YTS-1194\21

Quarterly Progress Report

December 30, 1996

Biological Monitoring Program for East Fork Poplar Creek

Submitted to

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Lockheed Martin Energy Systems

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Managed by Lockheed Martin Energy Research Corp.
for the
U.S. Department of Energy
under contract DE-AC05-96OR22464

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1. Introduction

In May 1985, a National Pollutant Discharge Elimination System (NPDES) permit was issued for the Oak Ridge Y-12 Plant. As a condition of the permit, a Biological Monitoring and Abatement Program (BMAP) was developed to demonstrate that the effluent limitations established for the Y-12 Plant protect 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). A second objective of the BMAP is to document the ecological effects resulting from the implementation of a water pollution control program designed to eliminate direct discharges of wastewaters to EFPC and to minimize the inadvertent release of pollutants to the environment. Because of the complex nature of the discharges to EFPC and the temporal and spatial variability in the composition of the discharges, a comprehensive, integrated approach to biological monitoring was developed. A new permit was issued to the Y-12 Plant on April 28, 1995 and became effective on July 1, 1995. Biological monitoring continues to be required under the new permit. The BMAP consists of four major tasks that reflect different but complementary approaches to evaluating the effects of the Y-12 Plant discharges on the aquatic integrity of EFPC. These tasks are (1) toxicity monitoring, (2) biological indicator studies, (3) bioaccumulation studies, and (4) ecological surveys of the periphyton, benthic macroinvertebrate, and fish communities.

Monitoring is currently being conducted at five primary sites, although sites may be excluded and/or others 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) concentration of mercury in the adjacent floodplain, (5) appropriate habitat distribution, and (6) access. The sampling sites include EFPC at kilometers (EFKs) 24.4 and 23.4 [upstream and downstream of Lake Reality (LR) respectively]; EFK 18.7, located off the ORR and below an area of intensive commercial and limited 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). Brushy Fork (BF) at kilometer (BFK) 7.6 is used as a reference stream in most tasks of the BMAP. Additional sites off the ORR are also used for reference, including Beaver Creek, Bull Run, Hinds Creek, Paint Rock Creek, and the Emory River in Watts Bar Reservoir (Fig. 1.2).

2. Toxicity Monitoring (*L. A. Kszos, D. S. Cicerone, A. J. Stewart and L. F. Wicker*)

2.1. Introduction

The ambient toxicity monitoring task includes three subtasks: toxicity monitoring, toxicity experiments, and supporting studies. Toxicity monitoring uses U.S. Environmental Protection Agency (EPA) approved methods with *Ceriodaphnia dubia* and fathead larvae to provide systematic information that can be used to determine changes in the biological quality of EFPC through time. Toxicity experiments are conducted to test specific hypotheses about stream water quality. The hypotheses are addressed experimentally by the systematic application of ambient toxicity test methods. Supporting studies are used to (1) investigate the relationship between the physicochemical and biological conditions in EFPC, particularly as they relate to processes or rates of ecological recovery and (2) develop better methods for accurately predicting ecological recovery with changes in water quality in EFPC. Toxicity monitoring at the upstream sites from Bear Creek Road [Lake Reality outfall or LR-o (EFK 23.8), LR

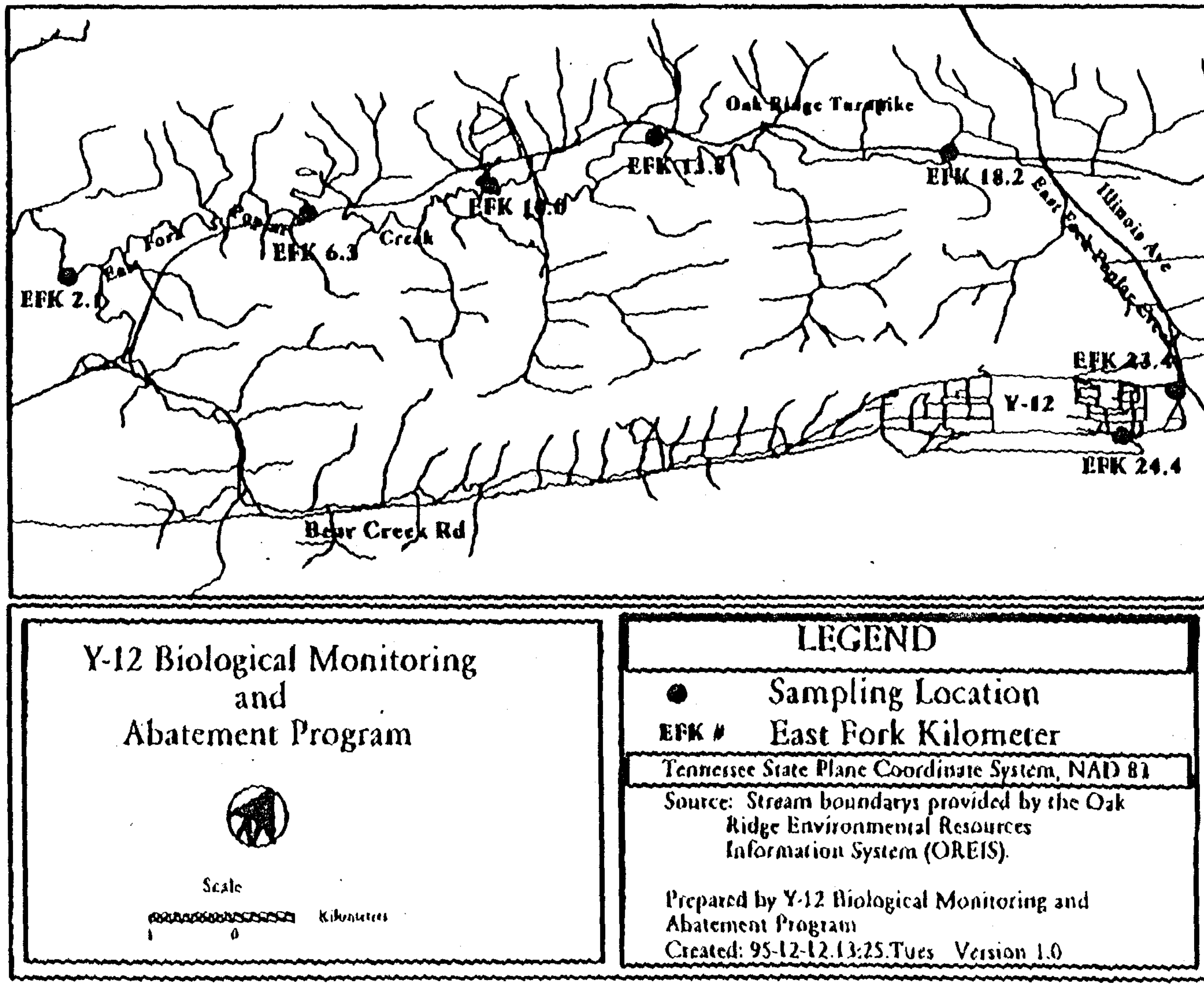

Figure 1.1. Location of biological monitoring sites on East Fork Poplar Creek in relation to the Oak Ridge Y-12 Plant.

