner diversity index ranged from 2.088 to 3.300 in July, and from 2.226 to 3.505 in January. The diversity index was lowest at Site 5 for both months (Table 12).

A comparison of the results of the Rapid Bioassessment Protocols from 1993 and 2002 indicated an increase in taxa richness from 12 to 16 over the nine years (Table 13). There were several species in common between the two samples, but the 2002 sample had additional taxa: Corbiculidae *Corbicula fluminea,* Lumbricidae, Veliidae *Rhagovelia spp.,* and Caenidae *Caenis spp.,* all of which are tolerant species. The Shannon-Wiener diversity index increased from 2.36 to 3.84 from 1993 to 2002, mainly as the result of a more evenly distributed community. No single individuals of any macroinvertebrate taxa were found in the 2003 RBA.

Table 12. Biological indices for the West Fork-White River macroinvertebrate communities.

July 2002

	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 7	3P-INT	RBA
Total Organisms	99	210	417	618	1697	605	1042	632	113
Taxa Richness	17	18	22	18	18	19	21	25	16
H\`	3.116	2.493	2.472	3.300	2.088	3.164	3.151	3.273	3.814
% EPT	0.377	0.253	0.435	0.451	0.482	0.405	0.335	0.469	0.311
% Chironomidae	0.172	0.395	0.170	0.152	0.054	0.281	0.332	0.021	0.062

January 2003

	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 7	3P-INT	RBA
Total Organisms	528	517	169	204	74	83	72	118	*
Taxa Richness	31	20	22	19	8	16	15	9	*
H\`	2.710	3.183	3.505	2.686	2.226	2.838	2.704	2.413	*
% EPT	0.400	0.344	0.378	0.296	0.337	0.274	0.133	0.5	*
% Chironomidae	0.282	0.344	0.183	0.377	0.338	0.398	0.306	0.000	*

* RBA was not performed in January 2003

Table 13. Comparison of the results of Rapid Bioassessment Protocols in 1993 and 2002.

Order	Family	Genus	RBA 2002	RBA 1993
Ephemeroptera				
	Baetidae	*Baetis*	2	0
		Caenis	10	0
	Isonychiidae	*Isonychia*	5	30
	Heptageniidae	*Stenonema*	15	11
Trichoptera				
	Hydropsychidae	*Cheumatopsyche*	15	36
	Philopotamidae	*Chimarra*	4	14
Diptera				
	Chironomidae		7	1
	Tipulidae	*Hexatoma*	4	1
		Tipula	6	0
Coleoptera				
	Dryopidae	*Helichus*	0	1
	Psephenidae	*Psephenus*	5	2
Hemiptera				
	Veliidae	*Rhagovelia*	10	0
Megaloptera				
	Corydalidae	*Corydalus*	7	2
	Sialidae	*Sialis*	5	0
Odonata				
	Coenagrionidae	*Argia*	7	1
Decapoda				
	Cambaridae		0	1
Veneroida				
	Corbiculidae	*Corbicula fluminea*	8	0
Oligochaeta				
	Lumbricidae		3	0
		Total numbers	113	100
		Taxa Richness	16	12
		Shannon H`	3.84	2.36

MEIOFAUNA

INTRODUCTION

Meiofauna are a size class of invertebrates found in virtually all aquatic environments. The word "meiofauna" was coined by Mare (1942), when she recognized a group of organisms smaller than macroinvertebrates that were escaping from the 1000-μ mesh net she was using for sampling the benthos of an estuary. Mare defined the meiofaunal size class to include organisms that would pass through a 1000-μ net, but would be retained by a 42-μ net. Size class is an obviously arbitrary criterion for defining a group of organisms, and various investigators have modified the size range of meiofauna to include organisms from a lower limit of 42 to 80 μ to an upper limit of 500 to 1000 μ. Organisms recognized as meiofauna are members of various taxonomic categories including Copepoda, Cladocera, Rotifera, Gastrotricha, Nematoda, Oligochaeta, Tardigrada, Ostracoda, Hydrachnidia, Isopoda, and Hydroidea.

