



UPDATED DATA ANALYSIS AND TEMPORAL TREND EVALUATIONS IN BIOTA: 2009 – 2015

Tennessee Valley Authority
Ash Recovery Project
Kingston, Tennessee

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ACRONYMS AND ABBREVIATIONS

BERA	Baseline Ecological Risk Assessment
COC	constituent of concern
CRM	Clinch River Mile
DQOs	data quality objectives
dw	dry weight
EDDs	electronic data deliverables
ERM	Emory River Mile
GSIs	gonadosomatic indices
KIF	Kingston Fossil Plant
LTM	long term monitoring
MDL	method detection limits
mg/kg	milligram per kilogram
ORNL	Oak Ridge National Laboratory
PLM	polarized light microscopy
QAPP	Quality Assurance Project Plan
QC	quality control
RAFI	TVA's Reservoir Fish Assemblage Index
SAP	Sampling and Analysis Plan
site	Tennessee Valley Authority Kingston Fossil Plant - Release Site in Roane County, TN
TRM	Tennessee River Mile
TVA	Tennessee Valley Authority
USEPA	U.S. Environmental Protection Agency

1 INTRODUCTION

In August 2012, a Baseline Ecological Risk Assessment (BERA) (Arcadis 2012a) was approved by the U.S. Environmental Protection Agency (USEPA). The BERA evaluated the potential ecological effects on biota from ash residuals in the river system at the Tennessee Valley Authority (TVA) Kingston Fossil Plant (KIF) Release Site, in Roane County, Tennessee (the site, Figure 1). The BERA focused primarily on data collected post-dredging. The BERA was developed in support of the Kingston Ash Recovery Project, Non-Time Critical Removal Action, River System Engineering Evaluation/Cost Analysis (TVA 2012), which evaluated alternatives for restoration of the river system impacted by the December 22, 2008 ash release.

In May 2013, a Long-Term Monitoring Sampling and Analysis Plan (LTM SAP) (Jacobs 2013) was approved by the USEPA for the TVA KIF Release Site. The LTM SAP described the data quality objectives (DQOs), sampling design, and sampling procedures for data collections necessary to assess the effectiveness of the selected removal action of monitored natural attenuation. The LTM SAP began in 2014, and the changes to sampling frequency or focused study area designs are discussed as part of each of the subsequent sections.

Monitoring for some ecological receptors is ongoing. The purpose of this report is to quantitatively assess the most recent dataset (i.e., 2015), and when possible, to evaluate temporal trends in constituent concentrations from 2009 through 2015. Consistent with the results of the BERA and the LTM SAP, selenium and arsenic were identified as constituents of concern (COCs) and are the focus of discussions for each receptor. In addition, percent ash is also considered a COC in sediment. This report evaluates data from 2009 through 2015 for the following biota:

- Fish;
- Benthic invertebrates; and
- Tree swallows.

The data included in this report were reported by analytical laboratories and validated via a quality assurance/quality control review as specified in the Quality Assurance Project Plan for the Tennessee Valley Authority Kingston Ash Recovery Project, Revision 1 (QAPP) (TVA 2010). A summary of the data validation process and data quality results is presented in the Section 5 of this report. The final section of this report provides an overall summary of the conclusions and risk management recommendations.

2 FISH

Many species of fish were selected for evaluation in the BERA because they represent various feeding guilds and are ubiquitous in the Emory, Clinch, and Tennessee River locations near the site. Fish may be exposed to ash-related constituents through their gills, ingestion of sediment and water, consumption of aquatic prey, and maternally transferring constituents to eggs. Exposure to ash-related constituents may lead to bioaccumulation over time, which may then affect the health of the fish community.

The main study objectives were to 1) compare community metric results among locations and across years; 2) evaluate fish reproductive condition among locations and years; 3) compare concentrations of metals and metalloids in fish tissues; 4) evaluate fish health condition among locations and years; and 5) relate concentrations measured at the study sites to reference area concentrations and literature-derived effects values, when available.

2.1 Fish Community

Historically, fish communities have been studied in the Tennessee and Clinch Rivers. Monitoring of the Emory River fish community began in 2009 after the ash release. A detailed description of the sampling locations and collection methods can be found in Evaluation of the Fish Community in the Vicinity of the Kingston Fossil Plant, 2001 – 2010 (Baker 2011a) and Evaluation of 2012 Fish Community Survey Results for the Kingston Fossil Plant Ash Recovery Project (Appendix A in Arcadis 2013).

Fish were collected using boat electrofishing and gill netting. Fifteen 300-meter runs were completed along area ranges. Area ranges consisted of Emory River Mile (ERM) 1.7 to ERM 4.5 (mid-point ERM 2.5), Clinch River Mile (CRM) 0.0 to 2.4 (mid-point CRM 1.5) and CRM 3.8 to 5.3 (mid-point CRM 4.4). Fish were identified to species, tallied, and examined for diseases, deformities, or any other anomalies (Baker 2011a). Total numbers of species were evaluated using TVA's Reservoir Fish Assemblage Index (RFAI) methodology as part of their National Pollutant Discharge Elimination System permit renewal requirements. The RFAI uses metrics from four categories (species richness, composition, abundance, and fish health). RFAI scores are ranked and assigned ratings (very poor, poor, fair, good, and excellent) (Baker 2011a). A summary of the results is presented in Appendix A. A summary of the 2015 fish community survey results is underway and will be included in the next annual report.

2.2 Spring Sport Fish

Spring sport fish have been studied in the TVA reservoirs and include five locations within the Watts Bar Reservoir. These consist of Emory River mile (ERM) 2.5 and Clinch River mile (CRM) 2.5 and three locations on the Tennessee River (Caney Creek, Blue Springs, and Watts Bar Forebay). A summary of collection and processing methodology can be found in Evaluation of Spring Sport Fish Survey Results for Watts Bar Reservoir, 2002 – 2011 (Baker 2011a).

The results from the 2015 survey were previously available and were included in Appendix A of the Updated Data Analysis and Temporal Trends Evaluations in Biota: 2009 – 2014 (Arcadis 2015). Overall, the results of the 2015 spring sport fish sampling were similar to previous years and do not indicate that

residual ash from the 2008 TVA KIF Release Site is posing a long-term risk to sport fish in the Emory and Clinch Rivers.

2.3 Fish Reproduction

Oak Ridge National Laboratory (ORNL) conducted fish reproductive studies that focused on assessing the health and condition of fish ovaries. A detailed description of the sampling locations and collection methods can be found in *Evaluating the Effects of the Kingston Fly Ash Release on Fish Reproduction: Spring 2009 – 2010 Studies* (Greeley, et al. 2012) and 2016 ORNL Progress Report for the TVA-Kingston Project (Appendix B).

Fish reproduction has been evaluated at TVA KIF since 2009. The ovary was chosen for evaluation of fish reproduction because it provides a route for maternal transfer of metals and metalloids to the developing eggs. In 2015, a detailed morphometric analysis was conducted on ovaries of fish collected at two reference locations (ERM 8.0 and CRM 8.0) and three impacted locations (ERM 1.0, ERM 3.0, and CRM 1.5) in conjunction with the spring fish bioaccumulation studies (Appendix B). Gonadosomatic indices (GSIs) were calculated for all three species evaluated, which included redear sunfish, bluegill sunfish, and largemouth bass. The GSI is the gonad weight divided by body weight, multiplied by 100. While some differences in ovary size were noted among sampling locations, there were no apparent differences in reproductive dysfunction for any of the three species. Differences in ovary size may be related to factors other than impact of ash, such as the timing of collection during spawning. Additional reproductive data processing is still underway to determine abundance of vitellogenic oocytes per ovary, measures of fecundity, and frequency of atresia. Results of these ongoing analyses will be provided in the next annual report, and will include a statistical evaluations of temporal and spatial trends.

Currently, the results from the 2015 reproductive evaluation continue to support the conclusion that residual ash from the 2008 TVA KIF Release Site is unlikely to pose significant long-term risks to the reproductive success of fish populations in the Watts Bar Reservoir.

2.4 Fish Bioaccumulation

Fish bioaccumulation studies have been ongoing at the TVA KIF Release Site since 2008. A detailed description of the sampling locations and collection methods can be found in *Fish Bioaccumulation Studies Associated with the Kingston Fly Ash Spill, Spring 2009 – Fall 2010* (Adams et al. 2012), *Trace Element Concentrations in Fish: 2010* (Arcadis 2012b), and in 2016 ORNL Progress Report for the TVA-Kingston Project (Appendix B).

Bioaccumulation of metals and metalloids were measured in fillets of largemouth bass, bluegill sunfish, and redear sunfish. Spring sampling was conducted in April and May of 2015. Fish were collected from two upstream references (ERM 8.0 and CRM 8.0) and three impacted locations (ERM 3.0, ERM 0.9, and CRM 1.5). Fish fillets were collected by TVA and ORNL staffs and/or their contractors, and sent to Pace Analytical Services, Inc., for analysis of metals and metalloids (Appendix B). Spatial and temporal trends for selenium, arsenic, and mercury concentrations in fish fillets were evaluated by ORNL, with details provided in Appendix B, and are summarized below.

Historically, selenium concentrations in all three species' fillets have been higher in individuals collected from impacted locations compared to the reference locations. In 2015, a similar trend occurred with the

highest mean concentrations recorded at ERM 1.0 for bluegill and redear sunfish and at ERM 3.0 for largemouth bass. Selenium concentrations continued to be highest in liver tissue, compared to both fillet and ovary tissue for all three species. During previous years of sampling, selenium concentrations have also been highest in redear sunfish for all tissue types. However, in 2015, the highest mean fillet concentration occurred in bluegill sunfish (0.865 milligrams per kilogram [mg/kg] wet weight at ERM 1.0). While this mean concentration increased from 2014, it is within the range of selenium concentrations since 2009. Selenium in liver tissue continued to be highest in redear sunfish at ERM 1.0 (2.5 mg/kg wet weight) compared to other species, locations, and tissue types. Temporal trends for fish fillets were evaluated at ERM 1.0, as this location has been collected annually since 2009. Mean concentrations of selenium in fillets in redear sunfish and largemouth bass decreased in 2015 compared to previous years, while concentrations in bluegill sunfish increased slightly. Overall, concentrations of selenium in all three species remain below the USEPA criterion of 11.3 mg/kg (muscle, dry weight [dw]) and 15.1 mg/kg dw in ovary tissue in all years of study (USEPA 2016).

Arsenic and mercury concentrations in fish fillets were also compared to regulatory guidelines and across all years of study. In general, arsenic concentrations remained below levels of concern, with no statistically significant changes in 2015 compared to previous years and no discernable differences between impacted and reference locations. Mercury is a legacy constituent not related to the ash release, but is the focus of fish consumption advisories for the Emory River. Mercury concentrations continued to be highest in largemouth bass, compared to both sunfish species, but all mean concentrations at ash-impacted locations were below the USEPA human health fish consumption criterion. Only the mean concentration of mercury in fillets from the reference location (ERM 8.0) was above the human health criterion. ERM 8.0 is upstream of the ash release and the elevated mercury concentrations are likely related to other legacy inputs from the Emory River.

2.5 Fish Health

Fish health studies have been conducted at the TVA KIF Release Site since 2009. A detailed description of the sampling locations and collection methods can be found in Fish Health Studies Associated with the Kingston Fly Ash Spill, Spring 2009 – Fall 2010 (Adams and Fortner 2012) and in 2016 ORNL Progress Report for the TVA-Kingston Project (Appendix B).

In 2015, the fish health study evaluated a variety of health metrics that assessed physiological and energetic responses in fish. Samples from three fish species (bluegill sunfish, redear sunfish, and largemouth bass), collected from two reference locations (ERM 8.0 and CRM 8.0) and three impacted locations (ERM 1.0, ERM 3.0, and CRM 1.5), were evaluated in conjunction with the spring fish bioaccumulation studies. At least six fish of each of the fish species were processed at ORNL and evaluated for basic health conditions. Blood analyses and a full suite of health parameters were measured, as specified in the LTM SAP.

Similar to previous years of study, there were no significant differences in any of the 24 fish health metrics evaluated from impacted locations compared to metrics from reference locations in 2015 (Appendix B). Furthermore, the evaluation of temporal trends of each metric did not identify significant patterns beyond the initial years of sampling. Histopathology samples were also collected but these results are not yet available and will be reported in the next annual report.

3 BENTHIC INVERTEBRATES

Benthic invertebrates are found living within or on top of sediments in the Emory, Clinch, and Tennessee Rivers. Benthic invertebrates in these rivers consist of mostly oligochaetes (aquatic worms), chironomids (larval midges), burrowing mayfly nymphs, and also crustaceans (crayfish and amphipods), bivalves (mussels and clams), snails, larval flies, leeches, and mites. Because of their close association with the sediments and water, benthic invertebrates have the potential for bioaccumulation of metals and metalloids. They may also transfer these constituents to fish and wildlife consumers. Snails and mayflies serve as a useful receptor in order to understand exposure and potential effects of these constituents on the benthic invertebrate community.

The main study objectives in 2015 were to assess impacts to the benthic community by 1) comparing community metric results among sites and across years; 2) comparing tissue concentrations of metals and metalloids in mayfly nymphs and mayfly adults for evaluating differences among sites and years; and finally 3) relating concentrations measured at the study sites to reference area concentrations and literature derived effects values, when available. A brief discussion of each objective is presented in the subsections below.

3.1 Benthic Invertebrate Community

Benthic invertebrate community evaluations in November 2015 were conducted on the Emory, Clinch, and Tennessee Rivers, similar to previous years. A detailed description of the sampling locations and collection methods can be found in Evaluation of Benthic Macroinvertebrate Communities in the Vicinity of TVA's Kingston Fossil Plant, 2009-2010 (Baker 2011b) and also in Appendix C of this report.

In 2015, seven transect locations on the Emory River (ERM 0.7, ERM 1.0, ERM 2.2, ERM 2.6, ERM 3.0, ERM 4.1, and ERM 6.0 [reference]) and four transect locations on the Clinch River (CRM 1.5, CRM 3.0, CRM 4.0, and CRM 6.0 [reference]) were monitored for population abundance and diversity. Ten grab samples were collected from each transect and benthic invertebrates within each sample were identified to the lowest possible taxon. The total number of taxa were tallied and used to generate benthic invertebrate community metrics in order to assess the overall health of the benthic invertebrate community. Population density, taxa richness, number of organisms, number of taxa, percent oligochaetes and chironomids, and other metrics were used to assess the benthic invertebrate community. Details on how these metrics are calculated are presented in Evaluation of Benthic Macroinvertebrate Communities in the Vicinity of TVA's Kingston Fossil Plant, 2009-2010 (Baker 2011b). At each sample location, water depth was also recorded along with a physical description of the sediment in the sample in order to estimate: percent ash, grain size, and substrate type. In addition to the benthic invertebrate community data collections, sediment chemistry data (percent ash, metals, and the percent sand, silt, clay, or gravel) were also collected from the Emory and Clinch Rivers. The purpose of the co-located data collections was to better interpret the various factors potentially influencing the benthic invertebrate community. Sediment quality associated with each of the transect locations is discussed in Section 3.3.