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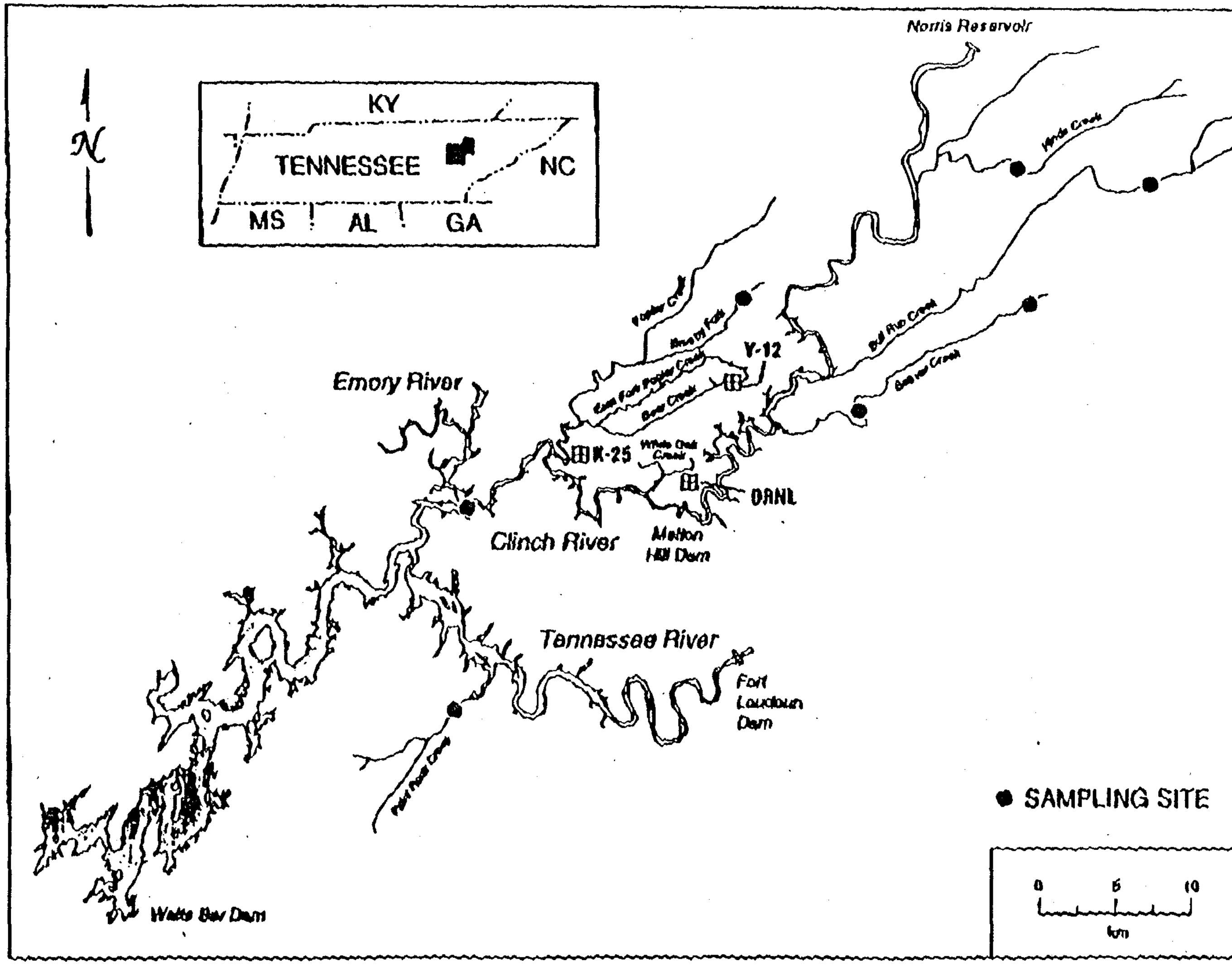

Figure 1.2. Location of reference sites in relation to the Oak Ridge Y-12 Plant.

inlet or LR-i (EFK 24.1) and Area Source Study Site 8 or AS-8 (EFK 24.6)] are conducted monthly. Ambient monitoring at six sites downstream from Bear Creek Road (EFKs 22.8, 21.9, 20.5, 18.2, 13.8, and 10.9) are tested quarterly.

2.2 Results/Progress

2.2.1 Toxicity Monitoring

Ambient water samples from EFK 24.6, EFK 24.1, and EFK 23.8 were evaluated for acute and chronic toxicity to *Ceriodaphnia dubia* during September 4-11 and October 9-16, 1996. During the November 13-21 testing period ambient water samples from EFK 24.6, EFK 24.1, and EFK 23.8 and downstream sites (EFKs 22.8, 21.9, 17.0, 18.2, 13.8, and 10.9) were also tested with *Ceriodaphnia dubia*. In each sampling period, daily grab samples from the ambient sites were collected by ESD personnel for testing. Results of ambient toxicity tests and chemical analyses are shown in Tables 2.1 and 2.2. During all test periods, *Ceriodaphnia* survival in water from each site was ≥80%. *Ceriodaphnia* reproduction in the water samples was not significantly reduced compared to the controls.

2.2.2 Special Studies

Data on the composition of sediment in LR and the characteristics of water entering and exiting LR has been used to develop information on the influence of biota on contaminant dynamics in LR. In November 1988, water in upper East Fork Poplar Creek (EFPC) was redirected so that it flowed through a new lined impoundment, referred to as Lake Reality (LR). By virtue of its location near the Department of Energy's Y-12 Plant, LR is used as a spill-control system; it also functions as a settling basin, and now contains 15 to 20 cm of sediments. Monitoring of water-quality conditions in EFPC at sites upstream and downstream from LR, and within LR itself, has shown that water exiting LR contains higher concentrations of suspended particulate matter than water entering the impoundment from upper EFPC, especially during base-flow conditions in summer. The suspended solids exiting the impoundment also have a higher ash content than suspended solids entering the impoundment. *In situ* monitoring at 15-minute intervals for 14-day periods during summer revealed diurnal variations in pH within LR (1.1 units) around the pH for zero charge of calcite. The diel changes in pH in LR result from photosynthesis (primarily algae) and respiration. The pH data, plus thermodynamic calculations using ten years of hardness and alkalinity data (obtained from the Y-12 Plant's BMAP for EFPC), strongly predicted the presence of calcite, a particulate-phase form of calcium carbonate. Calcite is known to precipitate from calcium-rich natural waters primarily due to the extraction of dissolved carbon dioxide during photosynthesis by algae.

