The Effects of Fly Ash Release From the TVA Kingston Steam Plant on Fish and Benthic Macroinvertebrates Communities

T. F. Baker, K. M. Lakin, D. R. Lowery - Tennessee Valley Authority, Office of Environment & Research, Chattanooga, TN
J. G. Smith - Oak Ridge National Laboratory, Oak Ridge, TN

INTRODUCTION

On December 22, 2008, a dike retaining fly ash and bottom ash in an 84-acre cell complex from Tennessee Valley Authority's (TVA) Kingston Fossil Plant failed. An estimated 5.4 million cubic yards of ash were released into the adjacent Emory River, with some of the ash deposits extending as far as 3.5 miles upstream (~ERM 6.0) of the Plant and some ash being carried as far downstream as Tennessee River mile 563 (~4 miles downstream of the Tennessee River confluence with the Clinch River).

The magnitude of the TVA Kingston Fossil Plant fly ash spill certainly suggests concern about the effects on aquatic organisms such as fish and invertebrates. A comprehensive assessment of the ecological consequences from the ash spill was initiated soon after the incident. Included in this assessment were studies of fish and benthic macroinvertebrate assemblages. These studies are being conducted in conjunction with studies of contaminant exposures (i.e., metals) in fish and invertebrates, fish health and reproductive studies and similar studies with other wildlife, including insect-eating and fish-eating birds, in order to evaluate any cause-and-effect relationships between levels of contaminants and biological effects.

OBJECTIVES

- Assess fish and benthic macroinvertebrate assemblages for potential short-term impacts resulting from the initial ash release and the ongoing construction and remediation activities at the Site
- Provide data for comparison with future results in order to detect and evaluate any potential trends and impacts on the fish and benthic macroinvertebrate populations as well as investigate possible relationships to other ecological receptors

METHODS

Fish Community Survey

- Fish assemblage sampled at 3 sites in autumn 2009 (Figure 1)
- Fifteen 300-meter electrofishing runs and ten overnight, experimental gill net sets per site
- All fish indentified and enumerated
- Surveys conducted prior to ash spill provide baseline for comparison

Spring Sport Fish Survey

- Quantitative survey of black bass at 2 sites in spring 2009 (Figure 1)
- Twelve 30-minute electrofishing runs at fixed stations at each site
- All bass measured, weighed, enumerated, and visually inspected for general health
- Surveys conducted prior to ash spill provide baseline for comparison (Figure 2)

Benthic Macroinvertebrates Community Survey

- Benthic organisms collected at 11 sites in January 2009 (Figure 1)
- Ten equally-spaced Ponar grabs (0.05 m^2) collected across the width of the reservoir (*i.e.,* transects) at each site
- Grab samples washed through a 0.6 mm mesh screen and remaining content preserved for taxonomic analysis
- The matrix from each grab sample (*i.e.,* 10) processed separately
- No surveys conducted prior to ash spill

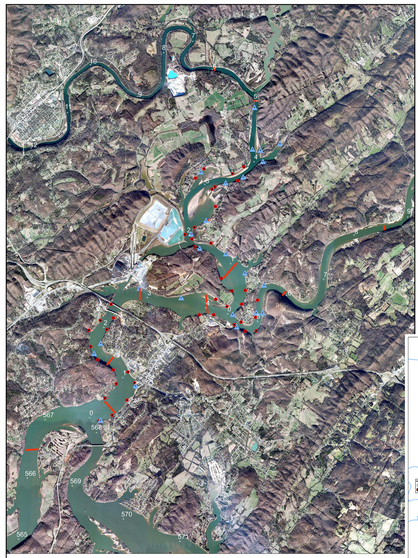

Figure 1. Sampling sites

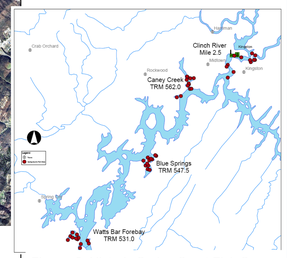

Figure 2. Historic Spring Sport Fish Survey sampling sites on Watts Bar Reservoir; far-field and Clinch River mile 2.5