November 2015 Emory River benthic invertebrate community abundance, composition, and diversity results among sites were consistent with metric results from previous years. While some differences in community metrics were identified among impacted locations or between impacted locations compared to

the reference location, these differences appear to be a reflection of spatial heterogeneity due to sediment differences and natural variability in benthic invertebrate communities found in a large river system, rather than negative impacts from residue ash. When results were evaluated from 2009 through 2015, there were no identifiable trends relating to the ash release such as decreasing invertebrate abundance or decreasing richness at sites closest to the ash release. Furthermore, temporal trends in community metrics from impacted sites were also found in reference sites not impacted from the ash release (ERM 6.0 and CRM 6.0). When benthic invertebrate community metrics were evaluated with the percentage of ash composition, no significant negative relationship was identified. Consequently, the results of the 2015 benthic invertebrate community surveys indicate that residual ash from the 2008 TVA KIF release is not causing distinguishable adverse effects on the benthic invertebrate population in the Emory River.

3.2 Benthic Invertebrate Bioaccumulation

A detailed description of the collection methods used for benthic invertebrate bioaccumulation can be found in Evaluation of Invertebrate Bioaccumulation of Fly Ash Contaminants in the Emory, Clinch, and Tennessee Rivers, 2009-2010 (Smith 2012) and in 2016 ORNL Progress Report for the TVA-Kingston Project (Appendix B).

In 2015, mayfly nymphs (*Hexagenia bilineata*) were collected from five locations on the Emory River (ERM 1.0, ERM 2.5, ERM 3.0, ERM 4.0, and ERM 6.0 [reference]) and two locations on the Clinch River (CRM 3.5 and CRM 6.0 [reference]). Mayfly adults were collected opportunistically as close to these same locations as possible. Mayfly nymphs were separated into depurated (only from ERM 1.0, ERM 2.5, ERM 6.0, and CRM 3.5) and non-depurated samples, and adult mayflies were separated by sex and life stage. All samples were analyzed for arsenic and selenium.

All mayfly nymph (depurated and non-depurated) and adult selenium concentrations were below the LTM remedial tissue monitoring endpoints (7 mg/kg dw). Selenium concentrations in both depurated and non-depurated nymphs from impacted locations ranged from 3.4 mg/kg dw to 5.7 mg/kg dw, compared to 2.4 mg/kg dw to 3.9 mg/kg dw at reference locations. Concentrations in both depurated and non-depurated mayfly nymphs were similar or lower compared to concentrations in previous years. Also similar to previous years, selenium in mayfly nymph tissue collected at ERM 1.0 continued to be approximately 2-times higher than the mean selenium concentration from the reference location (ERM 6.0). Selenium concentrations in mayfly adults collected in 2015 were lower or similar compared to concentrations from 2009 through 2014, with concentrations in adult mayflies from impacted locations ranging from 2.8 mg/kg dw to 5.7 mg/kg dw, compared to 2.3 mg/kg dw to 3.1 mg/kg dw at reference locations. While mean concentrations from impacted locations were higher than mean concentrations found at the reference locations, all concentrations were below the remedial tissue monitoring endpoint.

Similarly, all mayfly nymph (depurated and non-depurated) and mayfly adult arsenic concentrations in 2015 were below the LTM remedial tissue monitoring endpoints (34 to 83 mg/kg) at all sampling locations. Arsenic concentrations in both depurated and non-depurated nymphs from impacted locations ranged from 1.4 mg/kg dw to 9.3 mg/kg dw, compared to 0.99 mg/kg dw to 4.6 mg/kg dw at reference locations. Although arsenic concentrations in nymphs at two impacted locations (ERM 1.0 and CRM 3.5) continue to be higher than those collected at the corresponding references, arsenic concentrations in nymphs from ERM 1.0 and CRM 3.5 were still several times lower than the remedial tissue monitoring

endpoint range. Furthermore, mean arsenic concentrations in nymphs from all impacted locations continue to show decreasing or stabilizing trends over time. Arsenic concentrations in adult mayflies from impacted locations ranged from 0.083 mg/kg dw to 0.29 mg/kg dw, compared to 0.11 mg/kg dw to 0.46 mg/kg dw at reference locations. These results indicate no apparent differences in adult mayfly arsenic levels collected at impacted and reference locations.

3.3 Sediment Quality

Sediment sampling activities were conducted in November 2015 at seven locations on the Emory River (ERM 0.7, ERM 1.0, ERM 2.2, ERM 2.6, ERM 3.0, ERM 4.1, and ERM 6.0 [references]) and four locations on the Clinch River (CRM 1.5, CRM 3.0, CRM 3.75, and CRM 6.0 [references]) using two types of sediment sampling, as defined in the LTM SAP. The first sampling type included taking a 3-point composite of sediment from the left descending bank, center of channel, and right descending bank. These samples were analyzed for metals (selenium and arsenic), ash content, and grain size. The second sampling type included collecting co-located samples with the benthic invertebrate community surveys at ten discrete sample points from each transect. All sediment samples were collected using a decontaminated WILDCO Ponar Dredge Sampler. Composite samples were placed in high-density polyethylene 3-gallon tubs and were transported to a field laboratory where the overlay water was decanted prior to homogenization. Following homogenization, samples were split into labeled sterile containers for arsenic, selenium, polarized-light microscopy (PLM) analysis of ash content, and grain size. Similarly, co-located sediment samples were also homogenized, but were only analyzed for ash content. Once sub-samples were partitioned to the appropriate containers, the samples were custody sealed and placed on ice. Samples were shipped to their appropriate laboratories for analysis (RJ Lee for PLM analysis and TestAmerica for metals and grain size).

The LTM SAP identified three main COCs at the site with corresponding remedial goals for sediment. These include ash content or percent ash, arsenic, and selenium. The remedial goal for percent ash is 50% or less. The remedial goal for arsenic is a range of 29 to 41 mg/kg, and the remedial goal for selenium is a range of 3.0 to 3.2 mg/kg.

In 2015, composite sediment samples of percent ash ranged from 1% to 51% at impacted locations on the Emory River. The percent ash values at the Emory River reference location (ERM 6.0) were less than 1%. While one composite sample from ERM 0.7 had an ash content greater than the remedial goal of 50%, the mean percent ash values were less than the remedial goal of 50% at all impacted locations (Table 1). All percent ash values from composite sediment samples on the Clinch River were less than the remedial goal of 50%. The percent ash values at impacted locations ranged from 1% to 30%, with the highest percent ash recorded at CRM 3.75. The percent ash values at the Clinch River reference location (CRM 6.0) were less than 1% (Table 2).

Percent ash results in co-located sediment samples from impacted Emory River locations ranged from 1% to 56%, with the highest recorded ash percentage at ERM 1.0. While one grab sample from ERM 1.0 was above the remedial goal of 50%, the mean ash percentage from this location was only 18% which is well below the remedial goal. Percent ash results in co-located sediment samples from impacted Clinch River locations ranged from 1% to 28%, with the highest recorded ash percentage at CRM 3.75. All individual and mean results from the Clinch River were below the remedial goal of 50% (Table 3).

Selenium results for composite sediment samples on the Emory River ranged from 0.375 mg/kg to 3.61 mg/kg at impacted locations and 0.808 mg/kg to 1.65 mg/kg at the reference location. Only one concentration was above the remedial goal range of selenium in sediment and was collected from ERM 0.7. The mean selenium concentration at ERM 0.7 is 2.5 mg/kg, which is below the remedial goal range (Table 1). Selenium concentrations for composite samples on the Clinch River ranged from 0.903 mg/kg to 3.52 mg/kg at impacted locations and 0.603 mg/kg to 1.28 mg/kg at the reference location. Again, only one of these concentrations was above the selenium remedial goal and was collected from CRM 3.75. The mean concentration at CRM 3.75 is 2.5 mg/kg, which is below the remedial goal range (Table 2).

Arsenic results for composite sediment samples on the Emory River ranged from 1.4 mg/kg to 19.7 mg/kg at impacted locations and 2.37 mg/kg to 6.3 mg/kg at the reference location. All of these concentrations were below the remedial goal range of arsenic in sediment. Arsenic concentrations for composite samples on the Clinch River ranged from 8.14 mg/kg to 16.5 mg/kg at impacted locations and 5.49 mg/kg to 42.4 mg/kg at the reference location. While one concentration was above the remedial goal for arsenic on the Clinch River, this concentration was collected from the reference location at CRM 6.0 and is not related to the ash release (Table 2).

Grain size analysis was also conducted on composite sediment samples for the Emory and Clinch Rivers (Table 3). This analysis indicates that, similar to previous years of study, the sediment in both rivers is dominated by silt and sand. Combined, silt and sand average 89% of the substrate at sampling locations on the Emory River and 80% of the substrate at sampling locations on the Clinch River.

4 TREE SWALLOWS

Tree swallows (*Tachycineta bicolor*) were selected as a representative aerial-feeding insectivorous bird species for the site. Tree swallows are a breeding migratory resident in Tennessee (Nicholson 1997; Robinson 1990), and forage 100 to 200 meters around their nest during the breeding season. They commonly prey on a variety of insects, and when nest boxes are placed along aquatic areas, they feed primarily on emergent aquatic insects (U.S. Geological Survey 2003; Blancher and McNicol 1991; Quinney and Ankney 1985). As a result, tree swallow tissue residues often reflect the local sediment contamination for those chemicals that transfer into the aquatic emergent insects (McCarty and Winkler 1999; Froese et al. 1998).

In 2015, tree swallow colonies were installed at two locations along the Emory River (ERM 3.0 and ERM 1.4), and at one reference location (Tennessee River mile [TRM] 572.0) to continue supporting colonies that had been established during previous years of monitoring. Boxes were monitored daily at each colony from April through July. A detailed description of the collection methods can be found in Trace Element Concentrations and Productivity in Tree Swallows: 2009-2010 (Arcadis 2012c) and in Appendix D.

The main study objectives were to 1) determine the extent of maternal transfer of metals and metalloids to the eggs between locations and across years; 2) evaluate tree swallow reproductive success among locations and years; and 3) assess impacts to tree swallows by comparing concentrations measured at the study sites with literature-derived effects values, when available.

4.1 Tree Swallow Reproduction

The total number of eggs (clutch size), the number of eggs that hatched (hatching success), the number of young that survived to day 15 (fledgling success), and the number of females fledglings produced per nesting female (fecundity) were recorded in 2015 at ERM 1.4, ERM 3.0, and TRM 572.0 colonies. In addition, egg mass and volume were recorded, as well as morphological measures (egg length and width).

Similar to 2013 and 2014, results of the 2015 spatial analysis showed no differences ($p > 0.05$) in clutch size, hatching success, fledgling success, and fecundity among colonies (Appendix D). Furthermore, no differences were observed for the egg volume or egg mass or other morphological measures (i.e., egg length and egg width) among colonies.

An evaluation of temporal comparisons was conducted using data from 2013, 2014, and 2015 at ERM 1.4 and TRM 572.0. This evaluation indicated statistically lower hatching success at ERM 1.4 compared to the reference at TRM 572.0 ($p = 0.02$); however, no statistically significant differences were identified in fledgling success or fecundity over time ($p > 0.05$). These results indicate that impacts to the overall reproductive success of tree swallows at ERM 1.4 are unlikely to occur as a result of the ash release. Reproductive metrics were not collected at ERM 3.0 in 2013 or 2014 due to the construction activities occurring in the area during those years; consequently, temporal comparisons could not be evaluated for this colony. However, there were no statistically significant differences in 2015 metrics at ERM 3.0

compared to the reference colony and so it is unlikely that reproductive success has been significantly impacted at ERM 3.0.

4.2 Tree Swallow Bioaccumulation

In 2015, tree swallow eggs were collected to evaluate exposure of tree swallows to ash-related COCs. A total of 25 eggs were collected from each colony (ERM 1.4, ERM 3.0, and TRM 572.0). Following collection, eggs were frozen and shipped to Pace Analytical for trace element analysis. Arsenic was detected in only 2 of 75 samples, both of which were within the range of detection limits and were considered estimated (J-flagged). Given the low frequency of detection and the concentrations detected, arsenic is unlikely to be adversely impacting tree swallow populations and is not discussed further.

Selenium results indicated a statistically significant difference among the colonies ($p < 0.0001$), with higher average concentrations at ERM 1.4 and ERM 3.0 (3.86 milligrams per kilogram dry weight [mg/kg dw] and 4.03 mg/kg dw, respectively) compared to TRM 572.0 (3.50 mg/kg dw) ($p < 0.0001$). While the average selenium concentration at ERM 1.4 was higher in 2015 than in 2014, it was similar to 2013 data and the range of concentrations from ERM 1.4 was also within the range of concentrations from the reference site in 2015 (Appendix D). Selenium concentrations at ERM 3.0 were not available in 2014 or 2013 for comparison, but were within the range of concentrations from the reference site in 2015 (Appendix D). Literature studies of selenium have been reviewed and suggest threshold effects (EC_{10}) concentrations ranging from 7.7 to 60 mg/kg dw in various species of avian eggs (Janz, et al. 2010). Similar to previous years, 2015 selenium concentrations in eggs collected from ERM 1.4 and ERM 3.0 were below the most conservative of these literature values. While one egg collected in 2015 had a selenium concentration above the conservative EC_{10} (8.69 mg/kg dw), this egg was collected from the reference colony at TRM 572.0 and does not reflect potential impacts from the ash release (Appendix D).

Correlation analyses between reproductive metrics and selenium were conducted using available data from 2011 through 2015. These evaluations identified a weak statistically significant negative relationship between selenium concentrations and fledgling success; however, no relationship was identified between selenium concentrations and overall fecundity. Consequently, the correlation between selenium and fledgling success was not strong enough to adversely impact the overall reproduction of the tree swallow population near the ash release.

5 DATA QUALITY ASSURANCE/QUALITY CONTROL RESULTS

This section focuses on the evaluation of data quality and usability.

5.1 Analytical Data Review

TVA's contracted laboratories were required to submit three types of deliverables: a limited (Level 1) data package containing sample results and batch quality control (QC) sample results; a fully-documented (Level 4) data package including raw data for all analyses; and electronic data deliverables (EDDs) for storage in TVA's EarthSoft EQuIS® database.

EDDs were subjected to completeness and correctness testing during loading to TVA's EQuIS database; once loaded to the EQuIS database, the data were subjected to verification. As defined in the TVA-KIF-QAPP (TVA 2010), data verification involved comparison of the data loaded in the EQuIS database to the results reported in the Level 1 data package. In addition, data verification included review of the batch QC summary forms for compliance with the applicable methods and for data usability with respect to the project DQOs and the TVA-KIF-QAPP.

