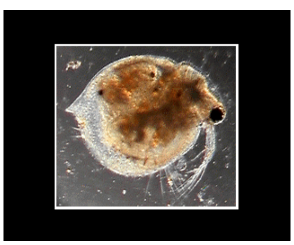
Y-12 NATIONAL SECURITY COMPLEX BIOLOGICAL MONITORING AND ABATEMENT PROGRAM

2008 CALENDAR YEAR REPORT



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UT-BATTELLE

Environmental Sciences Division

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1. Introduction

The National Pollutant Discharge Elimination System (NPDES) permit issued for the Oak Ridge Y-12 National Security Complex (Y-12 Complex) which became effective May 1, 2006, continued a requirement for a Biological Monitoring and Abatement Program (BMAP). The BMAP was originally developed in 1985 to demonstrate that the effluent limitations established for the Y-12 Complex protected the classified uses of the receiving stream (East Fork Poplar Creek: EFPC), in particular, the growth and propagation of aquatic life (Loar et al. 1989). The objectives of the current BMAP are similar, specifically to assess stream ecological conditions relative to regulatory limits and criteria, to assess ecological impacts as well as recovery in response to Y-12 operations, and to investigate the causes of continuing impacts. The BMAP consists of three tasks that reflect complementary approaches to evaluating the effects of the Y-12 Complex discharges on the biotic integrity of EFPC. These tasks include: (1) bioaccumulation monitoring, (2) benthic macroinvertebrate community monitoring, and (3) fish community monitoring. As required by the NPDES permit, the BMAP benthic macroinvertebrate community monitoring task includes studies to annually evaluate the receiving stream's biological integrity in comparison to TN Water Quality Criteria.

BMAP monitoring is currently being conducted at five primary EFPC sites, although sites may be excluded or added depending upon the specific objectives of the various tasks. Criteria used in selecting the sites include: (1) location of sampling sites used in other studies, (2) known or suspected sources of downstream impacts, (3) proximity to U.S. Department of Energy (DOE) Oak Ridge Reservation (ORR) boundaries, (4) appropriate habitat distribution, and (5) access. The primary sampling sites include upper EFPC at kilometers (EFKs) 24.4 and 23.4 [upstream and downstream of Lake Reality (LR) respectively]; EFK 18.7 (also EFK 18.2 and 19), located off the ORR and below an area of intensive commercial and light industrial development; EFK 13.8, located upstream from the Oak Ridge Wastewater Treatment Facility (ORWTF); and EFK 6.3 located approximately 1.4 km below the ORR boundary (Fig. 1.1). Actual sampling locations on EFPC may differ slightly by task according to specific requirements of the task. Brushy Fork (BF) at kilometer (BFK) 7.6 and Hinds Creek at kilometer (HCK) 20.6 are the most commonly used reference sites for the Y-12 BMAP. Additional sites off the ORR are also occasionally used for reference, including Beaver Creek, Bull Run, Cox Creek, and Paint Rock Creek (Fig. 1.2).

Summaries of the sampling designs for the three primary tasks of the Y-12 Complex BMAP for EFPC are presented in Tables 1.1–1.3. This report covers the 2008 period, although data collected outside this time period are included as appropriate. To address the biological monitoring requirements for Bear Creek and McCoy Branch, CERLCA-funded programs, data are summarized in Appendix A and Appendix B respectively. Data for these two watersheds are provided herein to address Section IX of the NPDES Permit for Y-12, where "Results of these CERCLA programs can be used to meet the biological monitoring requirements of this permit…". A summary of the toxicity testing results for Y-12 outfalls into upper EFPC is provided in Appendix C (these results have been previously reported) to provide a more thorough perspective of conditions in the stream.

Data summarized in this report are available from the Oak Ridge Environmental Information system (OREIS) in an Arc-GIS usable format (http://www-oreis.bechteljacobs.org/oreis/help/oreishome.html). Per requirements specified in the NPDES permit, data collected following TDEC monitoring protocols (TDEC 2006) is also submitted directly to TDEC in Excel format.

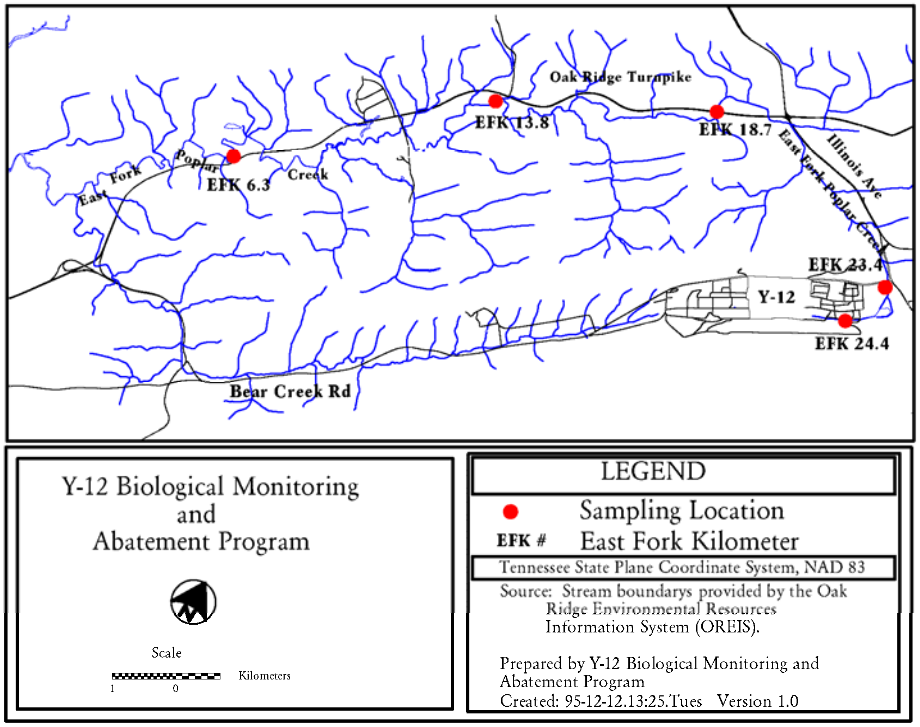

Fig. 1.1. Location of biological monitoring sites on East Fork Poplar Creek in relation to the Oak Ridge Y-12 National Security Complex.

ORNL-DWG-95M-7421R

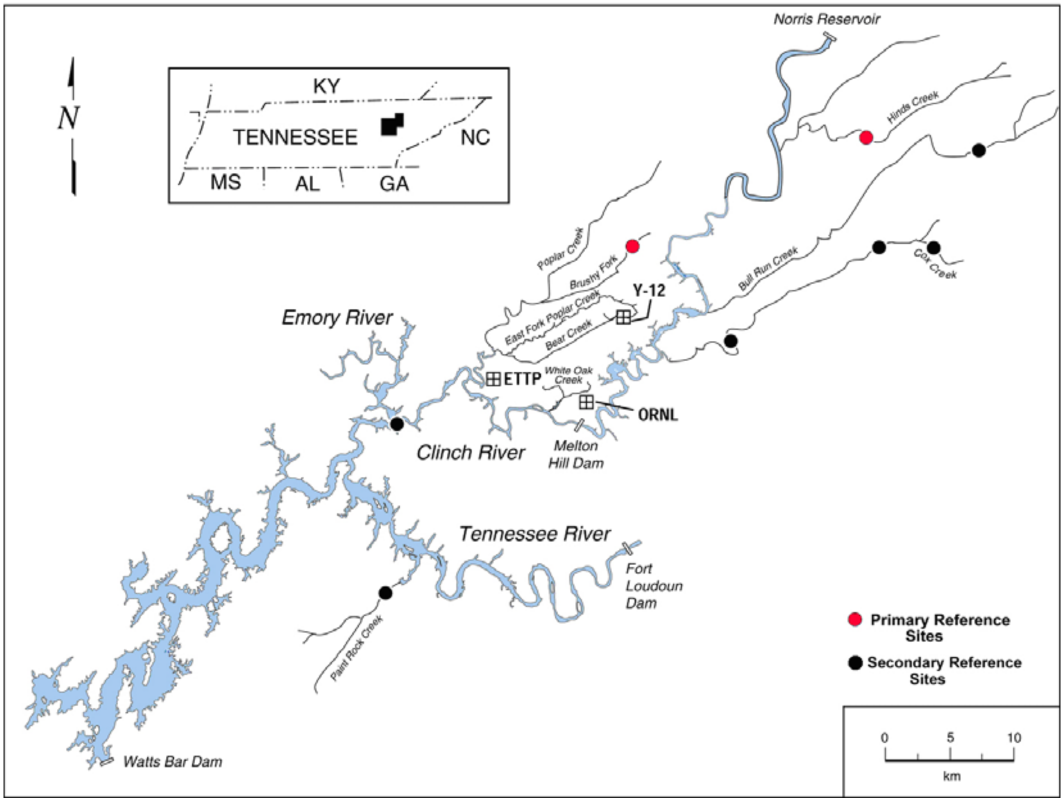

Fig. 1.2. Location of biological monitoring reference sites in relation to the Oak Ridge Y-12 National Security Complex.

Table 1.1. Summary of the Sampling Plan for the Bioaccumulation Monitoring Task

Site[a]	Sampling Initiated	Species	Mercury	PCBs	Metals
Spatial and Temporal Tracking					
EFK 24.5[b]	May 1991	Sunfish[c]	biannual	annual	
EFK 23.4	May 1985	Sunfish	biannual	annual	
EFK 18.2	May 1985	Sunfish	biannual	annual	
EFK 13.8	May 1985	Sunfish	biannual	annual	
EFK 6.3	May 1985	Sunfish	biannual	annual	
HCK 20.6	May 1985	Sunfish	biannual	annual	
PCK 1.6	Dec. 1987	Sunfish	annual		
CRK 15.0	Dec. 1987	Sunfish	annual		
Screening					
EFK 24.5	Dec. 1995	Stonerollers[d]	annual	annual	annual
HCK 20.6	Dec. 1995	Stonerollers	annual	annual	annual
EFK 23.4	May 1985	Largemouth bass[e]	annual	annual	

[a]EFK=East Fork Poplar Creek kilometer; PCK=Poplar Creek kilometer; CRK=Clinch River kilometer; HCK=Hinds Creek kilometer. Hinds Creek is the reference site.

[b]Actual site reach extends from EFK 24.2 through EFK 24.5.

[c]Sunfish to be collected are redbreast sunfish (*Lepomis auritus*), if available. Rock bass (*Ambloplites rupestris*) and/or bluegill sunfish (*Lepomis macrochirus*) are substituted for redbreast, if necessary. Muscle fillets from six individuals are analyzed from each site.

[d]Whole-body stonerollers (*Campostoma oligolepis*) are analyzed to evaluate ecological risks. Three 10-fish composites are analyzed from each site.

[e]Largemouth bass fillets are used to evaluate the maximum human health risks in EFPC, if available. Common carp were collected for this purpose in the early years of the BMAP. One "site" only is to be sampled for large fish, but a large sampling reach may be needed to obtain the desired number of fish.

Table 1.2. Summary of the Sampling Plan for the Benthic Macroinvertebrate Community Monitoring Task

Site[a]	Sample History	Frequency
BMAP protocols		
EFK 24.4	Jun 1985–present	Biannual (spring and fall)
EFK 23.4	Jun 1985–present	Biannual
EFK 13.8	Jun 1985–present	Biannual
BFK 7.6	Jan 1986–present	Biannual
HCK 20.6	Oct 1987–present	Biannual
State of Tennessee protocols		
EFK 24.4	2005–present	Annual (summer)
EFK 23.4	2005–present	Annual
EFK 13.8	2005–present	Annual
BFK 7.6	2005–present	Annual
HCK 20.6	2005–present	Annual

[a]EFK=East Fork Poplar Creek kilometer; BFK=Brushy Fork kilometer; HCK=Hinds Creek kilometer.

Table 1.3 Summary of the Sampling plan for the Fish Community Monitoring Task

Site[a]	Sample History	Frequency
EFK 24.4	Jun 1985–present	Annual (spring)
EFK 23.4	May 1985–present	Biannual (spring and fall)
EFK 18.7	Mar 1990–present	Biannual
EFK 13.8	May 1985–present	Biannual
EFK 6.3	Jun 1985–present	Biannual
BFK 7.6	Nov 1985–present	Biannual

[a]EFK=East Fork Poplar Creek kilometer; BFK=Brushy Fork kilometer.

2. Bioaccumulation Monitoring

2.1 Introduction

Bioaccumulation monitoring in EFPC in 2008 continued the long-term focus on accumulation of methylmercury and PCBs in sunfish species. Sunfish have been used as biological indicators to evaluate spatial and temporal trends in contaminant accumulation because they are relatively short-lived and sedentary, and therefore, representative of recent exposure at the site of collection. Adult (> 50 g) redbreast sunfish (*Lepomis auritus*) have been collected twice yearly (May/June and Nov/Dec) at five sites in EFPC (EFK 24.2, EFK 23.4, EFK 18.2, EFK 13.8, and EFK 6.3) when available. If adequate numbers of redbreast sunfish were not present, rock bass (*Ambloploites rupestrus*) has been used as an alternate species. Increasingly redbreast have become less common in EFPC and more difficult to collect, while rock bass have become more common. Rock bass typically contain about 15% higher concentrations of mercury than redbreast sunfish at the same site. Bluegill (*Lepomis macrochirus*) were collected once yearly (June) from the lower reaches of Poplar Creek embayment (PCK 1.6) and a nearby downstream section of the Clinch River arm of Watts Bar Reservoir (CRK 15.0) to assess the extent of downstream methylmercury bioaccumulation from the EFPC source.

While largemouth bass (*Micropterus salmoides*) have historically been taken to provide data on contaminant concentrations in larger fish predators, none were encountered in 2008. Stoneroller minnows (*Campostoma oligolepus*), an herbivorous forage fish, have been collected once yearly in upper EFPC (EFK 24.6), where inorganic mercury exposure was highest, and analyzed for total mercury; triplicate whole fish composite samples consisting of ten fish each are collected during each sampling period. Unlike fillets of higher trophic level fish, the whole body content of this species contains substantial inorganic mercury. Thus, concentrations of total mercury in stonerollers represents a maximum food-chain exposure to inorganic mercury for fish-eating birds and wildlife. Samples of axial muscle (fillet) were analyzed for total mercury (virtually all mercury in fish is methylmercury) in all collections (except stonerollers, as noted), while PCB analyses (quantified as Aroclor equivalents) were only conducted on fish taken in the May/June collections. Hinds Creek, a nearby stream northeast of Y-12 and also located in the Ridge and Valley physiographic province of East Tennessee, served as the reference site.

2.2 Results/Progress

Results of the 2008 monitoring are presented in Table 2.1. Redbreast sunfish were collected from even fewer sites in EFPC than in previous years; the only site in EFPC where redbreast were collected in 2008 was EFK 24.2. The elevated outlet from the diversion channel to EFPC, may be preventing rock bass from colonizing upstream of the channel, but rock bass appear to be replacing redbreast at all sites downstream of the channel. If this trend continues, rock bass will clearly have to be used as the bioindicator species in EFPC. To appropriately evaluate changes in mercury bioaccumulation over time, a rigorous comparison of contaminant concentrations between the two species is needed to account for species differences.

Mercury concentrations in redbreast sunfish did not differ significantly between EFK 24.2 and PCK 8.2 in Spring 2008, and while redbreast were not collected at intermediate sites in 2008, this finding is consistent with those of recent years and remains puzzling given the substantial dilution of EFPC flow between EFK 23.4 and EFK 6.3. In contrast, mercury concentrations in rock bass actually appeared to *increase* from upstream to downstream, with peak concentrations of mercury in fish at EFK 6.3 in both the spring and fall of 2008. The lowest mean concentration of mercury in sunfish

Table 2.1. Concentrations of mercury and PCBs [mean ± SE, mg/kg wet wt., (*range)*] in fillets of redbreast sunfish, rock bass, and bluegill from EFPC, downstream, and reference sites, 2008. Reference site shown in shaded boxes for comparison

Site	Mercury		PCBs
	Spring 2008	Fall 2008	Spring 2008
Redbreast sunfish			
Hinds Creek	0.08 ± 0.02	0.09 ± 0.02	0.01 ± 0.004
	(0.05 - 0.13)	*(0.04 - 0.15)*	*(0 - 0.03)*
EFK 24.2	0.60 ± 0.06	0.53 ± 0.08	1.14 ± 0.14
	(0.38 - 0.83)	*(0.38 - 0.91)*	*(0.71 - 1.55)*
PCK 8.2	0.62 ± 0.14	Not sampled	Not sampled
	(0.20 - 1.20)		
Rock bass			
Hinds Creek	0.18 ± 0.07	0.22 ± 0.03	0.07 ± 0.009
	(0.12 - 0.30)	*(0.10 - 0.29)*	*(0.05 - 0.11)*
EFK 6.3	1.09 ± 0.19	1.30 ± 0.12	0.16 ± 0.04
	(0.55 - 1.70)	*(1.02 - 1.84)*	*(0.02 - 0.32)*
EFK 13.8	0.92 ± 0.08	1.05 ± 0.11	0.16 ± 0.03
	(0.68 - 1.25)	*(0.80 - 1.53)*	*(0.06 - 0.29)*
EFK 18.2	0.90 ± 0.06	1.04 ± 0.04	0.16 ± 0.06
	(0.81 - 1.11)	*(0.88 - 1.13)*	*(0.05 - 0.40)*
EFK 23.4	0.87 ± 0.11	0.84 ± 0.11	0.46 ± 0.21
	(0.53 -1.24)	*(0.37 - 1.09)*	*(0.14 - 1.49)*
Bluegill			
PCK 1.6	0.25 ± 0.04	Not sampled	Not sampled
	(0.11 - 0.41)		
CRK 15.0	0.09 ± 0.02	Not sampled	Not sampled
	(0.07 - 0.17)		

occurred at EFK 24.2, the site with the highest concentration of waterborne mercury, continuing a pattern seen since the late 1990's. Although gradual dilution of the headwater mercury source within EFPC appears to have little effect on mercury bioaccumulation in fish, the abrupt dilution of EFPC in Poplar Creek embayment (PCK 8.2 and 1.6) and subsequently in the Clinch River/Watts Bar Reservoir (CRK 15.0), resulted in lower methylmercury bioaccumulation.