Meiofauna are now clearly recognized as distinctly different from macroinvertebrates, although they are believed to strongly interact with macroinvertebrates through competition and predation (Schmid-Araya et al. 2002). Many macroinvertebrates are larval stages of insects found in the benthos of streams (e.g. mayfly, caddisfly, stonefly larvae), and they are widely recognized by many aquatic resource managers of lakes, reservoirs, rivers, and streams. In contrast, meiofauna, which includes taxonomic categories with a different evolutionary history than insects, are unfamiliar to many persons working in rivers and streams. Certain groups are more often recognized in marine and lake environments (e.g. copepods, cladocerans, rotifers). Organisms recognized as macroinvertebrates may overlap in size with meiofauna, particularly in early life stages. Organisms that eventually outgrow the meiofauna size class are referred to as "temporary meiofauna", in contrast to those that remain in the meiofauna size class which are referred to as "permanent meiofauna."

The importance of meiofauna in stream ecosystems was overlooked for many years because it was generally held that they were not abundant and did not contribute substantially to either the biomass or ecosystem function of streams. Recent research has dispelled those notions (Robertson et al. 2000, Smith et al. 2001a, b). Meiofauna are now known to exist in high numbers in rivers and streams in both the benthos (benthic meiofauna) as well as within the water column (planktonic meiofauna). They are recognized as a link between the microbial/detrital trophic level and higher trophic levels including macroinvertebrates and fish (Schmid-Araya and Schmid 2000). Recent research has addressed their role in stream ecosystems as facilitators of nutrient cycling (Hakenkamp and Morin 2000) and integral components of food webs (Borchardt and Bott 1995, Schmid-Araya et al. 2002).

RATIONALE FOR INCLUSION OF MEIOFAUNA AND SUBSTRATE COMPOSTION

Fish, macroinvertebrate, and periphyton assemblages have been and continue to be the focus of attention in biological assessment of freshwater ecosystems (Barbour et al. 1999). However, at least some meiofauna taxonomic groups (e.g. copepods, nematodes) are recognized by marine researchers as indicators of environmental quality (Coull and Chandler 1992, Beier and Traunspurger 2001), and there is a growing interest in assessing the value of meiofauna as bioindicators in freshwater ecosystems (Smit and van der Hammen 1992, Di Sabatino et al 2000). While such efforts are only in their infancy, information on abundance and assemblage structure of meiofauna may prove valuable in the future. Hence, a survey of meiofauna was included in the biological assessment of the West Fork-White River, and represents the first known report on this size class of organisms in this river.

In addition to a catalog of meiofauna taxonomic categories found in the West Fork-White River, this report includes an analysis of the substrate composition of core samples from which benthic meiofauna were extracted. The concentration of silt (< 63-µ particles) is of particular interest because high silt concentration has been shown to adversely affect macroinvertebrate abundance and assemblage structure and fish egg development (Berkman and Rabeni 1987, Waters 1995). Because benthic meiofauna share the same microhabitat as macroinvertebrates, they may also be adversely affected by the presence of high silt concentrations. The information on meiofauna abundance and assemblage structure and silt concentration provided in this report will be analyzed in the future with similar information from 10 other Boston Mountain ecoregion streams to address the question of whether meiofauna are adversely influenced by the presence of high sediment concentrations (See Appendix B). Investigators in the future may find information on sediment levels in the West Fork-White River useful for tracking changes over time.

METHODS

Benthic meiofauna were extracted from nine core samples taken in riffles of the Site 3P-INT. A coring device was used to collect a 0.25-L substrate sample. Meiofauna were extracted by swirling and decanting using a Wisconsin bucket with an 80-μ net with a rinse of saturated calcium chloride to float organisms, followed by distilled water to re-adjust osmotic balance. A subsample of filtrate was collected for analysis of fine sediments. The contents of the Wisconsin bucket was washed into a sample container with 35 ml of buffered 5% formalin, and Rose Bengal was added to stain the organic material in the sample. The 0.25-L substrate core, filtrate subsample, and the preserved meiofauna sample were returned to the laboratory for analysis. The substrate core sample was separated using a set of sieves into fines (< 63 μ), sand (> 63 μ to 1000 μ), coarse sand (> 1000 μ to 2000 μ) and gravel (> 2000 μ). The subsample of filtrate containing sediment collected during extraction of meiofauna was dried and weighed and added to the weight of the fines.