Following receipt of the Level 4 data package, data were subjected to validation. As defined in the TVA-KIF-QAPP, data validation included review of raw data and associated QC summary forms for compliance with the applicable methods and for data usability with respect to the appropriate guidance documents. As stated in the QAPP: "Initially, 100% of the chemical analysis data will be reported in full documentation data packages for independent data validation. Depending on the nature and frequency of issues identified during data validation, the percentage of data undergoing full data validation may be reduced to a lesser percentage (such as 20%) or data verification may be substituted. The reduction in full data validation may be matrix specific, laboratory specific, or analyte specific. If after the percentage of full data validation has decreased, a trend in frequency of reporting issues, method non-compliances, or data usability issues is identified, data validation will be conducted for specific data points or the percentage of full data validation percentage may be increased until the issues have been minimized to their initial frequency." Data validation expands upon the completeness, correctness, and usability assessment performed during verification to include evaluation of instrumental QC analyses, review of sample preparation information, and recalculation of reported results from raw data. A summary of the data review efforts are presented in Table 4.

5.2 Data Quality Summary

Data validation was performed based on the sample results, summary QC data, and raw data provided by the laboratory. Data validation includes a review of the following QC measures (where applicable):

- Sample condition upon laboratory receipt;
- Initial calibration linearity;
- Blank analysis results greater than the method detection limits (MDL);

- Sample preparation and holding times;
- Initial calibration verification/continuing calibration verification standard recoveries;
- MDLs and linear ranges;
- Internal standard recoveries;
- Percent moisture;
- Matrix spike/matrix spike duplicate;
- Laboratory and field duplicate precision;
- Quantitation of positive results;
- Laboratory control sample/laboratory control sample duplicate recoveries and precision;
- Analytical sequence;
- Reporting limit standard recoveries (metals only);
- Serial dilutions (metals only);
- Post-digestion spike/post-digestion spike recoveries and precision (metals only);
- Internal standard recoveries;
- Inductively coupled plasma interference check standard results (metals only);
- Quantitation of positive results;
- MDL verification standards (metals only); and
- Standard reference material recoveries (metals only).

The data met the DQOs defined for this task and were acceptable for use for each of the receptors.

Table 5 summarizes the data quality for each receptor based on the review performed and as compared to the data quality measures identified in the TVA-KIF-QAPP.

6 SUMMARY

Based on the review of 2015 data and the spatial and temporal trends, the overall conclusions presented here do not change the risk management recommendations related to fish and benthic invertebrates provided in the BERA (Arcadis 2012a) or the recommendations and anticipated long-term monitoring requirements established in the LTM SAP for these biota (Jacobs 2013). However, the evaluation of tree swallows indicates potential risks associated with the ash spill are unlikely to be occurring for these receptors, and the analysis to date supports discontinuing monitoring of the tree swallow population. A request to remove the tree swallow sampling from future years of study under the LTM SAP was submitted to the USEPA on March 9, 2016 and was approved on March 21, 2016 (email correspondence between Craig Zeller, USEPA and Michelle Cagley, TVA). As such, tree swallow reproduction and bioaccumulation monitoring will not be evaluated in future years of study.

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TABLES



Table 1
2015 Emory River Composite Sediment Results

Tennessee Valley Authority
Kingston, Tennessee

Parameter	Remedial Goal	ERM 0.7				ERM 1.0				ERM 2.2				ERM 2.6				ERM 3.0				ERM 4.1				ERM 6.0			
		Mean	LB	CC	RB	Mean	LB	CC	RB	Mean	LB	CC	RB	Mean	LB	CC	RB	Mean	LB	CC	RB	Mean	LB	CC	RB	Mean	LB	CC	RB
Inorganics																													
Arsenic, Total (mg/kg)	29 to 41	11.7	18.1 J	7.14	9.96 J	12.6	12.6	12.1 J	13.2	11.0	3.28	10 J	19.7 J	11.5	6.59 J	8.68 J	19.1	6.3	2.49	6.21	10.1 J	3.4	5.8 J	3.04	1.4	4.3	2.37 J	6.3 J	4.12 J
Selenium, Total (mg/kg)	3.0 to 3.2	2.5	3.61 J	1.84 J	2.14 J	2.2	2.12	2.06 J	2.35 J	1.5	0.703 J	1.34 J	2.32 J	1.9	1.63 J	1.93 J	2.1	1.3	0.682 J	0.666 J	2.41 J	0.9	1.86 J	0.439 J	0.375 J	1.2	0.808 J	1.65 J	1.18 J
Physical Properties																													
Percent Ash (%)	50	32.7	51	11	36	29.7	33	18	38	7.3	1	4	17	14.3	10	1	32	6.0	2	5	11	1.0	1	1	1	1.0	1	1	1
Clay (%)	NA	8.3	10.1	10.1	4.6	10.4	12	11.6	7.5	14.1	19.1	10.1	13.2	15.6	10.4	23	13.4	11.1	7.4	10.8	15.2	10.8	18.9	4.3	9.1	9.9	10.1	11.9	7.7
Gravel (%)	NA	0.0	0	0	0	0.1	0.2	0	0	2.4	0	0	7.3	1.6	0	0	4.7	0.4	0	1.1	0	0.4	0	1.2	0	0.0	0	0	0
Sand (%)	NA	23.7	16.3	16.1	38.7	30.6	28.5	15.6	47.8	34.8	32.9	43.4	28.2	21.0	27.2	9.8	26.1	46.0	64.6	66.2	7.2	55.6	3.1	89	74.7	48.3	64.7	16.6	63.5
Sand, Coarse (%)	NA	1.3	0	1.8	2.2	0.7	1.4	0.3	0.3	3.9	0	2.5	9.3	1.2	0.3	1.3	2	1.8	1.3	3.9	0.2	0.8	0	2	0.5	1.7	0.4	0.3	4.4
Sand, Fine (%)	NA	21.2	16.2	13	34.4	28.9	25.4	14.5	46.8	27.7	30.8	39.3	12.9	18.5	26.2	7.2	22.1	40.0	58.4	55.3	6.2	52.9	2.9	83.7	72.2	44.8	63.3	15.6	55.4
Sand, Medium (%)	NA	1.2	0.1	1.3	2.1	1.1	1.7	0.8	0.7	3.2	2.1	1.6	6	1.3	0.7	1.3	2	4.2	4.9	7	0.8	1.8	0.2	3.3	2	1.8	1	0.7	3.7
Silt (%)	NA	68.0	73.6	73.8	56.7	58.9	59.3	72.8	44.7	48.6	48	46.5	51.3	61.8	62.4	67.2	55.8	42.5	28	21.9	77.6	33.3	78	5.6	16.2	41.8	25.2	71.5	28.8

Acronyms and Abbreviations:
% = percent
CC = Center of channel
ERM = Emory River mile
LB = Left descending bank
mg/kg = milligrams per kilogram
NA = Not applicable
RB = Right descending bank

Qualifiers:
J = estimated value

Table 2
2015 Clinch River Composite Sediment Results

Tennessee Valley Authority
Kingston, Tennessee

Parameter	Remedial Goal	CRM 1.5				CRM 3.0				CRM 3.75				CRM 6.0			
		Mean	LB	CC	RB	Mean	LB	CC	RB	Mean	LB	CC	RB	Mean	LB	CC	RB
Inorganics																	
Arsenic, Total (mg/kg)	29 to 41	12.7	12.1	16.5 J	9.64 J	10.4	9.39	13.6 J	8.14	12.3	9.35	13 J	14.4	18.7	42.4	8.35	5.49
Selenium, Total (mg/kg)	3.0 to 3.2	1.8	1.8	2.12 J	1.44 J	1.7	2.28 J	1.79 J	0.903	2.5	1.35	2.72 J	3.52 J	0.9	1.28 J	0.603 J	0.909
Physical Properties																	
Percent Ash (%)	50	9.0	5.0	17	5.0	7.0	13	7	1	18.0	20	4	30	1.0	1	1	1
Clay (%)	NA	21.9	9.9	32.2	23.6	17.8	14.6	20.1	18.8	14.0	7.9	25.1	9.1	4.1	0.5	4.2	7.5
Gravel (%)	NA	3.7	2.9	2.3	6.0	2.7	8.2	0	0	0.6	1.7	0	0	14.8	33.4	10.9	0
Sand (%)	NA	17.0	23.1	10.4	17.4	35.5	36.3	26.7	43.5	26.6	47.3	11.9	20.7	60.6	62.4	73.3	46.1
Sand, Coarse (%)	NA	3.9	0.9	3.7	7.2	1.5	3.5	0.9	0	0.9	1.1	1.2	0.3	16.6	34	14.3	1.4
Sand, Fine (%)	NA	9.8	20.5	3.8	5.2	32.0	29.6	25.3	41	25.2	45.7	10.3	19.7	34.3	9.1	51.3	42.5
Sand, Medium (%)	NA	3.2	1.7	2.9	5.0	2.1	3.2	0.5	2.5	0.5	0.5	0.4	0.7	9.7	19.3	7.7	2.2
Silt (%)	NA	57.4	64.1	55.1	53	43.9	40.9	53.2	37.7	58.8	43.1	63	70.2	20.5	3.6	11.6	46.4

Acronyms and Abbreviations:

% = percent
CC = Center of channel
ERM = Emory River mile
LB = Left descending bank
mg/kg = milligrams per kilogram
NA = Not applicable
RB = Right descending bank

Qualifiers:

J = estimated value

Table 3
2015 Emory and Clinch River Co-Located Sediment Results

Tennessee Valley Authority
Kingston, Tennessee

Parameter	Remedial Goal	Location	Minimum	Maximum	Mean	Drop 1	Drop 2	Drop 3	Drop 4	Drop 5	Drop 6	Drop 7	Drop 8	Drop 9	Drop 10
Percent Ash (%)	50	Emory River													
		ERM 0.7	3	38	19	30	38	5	3	4	9	28	28	21	25
		ERM 1.0	4	56	18	5	56	20	29	4	5	19	7	25	14
		ERM 2.2	1	27	9	4	1	8	3	5	3	2	8	25	27
		ERM 2.6	1	48	10	6	6	6	13	8	4	1	1	9	48
		ERM 3.0	1	19	7	4	1	2	5	1	7	7	19	7	16
		ERM 4.1	1	2	1	1	1	1	1	1	1	1	2	1	1
		ERM 6.0	1	1	1	1	1	1	1	1	1	1	1	1	1
		Clinch River													
		CRM 1.5	1	25	13	18	17	24	3	12	14	1	10	3	25
		CRM 3.0	1	16	6	4	1	4	16	9	8	7	4	3	2
		CRM 3.75	1	28	8	8	28	1	1	1	1	8	18	6	8
		CRM 6.0	1	1	1	1	1	1	1	1	1	1	1	1	1

Acronyms and Abbreviations:

% = percent

ERM = Emory River mile

Table 4
2015 Analytical Data Review

Tennessee Valley Authority
Kingston, Tennessee

Matrix	Number of COCs	Number of Samples by Matrix	Number of Equipment Blanks by Lab	Number of Analytical Results	Percentage Final-Verified	Percentage Validated
Fish (fillets, livers, and ovaries)	14	247	0	3,480	81%	19%
Mayfly Adults (whole body)	4	75	0	973	73%	27%
Mayfly Nymphs (depurated, non-depurated)	2	13	0	458	100%	0%
Tree Swallow (egg content)	4	75	0	949	73%	27%
Sediment	27	237	2	468	96%	4%

General Notes:

All biota samples were analyzed at Pace Analytical Services, Inc. Sediment samples were analyzed by RJ Lee Group and TestAmerica, Inc. (Nashville, TN; Burlington, VT; and North Canton, OH facilities).

Acronyms and Abbreviations:

COCs = chain of custody

Table 5
2015 Data Quality Review

Tennessee Valley Authority
Kingston, Tennessee

Matrix	Analytical Results (Total Count)	Acceptable (No Qualification) ^a		Acceptable (Estimated) ^b		Blank Qualified ^c		Rejected ^d	
Fish (fillets, livers, and ovaries)	3,480	2,587	74%	743	21%	150	4%	0	0%
Mayfly Adults (whole body)	973	742	76%	219	23%	12	1%	0	0%
Mayfly Nymphs (depurated, non-depurated)	458	424	93%	31	7%	3	1%	0	0%
Tree Swallow (egg content)	949	839	88%	79	8%	31	3%	0	0%
Sediment	468	425	91%	43	9%	0	0%	0	0%

Footnotes:

^a Acceptable, No Qualification – Qualification of data was not warranted based on a review of the applicable quality control measures.

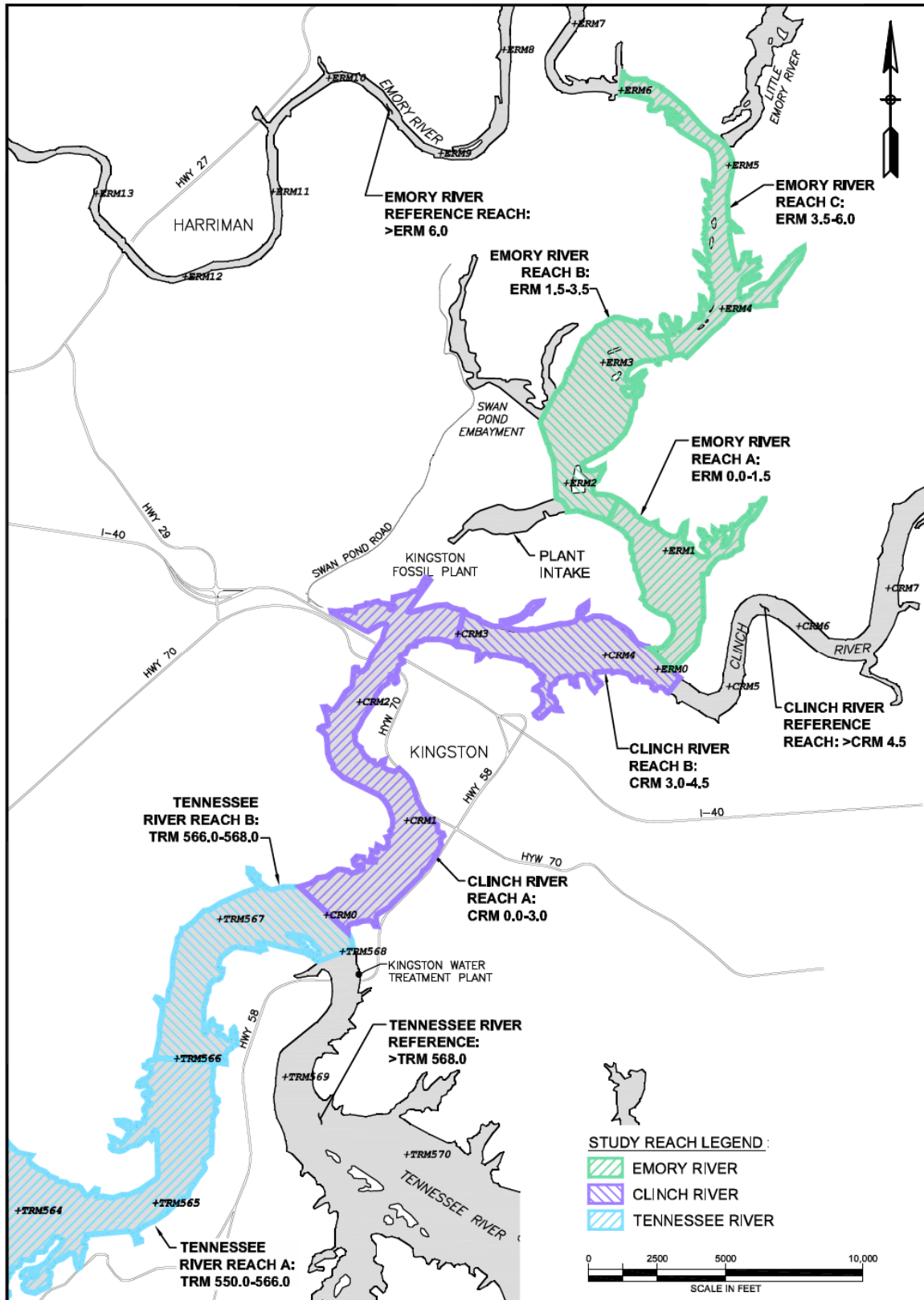
^b Acceptable, Estimated – Quantitation or detection limit is approximate due to limitations or bias identified during a review of the applicable quality control measures.