Long-term trends in mercury concentrations in fish at EFK 24.2 and EFK 23.4 are presented in Figs 2.1 and 2.2. They continue to depict the puzzling contradictory responses of methylmercury bioaccumulation to the source of inorganic mercury from the facility. Above Lake Reality in the 1990s (Fig. 2.1), methylmercury in fish declined at a rate very similar to the decrease in waterborne mercury concentration at Station 17. That correspondence was consistent with a key assumption of remedial strategies at the site; that methylmercury accumulation in fish in EFPC was proportional to waterborne total mercury. This assumption was the basis for derivation of the 200 ng/L aqueous mercury target guiding CERCLA efforts in UEFPC. The response of mercury in fish to the substantial decrease in waterborne mercury that followed start-up of the Big Spring Treatment System in late 2005 remains disappointing, with little change over the two years following that action. While a time lag would be expected as older, more highly contaminated fish are replaced by younger fish exposed only to the new conditions, the trend observed in sunfish at EFK 23.4 after bypass of Lake Reality would suggest that changes in mercury concentration in sunfish would be evident after a year. Lack of a clear response after two years suggests that the previous relationship between inorganic mercury concentration and methylmercury production/bioaccumulation observed in UEFPC is no longer representative of that site.

The long-term trend in mercury concentrations in fish at EFK 23.4 decidedly contradicts the observations at the upstream site, with little or no change occurring in mercury in fish over the period when mercury in water was decreasing (Fig. 2.2). As was the case at EFK 24.2, there also has been no clear response to the decreased mercury input that followed Big Spring Treatment System over the past two years.

PCB (Aroclor 1254/1260) concentrations in EFPC sunfish were highest at EFK 24.2 and EFK 23.4, but declined rapidly downstream (Table 2.1). PCB concentrations in EFPC sunfish at EFK 24.2 have decreased steadily since 1992 (Fig 2.3). However, the presence of PCB concentrations in fish well above that typical of the reference site indicates continuing inputs from legacy contamination within the Y-12 Complex.

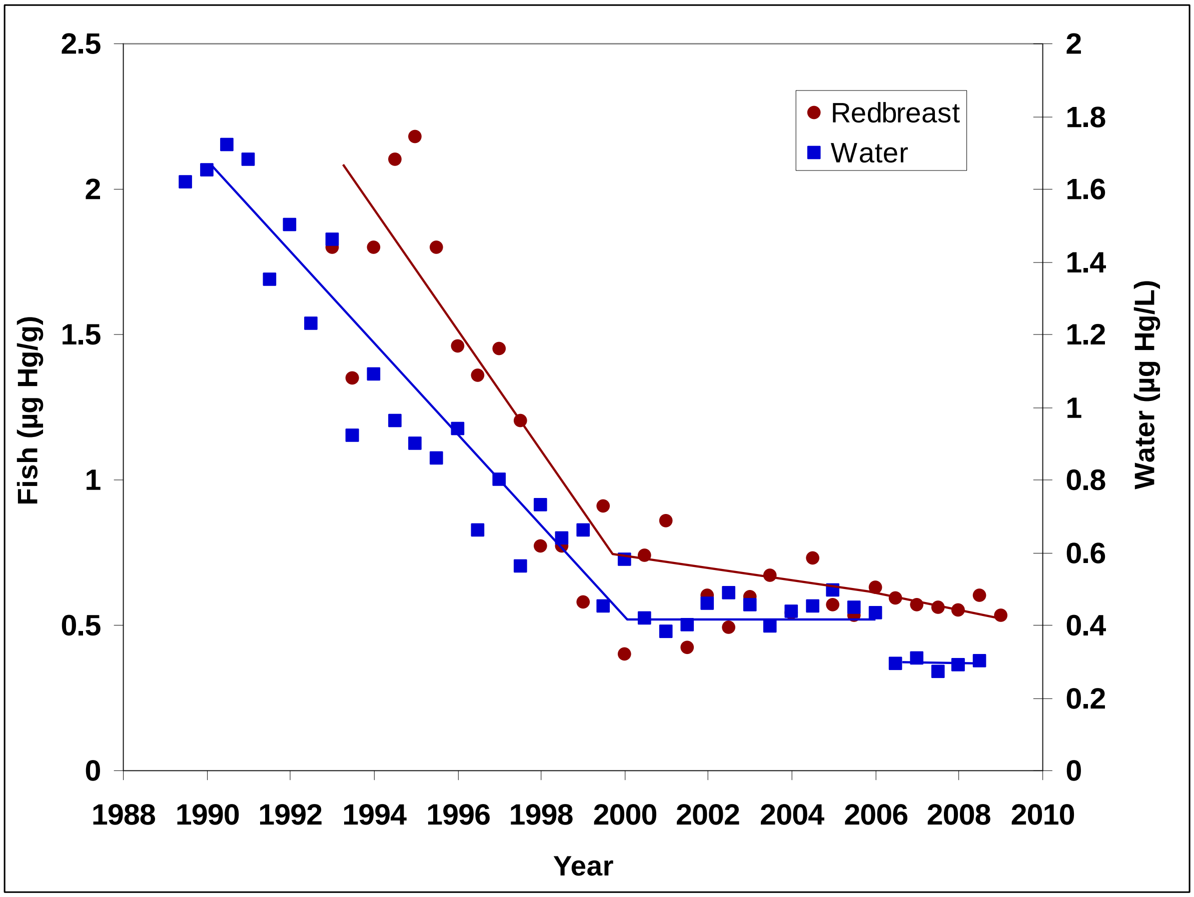

Fig. 2.1. Long-term trend in mean concentration of mercury in redbreast sunfish at EFK 24.2 versus 6-month average mercury concentration in water (grab samples) at Station 17 (EFK 23.4).

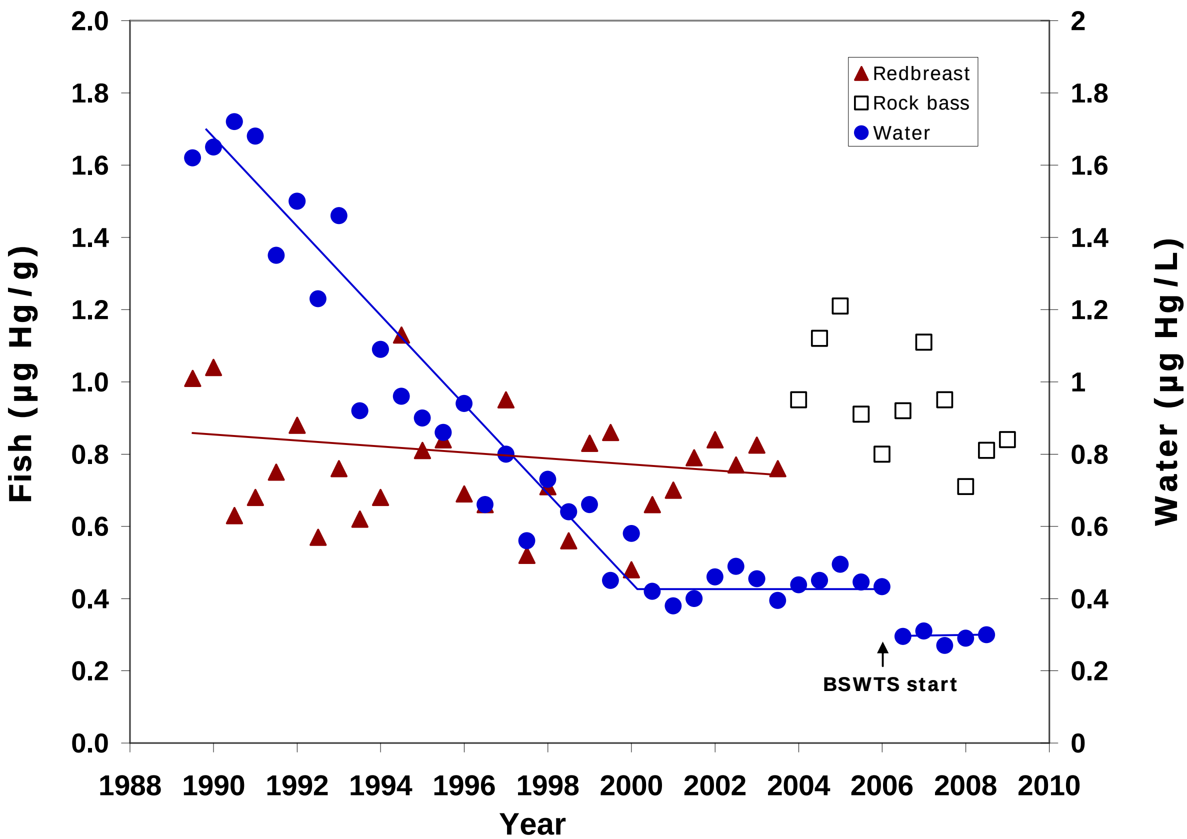

Fig. 2.2. Long-term trend in mean concentration of mercury in redbreast sunfish and rock bass at EFK 23.4 versus 6-month average mercury concentration in water (grab samples) at Station 17 (EFK 23.4).

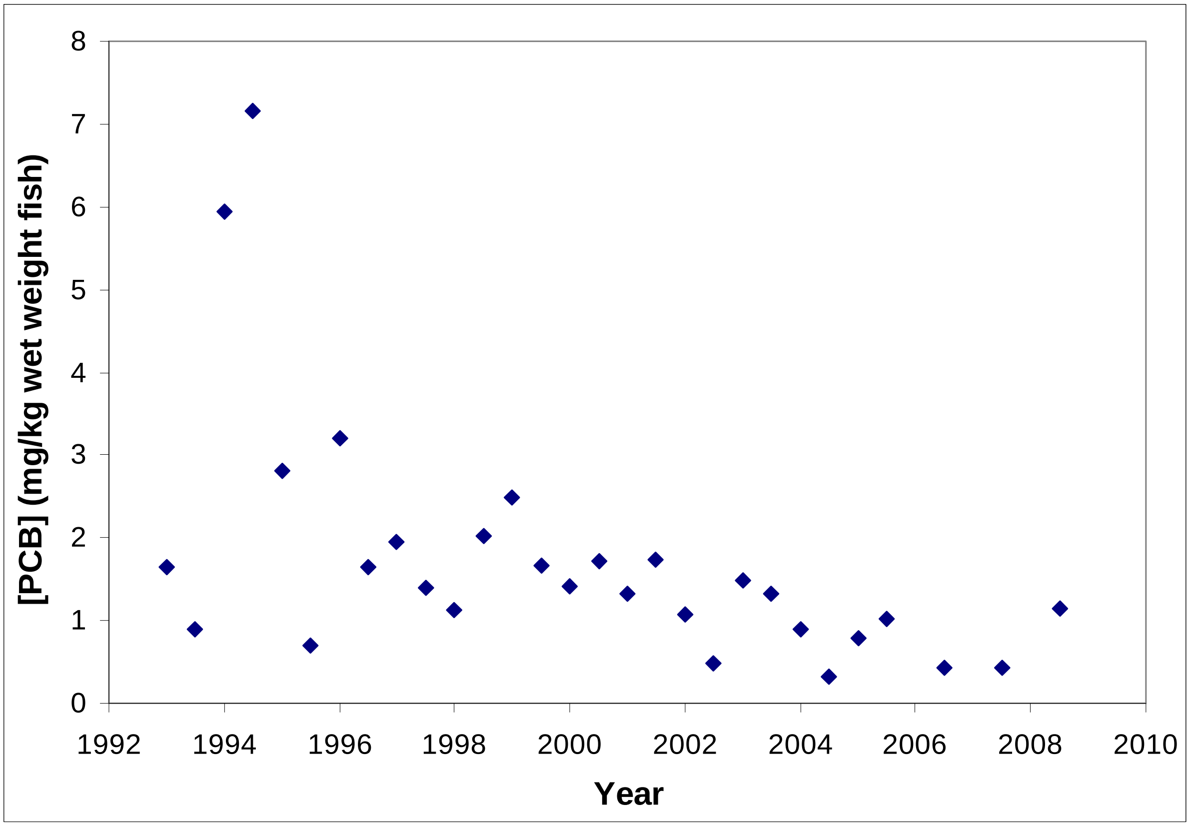

Fig. 2.3 Mean PCB concentrations in redbreast sunfish at EFK 24.2 over time.

3. Benthic Macroinvertebrate Community Monitoring

3.1 Introduction

The objectives of the benthic macroinvertebrate task are to monitor the benthic macroinvertebrate community in EFPC in order to provide information on the ecological condition of the stream and to evaluate the responses of macroinvertebrates to operational changes, abatement activities, or remedial actions at the Y-12 Complex as a measure of the effectiveness of these actions. To meet these objectives, routine quantitative benthic macroinvertebrate samples have been collected at least twice each year (April and October) since June 1985 from at least three sites in EFPC (EFK 24.4, EFK 23.4, and EFK 13.8). Two nearby reference sites on streams unimpacted by industrial discharges also have been monitored, including one site each on Brushy Fork (BFK 7.6) and Hinds Creek (HCK 20.6) (Figs.1.1 and 1.2). As required by TDEC for the Y-12 Complex NPDES permit, benthic macroinvertebrate samples also were collected in late FY2008 following TDEC sampling protocols (TDEC 2006). This report summarizes the results of samples collected in 2008, as well as, temporal trends.

3.2 Results/Progress

Results for benthic macroinvertebrate samples collected in 2008 following TDEC protocols are presented in Table 3.1, and a summary plot of the resulting Biotic Index scores from 2005-2008 is presented in Fig 3.1. Biotic Index scores have fluctuated between years at EFK 23.4 and HCK 20.6, but narrative ratings for these sites have not changed since 2005. EFK 23.4 has consistently biotic condition rating of slightly-impaired and HCK 20.6 has always had a rating of non-impaired. The index score for EFK 24.4 increased enough in 2007 to increase it's narrative rating to slightly-impaired in 2007, and in 2008 EFK 24.4 again rated as slightly impaired. Scores for EFK 13.8 and BFK 7.6 have fluctuated between ratings of slightly-impaired to non-impaired since 2005, with both sites having non-impaired ratings in 2008. For a site in which chemical and physical changes have reached steady state conditions long enough for the macroinvertebrate community structure and composition to reach steady-state conditions that are borderline between two impairment ratings, annual fluctuations between the two ratings would be excepted. Under steady-state conditions, invertebrate community structure and composition naturally fluctuate between years because of natural changes in prevailing environmental conditions (e.g., weather), and these changes would affect metric scores. Given the size of Brushy Fork's watershed and the predominance of agricultural landuse (particularly livestock grazing), some impairment of biological conditions is not be surprising.

Results for samples collected in 2008 with ORNL protocols are summarized in Fig. 3.2. Results in both April and October 2008 were generally similar to results from 2007, indicating that no major changes occurred in the macroinvertebrate community at any site in 2008. The macroinvertebrate community at EFK's 23.4 and 24.4 continues to be degraded relative to the reference sites, while the macroinvertebrate community at EFK 13.8 remains minimally degraded. Long-term trends in macroinvertebrate community metrics indicate that the magnitude of degradation varies seasonally. Differences between EFK 24.4 and EFK 23.4 are minimal in April, while in October the number of taxa (total and EPT) is somewhat higher at EFK 23.4. Similarly, the number of taxa (total and EPT) at EFK 13.8 is comparable to the reference sites in April, but slightly less during October. Densities of pollution-intolerant EPT taxa are typically higher at EFK 13.8 than at the reference sites, but the combination of high EPT density and reduced EPT taxa richness indicates that the EPT taxa present are predominantly the most pollution-tolerant species within this group.

Table 3.1. Benthic macroinvertebrate community metric values, Biotic Index scores, and biological condition narrative ratings based on Tennessee Department of Environment and Conservation (TDEC) standard protocols, East Fork Poplar Creek, Brushy Fork (BFK 7.6) and Hinds Creek (HCK 20.6), September 9, 2008[a,b,c]

Site	Metric values							Metric scores							INDEX score	Narrative rating
	EPT	TAXA	%OC	%EPT	NCBI	% NUTOL	% CLING	EPT score	TAXA score	%OC score	%EPT score	NCBI score	% NUTOL score	%CLING score		
EFK 24.4	4	26	22.9	17.7	5.3	34.4	35.9	2	4	6	2	4	6	2	**26**	**Slightly impaired**
EFK 23.4	6	27	40.2	7.35	5.9	44.1	37.7	2	4	4	0	4	4	4	**22**	**Slightly impaired**
EFK 13.8	6	30	16.9	53.5	4.75	61.3	38.3	2	6	6	6	4	2	4	**30**	**Slightly impaired**
BFK 7.6	7	23	2.68	29.9	4.45	37.5	64.7	4	4	6	2	6	4	6	**32**	**Non-impaired**
HCK 20.6	10	32	7.7	66.3	5.33	24.3	37.6	4	6	6	6	4	6	4	**36**	**Non-impaired**

[a]EPT = EPT taxa richness; TAXA = total taxa richness; %OC = % oligochaetes and chironomids; %EPT = % EPT abundance; NCBI = North Carolina Biotic Index; % NUTOL = % nutrient tolerant taxa; %CLING = % abundance of clinger taxa.