To test the prediction about the presence of calcite, sediment samples were collected from LR and analyzed by X-ray spectroscopy. Calcite was clearly detectable in LR sediments by this analysis method, but not detectable in sediment from one site in EFPC upstream of LR. Thus, biotic processes, perhaps augmented by increases in water temperature, apparently drive calcite production in LR. This phenomenon explains both the increase in concentration of suspended solids in water flowing through LR, and the higher inorganic content of the solids that are exported from LR. Numerous other studies have shown that various metals and organic compounds tend to sorb strongly to calcite particles. Thus, it seems clear that the biogenic precipitation of calcite in LR must influence the speciation, fate and biological availability of metals, such as zinc and cadmium. Laboratory experiments are now being designed to provide quantitative estimates of the effects of calcite formation and dissolution on the

Table 2.1. Results of *Ceriodaphnia dubia* toxicity tests of ambient sites from East Fork Poplar Creek conducted September – November, 1996

Sample	Concentration (%)	*Ceriodaphnia dubia*	
		Mean Survival (%)	Mean Reproduction (offspring/surviving female) (SD)
September 4 - 11, 1996			
Control	100	100	27.7 ± 5.3
EFK 24.6	100	90	30.0 ± 6.6
EFK 24.1	100	100	27.2 ± 7.3
EFK 23.8	100	100	33.9 ± 5.2
October 9-15, 1996			
Control	100	100	28.9 ± 4.5
EFK 24.6	100	100	25.6 ± 5.5
EFK 24.1	100	100	27.2 ± 4.4
EFK 23.8	100	100	25.0 ± 7.8
November 13 - 19, 1996			
Control	100	100	23.7 ± 11.6
EFK 24.6	100	100	25.1 ± 7.1
EFK 24.1	100	100	26.6 ± 4.5
EFK 23.8	100	90	28.9 ± 4.0
EFK 22.8	100	80	32.1 ± 4.5
EFK 21.9	100	100	29.3 ± 7.9
EFK 18.2	100	90	31.4 ± 4.2
EFK 17.0	100	90	31.9 ± 1.6
EFK 13.8	100	90	30.3 ± 8.2
EFK 10.9	100	100	31.8 ± 3.6

Note: EFK - East Fork Poplar Creek kilometer. SD = standard deviation.

Table 2.2. Summary (mean ± SD) of water chemistry analyses conducted during toxicity tests of ambient samples from East Fork Poplar Creek, September–November, 1996

Sample	pH (su)	Alkalinity (mg/L as $CaCO_3$)	Hardness (mg/L as $CaCO_3$)	Conductivity (µS/cm)
		September 4 - 11, 1996		
Control	8.28 ± 0.07	87.0 ± 3.9	98.3 ± 2.7	209.3 ± 6.4
EFK 24.6	8.05 ± 0.07	107.5 ± 3.9	141.3 ± 5.5	310.7 ± 16.2
EFK 24.1	8.12 ± 0.11	112.2 ± 4.1	145.0 ± 6.3	319.5 ± 16.1
EFK 23.8	8.06 ± 0.13	107.3 ± 8.1	140.3 ± 9.2	315.3 ± 21.3
		October 9 - 15, 1996		
Control	8.26 ± 0.06	90.4 ± 3.6	98.3 ± 2.1	203.3 ± 10.6
EFK 24.6	8.05 ± 0.05	122.0 ± 5.8	137.3 ± 6.4	302.8 ± 15.9
EFK 24.1	8.17 ± 0.02	122.8 ± 5.7	140.7 ± 6.0	308.8 ± 20.2
EFK 23.8	8.09 ± 0.06	126.2 ± 4.1	139.0 ± 5.0	328.7 ± 26.6
		November 13-19, 1996		
Control	8.22 ± 0.11	83.2 ± 1.5	99.3 ± 1.6	203.3 ± 11.2
EFK 24.6	8.03 ± 0.16	90.3 ± 18.9	127.3 ± 24.9	284.8 ± 62.5
EFK 24.1	8.08 ± 0.11	98.8 ± 12.1	134.7 ± 19.5	311.3 ± 35.8
EFK 23.8	8.02 ± 0.12	101.7 ± 13.4	136.0 ± 13.9	322.3 ± 41.3
EFK 22.8	8.14 ± 0.12	93.0 ± 12.2	128.0 ± 19.1	326.7 ± 58.7
EFK 21.9	8.12 ± 0.08	95.3 ± 12.5	136.7 ± 21.4	335.3 ± 68.3
EFK 18.2	8.15 ± 0.13	106.7 ± 22.0	141.3 ± 32.3	330.3 ± 78.2
EFK 17.0	8.15 ± 0.19	111.0 ± 26.0	147.3 ± 39.3	339.3 ± 95.8
EFK 13.8	8.09 ± 0.17	114.3 ± 35.2	138.0 ± 41.6	318.7 ± 83.7
EFK 10.9	8.07 ± 0.11	110.3 ± 26.5	146.0 ± 43.8	373.7 ± 91.6

Note: EFK - East Fork Poplar Creek kilometer. SD = standard deviation.

speciation of cadmium, a toxic metal present in LR sediments.

3. Biological Indicators of Fish Health

3.1 Bioindicators of Fish Health (*S. M. Adams*)

3.1.1 Introduction

This task involves the use and application of bioindicators of fish health, in addition to other investigative approaches, to evaluate the effects of water quality and other environmental variables on fish in EFPC. A suite of diverse bioindicators of fish health has been examined since fall 1985 to evaluate the health of a sentinel species, the redbreast sunfish (*Lepomis auritus*), in EFPC as a component of the BMAP program.

3.1.2 Results/Progress

The most consistently useful indicator of contaminant exposure to fish measured in the bioindicators task has been the activity of a specific detoxification enzyme, 7-ethoxy-*O*- resorufin (EROD). This enzyme typically increases in the liver tissue of fish when contaminant exposure is increased, and decreases when exposure is reduced. Chlorinated organic compounds such as PCBs are known to induce this enzyme system in fish. Therefore, as concentrations of PCBs change in EFPC, the levels of detoxification enzymes would also be expected to change. This has indeed been the case in EFPC. From 1988 to 1992, year-to-year changes in EROD activity have closely tracked PCB body burdens in fish, providing good evidence that these enzymes are accurately reflecting the biological availability of PCBs in EFPC (Fig. 3.1).

Remedial measures at the Y-12 Plant have resulted in both gradual and rapid changes in water quality in EFPC over the last several years. Gradual patterns in several water quality indicators appear to be related to the trends in PCB and EROD levels shown in Fig. 1. In addition, relatively rapid decreases in total residual chlorine in EFPC in response to large-scale dechlorination efforts initiated in late 1992 also coincided with a rapid rise in PCB levels and detoxification enzyme activity during this time. Although there is not yet reason to suspect an actual cause-and-effect relationship between increased PCB bioaccumulation in fish and dechlorination, these trends will continue to be monitored to determine whether dechlorination is somehow influencing the availability of PCBs to aquatic organisms in EFPC. An important component of this evaluation will be to look at the growth of fish and the availability of macroinvertebrates in the stream to determine if and by what mechanisms dechlorination is having a positive influence on these important ecological parameters within EFPC.