^c Blank Qualified – Result is considered “not-detected” because it was detected in an associated blank at a similar level.

^d Rejected – Unreliable result or detection limit; analyte may or may not be present in sample.

FIGURES





APPENDIX A

2015 TVA Fish Community Survey



Evaluation of 2015 Fish Community Survey Results for the Kingston Fossil Plant Ash Recovery Project

Fish community surveys in autumn 2015 were conducted on the Emory and Clinch Rivers. Sites included Emory River Mile (ERM) 2.5 and Clinch River Miles (CRMs) 4.4 and 1.5. Sample sites, collection procedures, and data analytical procedures in 2015 were the same as those detailed in *Evaluation of the Fish Community in the Vicinity of Kingston Fossil Plant, 2001-2010* (Baker 2011). Previous reports (Baker 2011 and Baker 2013) also provide more in-depth discussions of historical results.

Fish community surveys were conducted biennially in autumn from 2001 through 2007 at Clinch River sites immediately upstream (CRM 4.4) and downstream (CRM 1.5) of the KIF heated discharge to satisfy NPDES permit renewal requirements. Monitoring of the Emory River fish community (ERM 2.5) began in 2009 after the ash release. Surveys were conducted at the three sites annually in autumn for five consecutive years (2009–2013). The Clinch River sites also were surveyed during summer 2012 for the NPDES permit. Annual monitoring was reduced to biennial after 2013 as part of the *Long-Term Monitoring Sampling and Analysis Plan* (LTM SAP) (Jacobs 2013). The fish communities will be evaluated again in autumn 2017.

As in previous years, fish sampling methods included fifteen 300-meter boat electrofishing runs near the shoreline and ten overnight experimental gill net sets at each site. Fish collected were identified by species, counted, and examined for anomalies (such as disease, deformations, parasites, or hybridization). The resulting data were analyzed using TVA's Reservoir Fish Assemblage Index (RFAI) methodology. The RFAI uses 12 fish community metrics from four general categories — species richness and composition, trophic composition, abundance, and fish health — to evaluate the integrity of the fish community.

In autumn 2015, the fish communities at the three sites were assessed RFAI scores ranging from 43 to 47 and rated “good” (Table 1, Figure 1). The RFAI results for the Emory River site (ERM 2.5) in the immediate area of the ash release rated “good” during the six autumn surveys following the spill. Over the ten sample years (11 surveys) for the Clinch River sites, RFAI ratings have varied between “good” and “fair” with no apparent relation to the ash spill.

Results for species richness metrics (metrics 1–4 and 8) were similar during pre-spill and post-spill surveys (Tables 2–4, Figure 2). The number of indigenous species collected at the sites over the years indicated “good” to “moderate” representation of indigenous species. The metrics “number of centrarchid species”, “number of intolerant species”, and “number of top carnivore species” received the maximum number of points at each site during each of the post-spill surveys. A moderate to low “number of benthic invertivore species” was collected at the sites each survey, with no discernable difference between pre-and post-spill surveys.

Consistent with previous years, fish abundance (metric 11) was low in electrofishing and gill netting samples at each site in 2015 relative to expectations for transition zones in upper mainstream Tennessee River reservoirs (Table 5). However, the average numbers of fish per sampling method at each site in 2015 were similar to or higher than those of pre-spill surveys. With respect to historic catch rates for individual species, sites showed similarities in 2015 with relatively high numbers of logperch, largemouth bass, walleye, white bass, and Mississippi

silverside; relatively low numbers of yellow bass, green sunfish, and longear sunfish; and moderate numbers of spotfin shiners (Table 6). Additionally, at ERM 2.5 and CRM 1.5, appreciably higher numbers of threadfin shad were collected as compared to previous years, while relatively low numbers of bluegill were collected. CRM 4.4 differed in having low numbers of both gizzard shad and threadfin shad and relatively high numbers of bluegill. As a result, slight differences were observed in some composition metrics for 2015, but none suggestive of ash related effects.

Several of the species collected in relatively low numbers in 2015 are classified as tolerant; therefore, proportions of sample populations comprised of tolerant species (metric 5) declined in 2015, resulting in improved scores for this metric. During previous surveys, “percent tolerant individuals” consistently scored the lowest number of possible points at each site, with percentages ranging from about 66 to 90%. In 2015, percentages ranged from about 30 to 59%. Bluegill typically constitute a majority of tolerant individuals in the electrofishing samples at each site, followed by gizzard shad and largemouth bass, and then spotfin shiner and/or green sunfish. This was true for surveys conducted 2015, but scores improved mainly due to the lower composition of bluegill at ERM 2.5 and CRM 1.5 and the lower composition of gizzard shad at CRM 4.4. Additionally, bluegill typically is the dominant species (metric 6) in electrofishing samples at all sites, but threadfin shad were collected in unusually high numbers at ERM 2.5 and CRM 1.5 and were the dominant taxa.

Sites received low scores for “percent non-indigenous species” (metric 7) due to the large numbers of Mississippi silverside collected by electrofishing. Proportions of electrofishing sample populations comprised of non-indigenous species (1 to 23%) have been variable both spatially and temporally, resulting in high, moderate, and low scores. For electrofishing, the metric scores have depended largely upon the collection of Mississippi silverside. This species was first collected in Kentucky and Pickwick Reservoirs in 1993 and has continued to spread throughout the Tennessee River system. Because this is a small, schooling fish, their catch rates can be highly variably from year to year.

The percentages of fish with anomalies (i.e. visible lesions, bacterial and fungal infections, parasites, muscular and skeletal deformities, and hybridization) in the 2015 electrofishing and gill netting samples were low (0.0 to 0.7%) at each site. Percentages of fish with anomalies were elevated in 2009 and again in 2011; however, these percentages were comparable to historical conditions in most areas during the 2012 summer and fall sampling and remained low at all sites in 2013 and 2015. Given year-to-year variability in the incidence of anomalies and the fact that parasite loads in 2011 and 2012 were highest at sampling locations in the Clinch River upstream of the Emory River, there is no clear evidence that the increases were ash related.

Overall, the 2015 RFAI results for each location were within the range of expected variation based on historical results and the inherent variability in sampling reservoir fish communities. Collectively, the RFAI results for the ten sample years (11 surveys) indicate fish assemblages near KIF continue to be representative of those observed prior to the spill and, likewise, are representative of those expected in transition zones within upper mainstream Tennessee River reservoirs, indicating no apparent relation to the ash spill.

References

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Tables and Figures

Fish Community Survey Results Kingston Fossil Plant Ash Recovery Project, 2001-2015

**Updated
July 28, 2016**

Table 1. Reservoir Fish Assemblage Index (RFAI) scores for ERM 2.5, CRM 4.4, and CRM 1.5: 2001-2015.

Site	Pre-spill								Post-spill								Average Scores		
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2012	2013	2014	2015	Pre-Spill	Post-Spill	Long-Term
	A	---	A	---	A	---	A	---	A	A	A	Su	A	A	---	A			
ERM 2.5	---	---	---	---	---	---	---	---	44	44	42	---	46	43	---	46	---	44.2	44.2
CRM 4.4	45	---	42	---	44	---	36	---	38	42	44	44	43	44	---	43	41.8	42.6	42.3
CRM 1.5	42	---	44	---	41	---	34	---	36	42	36 ¹	40	41	41	---	47	40.3	40.4	40.4

A-Autumn; Su-Summer

1-RFAI score for CRM 1.5 in 2011 was originally reported as 37. The reclassification of redbreast sunfish from indigenous to non-indigenous resulted in a one-point reduction in the score for “Percent non-indigenous species” thereby reducing the final RFAI score by one point.

RFAI scoring range for five rating categories:

12-21 (“Very Poor”), 22-31 (“Poor”), 32-40 (“Fair”), 41-50 (“Good”), or 51-60 (“Excellent”)

Table 2. Individual metric scores, contributing species, and overall RFAI scores for CRM 1.5, 2001-2015.

Metric	Gear	Common Name	2001		2003		2005		2007		2009		2010		2011		2012		2013		2015			
			Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc	Summer Obs	Autumn Sc	Autumn Obs	Sc	Autumn Obs	Sc		
1. Number of indigenous species	Combined	(see Tables 6 and 7)	<u>32</u>	<u>5</u>	<u>32</u>	<u>5</u>	<u>30</u>	<u>5</u>	<u>24</u>	<u>3</u>	<u>27</u>	<u>3</u>	<u>34</u>	<u>5</u>	<u>26</u>	<u>3</u>	<u>31</u>	<u>5</u>	<u>33</u>	<u>5</u>	<u>31</u>	<u>5</u>	<u>36</u>	<u>5</u>
2. Number of centrarchid species (less Micropterus)	Combined		<u>7</u>	<u>5</u>	<u>6</u>	<u>5</u>	<u>5</u>	<u>5</u>	<u>5</u>	<u>5</u>	<u>6</u>	<u>5</u>	<u>6</u>	<u>5</u>	<u>7</u>	<u>5</u>	<u>6</u>	<u>5</u>	<u>6</u>	<u>5</u>	<u>5</u>	<u>5</u>	<u>7</u>	<u>5</u>
		Black crappie	12		1		--		2		2		4		2		3		--		--		2	
		Bluegill	540		365		330		364		970		704		319		388		545		772		265	
		Green sunfish	11		4		36		16		43		35		30		16		22		20		7	
		Longear sunfish	12		16		52		106		197		71		38		37		24		28		16	
		Redear sunfish	59		51		40		47		52		107		44		57		32		52		34	
		Warmouth	2		--		--		--		3		--		6		2		4		1		2	
White crappie	8		2		2		--		--		4		1		--		6		--		2			
3. Number of benthic invertivore species	Combined		<u>3</u>	<u>1</u>	<u>4</u>	<u>3</u>	<u>4</u>	<u>3</u>	<u>2</u>	<u>1</u>	<u>3</u>	<u>1</u>	<u>4</u>	<u>3</u>	<u>3</u>	<u>1</u>	<u>5</u>	<u>3</u>	<u>5</u>	<u>3</u>	<u>5</u>	<u>3</u>	<u>5</u>	<u>3</u>
		Black redhorse	--		--		--		--		--		--		3		2		1		2		--	
		Freshwater drum	10		30		9		8		11		13		11		16		13		8		8	
		Golden redhorse	--		1		--		1		1		2		--		1		--		--		1	
		Logperch	5		6		2		--		--		3		--		1		2		4		52	
		Northern hog sucker	--		--		4		--		--		--		--		--		2		1		2	
Spotted sucker	14		11		18		--		15		11		52		12		30		23		10			
4. Number of intolerant species	Combined		<u>5</u>	<u>5</u>	<u>6</u>	<u>5</u>	<u>7</u>	<u>5</u>	<u>3</u>	<u>3</u>	<u>5</u>	<u>5</u>	<u>6</u>	<u>5</u>	<u>5</u>	<u>5</u>	<u>6</u>	<u>5</u>	<u>8</u>	<u>5</u>	<u>7</u>	<u>5</u>	<u>7</u>	<u>5</u>
		Black redhorse	--		--		--		--		--		--		3		2		1		2		--	
		Brook silverside	17		34		5		11		20		21		--		1		7		6		26	
		Longear sunfish	12		16		52		106		197		71		38		37		24		28		16	
		Mooneye	--		1		4		--		--		--		--		--		--		--		--	
		Northern hog sucker	--		--		4		--		--		--		--		--		2		1		2	
		Rock bass	--		--		--		--		3		3		1		--		2		1		1	
		Skipjack herring	21		21		22		--		--		10		--		12		1		--		22	
		Smallmouth bass	6		2		21		1		23		8		7		14		16		15		10	
Spotted sucker	14		11		18		--		15		11		52		12		30		23		10			
5. Percent tolerant individuals	Electrofishing		<u>83.5%</u>	<u>0.5</u>	<u>75.8%</u>	<u>0.5</u>	<u>74.7%</u>	<u>0.5</u>	<u>76.7%</u>	<u>0.5</u>	<u>74.2%</u>	<u>0.5</u>	<u>66.3%</u>	<u>0.5</u>	<u>75.8%</u>	<u>0.5</u>	<u>79.3%</u>	<u>0.5</u>	<u>83.6%</u>	<u>0.5</u>	<u>79.8%</u>	<u>0.5</u>	<u>29.9%</u>	<u>2.5</u>
		Bluegill	45.0		43.8		34.0		46.1		45.5		40.5		35.8		40.1		47.2		51.9		12.3	
		Bluntnose minnow	0.2		0.6		0.3		0.1		1.3		3.9		0.1		2.3		2.3		2.5		0.1	
		Common carp	1.6		1.9		1.8		0.6		0.6		0.4		2.0		1.0		0.9		1.6		0.4	
		Gizzard shad	21.6		21.2		29.4		22.4		6.9		14.5		25.8		27.3		11.9		6.1		7.4	
		Golden shiner	0.8		0.6		--		--		0.1		--		--		--		--		--		--	
		Green sunfish	0.9		0.5		3.7		2.0		2.0		2.0		3.4		1.7		1.9		1.3		0.3	
		Largemouth bass	8.0		4.1		2.6		2.6		4.6		3.2		6.6		2.7		10.8		4.7		5.6	
		Redbreast sunfish	0.4		0.1		0.6		0.1		0.7		0.3		0.7		0.8		0.6		0.6		0.1	
		River carpsucker	0.1		--		--		--		--		--		--		--		--		--		--	
		Spotfin shiner	4.6		2.7		2.4		2.7		12.4		1.2		1.4		3.4		7.5		11.0		3.5	
		Striped shiner	--		--		--		--		--		0.2		--		--		--		--		--	
		White crappie	0.2		0.2		--		--		--		0.2		--		--		0.4		--		0.0	