[b]EFK = East Fork Poplar Creek kilometer; BFK = Brushy Fork kilometer (reference site); HCK = Hinds Creek kilometer (reference).

[c]Metric scoring and narrative ratings for Ecoregion 67f (TDEC 2006).

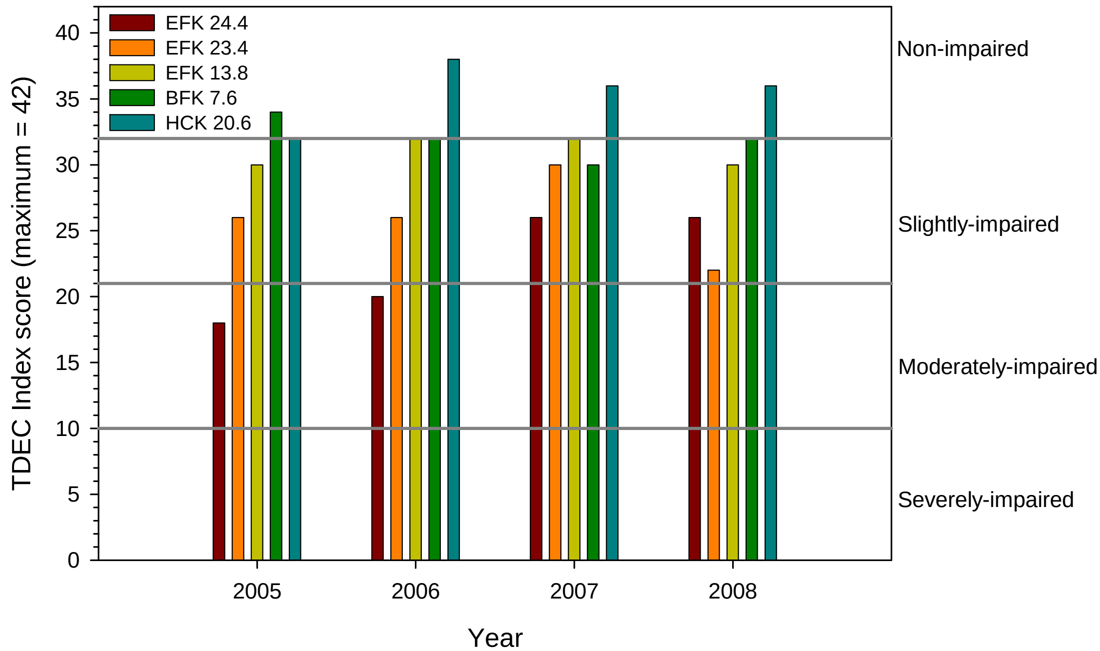

Fig. 3.1. Temporal trends in TDEC Biotic Index Scores for East Fork Poplar Creek, Brushy Fork (BFK 7.6) and Hinds Creek (HCK 20.6), August/September 2005 - 2008. Horizontal lines show the lower thresholds for biotic condition ratings; respective narrative ratings for each threshold are shown on right side of graph.

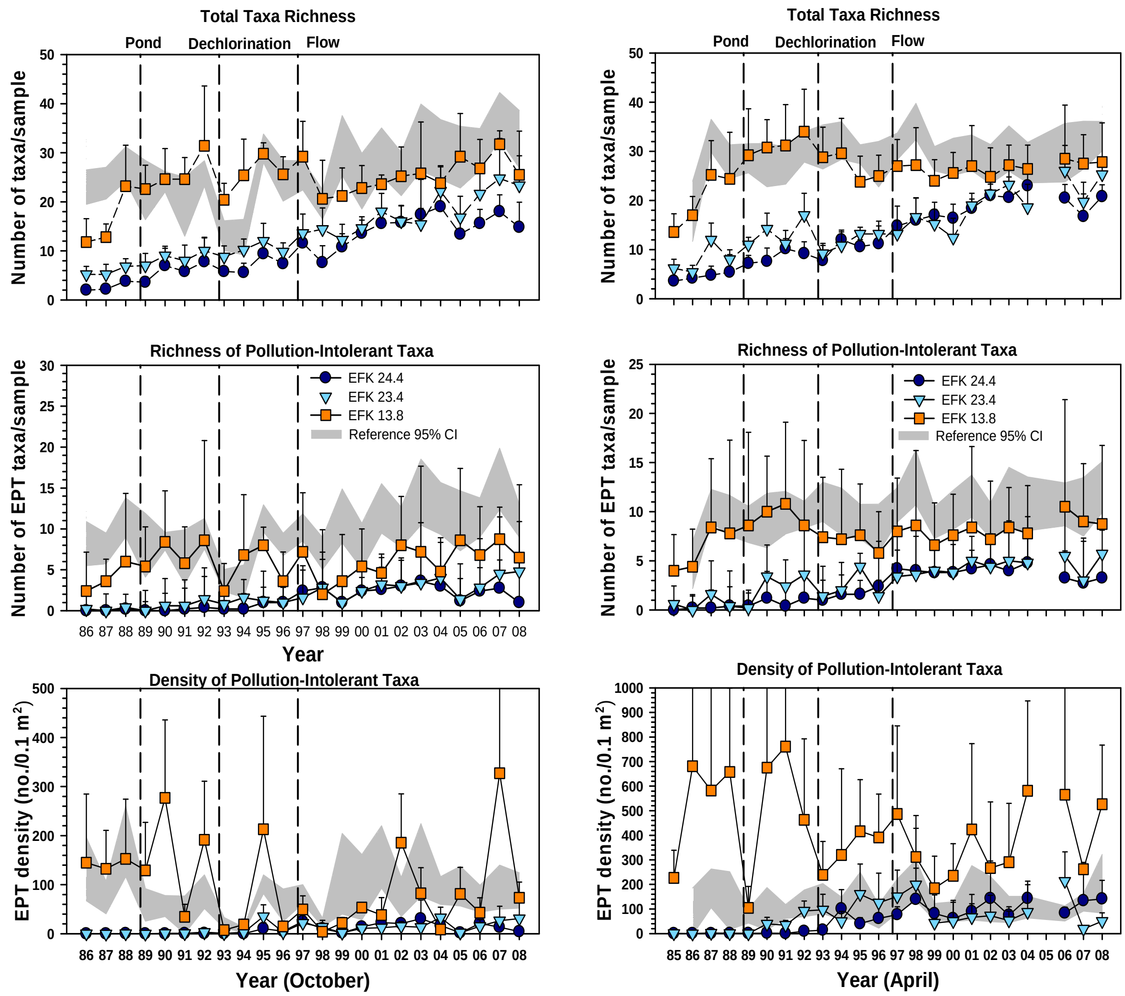

Fig. 3.2. Means and upper 95% confidence limits for taxonomic richness (number of taxa per sample), taxonomic richness of the pollution-intolerant Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (number of pollution-intolerant or EPT taxa/sample), and density of the pollution-intolerant taxa in the benthic macroinvertebrate communities at EFPC and reference streams, April and October sampling periods 1985-2008. The gray shading in each graph is the 95% confidence interval for reference site samples. Note the different scales on the y-axis between the April and October results for density of the pollution-intolerant taxa.

This condition is common in streams that are either recovering from or being subjected to a disturbance.

Dissolved oxygen concentrations and pH in EFPC and reference sites in 2008 were within normal ranges for streams in the Oak Ridge area (Table 3.2). Differences in seasonal changes in water temperatures evident between the EFPC and reference sites, illustrates one of the influences of flow management on EFPC. The raw water additions decrease the magnitude of differences between minimum and maximum temperatures, and generally keep temperatures cooler during the summer and warmer during the winter.

The influence of flow management was also evident from measurements of conductivity. The conductivity of streams in regions where the predominant geological formation is limestone generally increases as summer progresses because the proportion of stream flow from deep ground water increases (e.g., as is particularly evident at HCK 20.6). The concentrations of ions are normally elevated in deep ground water because it remains in contact with ion-rich minerals for much longer periods. Surface water runoff and shallow ground water, on the other hand, reach streams more rapidly, therefore, having less time to become enriched with ions that increase conductivity.

Discharge at EFKs 23.4 and 13.8 in September was ~ 9 times higher than at the reference sites because of raw water inputs for flow management (Table 3.2). Flow at EFK 24.4 was ~1.5 times less than at EFK 23.4 at this time because much of the water used for flow management was being discharged from the outfall just upstream of Station 17.

Habitat assessments following TDEC protocols (Arnwine and Denton 2001) indicated that the habitat score for EFK 24.4 (114) did not meet the TDEC goal for our ecoregion (i.e., score of ≥131; Table 3.3). EFPC within and in the vicinity of this sampling location has been extensively channelized, substrate quality is relatively poor, and the narrow riparian zone is dominated by early-growth woody vegetation. However, the riparian vegetation at EFK 24.4 has improved considerably in recent years, and now provides moderate shading over the stream channel (i.e., canopy cover, Table 3.2). EFK 23.4 receives similarly low scores for riparian vegetation (though less canopy cover; Table 3.3), but has better channel structure (i.e., more ideal riffle-pool frequency) and a more heterogeneous mixture of substrate sizes with relatively low embeddedness. Habitat at BFK 7.6 has rated as marginally acceptable since 2005, fluctuating between passing and failing scores primarily from the effects of wide-scale meteorological conditions (i.e., drought versus non-drought conditions), and lower quality substrate associated with the effects of surface water runoff and erosion caused by landuse practices in the watershed.

Table 3.2. East Fork Poplar Creek, Brushy Fork (BFK 7.6) and Hinds Creek (HCK 20.6) water quality results and physical characteristic measurements at benthic macroinvertebrate community monitoring sites, 2008

Site	Geographic coordinates[a]	D.O. (mg/L)			Temperature (°C)			pH			Conductivity (µS/cm)			Canopy cover (%)[b,c]	Discharge[c,d]	
		Apr	Sept	Oct	Apr	Sept	Oct	Apr	Sept	Oct	Apr	Sept	Oct		(L/sec)	(ft^3/sec)
EFK 24.4	35.98941 N 84.24285 E	6.1	8.7	8.0	15.9	18.3	15.1	7.9	7.9	7.9	250.0	261.0	235.0	72.1	264.4	9.35
EFK 23.4	35.99607 N 84.24026 E	6.3	10.6	8.7	15.7	18.6	14.4	8.4	7.9	8.2	249.4	262.9	237.2	0.0	401.8	14.19
EFK 13.8	35.9930315 N 84.314583 E	6.3	10.0	8.7	14.7	20.4	11.3	8.0	8.0	8.2	242.3	290.2	225.9	0.0	401.0	14.16
BFK 7.6	36.0543823 N 84.2334888 E	7.0	7.1	8.3	12.6	22.0	8.3	8.1	8.0	7.5	170.4	291.3	209.4	81.1	44.5	1.57
HCK 20.6	36.1578921 N 83.9996461 E	7.4	8.5	11.0	10.0	22.1	6.8	8.2	8.0	7.8	214.2	348.2	236.0	78.4	46.1	1.63

[a]Coordinates in decimal-degrees, Datum NAD27.
[b]Canopy covered measured with a spherical densiometer.
[c]Canopy cover and discharge were measured in September only.
[d]Discharge measured with a Marsh-McBirney Model 201 portable flow meter.

Table 3.3. Habitat assessment results for benthic macroinvertebrate community sampling sites in East Fork Poplar Creek and reference streams, September 9, 2008. Results are based on Tennessee Department of Environment and Conservation standard protocols for stream habitat assessments (Arnwine and Denton 2001)

Habitat parameter	**Sampling site/habitat score**				
	EFK 24.4	**EFK 23.4**	**EFK 13.8**	**BFK 7.6**	**HCK 20.6**
1. Epifaunal substrate/available cover	12	15	18	14	18
2. Embeddedness	8	15	14	11	13
3. Velocity/depth regime	18	18	20	16	20
4. Sediment deposition	9	15	15	14	16
5. Channel flow	20	20	20	15	15
6. Channel alteration	5	7	16	20	20
7. Frequency of riffles	19	18	15	14	20
8. Bank stability					
Left	6	9	8	5	4
Right	6	9	4	7	6
9. Vegetative protection					
Left	5	2	9	6	8
Right	2	2	9	8	10
10. Riparian vegetative zone width					
Left	2	2	9	10	2
Right	2	2	9	8	10
Total score	**114**	**134**	**166**	**148**	**162**
Ecoregion 67f habitat goal (≥131)	**Fail**	Pass	Pass	Pass	Pass

4. Fish Community Monitoring

4.1 Introduction

Fish population and community studies can be used to assess the ecological effects of water quality and/or habitat degradation. Fish communities, for example, include several trophic levels, and species that are at or near the end of food chains. Consequently, they integrate the direct effects of water quality and habitat degradation on primary producers (periphyton) and consumers (benthic invertebrates) that are utilized for food. Because of these trophic interrelationships, the well-being of fish populations has often been used as an index of water quality. Moreover, statements about the condition of the fish community are easily understood by the general public.

The primary activities conducted by the Fish Community Studies task in (EFPC) are: (1) biannual, quantitative estimates of the fish community at five EFPC sites and one reference stream site, and (2) if necessary, investigative procedures in response to fish kills near the Y-12 Security Complex. No fish kill events were reported in 2008 in EFPC. The quantitative sampling of fish populations at sites is conducted by electrofishing in March and September. The samples are based on multiple pass removal estimates using standard procedures (Adams et al. 1998). The sampling was conducted at one reference site and five EFPC sites, following the sample plan. The resulting data were used to estimate population size (numbers and biomass per unit area), and calculate Index of Biotic Integrity (IBI) values using procedures developed (Table 4.1) for EFPC sites (Ryon and Schilling 1998).

4.2 Results/Progress

Sampling in 2008 did not reveal any dramatic changes in species richness, density, or biomass in the spring (Table 4.2) or fall (Table 4.3). Redhorse suckers and darters, species sensitive to stress, continued to be more wide spread in 2008 samples compared to earlier samples, suggesting continued improvement in the fish communities. For example, the dusky darter (*Percina sciera*) was found at a second location, EFK 13.8, during the fall sample. This species had previously been found only at one other location in EFPC in 1999. The populations of other more abundant species, such as the minnows, remained fairly stable. Elsewhere in EFPC, no specimens of the federally threatened spotfin chub (*Erimonax monachus*) were collected.

Table 4.1. Index of Biotic Integrity (IBI) metrics used to assess fish communities in streams near Oak Ridge, Tennessee, in the Clinch River system

Category		Metric	Scoring criteria		
			5	3	1
Species richness and composition	1.	Total number of fish species[a]	>30	30-15	<15
	2.	Number and identity of darter species	>5 5-4	<4	
	3.	Number and identity of sunfish species	>4 4-2	<2	
	4.	Number and identity of sucker species	>4 4-2	<2	
	5.	Number and identity of sensitive species[b]	>13	13-7	<7
	6.	Proportion of individuals as tolerant species	<5%	5-20%	>20%
Trophic composition	7.	Proportion of individuals as generalist feeders	<20%	20-45%	>45%
	8.	Proportion of individuals as benthic insectivores	>45%	45-20%	<20%
	9.	Proportion of individuals as piscivores	>5%	5-1%	<1%
Fish abundance	10.	Density, individuals/m^2			
		EFK 24.4, 23.4	5.4-1.9	1.8-0.8	<0.8; >5.4
		EFK 18.7, 13.8	4.2-1.5	1.4-0.6	<0.6; >4.2
		EFK 6.3	3.6-1.3	1.2-0.2	<0.2; >3.6
		BFK 7.6	4.5-1.6	1.5-0.6	<0.6; >4.5
		HCK20.9	3.6-1.3	1.2-0.2	<0.2; >3.6
	11.	Proportion of individuals as lithophilic spawners[c]	>36%	36-18%	<18%
	12.	Proportion of individuals with disease, skin tumors, fin damage, skeletal anomalies, or external parasites	0-2%	>2-5%	>5%

[a]Number of native species, excluding recent introductions or stocked species.

[b]Sensitive species ranked as very intolerant, moderately intolerant, or slightly intolerant to stress, with a correction factor of 1.25, 1.0, or 0.8, respectively applied to the number in each category to achieve the numbers used in the criteria rankings.

[c]Percentages as used in Ohio EPA (1988).