3.2 Bioindicators of Reproductive Competence (*M. S. Greeley, Jr., and M. K. McCracken*)

3.2.1 Introduction

Successful reproduction of fish populations requires that adults be capable of producing and spawning viable gametes. To address the reproductive competence of adult fish in EFPC, various reproductive indicators, representing several different levels of reproductive organization related to

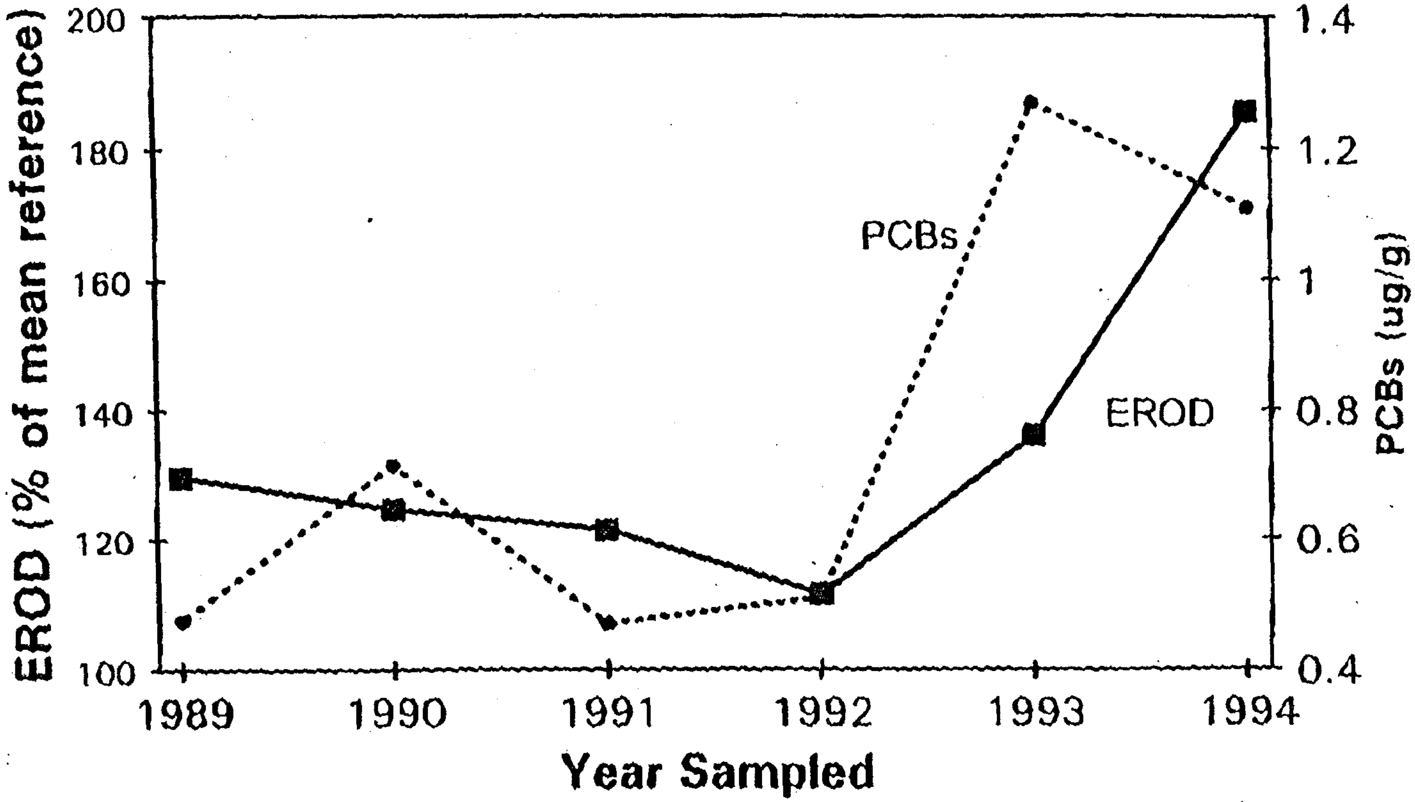

Fig. 1. Annual mean PCB concentration in fish from East Fork Poplar Creek and the annual means of detoxification enzyme (EROD) activity in these fish expressed as a percent difference from annual mean reference values.

gamete production, have been routinely examined in female redbreast sunfish sampled from EFPC and reference streams at the beginning of each annual breeding season since 1988. Establishment and maintenance of stable fish populations also requires that offspring be able to develop normally into subsequent reproductive cohorts. Beginning in 1990, water samples from several sites in EFPC and other streams on and about the ORR have been tested for their effects on fish developmental processes utilizing a medaka (*Oryzias latipes*) embryo-larval test.

3.2.2 Results/Progress

Redbreast sunfish were sampled from 5 sites in EFPC and 2 sites in reference streams during May and June, 1996, in order to assess reproductive competence at the beginning of the breeding season. Reproductive tissues obtained from these fish are currently being analyzed in the laboratory; results of these analyses will be presented in the next quarterly report.

A medaka embryo-larval test was conducted during November, 1996, in an ongoing attempt to characterize the cause of the continuing toxicity of water in upper EFPC to fish embryos in this test (Table 3.1). A water sample from the Water Intake Station on the Clinch River had relatively little effect on embryo survival when sterile-filtered, although there was a moderate reduction in survival in

Table 3.1. Results of medaka embryo-larval toxicity tests of sterile-filtered and unfiltered water samples from the Water Intake Station, the Flow Management Pipe, and the North/South Pipes

Sample	Concentration (%)	Survival (%)
Control[a]		
Unfiltered	100	80.0
Sterile-filtered	100	90.0
Water Intake Station		
Unfiltered	100	52.6
Sterile-filtered	100	95
Flow Management Pipe		
Unfiltered	100	33.3
Sterile-filtered	100	35.0
North/South Pipe		
Unfiltered	100	5.3
Sterile-filtered	100	5.0

[a] *Naya* brand bottled spring water

unfiltered water (possibly due either to particulate-borne compounds or to pathogens). Filtered and unfiltered water from the Flow Management Pipe at the junction with EFPC significantly reduced survival of medaka embryos in both cases. The greatest reduction in embryo survival occurred in water obtained directly from the North/South Pipes, and again filtration did not affect the results. The results of this preliminary special study suggest that water added to EFPC through the Flow Management Pipe should reduce the toxicity of upper EFPC water to fish embryos, but not to the extent originally expected. Future studies will examine whether the adverse effects of water from the Flow Management system on medaka embryos are reduced over time with further flushing of the system. Studies also continue to identify and characterize the specific factor(s) involved in the poor survival of medaka embryos in water from upper EFPC.

4. Bioaccumulation monitoring task

4.1 Routine bioaccumulation monitoring *(M.J. Peterson and G.R. Southworth)*

4.1.1 Introduction

Bioaccumulation monitoring conducted since 1985 as part of the EFPC BMAP has identified mercury and polychlorinated biphenyls (PCBs) as substances that accumulate to concentrations in fish that may pose health concerns to human consumers. Redbreast sunfish (*Lepomis auritus*) are collected twice annually from six sites along the length of EFPC to evaluate spatial and temporal trends in mercury and PCB contamination. The fall/winter collection of sunfish was initiated in November 1996. Results of analyses of these samples are expected to provide the first indications of changes in exposure or bioavailability of mercury and PCBs in upper EFPC as a result of flow management.