Table 2. (CRM 1.5, continued)

Metric	Gear	Common Name	2001		2003		2005		2007		2009		2010		2011		2012				2013		2015	
			Autumn		Autumn		Autumn		Autumn		Autumn		Autumn		Autumn		Summer	Autumn			Autumn		Autumn	
			Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc
5. Percent tolerant individuals (continued)	Gill Netting		<u>27.7%</u>	<u>1.5</u>	<u>24.5%</u>	<u>1.5</u>	<u>25.7%</u>	<u>1.5</u>	<u>37.7%</u>	<u>0.5</u>	<u>17.7%</u>	<u>1.5</u>	<u>23.7%</u>	<u>1.5</u>	<u>10.0%</u>	<u>2.5</u>	<u>21.5%</u>	<u>1.5</u>	<u>21.7%</u>	<u>1.5</u>	<u>6.0%</u>	<u>2.5</u>	<u>10.6%</u>	<u>2.5</u>
		Bluegill	6.1		2.8		--		5.2		--		0.6		2.0		--		--		--		0.7	
		Common carp	0.4		3.5		3.0		2.6		2.5		4.0		2.0		3.1		6.5		2.0		2.1	
		Gizzard shad	16.9		14.7		19.2		14.3		12.7		17.3		4.0		18.5		13.0		4.0		6.4	
		Largemouth bass	1.7		2.1		1.8		1.3		2.5		0.6		--		--		--		--		0.7	
		Longnose gar	--		1.4		0.6		14.3		--		0.6		--		--		--		--		--	
		White crappie	2.6		--		1.2		--		--		0.6		2.0		--		2.2		--		0.7	
6. Percent dominance by one species	Electrofishing	Bluegill	<u>45.0%</u>	<u>0.5</u>	<u>43.8%</u>	<u>0.5</u>	<u>34.0%</u>	<u>1.5</u>	<u>46.1%</u>	<u>0.5</u>	<u>45.5%</u>	<u>0.5</u>	<u>40.5%</u>	<u>0.5</u>	<u>35.8%</u>	<u>1.5</u>	<u>40.1%</u>	<u>0.5</u>	<u>47.2%</u>	<u>0.5</u>	<u>51.9%</u>	<u>0.5</u>	--	--
		Threadfin shad	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	<u>49.1%</u>	<u>0.5</u>
	Gill Netting	Blue catfish	--	--	--	--	--	--	--	--	<u>21.5%</u>	<u>1.5</u>	--	--	--	--	--	--	<u>26.1%</u>	<u>1.5</u>	<u>34.0%</u>	<u>0.5</u>	--	--
		Gizzard shad	<u>16.9%</u>	<u>1.5</u>	<u>14.7%</u>	<u>1.5</u>	<u>19.2%</u>	<u>1.5</u>	<u>14.3%</u>	<u>1.5</u>	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		Sauger	--	--	--	--	--	--	--	--	--	--	--	--	<u>30.0%</u>	<u>0.5</u>	--	--	--	--	--	--	--	--
		Striped bass	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		White bass	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	<u>21.3</u>	<u>1.5</u>
		Yellow bass	--	--	--	--	--	--	--	--	--	--	<u>18.5%</u>	<u>1.5</u>	--	--	<u>22.3%</u>	<u>1.5</u>	--	--	--	--	--	--
7. Percent non-indigenous species	Electrofishing		<u>2.3%</u>	<u>2.5</u>	<u>2.4%</u>	<u>2.5</u>	<u>12.7%</u>	<u>0.5</u>	<u>1.0%</u>	<u>2.5</u>	<u>11.6%</u>	<u>0.5</u>	<u>19.1%</u>	<u>0.5</u>	<u>6.6%</u>	<u>0.5</u>	<u>4.1%</u>	<u>1.5</u>	<u>4.9%</u>	<u>1.5</u>	<u>10.4%</u>	<u>0.5</u>	<u>12.7%</u>	<u>0.5</u>
		Common carp	1.6		1.9		1.8		0.6		0.6		0.4		2.0		1.0		0.9		1.6		0.4	
		Mississippi silverside	--		--		10.3		0.3		10.3		18.3		3.6		2.3		3.4		8.1		12.1	
		Redbreast sunfish	0.4		0.1		0.6		0.1		0.7		0.3		0.7		0.8		0.6		0.6		0.1	
		Striped bass	--		--		--		--		--		0.1		0.3		--		--		0.1		0.0	
		Yellow perch	0.3		0.4		--		--		0.1		--		--		--		0.1		--		0.0	
	Gill Netting		<u>7.4%</u>	<u>1.5</u>	<u>9.8%</u>	<u>0.5</u>	<u>13.8%</u>	<u>0.5</u>	<u>13.0%</u>	<u>0.5</u>	<u>6.3%</u>	<u>1.5</u>	<u>9.8%</u>	<u>0.5</u>	<u>6.0%</u>	<u>1.5</u>	<u>12.3%</u>	<u>0.5</u>	<u>13.0%</u>	<u>0.5</u>	<u>4.0%</u>	<u>2.5</u>	<u>9.2%</u>	<u>0.5</u>
		Common carp	0.4		3.5		3.0		2.6		2.5		4.0		2.0		3.1		6.5		2.0		2.1	
		Striped x white bass	0.9		--		--		--		--		--		--		--		--		--		--	
		Striped bass	6.1		6.3		10.8		10.4		3.8		5.8		4.0		9.2		6.5		2.0		7.1	
8. Number of top carnivore species	Combined		<u>11</u>	<u>5</u>	<u>12</u>	<u>5</u>	<u>11</u>	<u>5</u>	<u>10</u>	<u>5</u>	<u>10</u>	<u>5</u>	<u>12</u>	<u>5</u>	<u>10</u>	<u>5</u>	<u>10</u>	<u>5</u>	<u>11</u>	<u>5</u>	<u>9</u>	<u>5</u>	<u>12</u>	<u>5</u>
		Black crappie	12		1		--		2		2		4		2		3		--		--		2	
		Flathead catfish	6		15		7		8		1		11		1		11		3		1		4	
		Largemouth bass	98		37		32		21		125		69		68		31		141		83		138	
		Longnose gar	--		2		1		11		--		1		--		--		--		--		--	
		Rock bass	--		--		--		--		3		3		1		--		2		1		1	
		Sauger	4		4		8		--		14		5		15		--		2		3		1	
		Skipjack herring	21		21		22		--		--		10		--		12		1		--		22	
		Smallmouth bass	6		2		21		1		23		8		7		14		16		15		10	
		Spotted bass	25		8		14		1		8		--		2		4		2		3		3	
		Spotted gar	2		1		4		1		1		1		--		1		--		1		--	
		Walleye	--		--		--		1		--		--		--		3		3		3		10	
		White bass	5		6		6		1		3		17		6		1		1		--		32	
		White crappie	8		2		2		--		--		4		1		--		6		--		2	
		Yellow bass	19		22		14		5		5		32		1		29		3		8		5	

Table 2. (CRM 1.5, continued)

Metric	Gear	Common Name	2001 Autumn		2003 Autumn		2005 Autumn		2007 Autumn		2009 Autumn		2010 Autumn		2011 Autumn		2012				2013 Autumn		2015 Autumn	
			Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Summer Obs	Summer Sc	Autumn Obs	Autumn Sc	Obs	Sc	Obs	Sc
9. Percent top carnivores	Electrofishing		<u>10.7%</u>	<u>1.5</u>	<u>6.7%</u>	<u>1.5</u>	<u>5.4%</u>	<u>0.5</u>	<u>3.1%</u>	<u>0.5</u>	<u>6.0%</u>	<u>1.5</u>	<u>4.9%</u>	<u>0.5</u>	<u>8.2%</u>	<u>1.5</u>	<u>4.4%</u>	<u>0.5</u>	<u>12.7%</u>	<u>2.5</u>	<u>5.5%</u>	<u>0.5</u>	<u>6.3%</u>	<u>1.5</u>
		Black crappie	0.1		0.1		--		--		--		0.2		--		0.3		--		--		0.1	
		Flathead catfish	0.2		0.8		0.3		0.1		--		0.2		--		0.8		0.2		0.1		0.0	
		Largemouth bass	8.0		4.1		2.6		2.6		4.6		3.2		6.6		2.7		10.8		4.7		5.6	
		Rock bass	--		--		--		--		0.1		0.1		0.1		--		0.2		--		--	
		Skipjack herring	--		--		--		--		--		0.1		--		--		--		--		--	
		Smallmouth bass	0.5		0.2		0.9		0.1		0.8		0.3		0.8		0.4		0.8		0.5		0.4	
		Spotted bass	1.5		0.8		1.2		0.1		0.4		--		0.1		0.1		0.2		0.1		--	
		Spotted gar	0.2		--		0.3		0.1		--		0.1		--		0.1		--		0.1		--	
		Striped bass	--		--		--		--		--		0.1		0.3		--		--		0.1		0.0	
		White bass	--		0.1		--		--		0.0		0.5		0.2		--		0.1		--		0.1	
		White crappie	0.2		0.2		--		--		--		0.2		--		--		0.4		--		0.0	
		Yellow bass	--		0.1		--		--		--		--		--		--		0.1		--		--	
	Gill Netting		<u>42.0%</u>	<u>1.5</u>	<u>52.4%</u>	<u>2.5</u>	<u>48.5%</u>	<u>1.5</u>	<u>46.8%</u>	<u>1.5</u>	<u>38.0%</u>	<u>1.5</u>	<u>44.5%</u>	<u>1.5</u>	<u>52.0%</u>	<u>1.5</u>	<u>46.2%</u>	<u>1.5</u>	<u>28.3%</u>	<u>1.5</u>	<u>34.0%</u>	<u>1.5</u>	<u>61.7%</u>	<u>2.5</u>
		Black crappie	4.8		--		--		2.6		2.5		0.6		4.0		--		--		--		--	
		Flathead catfish	1.7		5.6		2.4		9.1		1.3		4.6		2.0		2.3		2.2		--		1.4	
		Striped x white bass	0.9		--		--		--		--		--		--		--		--		--		--	
		Largemouth bass	1.7		2.1		1.8		1.3		2.5		0.6		--		--		--		--		0.7	
		Longnose gar	--		1.4		0.6		14.3		--		0.6		--		--		--		--		--	
		Rock bass	--		--		--		--		--		0.6		--		--		--		2.0		0.7	
		Sauger	1.7		2.8		4.8		--		17.7		2.9		30.0		--		4.3		6.0		0.7	
		Skipjack herring	9.1		14.7		13.2		--		--		4.6		--		9.2		2.2		--		15.6	
		Smallmouth bass	--		--		--		--		--		--		--		--		--		2.0		0.7	
		Spotted bass	3.0		0.7		1.2		--		--		--		--		--		--		--		2.1	
		Spotted gar	--		0.7		0.6		--		1.3		--		--		--		--		--		--	
		Striped bass	6.1		6.3		10.8		10.4		3.8		5.8		4.0		9.2		6.5		2.0		7.1	
		Walleye	--		--		--		1.3		--		--		--		2.3		6.5		6.0		7.1	
		White bass	2.2		3.5		3.6		1.3		2.5		5.2		8.0		0.8		--		--		21.3	
		White crappie	2.6		--		1.2		--		--		0.6		2.0		--		2.2		--		0.7	
		Yellow bass	8.2		14.7		8.4		6.5		6.3		18.5		2.0		22.3		4.3		16.0		3.5	
10. Percent omnivores	Electrofishing		<u>25.1%</u>	<u>1.5</u>	<u>27.3%</u>	<u>1.5</u>	<u>32.2%</u>	<u>1.5</u>	<u>24.3%</u>	<u>1.5</u>	<u>9.6%</u>	<u>2.5</u>	<u>20.1%</u>	<u>2.5</u>	<u>29.4%</u>	<u>1.5</u>	<u>33.2%</u>	<u>1.5</u>	<u>16.3%</u>	<u>2.5</u>	<u>11.0%</u>	<u>2.5</u>	<u>9.0%</u>	<u>2.5</u>
		Black buffalo	--		--		0.2		--		--		0.1		--		0.3		0.2		--		0.0	
		Blue catfish	--		--		--		--		--		--		--		--		0.1		--		--	
		Bluntnose minnow	0.2		0.6		0.3		0.1		1.3		3.9		0.1		2.3		2.3		2.5		0.1	
		Channel catfish	0.2		1.6		0.5		0.5		0.5		0.8		1.0		0.5		0.7		0.5		0.5	
		Common carp	1.6		1.9		1.8		0.6		0.6		0.4		2.0		1.0		0.9		1.6		0.4	
		Gizzard shad	21.6		21.2		29.4		22.4		6.9		14.5		25.8		27.3		11.9		6.1		7.4	
		Golden shiner	0.8		0.6		--		--		0.1		--		--		--		--		--		--	
		Quillback	--		--		--		--		--		--		--		--		0.1		--		--	

Table 2. (CRM 1.5, continued)