Table 4.2. Fish density (number of fish/m²), biomass (g/m², in parentheses), and Index of Biotic Integrity (IBI) values (at bottom of table) for March 2008 in East Fork Poplar Creek (EFK)[a] and the reference site, Brushy Fork (BFK)

Species	EFK 24.4	EFK 23.4	EFK 18.7	EFK 13.8	EFK 6.3	BFK 7.6
Lampreys						
American brook lamprey *Lampetra appendix*						0.03 (0.16)
Minnows						
Largescale stoneroller *Campostoma oligolepis*	2.52 (27.87)	6.05 (32.92)	0.68 (6.47)	0.39 (4.38)	0.15 (1.16)	0.03 (0.16)
Spotfin shiner *Cyprinella spiloptera*					<0.01 (0.01)	
Bigeye chub *Hybopsis amblops*				0.02 (0.05)	0.03 (0.06)	0.01 (0.03)
Striped shiner *Luxilus crysoleucas*	0.52 (2.61)	1.93 (9.04)	0.21 (1.36)	0.50 (1.91)	0.35 (1.16)	0.17 (1.14)
Rosefin shiner *Lythrurus ardens*			<0.01 (<0.01)	0.03 (0.03)	0.01 (<0.01)	0.13 (0.15)
Emerald shiner *Notropis atherinoides*					<0.01 (0.01)	
Bluntnose minnow *Pimephales notatus*				0.02 (0.05)		
Fathead minnow *P. promelas*				<0.01 (<0.01)		
Western blacknose dace *Rhinichthys obtusus*	2.13 (3.09)	1.87 (2.37)	0.08 (0.14)	0.02 (0.03)		0.01 (0.01)
Creek chub *Semotilus atromaculatus*		<0.01 (<0.01)		<0.01 (<0.01)		
Suckers						
White sucker *Catostomus commersoni*			0.01 (0.21)	<0.01 (0.05)		
Northern hog sucker *Hypentelium nigricans*		0.05 (1.67)	0.05 (0.78)	0.01 (1.20)	0.05 (0.90)	0.01 (0.38)
Spotted sucker *Minytrema melanops*					<0.01 (0.12)	<0.01 (0.27)
Black redhorse *Moxostoma duquesnei*					<0.01 (0.26)	<0.01 (0.07)
Golden redhorse *M. erythrurum*			0.01 (0.02)	<0.01 (0.09)	<0.01 (0.38)	<0.01 (0.25)
Livebearers						
Western mosquitofish *Gambusia affinis*		0.02 (0.01)			<0.01 (<0.01)	0.02 (0.01)

Species	EFK 24.4	EFK 23.4	EFK 18.7	EFK 13.8	EFK 6.3	BFK 7.6
Sculpins						
Banded sculpin *Cottus carolinae*				0.07 (0.32)	0.05 (0.36)	0.18 (1.18)
Sunfishes						
Rock bass *Ambloplites rupestris*			0.02 (0.71)	0.02 (0.92)	0.01 (0.07)	0.04 (2.10)
Redbreast sunfish *Lepomis auritus*	0.01 (0.15)		<0.01 (<0.01)	0.01 (0.20)	0.05 (1.58)	0.05 (0.29)
Green sunfish *L. cyanellus*					0.03 (0.29)	
Warmouth *L. gulosus*				<0.01 (0.08)	<0.01 (0.03)	<0.01 (0.10)
Bluegill *L. macrochirus*		0.10 (1.01)	0.01 (0.25)	0.01 (0.23)	0.02 (1.13)	0.01 (0.07)
Redear sunfish *L. microlophus*					<0.01 (0.08)	
Spotted bass *Micropterus punctulatus*					<0.01 (0.02)	<0.01 (<0.01)
Largemouth bass *M. salmoides*		<0.01 (0.64)	<0.01 (0.36)		0.01 (1.42)	
Perches						
Greenside darter *Etheostoma blenniodes*			0.01 (0.08)	0.01 (0.08)	0.01 (0.02)	<0.01 (<0.01)
Blueside darter *E. jessiae*					0.01 (0.01)	0.04 (0.06)
Stripetail darter *E. kennicotti*				<0.01 (<0.01)		0.01 (0.01)
Redline darter *E. rufilineatum*			0.01 (0.02)	0.02 (0.03)	0.01 (0.01)	<0.01 (<0.01)
Snubnose darter *E. simoterum*		0.16 (0.34)	0.14 (0.11)	0.08 (0.08)	0.14 (0.14)	0.10 (0.11)
Logperch *Percina caprodes*					0.03 (0.25)	
Species richness	4	9	14	21	25	22
Density	5.28	10.18	1.23	1.21	0.97	0.85
Biomass	33.72	48.01	10.51	9.72	9.46	6.55
IBI number and (rating)[b]	26 (P)	20 (VP)	30 (P)	36 (P-F)	40 (F)	38 (P-F)

[a]Site designated by stream kilometer. [b]IBI numbers range from 12 (minimum) to 60 (maximum); ratings are as follows: very poor (12-22), poor (28-34), fair (40-44), good (48-52), and excellent (58-60), as per Karr (1981).

Table 4.3. Fish density (number of fish/m²), biomass (g/m², in parentheses), and Index of Biotic Integrity (IBI) values (at bottom of table) for September 2008 in East Fork Poplar Creek (EFK)[a] and the reference site, Brushy Fork (BFK)

Species	EFK 24.4[b]	EFK 23.4	EFK 18.7	EFK 13.8	EFK 6.3	BFK 7.6
Lampreys						
American brook lamprey *Lampetra appendix*	NS					0.05 (0.32)
Minnows						
Largescale stoneroller *Campostoma oligolepis*		3.85 (8.31)	0.20 (0.86)	0.31 (1.53)	0.09 (0.13)	0.10 (0.11)
Spotfin shiner *Cyprinella spiloptera*						<0.01 (<0.01)
Bigeye chub *Hybopsis amblops*			<0.01 (<0.01)	0.02 (0.03)	0.01 (0.03)	0.10 (0.15)
Striped shiner *Luxilus crysoleucas*		1.73 (7.44)	0.44 (2.25)	0.58 (2.45)	0.28 (0.95)	0.63 (3.49)
Rosefin shiner *Lythrurus ardens*			<0.01 (<0.01)	0.03 (0.03)	0.01 (<0.01)	0.23 (0.24)
Emerald shiner *Notropis athernoides*				<0.01 (0.01)		
Bluntnose minnow *Pimephales notatus*				0.02 (0.03)		
Western blacknose dace *Rhinichthys obtusus*		2.58 (2.83)	0.16 (0.24)	0.02 (0.02)	0.01 (0.01)	0.06 (0.07)
Creek chub *Semotilus atromaculatus*		0.03 (0.06)	0.01 (0.01)	0.03 (0.04)	0.01 (0.01)	0.01 (0.03)
Suckers						
White sucker *Catostomus commersoni*		0.01 (0.29)	0.01 (0.18)	<0.01 (0.09)		0.02 (0.57)
Northern hog sucker *Hypentelium nigricans*		0.17 (3.85)	0.07 (2.34)	0.05 (1.92)	0.05 (1.65)	0.05 (1.13)
Spotted sucker *Minytrema melanops*					<0.01 (0.09)	0.01 (0.02)
Black redhorse *Moxostoma duquesnei*		0.01 (0.18)	<0.01 (0.10)	<0.01 (0.03)	<0.01 (0.04)	<0.01 (0.01)
Golden redhorse *M. erythrurum*				<0.01 (0.02)	<0.01 (0.25)	0.01 (0.59)
Catfishes						
Yellow bullhead *Ameiurus natalis*				<0.01 (0.34)		<0.01 (0.07)

Species	EFK 24.4[b]	EFK 23.4	EFK 18.7	EFK 13.8	EFK 6.3	BFK 7.6
Livebearers						
Western mosquitofish *Gambusia affinis*		0.05 (0.01)	<0.01 (<0.01)	0.06 (0.03)	0.01 (<0.01)	0.26 (0.07)
Sculpins						
Banded sculpin *Cottus carolinae*			<0.01 (0.01)	0.07 (0.37)	0.03 (0.10)	0.21 (0.60)
Sunfishes						
Rock bass *Ambloplites rupestris*		<0.01 (0.14)	0.05 (2.06)	0.05 (1.57)	0.01 (0.48)	0.06 (1.75)
Redbreast sunfish *Lepomis auritus*		<0.01 (0.06)	<0.01 (0.05)	0.01 (0.29)	0.05 (1.41)	0.12 (0.85)
Green sunfish *L. cyanellus*				0.01 (0.10)	0.01 (0.21)	
Warmouth *L. gulosus*				0.01 (0.01)		
Bluegill *L. macrochirus*		0.14 (4.40)	<0.01 (0.08)	0.01 (0.34)	0.01 (0.29)	0.01 (0.07)
Hybrid sunfish *L. sp. X sp.*		<0.01 (0.10)		0.01 (0.01)		
Spotted bass *Micropterus punctulatus*					<0.01 (0.01)	
Largemouth bass *M. salmoides*		<0.01 (0.48)		<0.01 (0.12)	<0.01 (0.27)	
Perches						
Greenside darter *Etheostoma blenniodes*			0.02 (0.13)	0.03 (0.09)	0.01 (0.03)	0.01 (0.05)
Blueside darter *E. jessiae*					<0.01 (<0.01)	0.05 (0.07)
Stripetail darter *E. kennicotti*				0.01 (<0.01)		0.04 (0.03)
Redline darter *E. rufilineatum*			<0.01 (0.01)	0.03 (0.03)	0.02 (0.02)	0.01 (<0.01)
Snubnose darter *E. simoterum*		0.08 (0.16)	0.07 (0.05)	0.07 (0.07)	0.09 (0.07)	0.40 (0.20)
Logperch *Percina caprodes*				<0.01 (0.02)	0.02 (0.15)	
Dusky darter *P. sciera*				<0.01 (0.01)		
Species richness	NS	13	17	27	23	24
Density		8.65	1.04	1.42	0.73	2.44
Biomass		28.31	8.37	9.59	6.20	10.49

Species	EFK 24.4[b]	EFK 23.4	EFK 18.7	EFK 13.8	EFK 6.3	BFK 7.6
IBI number and (rating)[c]		24 (VP-P)	32 (P)	42 (F)	38 (P-F)	42 (F)

[a]Site designated by stream kilometer.
[b]NS = site not sampled this period.
[c]IBI numbers range from 12 (minimum) to 60 (maximum); ratings are as follows: very poor (12-22), poor (28-34), fair (40-44), good (48-52), and excellent (58-60), as per Karr (1981).

Integrating the 2008 species richness data into the long term data set (Figure 4.1) suggests several trends:

1. Improvement has occurred at all sites;
2. Recent changes have been less dramatic, with only minor improvements in past 5 years;
3. EFK 6.3 and EFK 13.8 have approached or passed reference conditions in overall species richness;
4. The most upstream site, EFK 24.4, remains isolated from rest of watershed with no improvement in species richness in past decade.

Similar improvements in density and biomass were also observed (Figures 4.2 and 4.3). Long-term improvements have occurred at most sites, although statistically significant only at EFK 24.4, EFK 23.4 and EFK 13.8. Densities at EFK 18.7 had been gradually declining over the past 5 years, but increases occurred during 2008. Densities at EFK 24.4 and EFK 23.4 remained much higher than the reference site suggesting some sort of enhanced production. This may reflect the dominance of the community by species fairly tolerant to stress, or it may be a result of nutrient enrichment. At EFK 6.3 and EFK 13.8, the presence of sensitive species, such as darters, at densities lower than at the reference stream indicate that recovery of lower EFPC is not complete.

The status of the EFPC sites relative to other streams in Tennessee is demonstrated by the IBI scores (Tables 4.2 and 4.3). The two upstream sites closest to the Y-12 Complex were consistently rated as very poor to poor. They rate very low in the species richness and composition metrics. As you progress downstream, the ratings improve overall slightly until the communities can be described as bordering on fair. The IBI improvements are related to increases in both richness and trophic level metrics. Finally, except for EFK 6.3 in the spring and EFK 13.8 in the fall, the EFPC IBI scores were slightly lower than those seen at the reference site, which were generally a fair designation. The failure of the reference site to consistently rate as good or excellent reflects stream conditions that might be expected in this area in the absence of the Y-12 Complex: That is, streams would still be stressed from rural or urban influences.

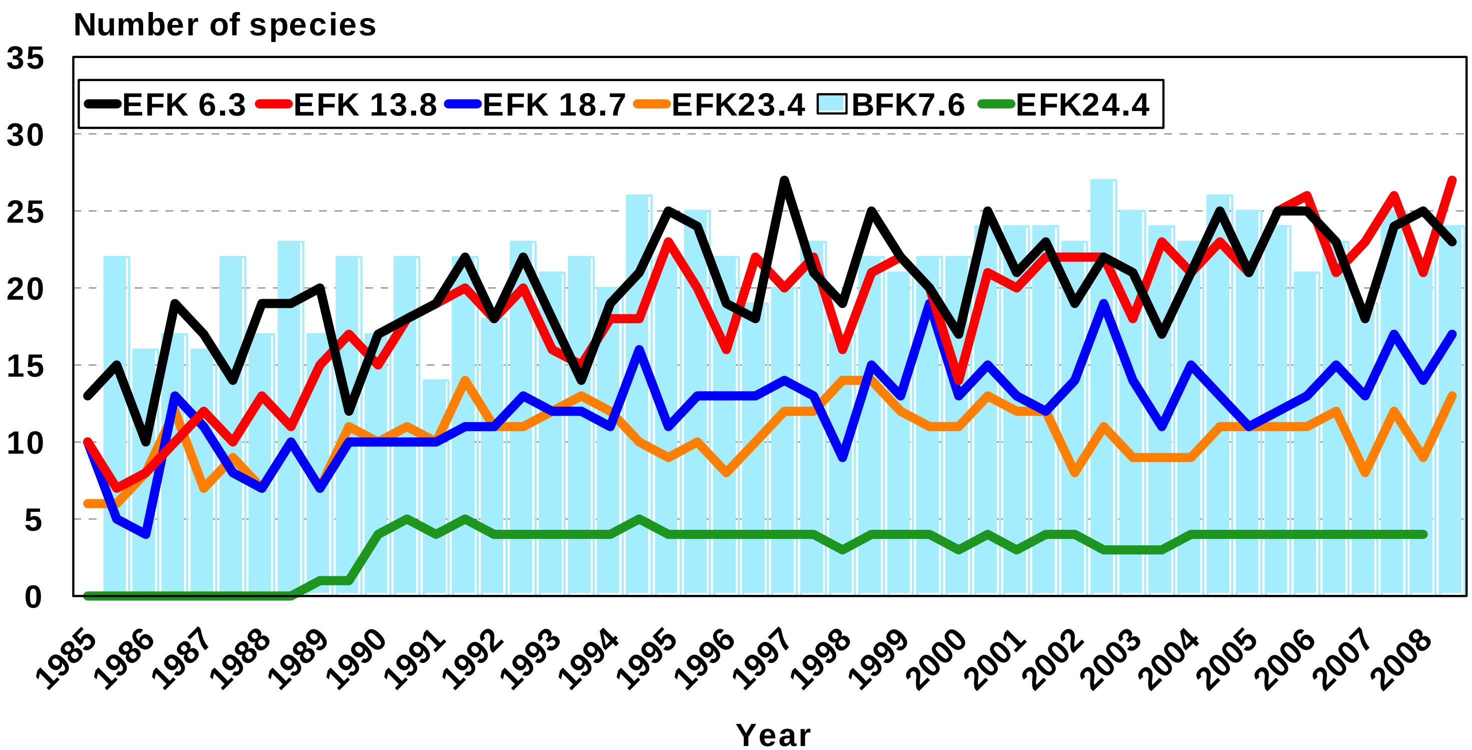

Fig. 4.1. Species richness (number of fish species) of fish communities in East Fork Poplar Creek (EFK) and a reference stream, Brushy Fork (BFK), 1985 through 2008.

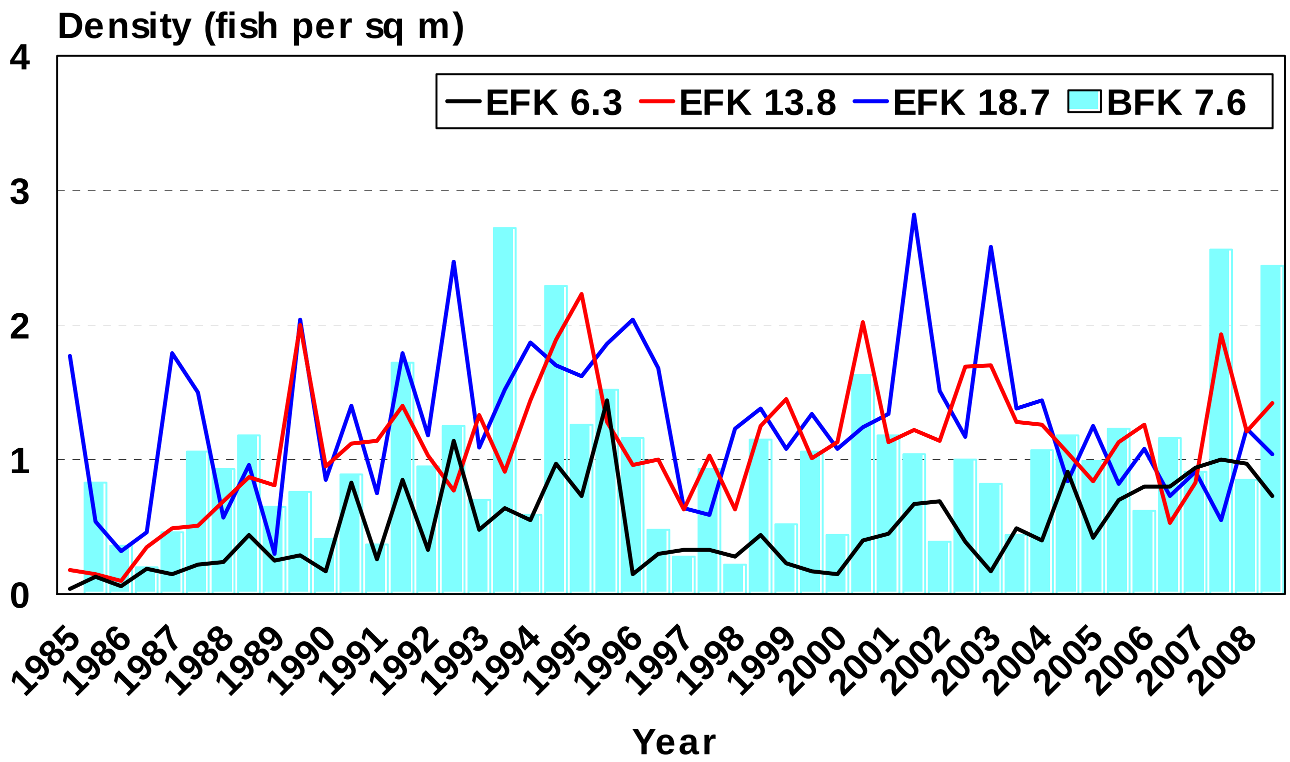

Fig. 4.2. Total density (fish/m^2) of fish communities in lower East Fork Poplar Creek (EFK) and a reference stream, Brushy Fork (BFK), 1985 through 2008.