Planktonic meiofauna were sampled using a modified Brown vacuum sampler (Brown et al. 1987) by filtering 300 L of water from an isolated pool at Site 3P-Int using the same Wisconsin net that was used for benthic sampling. Meiofauna were preserved in 5% formalin, stained with Rose Bengal, and returned to the laboratory for analysis. In the laboratory, benthic and planktonic meiofauna samples were transferred from formalin to 70% ethyl alcohol. All meiofauna within the size class between 80 μ and 1000 μ were enumerated and categorized into major taxonomic categories.

BASELINE MEIOFAUNA DATA

No historical record of meiofauna in the West Fork-White River has been found for comparative purposes, and little is known about meiofauna in the Boston Mountain ecoregion. Thus, the data included in this report constitute a baseline of information for future comparison. These data will be compared to other Boston Mountain streams in an independent study currently underway to assess the influence of sediment size on meiofauna abundance and assemblage structure (Appendix B).

Ten major meiofauna taxonomic categories were found in the nine benthic samples (Table 14). The mean meiofauna density was 2045 organisms/L. The relative abundance of

Table 14. Densities of major taxonomic categories of meiofauna from West Fork-White River Site 3P-INT sampled 5 August 2002.

Taxonomic Category	Organisms/L
Copepoda*	114
Rotifera	34
Cladocera	1
Ostracoda	20
Nematoda	83
Oligochaeta	90
Hirudinea	2
Hydrachnidia	303
Chironomidae**	1112
Ephemeroptera	217
Other***	69

Mean Density = 2045 Organisms/L

* Immature stages (nauplii and copepodites) included.
** Temporary meiofauna including individuals less than l mm in any body dimension.
*** Temporary meiofauna from Insecta orders Coleoptera, Trichoptera, Diptera, and Odonata.

taxonomic categories (Figure 11) was dominated by chironomid larvae comprising 55.4% of the total organisms sampled. While little is known about the response of meiofauna to anthropogenic disturbance in stream ecosystems, Chironomidae is known to be include highly tolerant species, and less taxa were represented than have been found in other streams in the region (Brown et al. 1989). Hydrachnidia (water mites) was the next most abundant group. Temporary meiofauna from various Insecta orders comprised 3.4% of the sample.

The planktonic sample had only 14 organisms including 2 cladocerans, 1 copepod nauplius, 1 rotifer, 2 tardigrades, 1 water mite, 3 chironomid larvae, 3 mayfly larvae, and 1 black fly larvae.

The total mean concentration of fine sediments (< 63 μ-size particles) was 18.25 g/L.

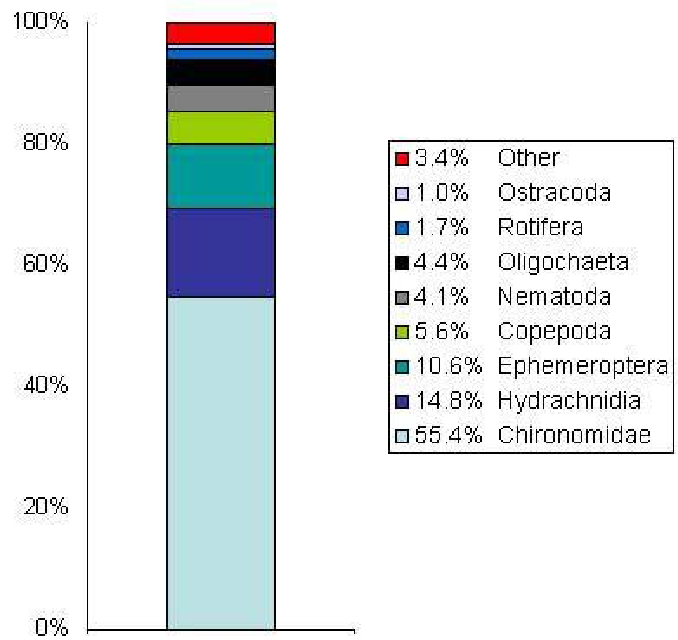

Figure 11. Relative proportion of major taxonomic groups of meiofauna from Site 3P-INT of the West Fork-White River shown as a percentage of total organisms.