Metric	Gear	Common Name	2001		2003		2005		2007		2009		2010		2011		2012				2013		2015	
			Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc	Summer Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc
10. Percent omnivores (continued)	Electrofishing	River carpsucker	0.1		--		--		--		--		--		--		--		--		--		--	
		Smallmouth buffalo	0.7		1.3		--		0.6		0.1		0.2		0.5		1.8		0.2		0.3		0.6	
		Striped shiner	--		--		--		--		--		0.2		--		--		--		--		--	
	Gill Netting		<u>45.0%</u>	<u>1.5</u>	<u>37.1%</u>	<u>1.5</u>	<u>35.3%</u>	<u>1.5</u>	<u>39.0%</u>	<u>1.5</u>	<u>48.1%</u>	<u>0.5</u>	<u>37.6%</u>	<u>1.5</u>	<u>34.0%</u>	<u>1.5</u>	<u>46.9%</u>	<u>0.5</u>	<u>50.0%</u>	<u>0.5</u>	<u>48.0%</u>	<u>0.5</u>	<u>29.8%</u>	<u>1.5</u>
		Black buffalo	1.3		--		--		--		--		0.6		--		--		--		--		--	
		Blue catfish	13.9		10.5		8.4		9.1		21.5		9.8		26.0		16.9		26.1		34.0		9.2	
		Channel catfish	7.4		4.9		3.0		5.2		8.9		4.6		--		3.1		2.2		2.0		3.5	
		Common carp	0.4		3.5		3.0		2.6		2.5		4.0		2.0		3.1		6.5		2.0		2.1	
		Gizzard shad	16.9		14.7		19.2		14.3		12.7		17.3		4.0		18.5		13.0		4.0		6.4	
		Quillback	--		--		--		--		--		--		--		--		--		--		0.7	
		Smallmouth buffalo	5.2		3.5		1.8		7.8		2.5		1.2		2.0		5.4		2.2		6.0		7.8	
11. Average number per run	Electrofishing		<u>77.9</u>	<u>0.5</u>	<u>54.9</u>	<u>0.5</u>	<u>64.7</u>	<u>0.5</u>	<u>52.1</u>	<u>0.5</u>	<u>142.1</u>	<u>1.5</u>	<u>115.8</u>	<u>1.5</u>	<u>59.2</u>	<u>0.5</u>	<u>64.5</u>	<u>0.5</u>	<u>76.9</u>	<u>0.5</u>	<u>99.1</u>	<u>0.5</u>	<u>142.9</u>	<u>1.5</u>
	Gill Netting		<u>23.1</u>	<u>1.5</u>	<u>14.3</u>	<u>1.5</u>	<u>16.7</u>	<u>1.5</u>	<u>7.7</u>	<u>0.5</u>	<u>7.9</u>	<u>0.5</u>	<u>17.3</u>	<u>1.5</u>	<u>5</u>	<u>0.5</u>	<u>13</u>	<u>1.5</u>	<u>4.6</u>	<u>0.5</u>	<u>5</u>	<u>0.5</u>	<u>14.1</u>	<u>1.5</u>
12. Percent anomalies	Electrofishing		<u>0.9</u>	<u>2.5</u>	<u>0.1</u>	<u>2.5</u>	<u>0.3</u>	<u>2.5</u>	<u>0.1</u>	<u>2.5</u>	<u>4.1</u>	<u>1.5</u>	<u>1.2</u>	<u>2.5</u>	<u>3.4</u>	<u>1.5</u>	<u>0.3</u>	<u>2.5</u>	<u>0.8</u>	<u>2.5</u>	<u>0.9</u>	<u>2.5</u>	<u>0.2</u>	<u>2.5</u>
	Gill Netting		<u>0.4</u>	<u>2.5</u>	<u>0</u>	<u>2.5</u>	<u>1.8</u>	<u>2.5</u>	<u>0</u>	<u>2.5</u>	<u>2.5</u>	<u>1.5</u>	<u>0.6</u>	<u>2.5</u>	<u>2</u>	<u>1.5</u>	<u>0.8</u>	<u>2.5</u>	<u>4.3</u>	<u>1.5</u>	<u>0</u>	<u>2.5</u>	<u>0.7</u>	<u>2.5</u>
RFAI Score			42		44		41		34		36		42		36		40		41		41		47	

Species percentages may not add to the observed value reported for a given metric due to rounding.

-- = No taxa.

0.0 = Present but in small numbers (percentage <0.05%).

Table 3. Individual metric scores, contributing species, and overall RFAI scores for CRM 4.4, 2001-2015.

Metric	Gear	Common Name	2001		2003		2005		2007		2009		2010		2011		2012				2013		2015	
			Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc	Summer Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc
1. Number of indigenous species	Combined	(see Tables 6 and 8)	<u>32</u>	<u>5</u>	<u>34</u>	<u>5</u>	<u>30</u>	<u>5</u>	<u>28</u>	<u>3</u>	<u>27</u>	<u>3</u>	<u>33</u>	<u>5</u>	<u>27</u>	<u>3</u>	<u>31</u>	<u>5</u>	<u>27</u>	<u>3</u>	<u>31</u>	<u>5</u>	<u>33</u>	<u>5</u>
2. Number of centrarchid species (less Micropterus)	Combined		<u>7</u>	<u>5</u>	<u>7</u>	<u>5</u>	<u>6</u>	<u>5</u>	<u>4</u>	<u>3</u>	<u>7</u>	<u>5</u>	<u>7</u>	<u>5</u>	<u>5</u>	<u>5</u>	<u>6</u>	<u>5</u>	<u>6</u>	<u>5</u>	<u>5</u>	<u>5</u>	<u>6</u>	<u>5</u>
		Black crappie	5		2		3		--		3		3		--		16		2		--		2	
		Bluegill	483		298		288		305		539		764		157		443		106		488		540	
		Green sunfish	4		3		14		1		25		49		42		7		36		8		2	
		Longear sunfish	10		25		13		40		112		31		7		13		13		16		2	
		Redear sunfish	74		50		67		35		73		89		51		40		34		38		65	
		Warmouth	1		3		--		--		3		3		2		--		1		1		1	
		White crappie	1		1		3		--		2		3		--		5		--		--		--	
3. Number of benthic invertivore species	Combined		<u>5</u>	<u>3</u>	<u>5</u>	<u>3</u>	<u>7</u>	<u>3</u>	<u>5</u>	<u>3</u>	<u>3</u>	<u>1</u>	<u>5</u>	<u>3</u>	<u>4</u>	<u>3</u>	<u>4</u>	<u>3</u>	<u>4</u>	<u>3</u>	<u>7</u>	<u>3</u>	<u>6</u>	<u>3</u>
		Black redhorse	1		1		2		1		2		3		4		--		1		2		5	
		Freshwater drum	6		17		12		10		8		18		3		22		2		8		4	
		Golden redhorse	1		2		5		2		--		1		--		1		2		7		2	
		Logperch	1		2		4		1		--		7		--		3		--		1		98	
		Northern hog sucker	--		--		--		--		--		--		1		--		--		2		5	
		River redhorse	--		--		1		--		--		--		--		--		--		--		--	
		Silver redhorse	--		--		1		--		--		--		--		--		--		1		--	
4. Number of intolerant species	Combined		<u>6</u>	<u>5</u>	<u>7</u>	<u>5</u>	<u>7</u>	<u>5</u>	<u>5</u>	<u>5</u>	<u>6</u>	<u>5</u>	<u>6</u>	<u>5</u>	<u>5</u>	<u>5</u>	<u>5</u>	<u>5</u>	<u>5</u>	<u>5</u>	<u>7</u>	<u>5</u>	<u>8</u>	<u>5</u>
		Black redhorse	1		1		2		1		2		3		4		--		1		2		5	
		Brook silverside	14		44		18		14		40		13		--		--		--		5		4	
		Longear sunfish	10		25		13		40		112		31		7		13		13		16		2	
		Mooneye	--		1		--		--		--		--		--		--		--		--		--	
		Northern hog sucker	--		--		--		--		--		--		1		--		--		2		5	
		River redhorse	--		--		1		--		--		--		--		--		--		--		--	
		Rock bass	--		--		--		--		3		--		--		3		--		--		3	
5. Percent tolerant individuals	Electrofishing		<u>81.8%</u>	<u>0.5</u>	<u>72.1%</u>	<u>0.5</u>	<u>77.0%</u>	<u>0.5</u>	<u>77.7%</u>	<u>0.5</u>	<u>74.3%</u>	<u>0.5</u>	<u>67.1%</u>	<u>0.5</u>	<u>71.5%</u>	<u>0.5</u>	<u>71.9%</u>	<u>0.5</u>	<u>77.5%</u>	<u>0.5</u>	<u>81.5%</u>	<u>0.5</u>	<u>58.9%</u>	<u>1.5</u>
		Bluegill	52.2		32.8		27.0		44.5		36.4		45.4		30.9		44.7		31.1		46.0		40.9	
		Bluntnose minnow	0.2		0.2		--		0.3		7.0		0.6		--		0.4		0.3		0.2		0.1	
		Common carp	3.8		1.6		1.9		1.2		1.0		1.0		1.8		1.9		3.3		2.5		1.4	
		Gizzard shad	9.5		24.8		36.1		24.6		6.4		9.6		18.2		17.3		16.2		0.1		2.1	
		Golden shiner	0.1		1.0		--		0.1		--		--		--		--		--		--		--	
		Green sunfish	0.4		0.3		1.3		0.1		1.7		2.9		8.4		0.7		10.8		0.8		0.2	
		Largemouth bass	9.2		6.9		7.4		4.0		6.4		4.7		10.8		3.6		14.4		5.1		8.5	
		Redbreast sunfish	0.3		--		--		--		0.1		0.4		0.4		--		0.3		0.1		--	
		Spotfin shiner	6.0		4.6		3.1		2.9		15.3		2.4		1.0		2.6		1.2		26.8		5.8	
		White crappie	--		--		0.2		--		0.1		0.2		--		0.5		--		--		--	

Table 3. (CRM 4.4, continued)

Metric	Gear	Common Name	2001 Autumn		2003 Autumn		2005 Autumn		2007 Autumn		2009 Autumn		2010 Autumn		2011 Autumn		2012 Summer		2012 Autumn		2013 Autumn		2015 Autumn	
			Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc
5. Percent tolerant individuals (continued)	Gill Netting		<u>22.5%</u>	<u>1.5</u>	<u>33.3%</u>	<u>0.5</u>	<u>22.9%</u>	<u>1.5</u>	<u>29.3%</u>	<u>1.5</u>	<u>10.4%</u>	<u>2.5</u>	<u>17.8%</u>	<u>1.5</u>	<u>8.3%</u>	<u>2.5</u>	<u>7.7%</u>	<u>2.5</u>	<u>16.7%</u>	<u>1.5</u>	<u>3.5%</u>	<u>2.5</u>	<u>17.7%</u>	<u>1.5</u>
		Bluegill	1.4		1.4		--		1.1		1.9		--		6.3		0.7		2.6		--		0.8	
		Common carp	3.8		3.7		6.4		5.4		3.8		2.0		--		1.4		1.3		--		1.5	
		Gizzard shad	16.4		26.4		11.0		21.7		1.9		15.8		--		5.6		10.3		3.5		13.8	
		Largemouth bass	0.5		0.9		3.7		--		1.9		--		--		--		2.6		--		1.5	
		Longnose gar	--		0.5		--		1.1		--		--		2.1		--		--		--		--	
		River carpsucker	--		--		0.9		--		--		--		--		--		--		--		--	
		White crappie	0.5		0.5		0.9		--		0.9		--		--		--		--		--		--	
6. Percent dominance by one species	Electrofishing	Bluegill	<u>52.2%</u>	<u>0.5</u>	<u>32.8%</u>	<u>1.5</u>			<u>44.5%</u>	<u>0.5</u>	<u>36.4%</u>	<u>1.5</u>	<u>45.4%</u>	<u>0.5</u>	<u>30.9%</u>	<u>1.5</u>	<u>44.7%</u>	<u>0.5</u>	<u>31.1%</u>	<u>1.5</u>	<u>46.0%</u>	<u>0.5</u>	<u>40.9</u>	<u>0.5</u>
		Gizzard shad	--	--	--	--	<u>36.1%</u>	<u>1.5</u>	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Gill Netting	Blue catfish	--	--	--	--	--	--	--	--	--	--	--	--	<u>22.9%</u>	<u>1.5</u>	--	--	--	--	--	--	--	--
		Gizzard shad	--	--	<u>26.4%</u>	<u>1.5</u>	<u>11.0%</u>	<u>2.5</u>	<u>21.7%</u>	<u>1.5</u>	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		Lake sturgeon	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	<u>14.0%</u>	<u>1.5</u>	--	--
		Striped bass	--	--	--	--	--	--	--	--	--	--	<u>21.8%</u>	<u>1.5</u>	--	--	--	--	--	--	--	--	--	--
		Walleye	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	<u>16.9</u>	<u>1.5</u>
		Yellow bass	<u>16.9%</u>	<u>1.5</u>	--	--	--	--	--	--	<u>25.5%</u>	<u>1.5</u>	--	--	--	--	<u>31.0%</u>	<u>0.5</u>	<u>16.7%</u>	<u>1.5</u>	<u>14.0%</u>	<u>1.5</u>	--	--
7. Percent non-indigenous species	Electrofishing		<u>4.7%</u>	<u>1.5</u>	<u>1.8%</u>	<u>2.5</u>	<u>2.9%</u>	<u>2.5</u>	<u>4.8%</u>	<u>1.5</u>	<u>7.5%</u>	<u>0.5</u>	<u>22.7%</u>	<u>0.5</u>	<u>5.2%</u>	<u>1.5</u>	<u>9.5%</u>	<u>0.5</u>	<u>3.9%</u>	<u>1.5</u>	<u>9.0%</u>	<u>0.5</u>	<u>23.1%</u>	<u>0.5</u>
		Common carp	3.8		1.6		1.9		1.2		1.0		1.0		1.8		1.9		3.3		2.5		1.4	
		Mississippi silverside	--		--		0.9		3.5		6.2		21.1		0.2		7.5		0.3		5.9		21.6	
		Muskellunge	--		--		--		--		--		--		0.2		--		--		--		--	
		Redbreast sunfish	0.3		--		--		--		0.1		0.4		0.4		--		0.3		0.1		--	
		Yellow perch	0.5		0.2		0.1		0.1		0.1		0.2		2.6		0.1		--		0.4		0.2	
	Gill Netting		<u>4.7%</u>	<u>2.5</u>	<u>12.0%</u>	<u>0.5</u>	<u>16.5%</u>	<u>0.5</u>	<u>15.2%</u>	<u>0.5</u>	<u>7.5%</u>	<u>1.5</u>	<u>23.8%</u>	<u>0.5</u>	<u>0.0%</u>	<u>2.5</u>	<u>4.9%</u>	<u>2.5</u>	<u>2.6%</u>	<u>2.5</u>	<u>7.0%</u>	<u>1.5</u>	<u>13.8%</u>	<u>0.5</u>
		Common carp	3.8		3.7		6.4		5.4		3.8		2.0		--		1.4		1.3		--		1.5	
		Striped x white bass	--		--		0.9		--		--		--		--		--		--		--		--	
8. Number of top carnivore species	Combined	Striped bass	0.9		8.3		9.2		9.8		3.8		21.8		--		3.5		1.3		7.0		12.3	
			<u>10</u>	<u>5</u>	<u>12</u>	<u>5</u>	<u>10</u>	<u>5</u>	<u>9</u>	<u>5</u>	<u>10</u>	<u>5</u>	<u>12</u>	<u>5</u>	<u>9</u>	<u>5</u>	<u>13</u>	<u>5</u>	<u>10</u>	<u>5</u>	<u>8</u>	<u>5</u>	<u>11</u>	<u>5</u>
		Black crappie	5		2		3		--		3		3		--		16		2		--		2	
		Flathead catfish	4		2		2		3		2		3		1		3		2		--		2	
		Largemouth bass	86		64		97		27		106		90		60		54		65		70		125	
		Longnose gar	--		1		--		1		--		--		1		--		--		--		--	
		Rock bass	--		--		--		--		3		--		--		3		--		--		3	
		Sauger	9		4		6		5		12		5		6		5		4		4		2	
		Skipjack herring	20		18		12		--		--		4		--		12		3		5		6	
		Smallmouth bass	6		4		29		5		14		16		10		5		7		17		15	
		Spotted bass	19		18		12		4		7		2		3		8		2		2		5	
		Spotted gar	--		5		--		--		--		1		--		3		1		1		--	
		Walleye	--		--		--		2		--		3		2		8		5		5		22	
		White bass	17		6		2		3		2		12		5		2		--		--		10	
		White crappie	1		1		3		--		2		3		--		5		--		--		--	
		Yellow bass	38		32		9		8		28		5		20		44		13		8		2	