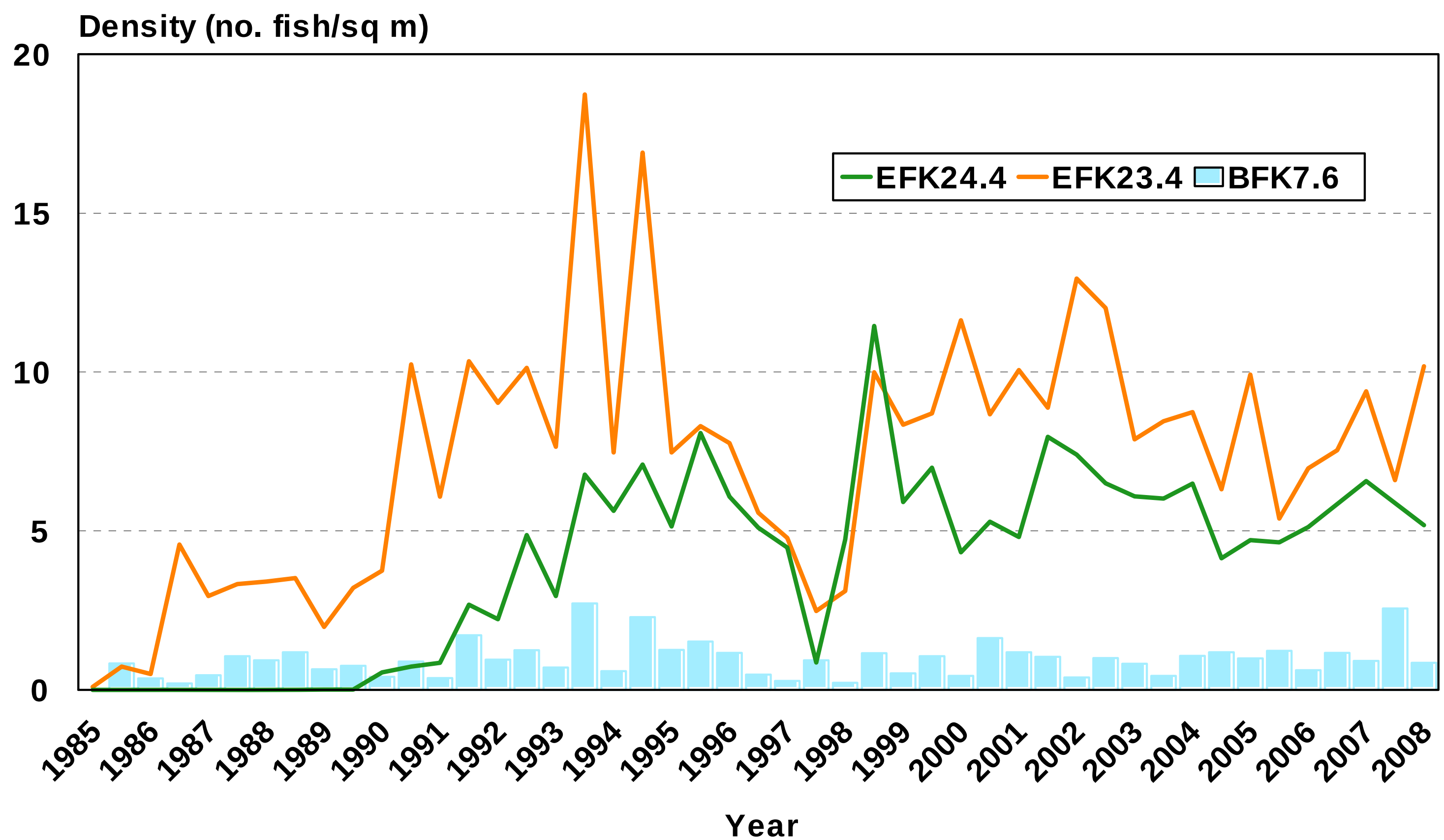

Fig. 4.3. Total density (fish/m^2) of fish communities in upper East Fork Poplar Creek (EFK) and a reference stream, Brushy Fork (BFK), 1985 through 2008.

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Appendix A

BEAR CREEK MONITORING

The Bear Creek monitoring summary provided herein includes a summary of fish bioaccumulation and fish community monitoring results (A.1), a summary of benthic macroinvertebrate community results (A.2), and a summary of the toxicity testing results from the watershed (A.3). The biomonitoring write-up in A.1 is excerpted by permission with limited modification (including original figure and table numeration) from the D1 2009 Remediation Effectiveness Report (covering FY 2008 data). Section A.2 includes results reported in the D1 2009 Remediation Effectiveness Report, as well as, results from samples collected in October 2008.

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Appendix A. BEAR CREEK MONITORING

A.1 SUMMARY FROM THE 2009 REMEDIATION EFFECTIVENESS REPORT (D1)

Bear Creek Valley Aquatic Biological Monitoring

To evaluate instream contaminant exposure and potential human and ecological risks in the Bear Creek Watershed, fish are collected twice a year and analyzed for a suite of metals and PCBs at sampling locations BCK 3.3, BCK 9.9, and BCK 12.4 (Figure 4.1). An evaluation of overall ecological health of the streams is conducted by monitoring fish and benthic macroinvertebrate communities at BCK 3.3, BCK 4.6, BCK 9.9, BCK 12.4, and NT-3 (a tributary to Bear Creek).

Mercury concentrations in rock bass from lower Bear Creek remained above 0.55 µg/g in Fall 2007 and Spring 2008 (Figure 4.11), approximately 3-fold higher than rock bass from the Hinds Creek reference site (Hinds Creek mean of 0.18 µg/g) and above the EPA-recommended AWQC of 0.3 µg/g. Concentrations of nickel, cadmium, and uranium have historically exceeded reference concentrations in stoneroller minnows from upper Bear Creek (associated with the S-3 site plume), and maintained that trend through 2008 (Figure 4.12, Figure 4.13, Figure 4.14). In general, these metals decrease in fish with distance downstream, with the exception of uranium where the BCK 9.9 and BKC 12.4 sites have similar levels in fish in some years (including spring of 2008). The uranium concentration in fish from BCK 12.4 in Fall 2007 was the second highest to-date, presumably due to the drought and relatively high inputs of deep groundwater during this period. PCB concentrations in stoneroller minnows in Fall 2007 and Spring 2008 averaged between 3-5 µg/g, continuing high levels in fish but well within historical levels (Figure 4.15).

The fish communities in Bear Creek have generally been stable or display minor variation in terms of species richness in recent samples (Figure 4.16). The downstream sites (BCK 3.3 and BCK 4.6) have appropriate values for their size compared to a larger reference stream (BFK 7.6) and a smaller reference stream (MBK 1.6). This is especially encouraging for BCK 4.6 as it is located in the middle of the stream restoration section where a new stream channel and habitat were created. The sample site in the middle section of Bear Creek (BCK 9.9) has shown a steady increase in species richness, aided perhaps in recent years by the bypass of the downstream weir near BCK 4.6 which allowed more upstream migration of fish species. BCK 12.4 and NT-3 fish communities are at or slightly below total richness values of comparable reference streams, (MBK 1.6 and PHK 1.6) suggesting they are more susceptible to stress, e.g., from below normal rainfall.

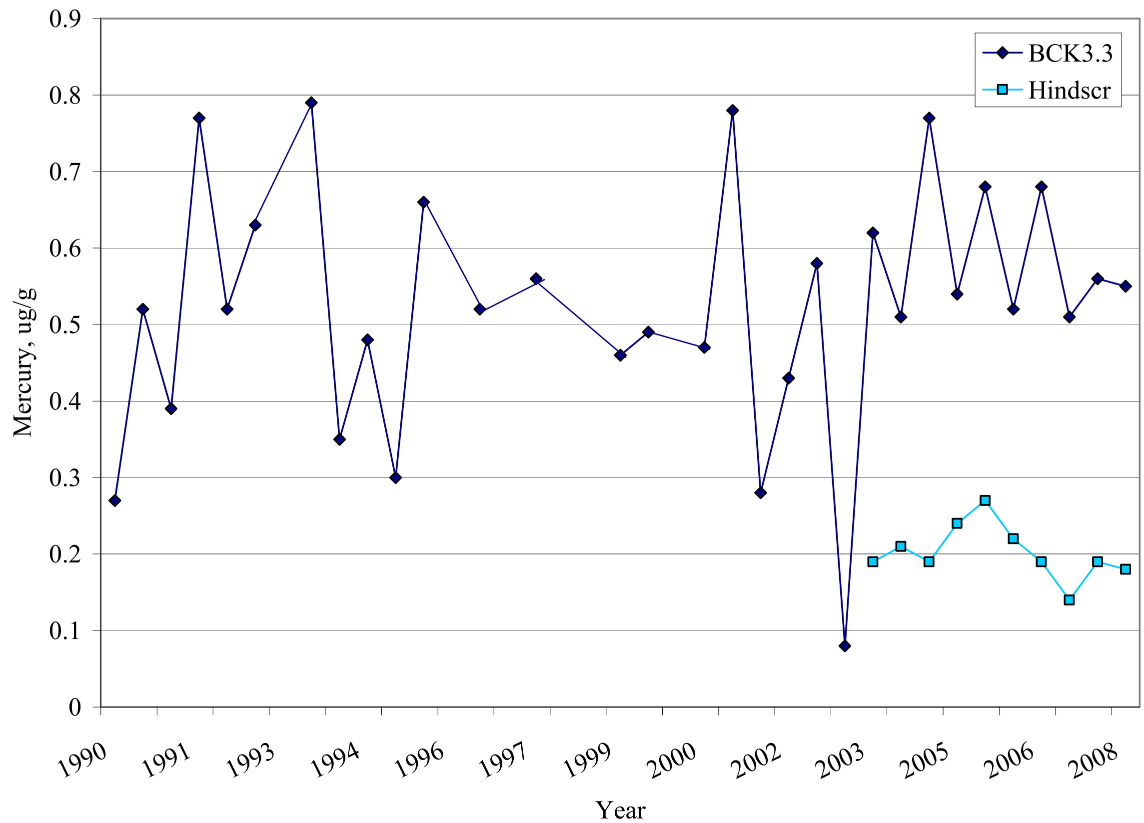

Fig. 4.11. Mean concentrations of mercury in rock bass from lower Bear Creek, BCK 3.3, 1987–2008.

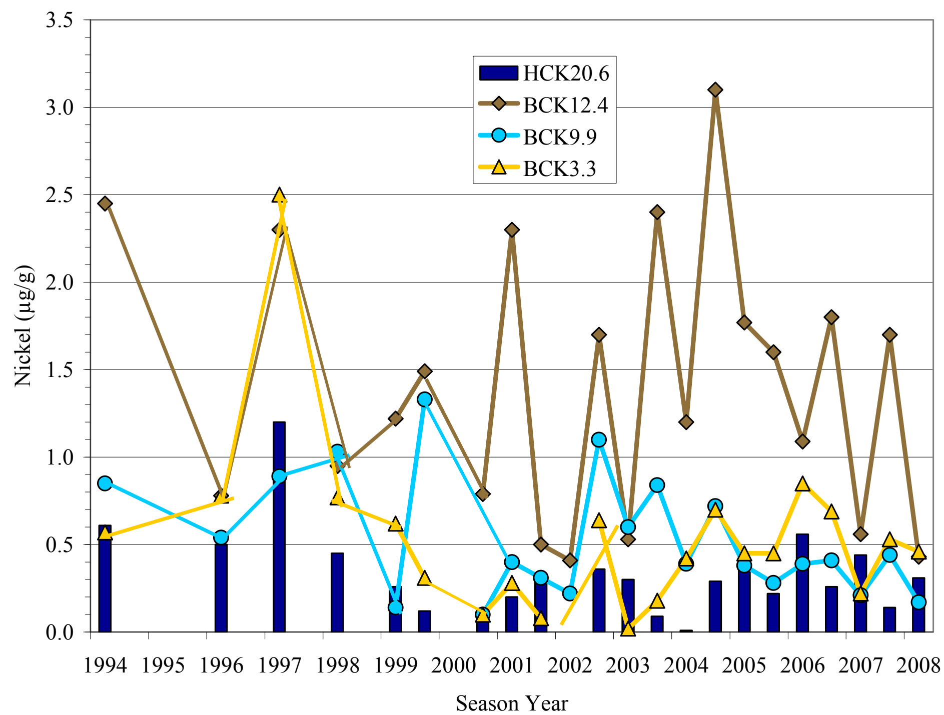

Fig. 4.12. Mean nickel concentrations in stoneroller minnows at three sites in Bear Creek and a reference site (HCK 20.6), 1994–2008.

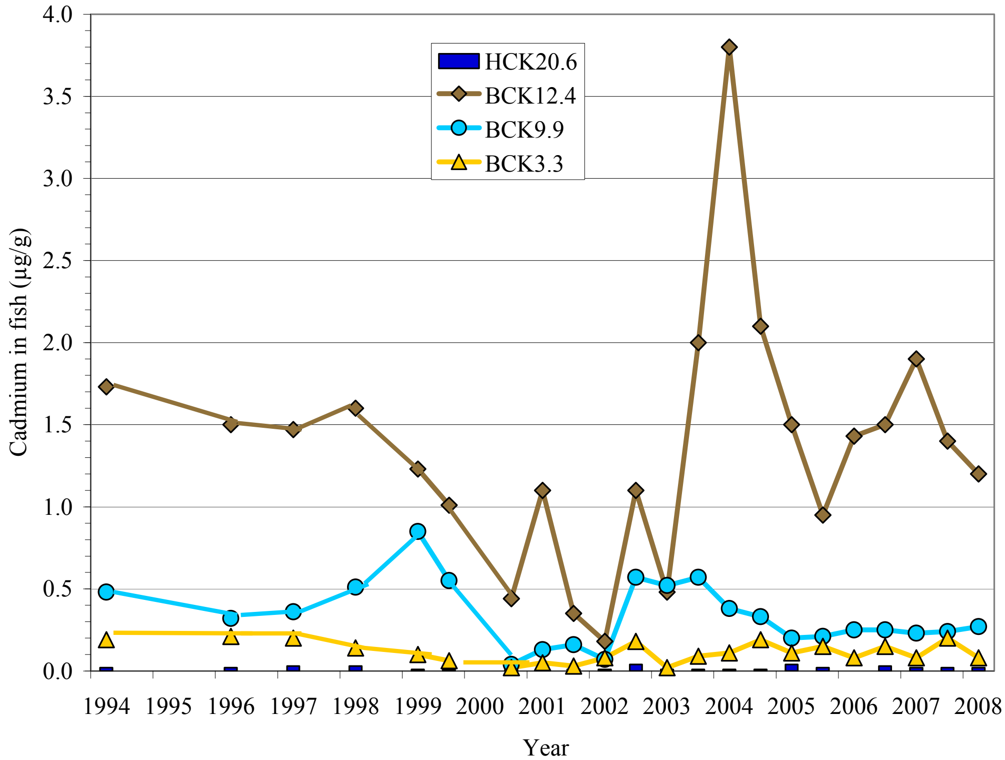

Fig. 4.13. Mean cadmium concentrations in stoneroller minnows at three sites in Bear Creek and a reference site (HCK 20.6), 1994–2008.

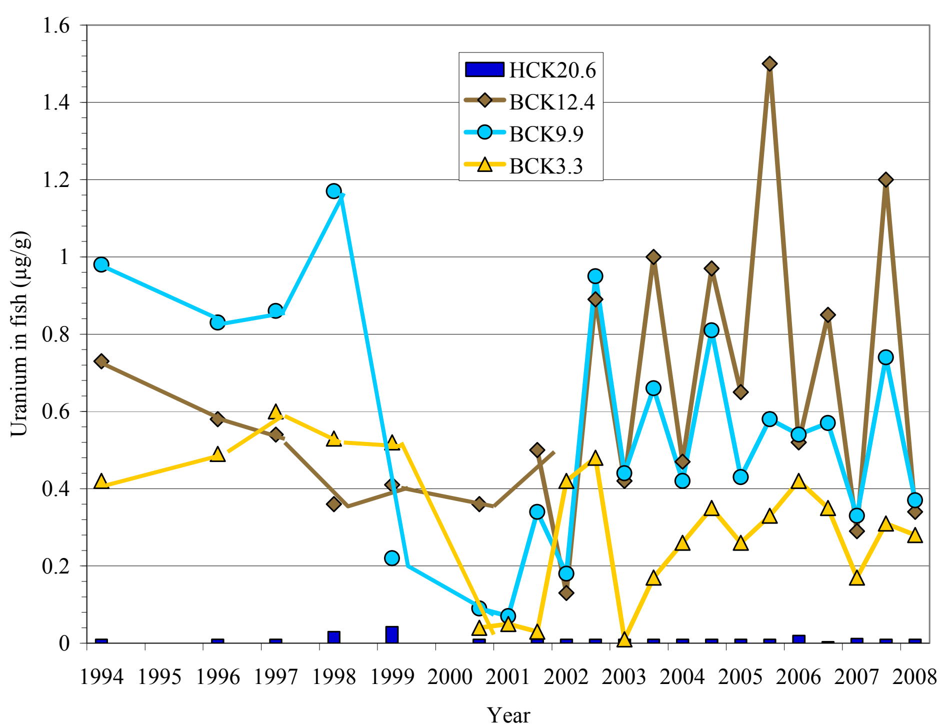

Fig. 4.14. Mean uranium concentrations in stoneroller minnows at three sites in Bear Creek and a reference site (HCK 20.6), 1994–2008.