The bioaccumulation task focuses primarily on evaluating contamination in filets of common sport fish such as sunfish and bass. Such data can be used to assess the potential risk to people who might eat fish from these creeks, but is less useful in evaluating ecological risks. Whole-body analysis of stream forage organisms are a more appropriate measure of evaluating ecological risk because 1) the whole organism (not just muscle) is eaten by terrestrial predators, 2) organisms such as minnows are more readily eaten by predators than game fish, and 3) lower organisms can have very different bioconcentration potentials. In 1996, three composite samples of stonerollers were analyzed for a suite of metals and PCBs at EFK 24.8, EFK 23.4, and EFK 18.2. Striped shiners, which more effectively accumulate methylmercury than the herbivorous stonerollers, were analyzed for mercury at the same sites. The metals results (including mercury) in forage fish are reported below. The PCB results in stonerollers will be reported with the sunfish PCB data in the next quarterly report.

4.1.2 Results/Progress

Mean metal concentrations in whole body analyses of EFPC forage fish are presented in Table 4.1, along with data for metal concentration in forage fish from Bear Creek, White Oak Creek, and the Hinds Creek reference site. Cadmium, uranium, zinc, and mercury concentrations in fish from upper EFPC (EFK 24.8 and EFK 23.4) were several fold higher than concentrations in forage fish from the reference site. A decreasing downstream gradient suggests that sources of all four metals arise within the Y-12 Plant. Copper, nickel, and lead concentrations in EFPC forage fish were higher than reference site concentrations at some sites in EFPC, but a clear downstream gradient was absent, and levels were

Table 4.1 Mean (± SE, n = 3) concentrations (μg/g wet wt) of metals in composite samples of stonerollers (*Campostoma anomalum*) from EFPC and other sites on the ORR

ANALYTE	SITE								
	EFK 24.8	EFK23.4	EFK18.2	BCK12.5**	BCK9.4	BCK3.3	WCK 3.5	WCK 2.9	Hinds Cr
Antimony	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Arsenic	0.068 ± 0.009	0.15 ± 0.020	0.19 ± 0.006	0.19 ± 0.005	0.19 ± 0.032	0.28 ± 0.0250	0.16 ± 0.009	0.17 ± 0.012	0.24 ± 0.004
Beryllium	<0.003	0.006 ± 0.001	0.018 ± 0.001	0.006 ± .003	0.010 ± 0.003	0.030 ± 0.002	0.004 ± 0.001	0.008 ± 0.002	0.014 ± 0.002
Cadmium	0.18 ± 0.00	0.18 ± 0.003	0.11 ± 0.004	1.50 ± 0.26	0.32 ± 0.027	0.21 ± 0.019	0.06 ± 0.020	0.02 ± 0.004	<0.02
Chromium	<0.5	0.65 ± 0.049	0.89 ± 0.015	<0.5	0.46 ± 0.13	1.06 ± 0.068	0.56 ± 0.018	0.56 ± 0.041	0.63 ± 0.079
Copper	5.4 ± 0.38	5.9 ± 1.04	4.13 ± 0.38	0.56 ± 0.032	2.9 ± 1.7	4.7 ± 0.51	6.4 ± 0.27	5.0 ± 0.70	2.9 ± 0.33
Lead	≤0.5	0.76 ± 0.052	1.83 ± 0.12	<0.5	<0.5	≤0.5	<0.5	<0.5	<0.5
Mercury	2.5 ± 0.25*	0.42 ± 0.037*	0.56 ± 0.19*	0.09 ± 0.007	0.10 ± 0.000**	0.10 ± 0.000*	0.22± 0.04**	0.15± 0.01**	0.033 ± 0.007*
Nickel	<0.5	1.08 ± 0.076	0.73 ± 0.009	0.78 ± 0.05	≤0.54	0.78 ± 0.04	<0.5	≤0.5	<0.5
Selenium	<0.5	<0.5	<0.5	0.82 ± 0.14	<0.5	<0.5	1.25 ± 0.16	0.64 ± 0.00	<0.5
Silver	≤0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.25 ± 0.009	<0.2	<0.2
Thallium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Uranium	0.92 ± 0.54	0.47± 0.020	0.26 ± 0.015	0.58 ± 0.11	0.83 ± 0.24	0.49 ± 0.24	0.017± 0.007	0.030 ± 0.006	0.010 ± 0.000
Zinc	80.7 ± 1.2	68.0 ± 2.0	44.3 ± 0.88	39 ± 0.88	41 ± 0.88	38 ± 3.6	62.3 ± 2.7	44.7 ± 3.2	29.0 ± 1.6

* striped shiner (*Luxilus chrysocephalus*)
** blacknose dace (*Rhinichthys atratulus*)

generally not more than twice background concentrations or detection limits. The mean copper concentration in the reference site fish was approximately three times higher than was typical of stonerollers from that site in three previous analyses associated with other programs, suggesting that copper results for EFPC fish may be biased high. Although well above background levels, cadmium in EFPC forage fish was nearly ten times lower than that in forage fish from the headwaters of Bear Creek, and about half that of fish in lower Bear Creek. Zinc was slightly higher in EFPC fish than in fish from WOC below ORNL, while uranium concentrations in EFPC fish were similar to those in fish from Bear Creek. The average total mercury concentrations in striped shiners exhibited a spatial trend similar to mercury concentrations in sunfish filets: concentrations were highest upstream of Lake Reality (EFK 24.8), and average concentrations at the two downstream sites (EFK 23.4 and EFK 18.2) were similar. However, the ratio between total mercury in sunfish vs. total mercury in shiners did vary by site. Total mercury concentration in shiners were approximately a factor of two higher than sunfish at EFK 24.8, but shiners were approximately 25% lower than sunfish at EFK 23.4 and EFK 18.2. The differences are likely due to high levels of inorganic mercury in forage fish near the Y-12 plant. Mercury speciation studies conducted for the Lower EFPC remedial investigation have shown that methylmercury concentrations in whole body analyses of forage species are about 25% or less concentrations found in sunfish fillets. Proportions of the much less toxic inorganic mercury in forage species are high enough (40 - 90%) that evaluations of risk to piscivorous wildlife based on assumptions of 100% methylmercury in forage species are likely to be substantially overestimated.

The 1996 screening provides a basis from which mercury and PCB concentrations in sunfish fillets can be used to estimate the potential ecological concerns associated with whole-body concentrations in shiners and rollers. Its is likely that substantial increases or decreases in mercury and PCBs in sunfish fillets would result in a similar change in forage fish, thus forage fish will not be monitored for these two contaminants in 1997. Whole-body analyses of herbivorous minnows for metals other than mercury is clearly a better alternative than sunfish fillets for evaluating biologically-meaningful metal contamination. Annual metals analysis of fish fillets in EFPC will therefore be replaced by analyses of whole stonerollers. Because stonerollers from EFK24.8 contained the highest concentrations of most metals of potential concern (e.g. uranium, zinc), this site/species will be monitored in future years.

4.2 Special Studies

4.2.1 Relationship between mercury in water and fish in EFPC (*G. R. Southworth and M. J. Peterson*)

4.2.1.1 Introduction

Efforts to establish a predictive empirical relationship between total mercury in water and methylmercury accumulation in fish in EFPC have indicated that mercury bioavailability in EFPC is much lower than it is in uncontaminated sites throughout North America. However, mercury availability at other contaminated sites might be similar. In 1996, data on mercury concentrations in fish and water in mercury -contaminated hard water streams in Virginia, Kentucky, and Tennessee were obtained to investigate the hypothesis that mercury bioavailability at those sites was similar to EFPC. If mercury bioavailability at other contaminated sites with similar water chemistry was similar to EFPC, data from those sites could be used to assess the relationship between total mercury in water and bioaccumulation in fish at aqueous mercury concentrations in the range (50 - 200 ng/L) that is the 1998 target for remedial actions in upper EFPC.