Table 3. (CRM 4.4, continued)

Metric	Gear	Common Name	2001 Autumn		2003 Autumn		2005 Autumn		2007 Autumn		2009 Autumn		2010 Autumn		2011 Autumn		2012 Summer		2012 Autumn		2013 Autumn		2015 Autumn	
			Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc
9. Percent top carnivores	Electrofishing		<u>12.3%</u>	<u>2.5</u>	<u>10.0%</u>	<u>1.5</u>	<u>11.1%</u>	<u>2.5</u>	<u>5.4%</u>	<u>0.5</u>	<u>8.0%</u>	<u>1.5</u>	<u>6.2%</u>	<u>1.5</u>	<u>14.6%</u>	<u>2.5</u>	<u>7.4%</u>	<u>1.5</u>	<u>16.2%</u>	<u>2.5</u>	<u>6.5%</u>	<u>1.5</u>	<u>10.0%</u>	<u>1.5</u>
		Black crappie	0.2		0.2		0.3		--		0.1		0.2		--		1.6		--		--		0.1	
		Flathead catfish	0.1		0.1		0.1		0.1		--		--		--		0.2		--		--		0.1	
		Hybrid bass	--		--		--		--		--		0.1		--		--		--		--		--	
		Largemouth bass	9.2		6.9		7.4		4.0		6.4		4.7		10.8		3.6		14.4		5.1		8.5	
		Muskellunge	--		--		--		--		--		--		0.2		--		--		--		--	
		Rock bass	--		--		--		--		0.2		--		--		0.1		--		--		--	
		Sauger	--		--		--		--		--		--		--		--		--		--		0.1	
		Skipjack herring	--		0.2		--		--		--		--		--		--		--		--		--	
		Smallmouth bass	0.7		0.4		2.0		0.7		0.9		0.5		1.2		0.4		0.9		1.3		0.8	
		Spotted bass	1.6		1.3		1.0		0.4		0.3		0.1		0.2		0.4		0.6		--		0.4	
		Spotted gar	--		0.6		--		--		--		0.1		--		0.3		0.3		0.1		--	
		White bass	0.2		--		--		--		--		0.5		0.2		0.2		--		--		0.1	
		White crappie	--		--		0.2		--		0.1		0.2		--		0.5		--		--		--	
		Yellow bass	0.2		0.2		0.1		0.1		0.1		--		2.0		--		--		--		--	
	Gill Netting		<u>44.1%</u>	<u>1.5</u>	<u>39.4%</u>	<u>1.5</u>	<u>42.2%</u>	<u>1.5</u>	<u>32.6%</u>	<u>1.5</u>	<u>49.1%</u>	<u>1.5</u>	<u>45.5%</u>	<u>1.5</u>	<u>54.2%</u>	<u>2.5</u>	<u>54.2%</u>	<u>2.5</u>	<u>42.3%</u>	<u>1.5</u>	<u>49.1%</u>	<u>1.5</u>	<u>48.5%</u>	<u>1.5</u>
		Black crappie	1.4		--		--		--		1.9		--		--		--		2.6		--		0.8	
		Flathead catfish	1.4		0.5		0.9		2.2		1.9		3.0		2.1		0.7		2.6		--		0.8	
		Hybrid black bass	--		--		--		--		--		--		--		--		--		1.8		--	
		Striped x white bass	--		--		0.9		--		--		--		--		--		--		--		--	
		Largemouth bass	0.5		0.9		3.7		--		1.9		--		--		--		2.6		--		1.5	
		Longnose gar	--		0.5		--		1.1		--		--		2.1		--		--		--		--	
		Rock bass	--		--		--		--		--		--		--		1.4		--		--		2.3	
		Sauger	4.2		1.9		5.5		5.4		11.3		5.0		12.5		3.5		5.1		7.0		0.8	
		Skipjack herring	9.4		7.4		11.0		--		--		4.0		--		8.5		3.8		8.8		4.6	
		Smallmouth bass	--		--		--		--		--		--		4.2		--		1.3		--		--	
		Spotted bass	1.9		2.8		0.9		1.1		--		--		--		--		--		1.8		--	
		Striped bass	0.9		8.3		9.2		9.8		3.8		21.8		--		3.5		1.3		7.0		12.3	
		Walleye	--		--		--		2.2		--		3.0		4.2		5.6		6.4		8.8		16.9	
		White bass	7.0		2.8		1.8		3.3		1.9		4.0		8.3		--		--		--		6.9	
		White crappie	0.5		0.5		0.9		--		0.9		--		--		--		--		--		--	
		Yellow bass	16.9		13.9		7.3		7.6		25.5		5.0		20.8		31.0		16.7		14.0		1.5	
10. Percent omnivores	Electrofishing		<u>15.2%</u>	<u>2.5</u>	<u>30.4%</u>	<u>1.5</u>	<u>39.0%</u>	<u>1.5</u>	<u>28.0%</u>	<u>1.5</u>	<u>15.6%</u>	<u>2.5</u>	<u>11.6%</u>	<u>2.5</u>	<u>21.8%</u>	<u>2.5</u>	<u>22.0%</u>	<u>1.5</u>	<u>21.6%</u>	<u>2.5</u>	<u>4.1%</u>	<u>2.5</u>	<u>4.4%</u>	<u>2.5</u>
		Black buffalo	0.1		0.3		0.3		--		--		0.1		0.4		0.1		--		0.1		--	
		Blue catfish	--		--		--		--		--		--		0.2		--		--		--		0.1	
		Bluntnose minnow	0.2		0.2		--		0.3		7.0		0.6		--		0.4		0.3		0.2		0.1	
		Channel catfish	0.8		0.6		0.5		1.5		1.0		0.2		0.8		0.9		1.8		0.8		0.5	
		Common carp	3.8		1.6		1.9		1.2		1.0		1.0		1.8		1.9		3.3		2.5		1.4	
		Gizzard shad	9.5		24.8		36.1		24.6		6.4		9.6		18.2		17.3		16.2		0.1		2.1	
		Golden shiner	0.1		1.0		--		0.1		--		--		--		--		--		--		--	
		Smallmouth buffalo	0.8		2.0		0.3		0.3		0.2		0.1		0.4		1.3		--		0.4		0.3	

Table 3. (CRM 4.4, continued)

Metric	Gear	Common Name	2001 Autumn		2003 Autumn		2005 Autumn		2007 Autumn		2009 Autumn		2010 Autumn		2011 Autumn		2012 Summer		2012 Autumn		2013 Autumn		2015 Autumn	
			Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc
10. Percent omnivores (continued)	Gill Netting		<u>44.6%</u>	<u>1.5</u>	<u>51.9%</u>	<u>0.5</u>	<u>33.9%</u>	<u>1.5</u>	<u>45.7%</u>	<u>1.5</u>	<u>36.8%</u>	<u>1.5</u>	<u>35.6%</u>	<u>1.5</u>	<u>27.1%</u>	<u>1.5</u>	<u>30.3%</u>	<u>1.5</u>	<u>34.6%</u>	<u>1.5</u>	<u>15.8%</u>	<u>2.5</u>	<u>36.2%</u>	<u>2.5</u>
		Black buffalo	0.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		Blue catfish	16.4		12.0		5.5		14.1		19.8		10.9		22.9		14.8		10.3		10.5		8.5	
		Channel catfish	7.0		4.2		4.6		3.3		10.4		3.0		4.2		6.3		10.3		1.8		6.2	
		Common carp	3.8		3.7		6.4		5.4		3.8		2.0		--		1.4		1.3		--		1.5	
		Gizzard shad	16.4		26.4		11.0		21.7		1.9		15.8		--		5.6		10.3		3.5		13.8	
		Quillback	--		0.5		--		--		--		--		--		--		--		--		--	
		River carpsucker	--		--		0.9		--		--		--		--		--		--		--		--	
		Smallmouth buffalo	--		5.1		5.5		1.1		0.9		4.0		--		2.1		2.6		--		6.2	
11. Average number per run	Electrofishing		<u>61.3</u>	<u>0.5</u>	<u>60.0</u>	<u>0.5</u>	<u>71.0</u>	<u>0.5</u>	<u>45.5</u>	<u>0.5</u>	<u>98.3</u>	<u>0.5</u>	<u>112.2</u>	<u>1.5</u>	<u>33.3</u>	<u>0.5</u>	<u>65.9</u>	<u>0.5</u>	<u>22.3</u>	<u>0.5</u>	<u>70.7</u>	<u>0.5</u>	<u>87.8</u>	<u>0.5</u>
	Gill Netting		<u>21.3</u>	<u>1.5</u>	<u>21.6</u>	<u>1.5</u>	<u>10.9</u>	<u>0.5</u>	<u>9.2</u>	<u>0.5</u>	<u>10.6</u>	<u>0.5</u>	<u>10.1</u>	<u>0.5</u>	<u>4.8</u>	<u>0.5</u>	<u>14.2</u>	<u>1.5</u>	<u>7.8</u>	<u>0.5</u>	<u>5.7</u>	<u>0.5</u>	<u>13</u>	<u>1.5</u>
12. Percent anomalies	Electrofishing		<u>1.3</u>	<u>2.5</u>	<u>0.2</u>	<u>2.5</u>	<u>1.2</u>	<u>2.5</u>	<u>0.4</u>	<u>2.5</u>	<u>2.8</u>	<u>1.5</u>	<u>1.1</u>	<u>2.5</u>	<u>8.6</u>	<u>0.5</u>	<u>0.2</u>	<u>2.5</u>	<u>3.6</u>	<u>1.5</u>	<u>0.6</u>	<u>2.5</u>	<u>0.2</u>	<u>2.5</u>
	Gill Netting		<u>2.3</u>	<u>1.5</u>	<u>0</u>	<u>2.5</u>	<u>2.8</u>	<u>1.5</u>	<u>0</u>	<u>2.5</u>	<u>2.8</u>	<u>1.5</u>	<u>0</u>	<u>2.5</u>	<u>0</u>	<u>2.5</u>	<u>0.7</u>	<u>2.5</u>	<u>0</u>	<u>2.5</u>	<u>1.8</u>	<u>2.5</u>	<u>0</u>	<u>2.5</u>
RFAI Score			45		42		44		36		38		42		44		44		43		44		43	

Species percentages may not add to the observed value reported for a given metric due to rounding.

-- = No taxa.

0.0 = Present but in small numbers (percentage <0.05%).

Table 4. Individual metric scores, contributing species, and overall RFAI scores for ERM 2.5, 2009-2015.

Metric	Gear	Common Name	2009		2010		2011		2012		2013		2015	
			Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc	Obs	Sc
1. Number of indigenous species	Combined	(see Tables 6 and 9)	<u>31</u>	<u>5</u>	<u>34</u>	<u>5</u>	<u>27</u>	<u>3</u>	<u>28</u>	<u>3</u>	<u>36</u>	<u>5</u>	<u>33</u>	<u>5</u>
2. Number of centrarchid species (less Micropterus)	Combined	Black crappie	3		13		5		21		20		5	
		Bluegill	515		330		1012		1674		867		367	
		Green sunfish	9		43		24		42		7		6	
		Longear sunfish	38		6		6		25		8		3	
		Redear sunfish	132		56		64		96		89		69	
		Warmouth	7		7		8		20		16		3	
		White crappie	2		4		7		11		9		3	
3. Number of benthic invertivore species	Combined	Black redhorse	<u>1</u>	<u>3</u>	<u>1</u>	<u>3</u>	--	<u>3</u>	<u>1</u>	<u>3</u>	<u>4</u>	<u>3</u>	<u>4</u>	<u>3</u>
		Freshwater drum	6		6		1		8		7		6	
		Golden redhorse	2		2		4		--		2		1	
		Logperch	--		12		--		--		23		46	
		Northern hog sucker	1		--		1		3		3		--	
		Spotted sucker	19		28		17		29		47		16	
4. Number of intolerant species	Combined	Black redhorse	<u>1</u>	<u>5</u>	<u>1</u>	<u>5</u>	--	<u>3</u>	<u>1</u>	<u>5</u>	<u>4</u>	<u>5</u>	<u>4</u>	<u>5</u>
		Brook silverside	56		29		8		39		92		13	
		Longear sunfish	38		6		6		25		8		3	
		Northern hog sucker	1		--		1		3		3		--	
		Rock Bass	--		--		--		--		--		1	
		Skipjack herring	--		25		--		11		11		13	
		Smallmouth bass	2		1		1		4		1		3	
		Spotted sucker	19		28		17		29		47		16	
5. Percent tolerant individuals	Electrofishing		<u>79.1%</u>	<u>0.5</u>	<u>78.7%</u>	<u>0.5</u>	<u>90.1%</u>	<u>0.5</u>	<u>89.5%</u>	<u>0.5</u>	<u>78.4%</u>	<u>0.5</u>	<u>56.5%</u>	<u>1.5</u>
		Bluegill	39.5		21.4		69.2		74.3		53.3		24.3	
		Bluntnose minnow	3.2		1.2		1.8		1.0		0.1		1.6	
		Common carp	1.0		1.0		0.4		0.4		0.7		1.2	
		Gizzard shad	9.0		41.1		7.6		1.2		1.1		16.4	
		Golden shiner	--		--		--		--		0.1		--	
		Green sunfish	0.7		2.8		1.6		1.9		0.4		0.4	
		Largemouth bass	11.7		7.7		8.6		7.5		7.1		7.3	
		Redbreast sunfish	0.2		0.1		--		0.2		--		--	
		Spotfin shiner	13.8		3.1		0.3		2.7		15.0		5.2	
		White crappie	--		0.1		0.5		0.4		0.6		0.1	
	Gill Netting		<u>7.5%</u>	<u>2.5</u>	<u>15.4%</u>	<u>2.5</u>	<u>4.9%</u>	<u>2.5</u>	<u>11.3%</u>	<u>2.5</u>	<u>21.3%</u>	<u>1.5</u>	<u>11.0%</u>	<u>2.5</u>
		Bluegill	0.9		0.7		--		2.4		--		--	
		Common carp	0.9		1.5		3.3		0.6		7.4		1.4	
		Gizzard shad	2.8		11.0		--		5.4		12.8		9.0	
		Largemouth bass	0.9		0.7		1.6		1.2		--		--	
		River carpsucker	--		--		--		--		1.1		--	
		White crappie	1.9		1.5		--		1.8		--		0.7	
6. Percent dominance by one species	Electrofishing	Bluegill	<u>39.5%</u>	<u>1.5</u>	--	--	<u>69.2%</u>	<u>0.5</u>	<u>74.3%</u>	<u>0.5</u>	<u>53.3%</u>	<u>0.5</u>	--	--
		Gizzard shad	--	--	<u>41.1%</u>	<u>0.5</u>	--	--	--	--	--	--	--	--
		Threadfin	--	--	--	--	--	--	--	--	--	--	<u>24.6%</u>	<u>1.5</u>
	Gill Netting	Blue catfish	--	--	--	--	<u>29.5%</u>	<u>0.5</u>	--	--	<u>20.2%</u>	<u>1.5</u>	--	--
		Channel catfish	<u>47.7%</u>	<u>0.5</u>	--	--	--	--	--	--	--	--	--	--
		Skipjack herring	--	--	<u>18.4%</u>	<u>1.5</u>	--	--	--	--	--	--	--	--
		Threadfin shad	--	--	--	--	--	--	--	--	--	--	<u>32.4%</u>	<u>0.5</u>
		Yellow bass	--	--	--	--	--	--	<u>23.8%</u>	<u>1.5</u>	--	--	--	--