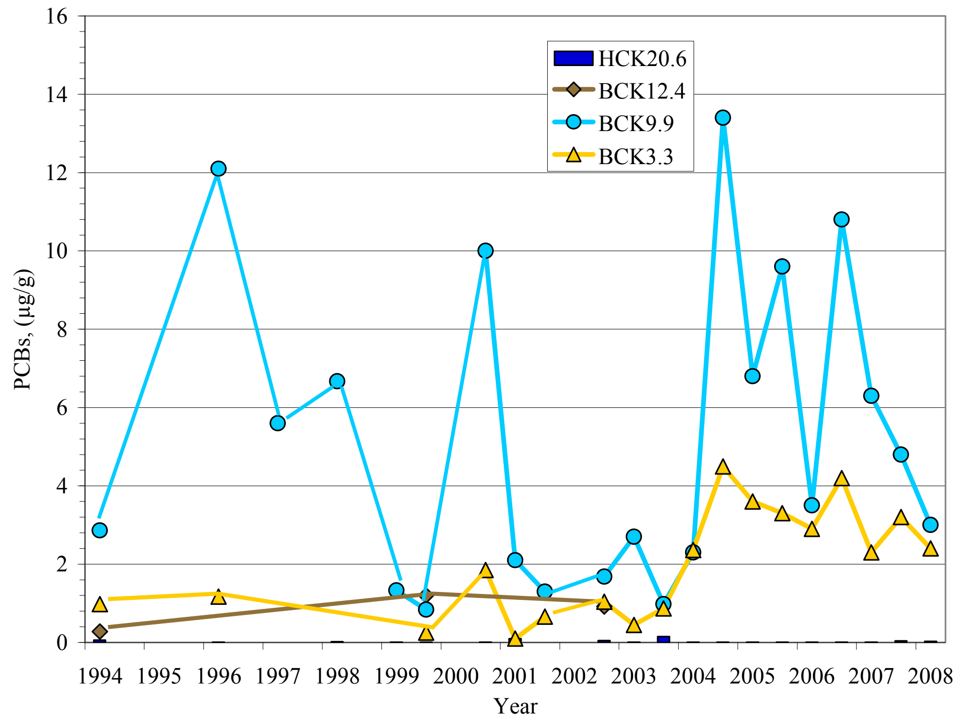

Fig. 4.15. Mean PCB concentrations in stoneroller minnows at three sites in Bear Creek and a reference site (HCK 20.6), 1994–2008.

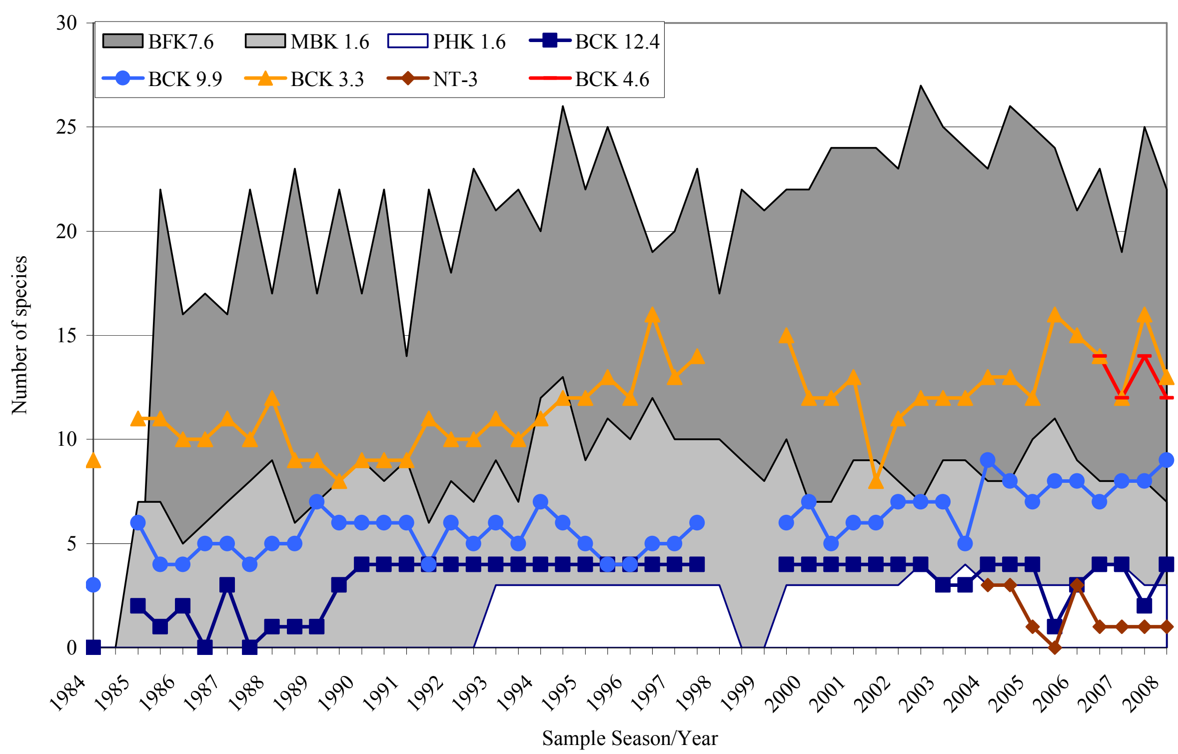

Fig. 4.16. Species richness (number of species) in samples of the fish community in Bear Creek (BCK), NT-3, and reference streams, Brushy Fork (BFK), Mill Branch (MBK), and Pinhook Branch (PHK), 1984–2008. Interruptions in data lines for BCK and PHK sites indicate missing samples.

A.2 BENTHIC MACROINVERTEBRATE COMMUNITY MONITORING

The objectives of the benthic macroinvertebrate task are to monitor the benthic macroinvertebrate community in Bear Creek to provide information on the ecological condition of the stream and evaluate the response of macroinvertebrates to remedial actions in Bear Creek Valley as a measure of their effectiveness. To meet these objectives, routine quantitative benthic macroinvertebrate samples (ORNL protocols) have been collected at least once or twice annually (April or April and October) since 1984 from at least three sites in Bear Creek (BCK 3.3, BCK 9.9, and BCK 12.4) and three nearby reference sites including two on Gum Hollow Branch (GHK 1.6 and GHK 2.9) and one on Mill Branch (MBK 1.6); only results from samples collected since 1996 are included in this summary to improve readability. Also included are the results of biannual sampling at a single site in North Tributary of Bear Creek (NT3 0.1) that was initiated in April 2004. As required by the Tennessee Department of Environment and Conservation (TDEC), collection of benthic macroinvertebrate samples following TDEC sampling protocols was initiated in 2006 (TDEC 2006). This summary includes results of samples collected in 2008, as well as temporal trends 2006.

Results/Progress

Results of quantitative samples collected with ORNL protocols show that upper Bear Creek (BCK 12.4) and NT-3 continue to support substantially fewer pollution-intolerant macroinvertebrate taxa than nearby reference streams (~3-fold difference, Fig. A.1). The number of taxa (total and pollution-intolerant) at BCK 9.9 was within the reference range in 2008, but the reference range was lower in 2008 most likely possibly due to ongoing drought and the continuing negative effects of sediment runoff from a small gravel access road built ~ 300 m upstream of GHK 1.6. Taxa richness values for BCKs 3.3 and 4.6 were comparable to slightly higher than at the reference sites.

Results based on TDEC protocols showed that relative to expected conditions for reference streams for our ecoregion (TDEC 2006), the benthic macroinvertebrate community at BCK 9.9, BCK 12.4, and NT-3 rated as moderately impaired in 2008 (Table A.1). This was lower than in the previous two years when biotic conditions were rated as slightly-impaired at all three sites (Fig. A.2). The decrease in condition at these three sites probably reflects the effects of the drought in 2008.

With few exceptions, D.O., temperature, and pH were within the normal ranges for streams in the Oak Ridge area (Table A.2). In October, the D.O. concentration at BCK 9.9 (3.4 mg/L) was below the concentration considered healthy for aquatic biota (i.e., 5.0 mg/L). Water level at BCK 9.9 was very low with little discernable flow, and the measurement was taken approximately 2.5 hr of sunrise. The stagnant conditions created by lack of flow and an early morning measurement, when D.O. concentrations are normally at their lowest, were probably important factors that contributed to the low concentration. Dissolved oxygen at NT3 0.1 in September (measured around noon) was higher than the water quality meter's limit of measurement (i.e., 15 mg/L). Water was present in the stream, but there was no measurable flow. Additionally, there was considerable growth of green filamentous algae and the water temperature was >30 ºC, which provided ideal conditions for super saturation of oxygen.

The spatial pattern for conductivity was typical for Bear Creek, with the lowest and near normal values at BCK 3.3, and very high values at BCK 12.4 (Table A.2). As is typical of streams in the Oak Ridge area, conductivity increased during the summer as water levels decreased and the proportion of stream flow from deep groundwater increased.

Habitat scores for BCK 9.9, BCK 12.4, and NT3 0.1 failed to meet TDEC habitat goals for the ecoregion in which the Oak Ridge Reservation exits (i.e., index score ≥131) in 2008 (Table A.3). Flow, sediment quality, substrate embeddedness, bank stability and low coverage of vegetation on stream banks were some of the factors that contributed to lower habitat quality at these sites. However, except for NT3 where riparian vegetation is still in an early stage of growth, canopy cover over Bear Creek was very good (i.e., >75%), which helps moderate water temperature (Table A.3).

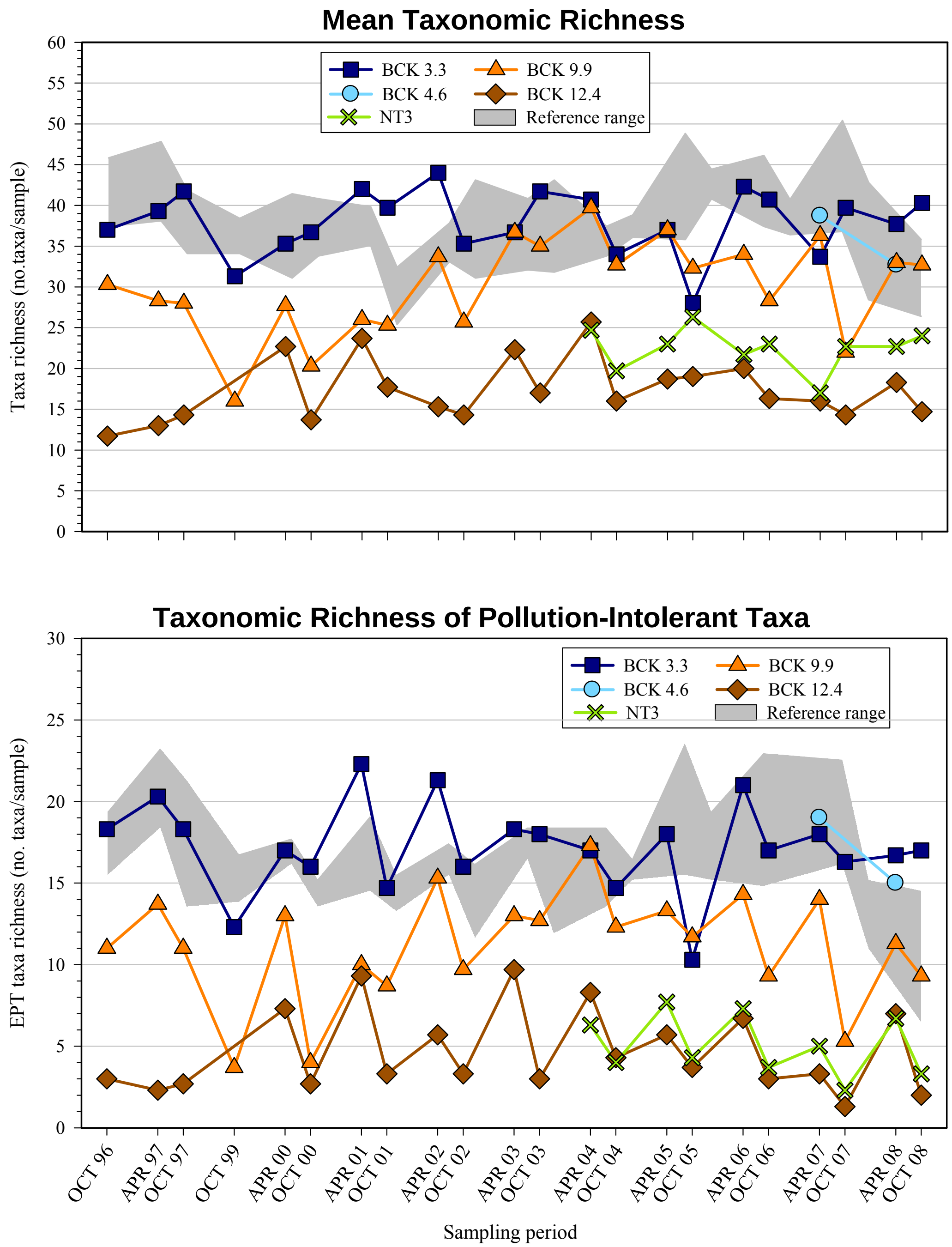

Fig. A.1. Mean (n = 3) taxonomic richness of the pollution-intolerant taxa for the benthic macroinvertebrate community at sites in Bear Creek, NT-3, and range of mean values among reference streams (two sites in Gum Hollow Branch and one site in Mill Branch), October 1996 – October 2008.

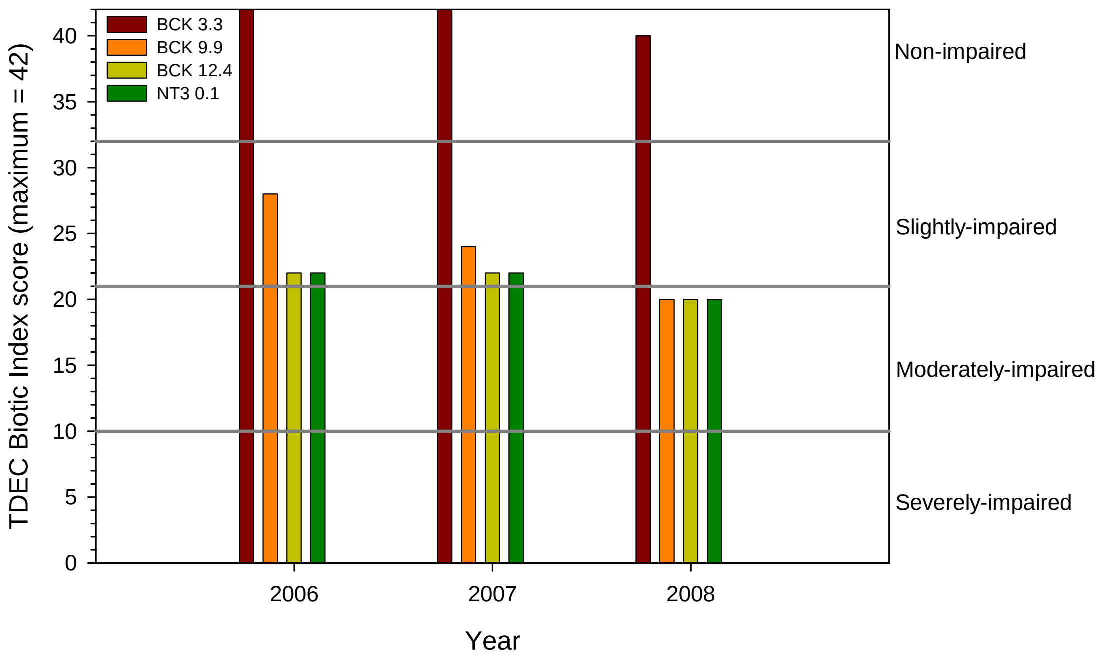

Fig. A.2. Temporal trends in TDEC Biotic Index Scores for Bear Creek and NT-3, 2006 – 2008. Horizontal lines show the lower thresholds for biotic condition ratings; respective narrative ratings for each threshold band are shown on right side of graph.

A.3 BEAR CREEK TDEC PROTOCOL RESULTS

Table A.1. Benthic macroinvertebrate community metric values, Biotic Index scores, and biological condition narrative ratings based on Tennessee Department of Environment and Conservation (TDEC) standard protocols for Bear Creek and North Tributary Number 3 (NT3), August 19, 2008[a,b,c]

Site	Metric values							Metric scores							INDEX score	Narrative rating
	EPT	TAXA	%OC	%EPT	NCBI	% NUTOL	% CLING	EPT score	TAXA score	%OC score	%EPT score	NCBI score	% NUTOL score	%CLING score		
BCK 3.3	12	34	11.9	61.9	3.79	37.7	81.1	6	6	6	6	6	4	6	**40**	**Non-impaired**
BCK 9.9	4	22	8.5	10.9	5.23	62.4	29.1	2	4	6	0	4	2	2	**20**	**Moderately impaired**
BCK 12.4	3	13	16.7	14.8	5.52	64.8	72.2	0	2	6	0	4	2	6	**20**	**Moderately impaired**
NT3 0.1	1	21	41.9	1.1	4.69	3.9	10.6	0	4	4	0	6	6	0	**20**	**Moderately impaired**

[a]EPT = EPT taxa richness; TAXA = total taxa richness; %OC = % oligochaetes and chironomids; %EPT = % EPT abundance; NCBI = North Carolina Biotic Index; % NUTOL = % nutrient tolerant taxa; %CLING = % abundance of clinger taxa.

[b]BCK= Bear Creek kilometer; NT3 = North Tributary #3.