4.2.1.2 Results/Progress

Mercury concentrations in sunfish exceed background levels in Big Bayou Creek (Paducah, Kentucky), White Oak Creek (Oak Ridge, Tennessee), North Fork Holston River (Saltville, Virginia), and the South River (Waynesboro, Virginia) as well as EFPC. Water samples were collected at those sites under late summer baseflow and analyzed for total mercury by atomic fluorescence spectrometry. Redbreast sunfish (longear sunfish at Paducah) are routinely collected at most of those sites by Y-12, ORNL. and PGDP BMAPs, and analyzed for total mercury. Fish were collected at the South River site and analyzed at ORNL, while data on mercury concentrations in fish from the North Fork Holston River were provided by Olin Corporation, which regularly monitors mercury levels in fish below the Saltville site.

Mercury bioavailability at contaminated sites in Virginia and Kentucky was strikingly higher than at sites in Oak Ridge (EFPC and White Oak Creek). In Fig. 4.1, sites at which mercury concentrations in sunfish are similar are paired, and total mercury concentrations in water are compared. At the South River site, mercury concentration in water was less than 100 ng/L, while at EFK 24.8 within the Y-12 Plant, where mercury in fish was nearly identical to that at the Virginia site, total water-borne mercury exceeded 1400 ng/L. The pattern was repeated when the North Fork Holston River site was compared with EFK 23.4 (Station 17). Although mercury in redbreast sunfish was about 0.6 mg/kg at the two sites, aqueous mercury in the Virginia river was less than 50 ng/L, while in EFPC it was nearly 1500 ng/L. White Oak Creek and Big Bayou Creek at Paducah each contained sunfish that averaged around 0.3 mg/kg mercury, but the aqueous mercury concentration in White Oak Creek was much higher.

Two conclusions can be drawn from this study. First, other mercury-contaminated streams cannot be used as surrogates for predicting the degree of reduction needed in mercury concentration in EFPC to achieve target concentrations of mercury in resident fish; and second, something distinct about the chemical composition of water in upper EFPC and White Oak Creek may act to reduce bioavailability of mercury. Much of the flow in both streams is comprised of process (drinking) water that is obtained from the same water treatment plant. The chemistry of both streams is also strikingly altered by industrial discharges from both facilities, which have many chemical similarities.

4.2.2 Effects of Methylmercury on Fish-Eating Birds in EFPC *(T. L. Ashwood)*

4.2.2.1 Introduction

Kingfishers are highly piscivorous birds that consume up to half their bodyweight each day in fish or crayfish. Because kingfishers are territorial during the breeding season, their food intake and the food they provide their nestlings all comes from a relatively small area of a stream or lake. If fish within these territories are contaminated, then the adults and nestlings are highly exposed. For two years, the Oak Ridge Reservation (ORR) ecological risk assessment (Sample et al. 1995, 1996) has identified kingfishers as being highly at risk on all ORR streams.

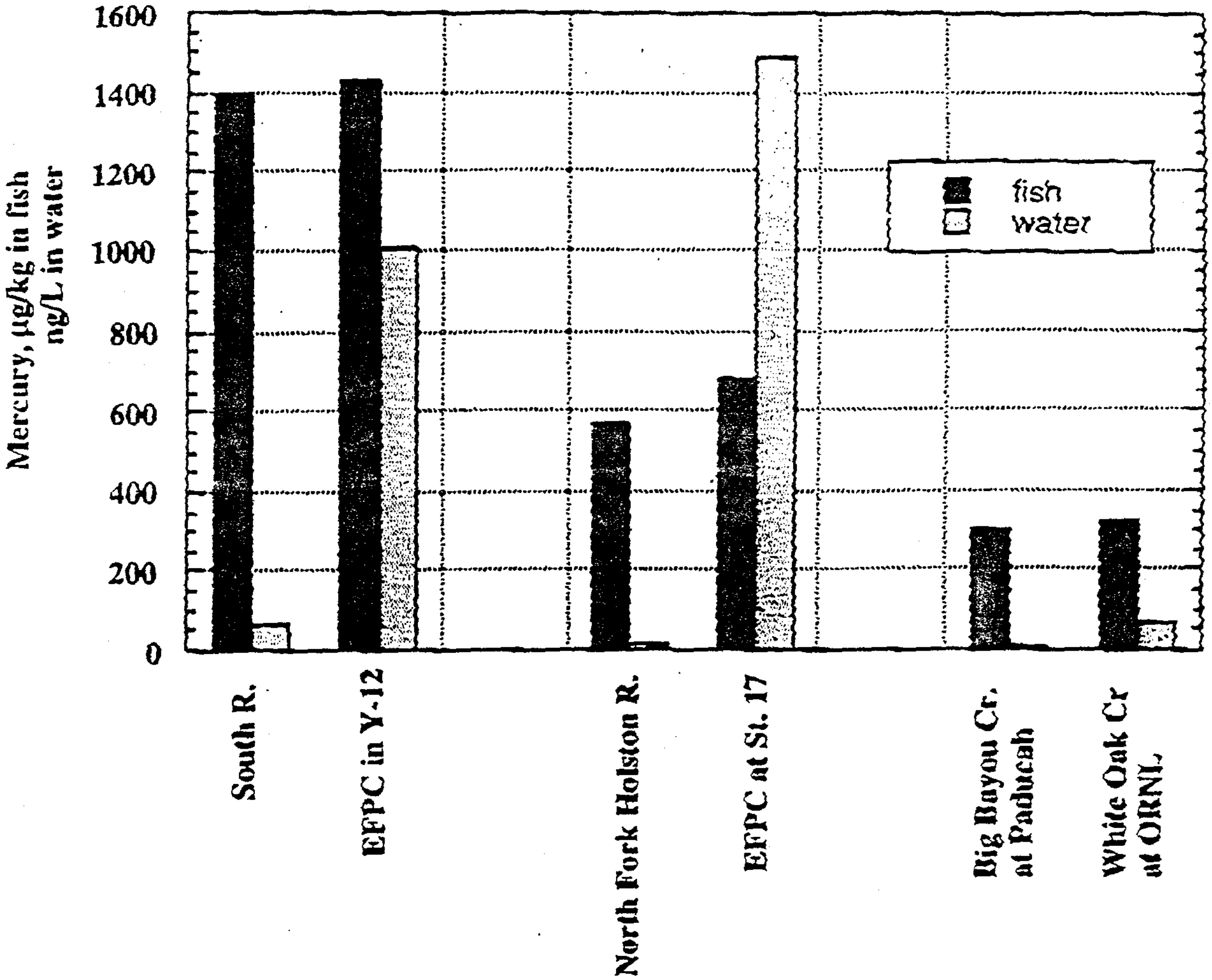

Fig. 4.1 Comparison of mercury in fish and mercury in water at sites receiving Oak Ridge process water versus other mercury-contaminated streams.