RESULTS AND DISCUSSION

Fish Community Survey

- Fish community examined at 3 sites in 2009; 2 sites (CRMs 4.4 and 1.5) sampled as part of monitoring program for Kingston Fossil Plant in 2001, 2003, 2005, and 2007; additional site established in Emory River (mile 2.5) in 2009 to evaluate immediate near-field effects
- Total of 5198 fish and 38 species collected in 2009; species richness was 35 at immediate near-field site (ERM 2.5), 31 at CRM 4.4, and 32 at CRM 1.5; difference primarily in "incidental" species with historic median catch rates of 0 to 1
- Community results evaluated using multi-metric scoring method (Reservoir Fish Assemblage Index or RFAI) developed by TVA in early 1990s as part of TVA's Valley-wide Reservoir Vital Signs Monitoring Program
- RFAI scores at the 3 sites in 2009 in the fair to good range, with the highest score nearest spill area (Figure 3)
- ERM 2.5 scored higher in number of native species, number of benthic invertivores, and % non-native species
- Difference in % non-native largely due to significantly higher numbers of inland silversides collected at 2 downstream sites
- Given defined variability in the sampling methodology, RFAI scores for 2 downstream sites in 2009 and 2007 close and considered similar (not different)

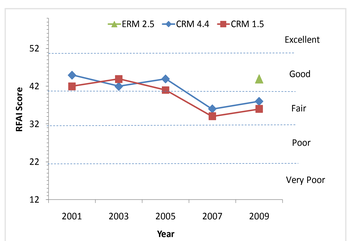

Figure 3. Reservoir Fish Assemblage Index Scores, 2001-2009.

Spring Sport Fish Survey

- Black bass population examined at 2 sites in 2009; 1 site (CRM 2.5) sampled as part of TVA's Valley-wide Monitoring Program in 2002, 2003, 2004, and 2005; additional site established in Emory River (mile 2.5) in 2009 to evaluate immediate near-field effects
- A total of 695 black bass collected during 2009 survey (Table 1)
- Five years of data from Clinch River with 2009 catch rate highest observed (62.7 fish/hr; Table 1)
- Catch rate in Emory River (53.2 fish/hr) lower than in Clinch River in 2009, but similar to Clinch River's long-term average of 49.5 fish/hr
- Length frequency histogram for largemouth bass illustrates a bimodal distribution for both locations (Figure 4) with good representations of all size classes up to 21-22 inches; typical of Tennessee River mainstem reservoirs with desirable size class distributions
- Anomalies observed in less than 1.9% of bass collected; lower than 2002-2005 average of 3.7% for CRM 2.5 and 2.7% for 3 far-field sites sampled on Watts Bar in 2009
- Increase in number of bass with parasites in 2009 (Table 2); increase also observed at far-field sites on Watts Bar (Figure 5) from 2007 to 2009 as well as on many other Valley reservoirs

River	Year	Total # of Bass	EF Catch Rate (no./hr.)	Mean Weight (lbs.)	% Harvestable	Bass >4 lbs.	Bass >5 lbs.	Largest Bass (lbs.)
EMORY 2.5	2009	319	53.2	1.2	68.7	9	2	5.7
CLINCH 2.5	2009	376	62.7	1.5	72.3	7	1	6.8
	2005	252	42.0	1.6	89.9	2	1	5.2
	2004	256	42.7	1.4	92.7	1	1	5.9
	2003	289	48.1	1	75.7	1	0	4.2
	2002	311	51.8	1.2	68.1	6	2	6.4

Table 1. Summary of black bass collected in the Emory and Clinch Rivers, 2002 to 2005 and 2009.

River	Year	Total Parasites	Lesions	Emaciated/ Skinny	Scolio-sis	Fin rot	Fungus	Blind-eye	Cancerous growth	Pop-eye	Deformed	Total Anomalies
EMORY 2.5	2009	30 (9.4%)*	1	-		1	2					4 (1.3%)*
CLINCH 2.5	2009	49 (13%)	6		2			1				9 (2.4%)
	2005	9 (3.6%)	2		1		3	1	1			8 (3.2%)
	2004	1 (0.4%)	5	1			7	1				14 (5.5%)
	2003	1 (0.3%)	2	1			6	1		1		11 (3.8%)
	2002	0 (0%)	3				3	1				7 (2.3%)

*Percent of total number of black bass collected

Table 2 . Anomalies in black bass collected in the Emory and Clinch Rivers, 2002 to 2005 and 2009.