[c]Metric scoring and narrative ratings for Ecoregion 67f (TDEC 2006).

Table A.2. Bear Creek water quality results and physical characteristic measurements at benthic macroinvertebrate community monitoring sites, 2008

Site	Geographic coordinates[a]	D.O. (mg/L)			Temperature (°C)			pH			Conductivity (μS/cm)			Canopy cover (%)[b,c]	Discharge[c,d]	
		Apr	Sept	Oct	Apr	Sept	Oct	Apr	Sept	Oct	Apr	Sept	Oct		(L/sec)	(ft^3/sec)
BCK 3.3	35.9434114 N 84.3493407 W	6.3	8.6	7.1	11.8	20.2	16.0	8.0	8.0	8.1	187.6	356.7	330.0	76.6	14.8	0.523
BCK 9.9	35.9603597 N 84.2971316 W	6.1	6.1	3.4	13.3	20.9	15.8	8.0	7.9	7.7	377.7	567.0	577.0	91.0	0.05	0.0018
BCK 12.4	35.9729943 N 84.2776131 W	6.0	7.9	7.2	14.1	22.4	17.1	7.8	7.7	7.7	762.0	1250.0	1304.0	93.0	0.02	0.0007
NT3 0.1	35.9698871 N 84.2832237 W	6.6	>15.0	9.6	16.1	32.4	11.4	8.1	8.4	8.1	188.3	481.9	454.6	0.0	0.0[e]	0.0

[a]Coordinates in decimal-degrees, Datum NAD27.
[b]Canopy covered measured with a spherical densiometer.
[c]Canopy cover and discharge were measured in September only.
[d]Discharge measured with a Marsh-McBirney Model 201 portable flow meter.
[e]Water was present in channel but there was no measureable flow.

Table A.3. Habitat assessment results for benthic macroinvertebrate community sampling sites in Bear Creek (BCK) and North Tributary Number 3 (NT3), August 19, 2008. Results are based on Tennessee Department of Environment and Conservation standard protocols for stream habitat assessments (Arnwine and Denton 2001)

Habitat parameter	**Sampling site/habitat score**			
	BCK 3.3	**BCK 9.9**	**BCK 12.4**	**NT3 0.1**
1. Epifaunal substrate/available cover	20	14	13	10
2. Embeddedness	15	9	14	9
3. Velocity/depth regime	20	15	10	3
4. Sediment deposition	17	10	8	10
5. Channel flow	20	9	8	3
6. Channel alteration	20	20	6	16
7. Frequency of riffles	18	13	8	16
8. Bank stability				
Left	4	5	2	5
Right	6	5	2	5
9. Vegetative protection				
Left	6	5	2	5
Right	6	5	2	5
10. Riparian vegetative zone width				
Left	10	10	10	5
Right	10	10	7	5
Total score	**172**	**130**	**92**	**97**
Ecoregion 67f habitat goal (≥131)	Pass	**Fail**	**Fail**	**Fail**

A.4 BEAR CREEK TOXICITY MONITORING

Water samples from Bear Creek kilometer (BCK) 12.4, North Tributary (NT)-1, and BCK 9.9 were evaluated for chronic toxicity to the freshwater microcrustacean *Ceriodaphnia dubia* twice during FY 2009 (Tables A.4.1 and A.4.2). Statements of significance for the toxicity tests were determined using appropriate U.S. Environmental Protection Agency-recommended methods (USEPA 2002) and SAS[1] procedures and software for analysis of variance and multiple comparison tests.

Toxicity test results and chemical analyses of water collected from the two sites in Bear Creek and from NT-1 are shown in Tables A.4.1 and A.4.2, respectively. *Ceriodaphnia* reproduction was significantly reduced in water samples from both BCK 12.4 and NT-1 in October 2008 (Table A.4.1). In contrast, neither survival nor reproduction was significantly reduced in samples from these two sites in a test conducted in April 2009, nor in samples collected from BCK 9.9 during either test.

These results continued trends exhibited in recent toxicity tests of these sites. Samples from at least one of the two locations in the upper Bear Creek watershed, BCK 12.4 and NT-1, significantly reduced *Ceriodaphnia* reproduction during six of the eight toxicity tests conducted since 2005, while samples from BCK 9.9 did not significantly reduce *Ceriodaphnia* survival or reproduction during any test.

Toxicity in these tests was closely associated with location within the watershed, occurring only at NT-1 and BCK 12.4, both immediately downstream of the S-3 Site (Table A.4.1). Toxicity at these sites was also correlated with season (highest toxicity occurring during fall tests) and with water physio-chemical characteristics (toxicity being associated with high water conductivity and hardness) (Table A.4.2). The relationship between toxicity, seasonality, and water quality characteristics is illustrated for BCK 12.4 in Figure A.4.1. In a previous report (Y-12 National Security Complex Biological Monitoring and Abatement Program, July 2008), both conductivity and toxicity, as indicated by relative reductions in *Ceriodaphnia* reproduction during the tests, were shown to be inversely correlated with stream flow as measured just downstream of BCK 12.4.

In summary, toxicity is regularly observed in water samples from NT-1 and BCK 12.4 during *Ceriodaphnia* toxicity tests conducted in the fall when stream flow is relatively low and groundwater inputs from the S-3 site predominate. Toxicity is only rarely observed at these locations in the spring when rainfall is higher and stream flow is relatively high. Toxicity has not been observed further downstream at BCK 9.9 in either season.

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[1] Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof.

Table A.4.1. Results of chronic *Ceriodaphnia* toxicity tests of Bear Creek in FY 2009.
Asterisks (*) indicate concentrations that differ significantly from the control ($\alpha = 0.05$)

Date/Location	Survival (%)	Mean (sd) offspring/ female
October 10 – 16, 2008		
Control	100	37.9 (4.0)
BCK 12.4	100	13.2 (4.5) *
NT-1	100	13.8 (7.4)*
BCK 9.9	100	39.8 (4.0)
April 15 – 22, 2009		
Control	100	19.6 (1.8)
BCK 12.4	100	20.6 (5.4)
NT-1	100	21.1 (1.4)
BCK 9.9	100	19.4 (2.2)

Note: BCK = Bear Creek kilometer; NT = North Tributary; sd = standard deviation.

Table A.4.2. Summary (mean ± sd) of water chemistry analyses conducted during FY 2009 toxicity tests of Bear Creek

Date/Sample	pH (standard units)	Alkalinity (mg/L as $CaC0_3$)	Hardness (mg/L as $CaC0_3$)	Conductivity (µS/cm)
October 10 – 16, 2008				
BCK 12.4	7.89 (0.05)	326 (19)	699 (68)	1690 (238)
NT-1	7.88 (0.06)	300 (35)	587 (113)	1539 (183)
BCK 9.9	8.12 (0.17)	258 (40)	356 (42)	737 (77)
April 15 – 22, 2009				
BCK 12.4	7.73 (0.29)	174 (26)	269 (55)	698 (164)
NT-1	8.12 (0.19)	192 (38)	289 (72)	743 (158)
BCK 9.9	8.15 (0.14)	137 (29)	173 (39)	384 (84)

Note: BCK = Bear Creek kilometer; NT = North Tributary; sd = standard deviation.

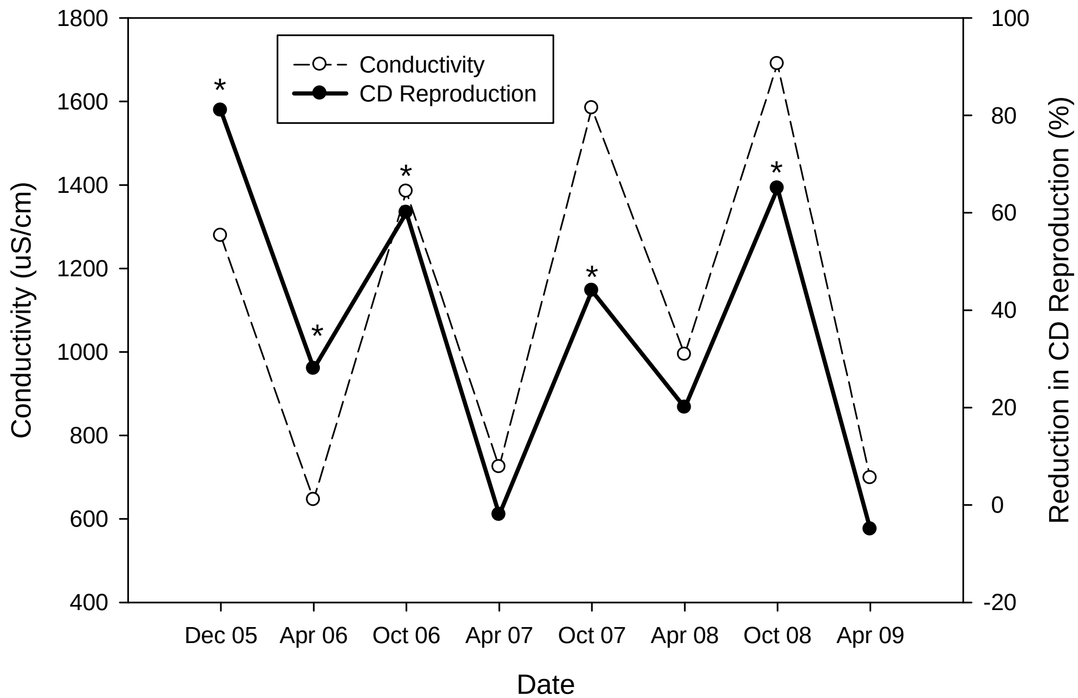

Fig. A.4.1. Relationship between sample conductivity and reductions in Ceriodaphnia dubia (CD) reproduction during chronic toxicity tests of water samples from BCK 12.4. Conductivity is the mean of measurements conducted on renewal water samples used for each toxicity test. Asterisks indicate statistically significant (α = 0.05) reductions in CD reproduction from controls.

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Appendix B

MCCOY BRANCH MONITORING

The McCoy Branch monitoring summary provided herein includes a summary of fish bioaccumulation and fish community monitoring results (B.1), and a summary of of benthic macroinvertebrate community results (B.2). The biomonitoring write-up in B.1 is excerpted by permission with limited modification (including original figure and table numeration) from the D1 2009 Remediation Effectiveness Report (covering FY 2008 data). Section B.2 includes results reported in the D1 2009 Remediation Effectiveness Report, as well as, results from samples collected in October 2008.

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Appendix B. MCCOY BRANCH MONITORING

B.1 SUMMARY FROM THE 2008 REMEDIATION EFFECTIVENESS REPORT (D1)

Biota Monitoring

Fly-ash disposal from Y-12 into the FCAP, as well as direct disposals of ash into Rogers Quarry, affected water quality in the lower reaches of McCoy Branch and the quarry. Biological monitoring studies have documented contaminants in fish and impacts to biota in the lower reaches of the McCoy Branch watershed and Rogers Quarry. To evaluate in-stream exposure and potential human health risks in the McCoy Branch watershed, adult largemouth bass are collected from Rogers Quarry and analyzed for key COCs. An evaluation of overall ecological health in the stream is conducted by monitoring the fish and benthic macroinvertebrate communities.

Average selenium concentrations in largemouth bass in Rogers Quarry were slightly higher than the previous six years (2.4 µg/g) and remained elevated above typical background concentrations (0.5 µg/g), suggesting possible continuing low level inputs from the FCAP site (Figure 5.6). Arsenic concentrations were at background levels. Average mercury concentrations in bass from Rogers Quarry (Figure 5.7) were slightly higher in 2008 (0.86 µg/g) than in 2007, were lower than levels from 2004-2006, and remained well within the range typical of the past ten years. The large increase in mercury concentrations in fish following the elimination of fly-ash discharges is probably a consequence of the reduction in selenium inputs associated with that action (selenium is known to have an antagonistic effect on mercury bioaccumulation).

The species richness (number of species) of the fish community at MCK 1.6 in McCoy Branch had been declining since 2004, but sampling in the last year showed a modest increase (Figure 5.8). Also, species richness values in comparable reference streams have declined, perhaps due to low water associated with below normal rainfall in the area.

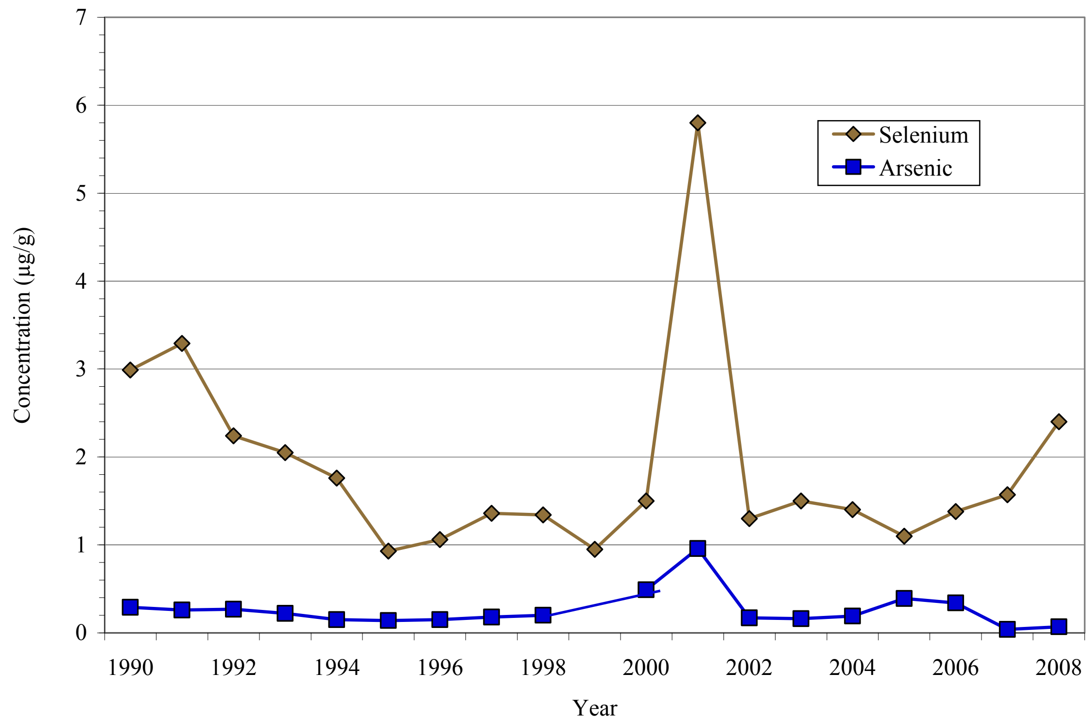

Fig. 5.6. Mean concentrations of selenium and arsenic in fillets of largemouth bass from Rogers Quarry.

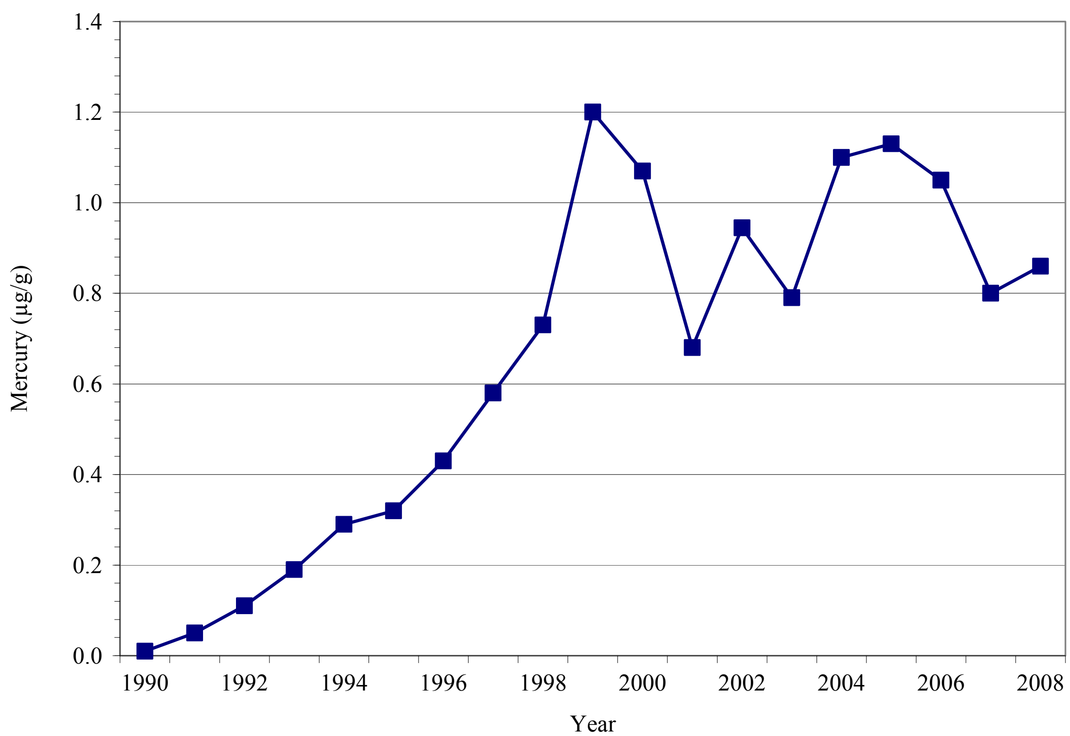

Fig. 5.7. Mean concentrations of mercury in fillets of largemouth bass from Rogers Quarry.