PHYSICAL CHARACTERIZATION OF FISH HABITAT

INTRODUCTION

Because biological communities and chemical water quality of streams are very responsive to alterations in physical structure, characterization of physical parameters is a critical component of the evaluation of the environmental quality of streams (Gorman and Karr 1978, Kaufman et al. 1999). The Environmental Preservation Division of the ADEQ measured physical characteristics of the West Fork-White River including channel dimensions, gradient, sinuosity, and substrate composition. In addition, we examined physical characteristics specifically related to fish habitat.

METHODS

We conducted habitat surveys of riparian vegetation, bank erosion, fish cover, and canopy angle March and April 2003 at the eight West Fork-White River sampling sites using methods outlined by Kaufmann et al. (1999), Platts et al. (1983) and Simonson et al. (1994). Transect lines were run perpendicular to the river channel for a 250-m reach at 25-m intervals. The transect lines were equally distributed 125 m above and 125 m below the sampling site except at Sites 3 and 6 where fewer transects were placed above and more below the sampling site due to property access limitations. At each transect line, a 50-m line was measured perpendicular to the left bank and to the right bank (for a total of 100-m riparian corridor), and riparian vegetation was expressed as a percentage of trees, shrub, grass and forbs, bare, rock, road, and house on each side of the river. Canopy angle was measured at the midpoint of the river at each transect. Bank erosion and fish cover (boulders, aquatic vegetation, woody debris, and undercut banks) were expressed as a percentage of the area between transects. Measurements from each transect were averaged for each parameter (Table 15).

RIPARIAN VEGETATION AND FISH COVER

The proportion of trees in the riparian corridor was highest (75%) at Site 3 (Winn Creek). Sites 5 and 6 had the highest proportion of grass and were bordered by pasture on at least one bank at each site. At Site 6, there was evidence of cattle grazing and crossing at the

Table 15. West Fork-White River habitat characteristics, fish cover, and major fish taxonomic groups. All values are expressed as the average of the percentages except canopy angle that is expressed as the average of the degrees.

Habitat characteristics

	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 7	3P-INT
Tree	0.27	0.18	0.75	0.5	0.04	0.44	0.42	0.11
Shrub	0.32	0.31	0.08	0.21	0.20	0.03	0.08	0.13
Grass	0.23	0.38	0.04	0.13	0.46	0.45	0.40	0.47
Bare	0.06	0.06	0.12	0.16	0.29	0.01	0.10	0.07
Rock	0.01	0.02	0	0	0	0	0	0.10
Road	0.04	0.05	0	0	0	0.06	0	0.11
House	0.07	0	0	0	0	0	0	0
Canopy angle	71	85	77	59	3	61	34	76
Erosion	0.09	0.24	0.15	0.34	0.40	0.32	0.38	0.22

Fish cover

	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 7	3P-INT
Boulder	0.38	0.3	0.14	0.13	0.09	0	0	0.23
Aquatic Vegetation	0.05	0	0	0	0.1	0.08	0.14	0.01
Woody Debris	0.14	0.02	0.07	0.04	0.01	0.04	0.04	0.08
Undercut Bank	0.1	0.09	0.18	0.06	0	0.07	0.04	0.03
Total Fish Cover	0.67	0.41	0.39	0.23	0.20	0.19	0.18	0.35

Major fish taxonomic groups

	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 7	3P-INT
Campostoma spp.	0.34	0.61	0.45	0.36	0.50	0.05	0.26	0.39
Cyprinidae	0.21	0.07	0.09	0.17	0.20	0.22	0.19	0.26
Centrarchidae	0.11	0.01	0.14	0.10	0.11	0.39	0.19	0.10
Percidae	0.28	0.22	0.27	0.28	0.18	0.09	0.21	0.22
Catostomidae	0.00	0.00	0.02	0.01	0.00	0.23	0.07	0.00
Ictaluridae	0.02	0.09	0.03	0.08	0.01	0.01	0.02	0.03

upstream end of the 250-m reach that was surveyed. Site 5, with almost no canopy cover, had a pasture on the left bank and bare rock with few trees and shrubs on the right bank. The riparian corridors of Sites 1, 2, and, 3 were relatively evenly distributed with trees, shrubs and grass. Fish cover was relatively high at Sites 1 and 2, 67% and 41% respectively. It decreased markedly moving downstream from a high of 67% at Site 1 to 18% at site 7. Boulders were the major component of fish cover (Table 15).