4.2.1.2 Results/Progress

As part of the mercury study, kingfishers were surveyed in two areas on EFPC. Adult kingfishers of both sexes were observed during the breeding season (March-May) in the vicinity of Lake Reality and along EFPC where it flows through Jackson Farm. At Lake Reality, kingfishers were observed along upper EFPC as far upstream as where the stream enters the security area of the Y-12 Plant. At Jackson Farm, kingfishers were observed along the stream in the horse pasture area of the farm.

We were unable to conclusively identify any kingfisher nests at either location. Kingfishers prefer steep banks with sufficient height above water to minimize the risk of nest flooding. Because they dig their own burrows, kingfishers prefer loose soil. Locations believed to be suitable for kingfisherburrows are scarce along the banks of upper EFPC. At Jackson Farm, the banks may be too low for kingfisher nests, although rough-winged swallows were observed nesting in the banks at Jackson Farm.

Because no kingfisher nests were found, no samples were collected and no data regarding hatching or fledging success were collected during FY 1996. This lack of success in FY 1996 is most probably due to the *ad hoc* nature of the observations. Utilization of a dedicated observer with specific experience in bird surveys during FY 1997 will be much more likely to locate the nests and obtain reproductive data and samples. The high potential for risks to these birds suggests that they may be suffering reproductive impairment along EFPC. The presence of adults throughout the year and during the breeding season cannot be taken as an indication that the birds are successfully reproducing.

4.2.3 PCB Source Identification *(J. F. McCarthy)*

Semi-permeable membrane devices (SPMDs) were deployed during the last quarter at 21 sites in upper EFPC and within the storm drain network in an attempt to identify the sources of PCB being bioaccumulated by fish and clams. Results of these studies will be reported in future quarterly reports.

5. Community Studies

5.1 Periphyton (W. R. Hill)

5.1.1 Introduction

Periphyton monitoring in EFPC occurs four times a year (as close to a quarterly sampling regime as environmental conditions will allow). Rocks and their associated periphyton are collected from three sites on EFPC (EFKs 24.4, 23.4, 6.3) and one site on Brushy Fork (BFK 7.6). Four rocks from each site are used in determining algal biomass (chlorophyll *a*), rate of photosynthesis (^{14}C incorporation), and algal community composition. To compare photosynthesis (PS) rates for periphyton among sites with different algal biomass, the PS data are divided by the chlorophyll *a* amounts. The resulting chlorophyll-specific photosynthetic rates provide an index of physiological condition of the algal component of the periphyton.

5.1.2 Results/Progress

Periphyton biomass and photosynthesis was measured October 31,1996. The results of these measurements appear in Table 5.1. Overall, periphyton biomass and photosynthesis in EFPC were roughly similar to that measured previously in July. However, photosynthesis and chlorophyll-specific photosynthesis at EFK 24.4 were lower than in July. The other two EFPC sites exhibited modest gains in biomass and photosynthesis, and the reference site (BFK 7.6) showed two-fold increases in biomass and photosynthesis. No significant spates occurred for at least a month prior to sampling, so increases in biomass and photosynthesis were not unexpected. Loss of canopy cover at shaded downstream (EFK 6.3) and reference (BFK 7.6) sites may have stimulated primary production at these sites and contributed to the increases in photosynthesis we measured in the laboratory. The contrasting decrease in photosynthesis at EFK 24.4 could well be the result of the lower temperatures and turbulent base flow caused by flow augmentation. If photosynthesis *in situ* was indeed diminished by flow augmentation, then growth and reproduction of the major fish species at EFK could also be affected by flow augmentation.

The next sampling of periphyton biomass and photosynthesis in EFPC is scheduled for January 1997. This sampling episode may confirm impacts of flow augmentation. Periphyton and stonerollers samples collected in the Fall of 1996 for metal accumulation will be submitted for ICP analysis of metals in January. A paper describing the accumulation of PCBs by periphyton and stonerollers in upper EFPC was accepted for publication by *Archives of Environmental Contamination and Toxicology* in November.

Table 5.1. Means and standard errors for biomass, photosynthesis, and chlorophyll-specific photosynthesis rates of periphyton collected from EFPC and Brushy Fork, October 31, 1996

Site	Algal biomass (μg chla/cm^2)	Photosynthesis (μgC/cm^2/h)	Chlorophyll-specific photosynthesis (μgC/μgchla/cm^2/h)
EFK 24.4	49.5 ± 4.5	7.62 ± 0.77	0.15 ± 0.01
EFK 23.4	42.7 ± 8.9	10.26 ± 2.42	0.24 ± 0.02
EFK 6.3	29.5 ± 6.1	8.45 ± 0.82	0.33 ± 0.07
BFK 7.6	10.0 ± 3.2	2.41 ± 0.76	0.28 ± 0.07

Note: EFK = East Fork kilometer, BFK = Brushy Fork kilometer

5.2 Benthic Macroinvertebrate Community Monitoring (*J. G. Smith*)

5.2.1 Introduction

The objectives of the benthic macroinvertebrate task are to monitor the benthic macroinvertebrate community in EFPC to provide information on the ecological condition of the stream, and to evaluate the response of macroinvertebrates to operational changes, abatement activities, or remedial actions at the Y-12 Plant as a measure of the effectiveness of these actions. To meet these objectives, routine quantitative benthic macroinvertebrate samples have been collected at least twice annually (April and October) since 1985 from four sites on EFPC (EFK 24.4, EFK 23.4, EFK 13.8, and EFK 6.3). Since 1986, two reference sites unimpacted by industrial discharges have also been monitored: one site each on BF at kilometer 7.6 (BFK 7.6) and Hinds Creek at kilometer 20.6 (HCK 20.6) (Figs. 1.1 and 1.2).

5.2.2 Results/Progress

Average values for total taxonomic richness and richness of the Ephemeroptera, Plecoptera, and Trichoptera (EPT richness) for samples collected during the April sampling periods from 1986 through 1996 are presented in Fig. 5.1. These two metrics have consistently helped determine the condition of stream sites, and detect temporal changes within sites. EPT richness is particularly useful because the three major insect orders it incorporates are generally intolerant of poor water quality. Total and EPT richness values were clearly and persistently low at EFK 24.4 and EFK 23.4 compared with the reference sites from 1986 through 1996. However, total richness values for EFK 23.4 and EFK 24.4 have generally increased while values for the reference sites have shown no consistent trends of change. EPT richness has increased at these two sites, but the increases have been more subtle. EPT taxa were rarely collected until after 1990 and 1991 at EFK 23.4 and EFK 24.4 respectively.

Values for total and EPT richness were also consistently lower at EFK 6.3 than at either reference site, but the magnitude of difference was less than for EFK 24.4 or EFK 23.4. After 1990 total richness values for EFK 6.3 and the reference sites generally differed by less than a factor of 2X. From 1989 through 1996, values for total richness at EFK 13.8 consistently changed within the ranges exhibited by the reference sites. This was also true for EPT richness except for the most recent collection period in April (1996). Although EPT richness values declined between 1995 and 1996 at EFK 13.8 and the reference sites, the magnitude of decline at EFK13.8 was enough to result in a much greater difference from the reference sites than in past April sampling periods. It is not known if this larger difference was caused by an actual change associated with natural or unnatural factors, or if it was the result of a sampling artifact.