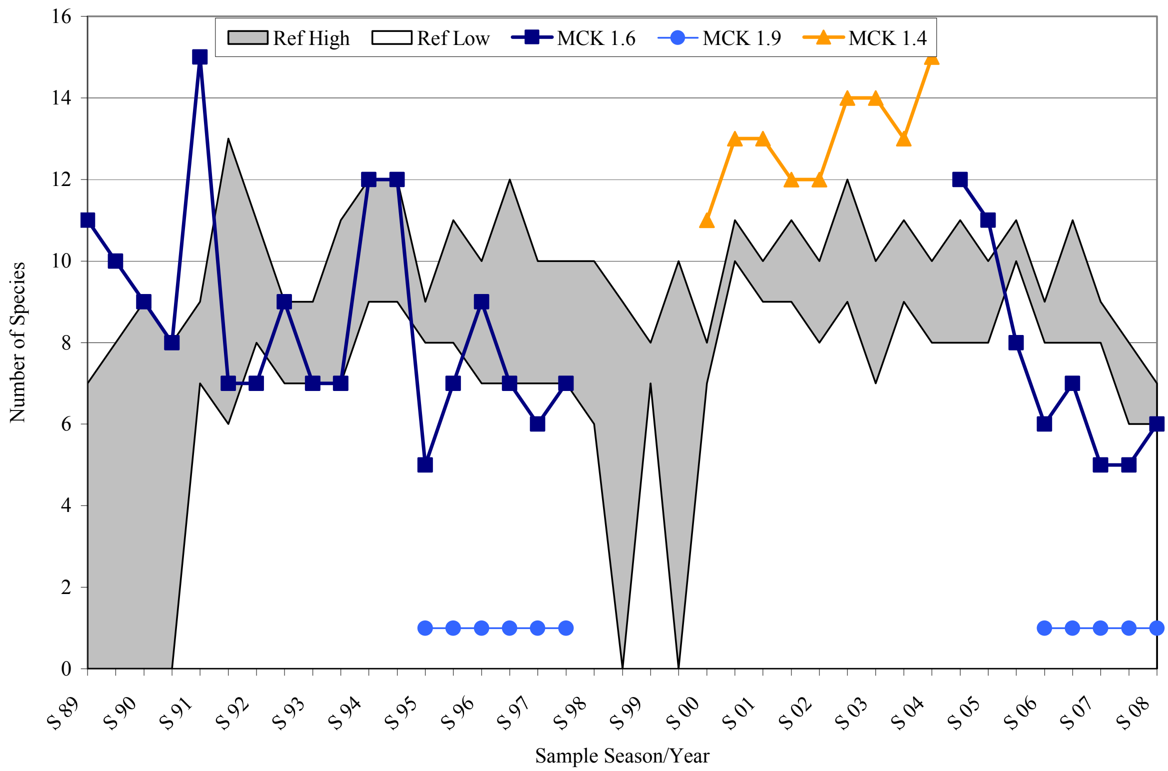

Fig. 5.8. Species richness (number of species) in samples of the fish community in McCoy Branch (MCK) and three reference streams, Scarboro Creek (SCK), Grassy Creek (GCK), and Ish Creek (ISK), 1989–2008.

B.2 BENTHIC MACROINVERTEBRATE COMMUNITY MONITORING

The objectives of the benthic macroinvertebrate community task are to monitor the benthic macroinvertebrate community in McCoy Branch in order to provide information on ecological conditions and trends in the stream. To meet these objectives, except for a period of ~ 4 yr in the mid-1990s, routine quantitative benthic macroinvertebrate samples (ORNL protocols) have been collected approximately twice annually (April and October) since 1989 from two sites in McCoy Branch including MCK 1.4 and MCK 1.9; only results from samples collected since 1996 are included in this summary to improve readability. The results for McCoy Branch sites have been compared with results from several reference sites on the Oak Ridge Reservation that are routinely monitored for other projects (i.e., reference sites in upper First Creek, Fifth Creek, Walker Branch, Gum Hollow Branch, and Mill Branch). As required by the Tennessee Department of Environment and Conservation (TDEC), collection of semi-quantative benthic macroinvertebrate samples following TDEC sampling protocols was initiated in 2006 (TDEC 2006). This report summarizes the results of the samples collected in 2008 and temporal trends since 2006.

Results/Progress

The total number of taxa (i.e., taxa richness) and number of pollution-intolerant benthic macroinvertebrate taxa (i.e., EPT taxa richness) at both sites in McCoy Branch generally continue to be slightly to marginally reduced relative to nearby reference sites (Fig B.1). The difference is most notable during October sampling periods particularly at MCK 1.4 (Fig B.1).

Results based on TDEC protocols indicated that the macroinvertebrate community at MCK 1.4 was slightly impaired in 2008, while MCK 1.9 remained classified as non-impaired (Table B.1). While the Biotic Index rating in 2008 for MCK 1.4 was lower than in the previous 2 years, the Index score was only two points lower, thus, there was actually little change in 2008 (Fig. B.2).

Water quality measurements in 2008 showed no major changes from previous years (Table B.2). Dissolved oxygen, pH, and conductivity were all within normal ranges of reference streams in the Oak Ridge area. Water temperature at MCK 1.9 was comparable to reference streams that originate on the south slope of Chestnut Ridge, while slight differences in temperature between MCK 1.9 and MCK 1.4 reflected the effects of Rogers Quarry upstream of MCK 1.4 and the absence of canopy over the stream.

Habitat assessments for McCoy Branch sites indicated that the met TDEC's goal (i.e., score ≥131) for our ecoregion (Table B.3). One habitat characteristic that is not fully captured by this assessment is the extent of canopy coverage which helps lower temperatures. At MCK 1.4, other than tall grasses and weedy vegetation, there is little to no canopy over much of the stream downstream of Bethel Valley Road

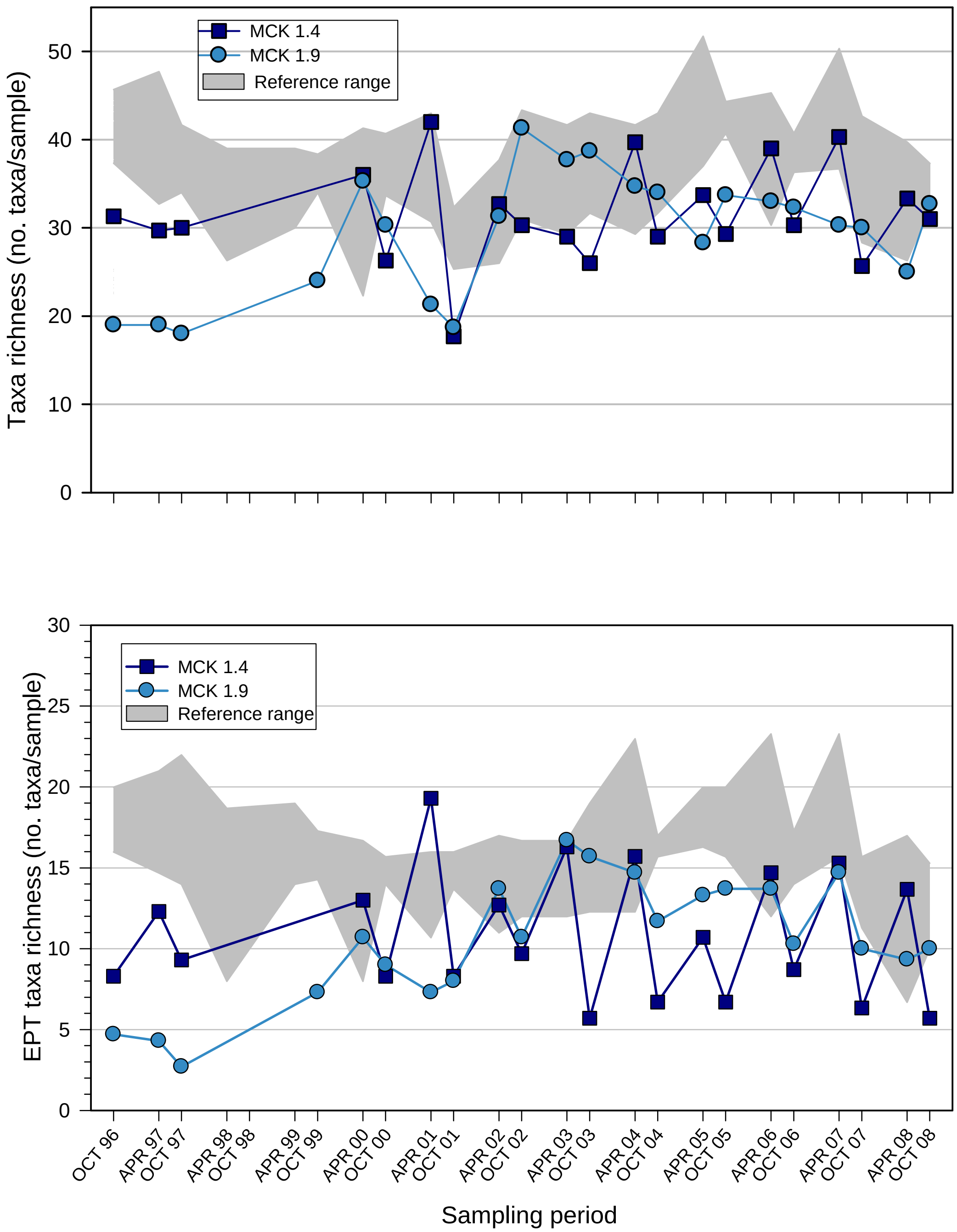

Fig. B.1. Mean (n = 3) taxonomic richness of the pollution-intolerant taxa for the benthic macroinvertebrate community at sites in McCoy Branch, and range of mean values among reference streams on or immediately adjacent to the Oak Ridge Reservation, 1996–2008. Reference values in April include reference sites on First Creek, Fifth Creek, Gum Hollow Branch (2 sites), Mill Branch, Walker Branch, and White Oak Creek; reference values in October include reference sites on Gum Hollow Branch (2 sites) and Mill Branch only. MCK = McCoy Branch kilometer.

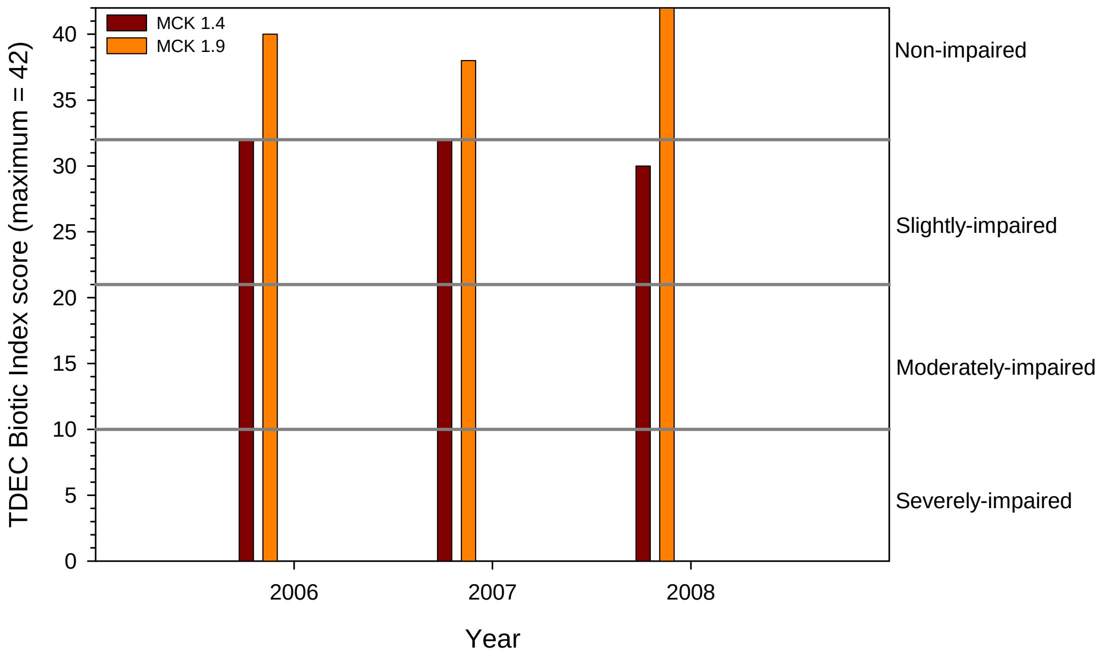

Fig. B.2. Temporal trends in TDEC Biotic Index Scores for McCoy Branch, 2006 – 2008. Horizontal lines show the lower thresholds for biotic condition ratings; respective narrative ratings for the threshold bands are shown on right side of graph.

B.3 McCoy Branch TDEC Protocol Results

Table B.1. Benthic macroinvertebrate community metric values, Biotic Index scores, and biological condition narrative ratings based on Tennessee Department of Environment and Conservation (TDEC) standard protocols for McCoy Branch, August 20, 2008[a,b,c]

Site	Metric values							Metric scores							INDEX score	Narrative rating
	EPT	TAXA	%OC	%EPT	NCBI	% NUTOL	% CLING	EPT score	TAXA score	%OC score	%EPT score	NCBI score	% NUTOL score	%CLING score		
MCK 1.4	6	33	11.8	32.7	5.17	70.0	74.1	2	6	6	4	4	2	6	**30**	**Slightly-impaired**
MCK 1.9	13	38	9.0	54.8	2.3	20.4	71.9	6	6	6	6	6	6	6	**42**	**Non-impaired**

[a]EPT = EPT taxa richness; TAXA = total taxa richness; %OC = % oligochaetes and chironomids; %EPT = % EPT abundance; NCBI = North Carolina Biotic Index; % NUTOL = % nutrient tolerant taxa; %CLING = % abundance of clinger taxa.

[b]MCK= McCoy Branch kilometer.

[c]Metric scoring and narrative ratings for Ecoregion 67f (TDEC 2006).

Table B.2. McCoy Branch water quality results and physical characteristic measurements at benthic macroinvertebrate community monitoring sites, 2008

Site	Geographic coordinates[a]	D.O. (mg/L)			Temperature (°C)			pH			Conductivity (µSeimens/cm)			Canopy cover (%)[b,c]	Discharge[c,d]	
		Apr	Sept	Oct	Apr	Sept	Oct	Apr	Sept	Oct	Apr	Sept	Oct		(L/sec)	(ft^3/sec)
MCK 1.4	35.96547 N 84.24835 W	8.0	7.0	8.3	12.1	21.9	16.4	-[e]	7.8	8.0	232.5	237.2	220.9	0	1.36	0.048
MCK 1.9	35.97087 N 84.2493 W	6.4	8.9	8.9	15.1	16.4	14.0	-[e]	8.0	8.4	209.2	270.8	257.3	83.8	1.30	0.046

[a]Coordinates in decimal-degrees, Datum NAD27.
[b]Canopy covered measured with a spherical densiometer.
[c]Canopy cover and discharge were measured in September only.
[d]Discharge measured with a Marsh-McBirney Model 201 portable flow meter.
[e]pH meter malfunctioned during sample collection.

Table B.3. Habitat assessment results for benthic macroinvertebrate community sampling sites in McCoy Branch, August 20, 2008. Results are based on Tennessee Department of Environment and Conservation standard protocols for stream habitat assessments (Arnwine and Denton 2001)

Habitat parameter	Sampling site/habitat score	
	MCK 1.4	**MCK 1.9**
1. Epifaunal substrate/available cover	18	18
2. Embeddedness	15	18
3. Velocity/depth regime	13	19
4. Sediment deposition	18	17
5. Channel flow	20	20
6. Channel alteration	15	20
7. Frequency of riffles	18	20
8. Bank stability		
Left	9	9
Right	9	9
9. Vegetative protection		
Left	8	9
Right	8	9
10. Riparian vegetative zone width		
Left	9	10
Right	9	10
Total score	**169**	**188**
Ecoregion 67f habitat goal (≥131)	Pass	Pass

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Appendix C

Y-12 COMPLEX TOXICITY MONITORING PROGRAM SUMMARY INFORMATION THROUGH 2008 FOR OUTFALLS 200, 135 AND 125

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Appendix C. Y-12 COMPLEX TOXICITY MONITORING PROGRAM SUMMARY INFORMATION THROUGH 2008 FOR OUTFALLS 200, 135 AND 125

In accordance with the Y-12 National Security Complex NPDES permit (Part III-E, p. 29) implemented in spring 2006, a biomonitoring program was required that evaluates the toxicity of three outfalls to East Fork Poplar Creek (Outfalls 200, 135 and 125). Water from each outfall was tested once during 2008 with fathead minnow larvae and *Ceriodaphnia dubia*. Table C.1 summarizes the results of these toxicity tests. The IC_{25} is the concentration of effluent that causes a twenty-five percent reduction in *Ceriodaphnia* survival or reproduction or fathead minnow survival or growth. The IC_{25} was greater than the highest tested concentration of each effluent (100% for Outfall 200, 20% for Outfall 135, and 36% for Outfall 125); therefore, toxicity was not demonstrated by these tests.

Details of these tests have been reported previously as specified by the NPDES permit.

Table C.1. Y-12 Complex Biomonitoring Program summary information for Outfalls 200, 135 and 125 for 2008[a]

Site	Test date	Species	IC_{25}[b] (%)
Outfall 200	12/16/08	*Ceriodaphnia*	>100
Outfall 200	12/16/08	Fathead minnow	>100
Outfall 135	12/16/08	*Ceriodaphnia*	>20
Outfall 135	12/16/08	Fathead minnow	>20
Outfall 125	12/16/08	*Ceriodaphnia*	>36
Outfall 125	12/16/08	Fathead minnow	>36

[a]Summarized are the inhibition concentrations$_{25}$ (IC_{25}) for the discharge monitoring locations, Outfalls 200, 135 and 125.

[b]IC_{25} as a percentage of full-strength effluent from Outfalls 200, 135 and 125 diluted with laboratory control water. The IC_{25} is the concentration that causes a twenty-five percent reduction in *Ceriodaphnia* survival or reproduction or fathead minnow survival or growth.