PHYSICAL HABITAT AND FISH

The relationship between physical characteristics (riparian tree cover, erosion, fish cover and canopy angle) and major fish taxonomic categories: *Campostoma* (stonerollers), other Cyprinidae (minnows), Centrarchidae (sunfishes), Percidae (perches), Catostomidae (suckers), and Ictaluridae (freshwater catfishes) was analyzed using the Pearson product moment of correlation coefficients (r), (McClave and Dietrich 1991) (Table 16). Seven significant correlations were found. Erosion was negatively correlated with fish cover (r = -0.908, P = 0.002) and canopy angle (r = -0.750, P = 0.032). Lack of trees along the banks significantly increased erosion. Fish cover was reduced where tree roots that stabilize banks were absent. Catostomidae and Centrarchidae were negatively correlated with *Campostoma*, (r = -0.851, P = 0.007) and (r = -0.919, P = 0.001) respectively. Some Catostomidae species and *Campostoma* are tolerant fishes, and these correlations suggest competition between them in degraded habitats, as was suggested at Site 6 in Figure 7. Tolerant catostomids and *Campostoma* may be replacing sensitive centrarchids in the West Fork-White River.

The other three correlations suggest a pool/riffle habitat preference since these analyses were based on total fishes from both microhabitats at each site. Percidae were negatively correlated with Centrarchidae (r = -0.0726, P = 0.042) and with Catostomidae (r = -0.804, P = 0.016). Percidae are primarily riffle dwellers and the Centrarchidae and Catostomidae reside in pools. Catostomidae and Centrarchidae were positively correlated and are both pool dwellers (r = 0.953, P = 0.000).

Table 16. Pearson correlation between habitat variables and major fish taxonomic groups. The *r* value is reported above the probability.

	Tree Cover	Erosion	Fish Cover	Canopy Angle	% *Campostoma*	% Other Cyprinids	% Centrarchidae	% Percidae	% Catostomidae
Erosion	-0.188 0.655								
Fish Cover	-0.062 0.885	-0.908 **0.002**							
Canopy Angle	0.305 0.463	-0.750 **0.032**	0.560 0.149						
% *Campostoma*	-0.326 0.431	-0.186 0.659	0.290 0.487	0.078 0.855					
% Other Cyprinids	-0.400 0.326	0.190 0.652	-0.144 0.734	-0.329 0.427	-0.578 0.133				
% Centrarchidae	0.349 0.396	0.262 0.531	-0.427 0.291	-0.163 0.699	-0.919 **0.001**	0.407 0.317			
% Percidae	0.231 0.582	-0.514 0.193	0.580 0.132	0.317 0.444	0.524 0.182	-0.326 0.430	-0.726 **0.042**		
% Catostomidae	0.296 0.476	0.295 0.479	-0.446 0.268	-0.045 0.916	-0.851 **0.007**	0.254 0.544	0.953 **0.000**	-0.804 **0.016**	
% Ictaluridae	0.046 0.913	-0.044 0.917	0.078 0.854	0.473 0.237	0.523 0.184	-0.601 0.115	-0.601 0.115	0.430 0.287	-0.394 0.334

FINDINGS AND RECOMMENDATIONS

Biological assessment has revealed some significant impairment to the West Fork-White River biological community. We found a decreased diversity of fish with 22 species not found in our survey that were reported historically. Nine of these are of special concern including two species (checkered madtom and yoke darter) that are endemic to the White River basin. However, fish species richness was moderate over the course of the river, and one intensively sampled site compared favorably to less disturbed Boston Mountain ecoregion streams in fish density, biomass, and species richness.

The macroinvertebrate assemblage was less diverse than expected in Ozark streams and was composed largely of pollution tolerant species (e.g., chironomids), especially during summer. In the winter, however, macroinvertebrate samples from small upstream reaches contained more sensitive species (e.g., stoneflies) than downstream reaches, indicating better upstream conditions and potential for recolonization downstream after restoration. The relative abundance of meiofauna taxa corroborated findings from macroinvertebrates, being composed largely of pollution tolerant taxa and having less diversity than expected compared to other streams in the region.