These results indicate that the macroinvertebrate community at EFK 23.4 and EFK 24.4 remained significantly degraded through 1996. However, subtle but persistent increases in total richness and richness of pollution tolerant taxa at these sites indicate that some improvements have occurred in upper EFPC since 1986. Within approximately 10 km downstream of EFK 23.4 (i.e., EFK 13.8), the benthic macroinvertebrate community, as judged from total and EPT richness only, exhibits characteristics that indicate minimal or no impact relative to reference conditions.

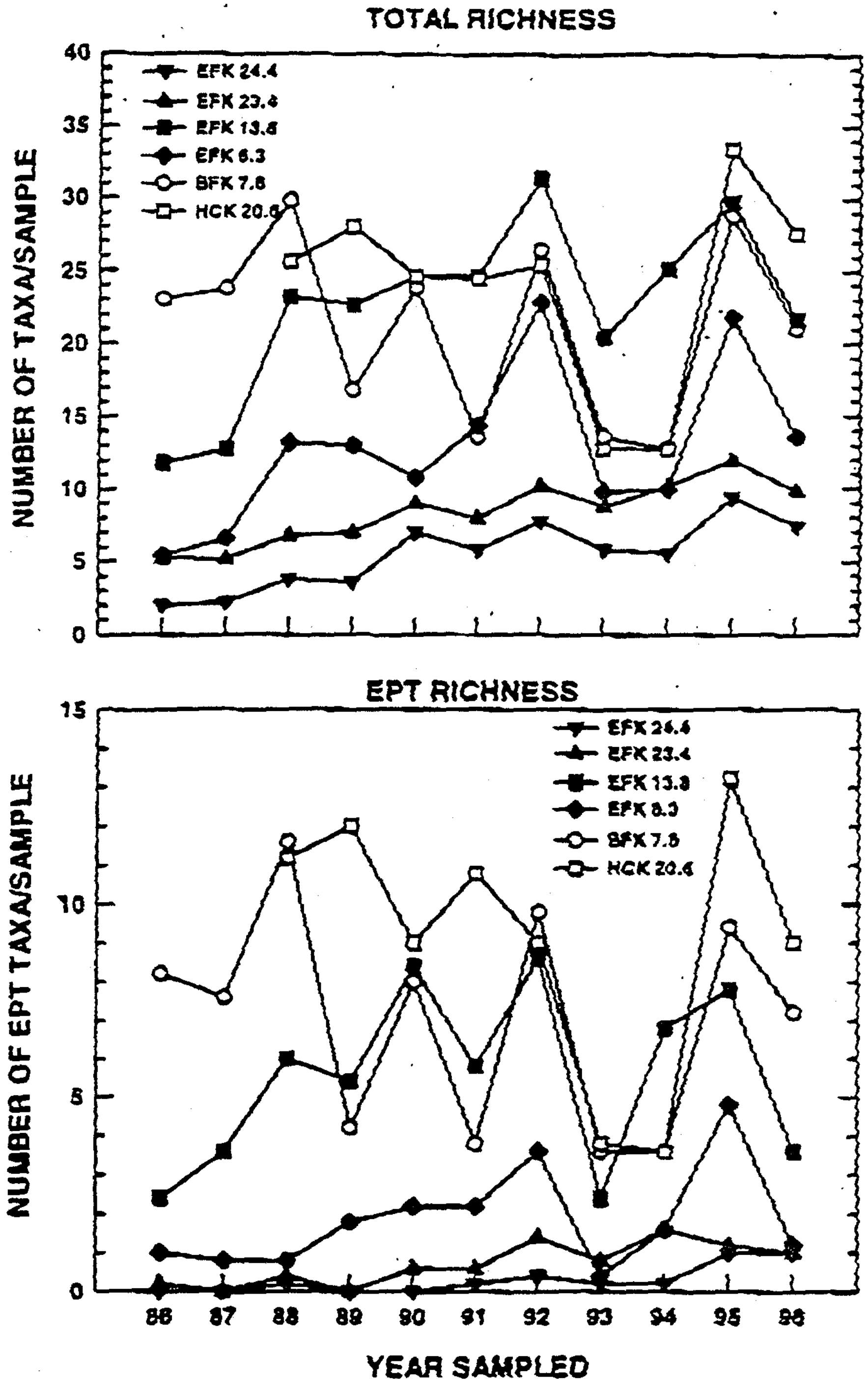

Fig. 5.1. Mean values for total taxonomic richness and richness of the Ephemeroptera, Plecoptera, and Tricoptera (EPT) of the benthic macroinvertebrate communities in EFPC and reference sites in Brushy Fork and Hinds Creek. Values are based on samples collected during the April sampling periods from 1986 through 1996.

5.3 Fish community monitoring (*M. G. Ryon*)

5.3.1 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 two primary activities conducted by the Fish Community Studies task in EFPC are: (1) biannual, quantitative estimates of the fish community at six EFPC sites and two reference stream sites; and (2) investigative procedures in response to fish kills near the Y-12 Plant. The quantitative sampling of the fish populations at sites is conducted by electrofishing in March–April and September–October. The resulting data are used to estimate population size (numbers and biomass per unit area), determine length frequency, estimate production, and calculate Index of Biotic Integrity values. Fish kill investigations are conducted in response to chemical spills, unplanned water releases, or when dead fish are observed in EFPC. The basic tool used for fish kill investigations is a survey of upper EFPC (above Bear Creek Road to the North/South Pipes) in which numbers and locations of dead, dying, and stressed fish are recorded. This baseline is supplemented by special toxicity tests, histopathological examinations, and water quality measurements in an effort to determine the cause of observed mortality.

5.3.2 Results/Progress

This quarter, quantitative fish community sampling was completed for the EFPC sites and the reference sites, as *per* the plan schedule. Data from these quantitative surveys of EFPC sites were entered into computer databases and will be processed through quality assurance procedures during the next quarter.

During September 1996, 5 daily surveys were conducted of EFPC above Bear Creek Rd. to evaluate the background levels of mortality. A total of 5 dead stonerollers were found. The average dead per survey, 1 fish, was lower than prior background mortality levels of approximately 6 fish per survey. The lower rate could be incidental or may reflect improved conditions associated with the flow management instituted this summer. The absence, at least to this date, of any substantial fish kills particularly in the late November time frame also is notable. Because of this possible improved rate of mortality, a background survey will be conducted in December to provide additional data.

6. References

Ham, K.D., S.M. Adams, and M.J. Peterson. In press. Application of multiple bioindicators to differentiate spatial and temporal variability from the effects of contaminant exposure in fish. Ecotoxicol. Environ. Saf.

Loar, J. M., S. M. Adams, L. J. Allison, J. M. Giddings, J. F. McCarthy, G. R. Southworth, J. G. Smith, and A. J. Stewart. 1989. The Oak Ridge Y-12 Plant Biological Monitoring and Abatement Program for East Fork Poplar Creek. ORNL/TM-10265. Oak Ridge National Laboratory, Oak Ridge, Tennessee.