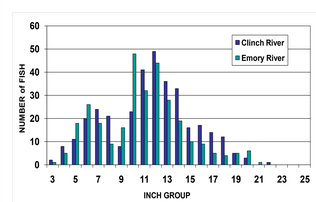

Figure 4. Length frequency histogram for largemouth bass collected in Clinch and Emory Rivers, Spring 2009

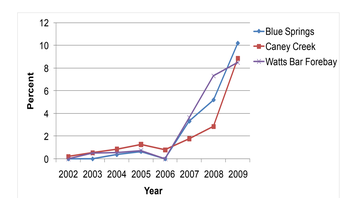

Figure 5. Percent of black bass with parasites at far-field locations on Watts Bar Reservoir, 2002-2009

Reservoir Benthic Macroinvertebrates Survey

- Benthic community sampled at 11 sites in January, 2009; 3 in the Emory River, 6 in the Clinch River, and 2 in the Tennessee River; at least one upstream site served as a reference for each river
- Strong differences among Clinch River sites in densities and taxa richness; less pronounced differences among sites within the other two rivers (Figure 6 and 7)
- Reference sites on Clinch River had significantly higher numbers of individuals than other sites due to high number of tubificid worms (both sites) and chironomids (CRM 6.0)
- The mayfly *Hexagenia* and the fingernail clam *Musculium* most abundant in the Clinch River and generally less abundant at more riverine sites (Figure 8)
- NMS Ordination (Bray-Curtis Similarly), sites generally grouped more closely by river (Figure 9) and, apparently, channel morphology

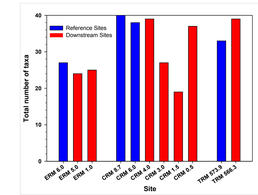

Figure 6. Total density of benthic macroinvertebrates

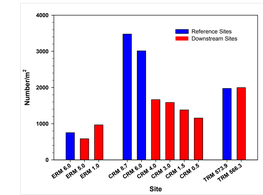

Figure 7. Benthic macroinvertebrate taxa richness

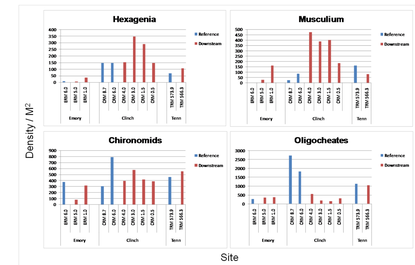

Figure 8. Densities of various benthic macroinvertebrates

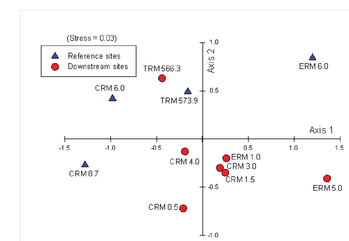

Figure 9. Nonmetric Multideminsional Scaling Ordination (Bray Curtis Similarity)

SUMMARY

- Fish community structure and sport fish population (i.e., largemouth bass) results were similar to those observed prior to ash release; future sampling is required to detect any long-term effects.
- Benthic macroinvertebrate results provide a baseline for future comparison; no historical data were available for the affected environment.
- Benthic community structure was clearly different between reference sites and downstream sites in the Clinch River and Emory River, but there was little difference between sites in the Tennessee River.
- Those differences appear to be primarily related to changes in channel morphology and the complexity of converging river systems. This makes it difficult to draw definitive conclusions about ash-related effects at this time; future sampling and assessments will attempt to evaluate the ash-related effects.
- Sampling for bioaccumulation found *Hexagenia* and other benthic organisms were present immediately adjacent to the area of ash release — an area where benthos were assumed smothered by ash; additional benthic community sampling sites were added in winter 2009.