Riparian corridors were very disturbed at sites in downstream reaches, and at some sites, stream channels were much wider than expected given their watershed area, and no trees remained along the banks.

The wastewater treatment plant for the community of West Fork was obviously not functioning correctly, resulting in impairment of the riverine biological community.

We strongly recommend that some restoration of the West Fork-White River be initiated soon while the biological community remains capable of responding in a relatively brief time period. The physical structure of the stream should receive some immediate protection. Biological communities are assembled on and respond directly to physical conditions in streams (sediments, flow conditions, percent riffle and pool, etc.), and impairment of these conditions has occurred. Gravel mining should not be permitted in the bankfull limits of the stream channels in this basin. Vehicular access to stream banks should be limited.

The riparian corridor should be restored and protected because it contributes to the physical integrity of the stream channel, retards erosion, moderates temperatures, and supplies organic matter for trophic support of stream biota. Removal of riparian vegetation should not be permitted, and replanting of riparian woodland should be encouraged and subsidized. Access to the river by livestock should be limited to control bank erosion.

The wastewater treatment plant for the community of West Fork should be upgraded, and residential septic systems near the river should be examined and repaired, if necessary. Removal of water from the river for any purpose should be monitored and evaluated. The poorest water quality occurs during summer low flow periods, and water removal exacerbates the problem.

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Appendix A. Modification of Odum's index of similarity to compare the number of species between two samples (Odum, 1971).

$$\text{Similarity} = \Sigma C / A + B + D$$

ΣC = sum of the proportions of species common to both sample A and sample B

A = total proportions of sample A (=100)

B = total proportions of sample B (=100)

D = sum of the differences of the proportions of species common to sample A and B

Appendix B. Synopsis of related research.

MEIOFAUNA RESPONSES TO ANTHROPOGENIC DISTURBANCE: DOES SEDIMENT SIZE INFLUENCE ABUNDANCE AND ASSEMBLAGE STRUCTURE?

Meiofauna are a size class of aquatic invertebrates (lower limit of 42 μm and upper limit of 1000 μm) that collectively comprise a trophic level in aquatic ecosystems that transfers energy from microbial/detrital levels to higher consumers. Meiofauna assemblages represent one of the least studied constituents of stream ecosystems. Dissertation research by Andrea Radwell is underway at the University of Arkansas designed to evaluate the response of meiofauna assemblages to stream/watershed anthropogenic disturbance with specific reference to the influence of sediment size.

Inorganic sediment deposition from natural processes of erosion is an integral part of stream ecosystems. However, excessive sediment deposition, also referred to as siltation, is often associated with anthropogenic disturbance and is recognized as a major pollutant of United States waters. The presence of excessive sediments in streams is an important result of a wide range of disturbances associated with agricultural practices, logging, urbanization, and gravel mining. Altered flood regimes, changed channel morphology, increased lateral activity, and other hydrologic alterations are often directly related to the presence of excessive sediment.

Adverse effects of excessive sediment on macroinvertebrates and fishes have been documented. Stream meiofauna share much of the same microhabitat as macroinvertebrates and are subjected to the same disturbances associated with sedimentation. However, the effect of sediment on meiofauna of streambeds has received minimal attention. An important goal of this research is to contribute to a better understanding of an important anthropogenic influence on meiofauna. This information may be useful in development of appropriate management protocols for streams.

The research consists of two components. First, a set of artificial stream channels was deployed across the Illinois River with sediment size as the manipulated variable. After colonization, benthic core samples were taken from each channel. Significantly fewer meiofauna were found in cores with high concentrations of fine sediment, and meiofauna assemblage structure differed among cores with varying fine sediment concentrations. The second component is a field study of headwater riffles of 11 Boston Mountain streams varying in degree of environmental disturbance (Big Piney Creek, Hurricane Creek, Kings River, Middle Fork Illinois Bayou, Mulberry River, North Fork Illinois Bayou, Richland Creek, Upper Buffalo River, War Eagle Creek, Main Fork White River, and West Fork White River). Nine benthic core samples were taken from each stream. Meiofauna abundance and assemblage structure, and percent substrate composition of each core from each river will be determined. Planktonic meiofauna were also sampled in a pool at each site. Data will be analyzed to determine the influence of fine sediments on meiofauna abundance and assemblage structure in natural channels.