Table 4. (ERM 2.5, continued)

Metric	Gear	Common Name	2009		2010		2011		2012		2013		2015	
			Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Obs	Autumn Obs	Sc	Autumn Obs	Sc	Autumn Obs	Sc
7. Percent non-indigenous species	Electrofishing		<u>1.6%</u>	<u>2.5</u>	<u>9.3%</u>	<u>0.5</u>	<u>1.2%</u>	<u>2.5</u>	<u>0.8%</u>	<u>2.5</u>	<u>1.5%</u>	<u>2.5</u>	<u>7.3%</u>	<u>0.5</u>
		Common carp	1.0		1.0		0.4		0.4		0.7		1.2	
		Grass carp	--		0.1		--		--		--		--	
		Mississippi silverside	--		7.7		0.6		0.1		0.2		4.3	
		Redbreast sunfish	0.2		0.1		--		0.2		--		--	
		Striped bass	--		0.1		--		--		--		--	
		Yellow perch	0.4		0.3		0.1		0.0		0.6		1.9	
	Gill Netting		<u>1.9%</u>	<u>2.5</u>	<u>4.4%</u>	<u>2.5</u>	<u>3.3%</u>	<u>2.5</u>	<u>3.6%</u>	<u>2.5</u>	<u>13.8%</u>	<u>0.5</u>	<u>2.8%</u>	<u>2.5</u>
		Common carp	0.9		1.5		3.3		0.6		7.4		1.4	
		Muskellunge	--		--		--		0.6		--		--	
		Striped bass	0.9		2.9		--		2.4		6.4		1.4	
8. Number of top carnivore species	Combined		<u>10</u>	<u>5</u>	<u>12</u>	<u>5</u>	<u>9</u>	<u>5</u>	<u>12</u>	<u>5</u>	<u>12</u>	<u>5</u>	<u>12</u>	<u>5</u>
		Black crappie	3		13		5		21		20		5	
		Flathead catfish	3		6		3		4		2		7	
		Largemouth bass	180		125		144		190		134		117	
		Rock bass	--		--		--		--		--		1	
		Sauger	1		4		10		2		3		--	
		Skipjack herring	--		25		--		11		11		13	
		Smallmouth bass	2		1		1		4		1		3	
		Spotted bass	8		11		--		1		17		8	
		Spotted gar	11		2		--		1		4		2	
		Walleye	--		1		4		7		2		10	
		White bass	1		8		1		13		2		11	
		White crappie	2		4		7		11		9		3	
		Yellow bass	1		22		1		41		8		3	
9. Percent top carnivores	Electrofishing		<u>12.4%</u>	<u>2.5</u>	<u>9.6%</u>	<u>1.5</u>	<u>9.5%</u>	<u>1.5</u>	<u>8.2%</u>	<u>1.5</u>	<u>9.5%</u>	<u>1.5</u>	<u>8.8%</u>	<u>1.5</u>
		Black crappie	--		0.8		0.3		0.1		1.0		0.3	
		Flathead catfish	--		0.2		--		--		--		--	
		Largemouth bass	11.7		7.7		8.6		7.5		7.1		7.3	
		Rock bass	--		--		--		--		--		0.1	
		Skipjack herring	--		--		--		--		0.1		--	
		Smallmouth bass	0.2		0.1		0.1		0.1		0.1		0.2	
		Spotted bass	0.5		0.4		--		--		0.6		0.5	
		Spotted gar	--		0.1		--		--		0.1		0.1	
		Striped bass	--		0.1		--		--		--		--	
		White bass	--		0.1		--		--		--		0.1	
		White crappie	--		0.1		0.5		0.4		0.6		0.1	
		Yellow bass	--		0.1		0.1		0.0		--		0.1	
	Gill Netting		<u>22.4%</u>	<u>0.5</u>	<u>52.2%</u>	<u>2.5</u>	<u>32.8%</u>	<u>1.5</u>	<u>63.7%</u>	<u>2.5</u>	<u>40.4%</u>	<u>1.5</u>	<u>31.7%</u>	<u>1.5</u>
		Black crappie	2.8		0.7		1.6		10.7		3.2		--	
		Flathead catfish	2.8		2.2		4.9		2.4		2.1		4.8	
		Largemouth bass	0.9		0.7		1.6		1.2		--		--	
		Muskellunge	--		--		--		0.6		--		--	
		Sauger	0.9		2.9		16.4		1.2		3.2		--	
		Skipjack herring	--		18.4		--		6.5		10.6		9.0	
		Spotted bass	--		0.7		--		0.6		--		0.7	
		Spotted gar	10.3		0.7		--		0.6		2.1		0.7	
		Striped bass	0.9		2.9		--		2.4		6.4		1.4	
		Walleye	--		0.7		6.6		4.2		2.1		6.9	
		White bass	0.9		5.1		1.6		7.7		2.1		6.2	
		White crappie	1.9		1.5		--		1.8		--		0.7	
		Yellow bass	0.9		15.4		--		23.8		8.5		1.4	

Table 4. (ERM 2.5, continued)

Metric	Gear	Common Name	2009		2010		2011		2012		2013		2015	
			Autumn		Autumn		Autumn		Autumn		Autumn		Autumn	
			Obs	Sc	Obs	Sc	Obs	Obs	Obs	Sc	Obs	Sc	Obs	Obs
10. Percent omnivores	Electrofishing		<u>13.5%</u>	<u>2.5</u>	<u>44.4%</u>	<u>0.5</u>	<u>10.1%</u>	<u>2.5</u>	<u>3.1%</u>	<u>2.5</u>	<u>3.2%</u>	<u>2.5</u>	<u>20.2%</u>	<u>2.5</u>
		Black buffalo	0.1		0.2		0.1		--		0.4		--	
		Bluntnose minnow	3.2		1.2		1.8		1.0		0.1		1.6	
		Channel catfish	0.2		0.7		0.1		0.4		0.3		0.7	
		Common carp	1.0		1.0		0.4		0.4		0.7		1.2	
		Gizzard shad	9.0		41.1		7.6		1.2		1.1		16.4	
		Golden Shiner	--		--		--		--		0.1		--	
		Smallmouth buffalo	0.1		0.2		--		0.1		0.5		0.3	
	Gill Netting		<u>65.4%</u>	<u>0.5</u>	<u>42.6%</u>	<u>1.5</u>	<u>45.9%</u>	<u>1.5</u>	<u>28.0%</u>	<u>1.5</u>	<u>50.0%</u>	<u>0.5</u>	<u>27.6%</u>	<u>1.5</u>
		Black buffalo	0.9		--		--		--		--		0.7	
		Blue catfish	12.1		11.8		29.5		12.5		20.2		9.7	
		Channel catfish	47.7		13.2		13.1		7.1		4.3		5.5	
		Common carp	0.9		1.5		3.3		0.6		7.4		1.4	
		Gizzard shad	2.8		11.0		--		5.4		12.8		9.0	
		Quillback	0.9		1.5		--		--		--		--	
		River carpsucker	--		--		--		--		1.1		--	
		Smallmouth buffalo	--		3.7		--		2.4		4.3		1.4	
11. Average number per run	Electrofishing		<u>86.5</u>	<u>0.5</u>	<u>102.4</u>	<u>0.5</u>	<u>97.5</u>	<u>0.5</u>	<u>149.9</u>	<u>1.5</u>	<u>108.5</u>	<u>1.5</u>	<u>100.8</u>	<u>0.5</u>
	Gill Netting		<u>10.7</u>	<u>0.5</u>	<u>13.6</u>	<u>1.5</u>	<u>6.1</u>	<u>0.5</u>	<u>16.8</u>	<u>1.5</u>	<u>9.4</u>	<u>0.5</u>	<u>14.5</u>	<u>1.5</u>
12. Percent anomalies	Electrofishing		<u>4.3</u>	<u>1.5</u>	<u>1.6</u>	<u>2.5</u>	<u>4.5</u>	<u>1.5</u>	<u>2.1</u>	<u>1.5</u>	<u>0.7</u>	<u>2.5</u>	<u>0.5</u>	<u>2.5</u>
	Gill Netting		<u>0.9</u>	<u>2.5</u>	<u>0</u>	<u>2.5</u>	<u>0</u>	<u>2.5</u>	<u>0.6</u>	<u>2.5</u>	<u>0</u>	<u>2.5</u>	<u>0</u>	<u>2.5</u>
RFAI Score			44		44		42		46		43		46	

Species percentages may not add to the observed value reported for a given metric due to rounding.

-- = No taxa.

0.0 = Present but in small numbers (percentage <0.05%).

Table 5. Scoring criteria for forebay, transition, and inflow sections of upper mainstream reservoirs in the Tennessee River Valley. Upper mainstream reservoirs include Chickamauga, Fort Loudoun, Melton Hill, Nickajack, Tellico, and Watts Bar.

Metric	Gear	Scoring Criteria								
		Forebay			Transition			Inflow		
		1	3	5	1	3	5	1	3	5
1. Number of indigenous species	Combined	<14	14-27	>27	<15	15-29	>29	<14	14-27	>27
2. Number of Centrarchid species	Combined	<2	2-4	>4	<2	2-4	>4	<3	3-4	>4
3. Number of benthic invertivores species	Combined	<4	4-7	>7	<4	4-7	>7	<3	3-6	>6
4. Number of intolerant species	Combined	<2	2-4	>4	<2	2-4	>4	<2	2-4	>4
5. Percent tolerant individuals	Electrofishing	>62%	31-62%	<31%	>62%	31-62%	<31%	>58%	29-58%	<29%
	Gill netting	>28%	14-28%	<14%	>32%	16-32%	<16%			
6. Percent dominance by one species	Electrofishing	>50%	25-50%	<25%	>40%	20-40%	<20%	>46%	23-46%	<23%
	Gill netting	>29%	15-29%	<15%	>28%	14-28%	<14%			
7. Percent non-indigenous species	Electrofishing	>4%	2-4%	<2%	>6%	3-6%	<3%	>17%	8-17%	<8%
	Gill netting	>16%	8-16%	<8%	>9%	5-9%	<5%			
8. Number of top carnivore species	Combined	<4	4-7	>7	<4	4-7	>7	<3	3-6	>6
9. Percent top carnivores	Electrofishing	<5%	5-10%	>10%	<6%	6-11%	>11%	<11%	11-22%	>22%
	Gill netting	<25%	25-50%	>50%	<26%	26-52%	>52%			
10. Percent omnivores	Electrofishing	>49%	24-49%	<24%	>44%	22-44%	<22%	>55%	27-55%	<27%
	Gill netting	>34%	17-34%	<17%	>46%	23-46%	<23%			
11. Average number per run	Electrofishing	<121	121-241	>241	<105	105-210	>210	<51	51-102	>102
	Gill netting	<12	12-24	>24	<12	12-24	>24			
12. Percent anomalies	Electrofishing	>5%	2-5%	<2%	>5%	2-5%	<2%	>5%	2-5%	<2%
	Gill netting	>5%	2-5%	<2%	>5%	2-5%	<2%			

Table 6. Total number of individuals collected of each species in RFAI electrofishing and gill netting samples combined: 2001-2015.

Common Name	Indigenous	CRM 1.5											CRM 4.4											ERM 2.5					
		2001	2003	2005	2007	2009	2010	2011	2012	2012	2013	2015	2001	2003	2005	2007	2009	2010	2011	2012	2012	2013	2015	2009	2010	2011	2012	2013	2015
		A	A	A	A	A	A	A	Su	A	A	A	A	A	A	A	A	A	Su	A	A	A	A	A	A	A	A	A	A
Paddlefish	X	1	1*	.	1	.	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Lake sturgeon	X	.	.	.	.	.	1	1	1	4	4	1	.	.	.	.	.	1	1	3	1	8	3	.	.	1	.	.	.
Longnose gar	X	.	2	1	11	.	1	.	.	.	.	.	.	1	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.
Spotted gar	X	2	1	4	1	1	1	.	1	.	1	.	.	5	.	.	.	1	.	3	1	1	.	11	2	.	1	4	2
Skipjack herring	X	21	21	22	.	.	10	.	16	1	.	22	20	18	12	.	.	4	.	15	3	5	6	.	25	.	11	11	13
Gizzard shad	X	292	196	317	186	157	282	231	289	143	93	168	122	280	396	188	96	178	91	179	62	3	45	120	646	111	36	30	261
Threadfin shad	X	3	1	3	.	1	16	4	4	7	2	1053	2	2	.	5	4	.	11	46	5	7	8	2	12	27	.	2	419
Mooneye	X	.	1	4	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Common carp		20	21	22	7	15	14	19	16	13	25	11	43	22	27	13	19	19	9	21	12	27	20	14	18	8	11	19	20
Largescale stoneroller	X	.	.	.	.	.	5	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.
Golden shiner	X	9	5	.	.	3	.	.	.	.	.	.	1	9	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.
Emerald shiner	X	44	13	.	.	.	.	.	.	.	.	.	11	.	9	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spotfin shiner	X	54	22	23	21	264	20	12	33	87	164	76	55	41	33	20	225	40	5	26	4	284	77	179	48	4	61	244	79
Striped shiner	X	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Steelcolor shiner	X	.	.	1	.	.	.	.	.	2	4	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	.
Bluntnose minnow	X	2	5	3	1	28	68	1	22	27	37	3	2	2	.	2	103	10	.	4	1	2	1	41	19	27	22	2	24
Bullhead minnow	X	.	.	.	.	.	.	.	13	.	28	7	.	.	.	1	.	.	1	11	.	.	.	1	5	.	.	4	7
Northern hog sucker	X	.	.	4	.	.	.	.	.	2	1	2	.	.	.	.	.	.	1	.	.	2	5	1	.	1	3	3	.
River carpsucker	X	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Quillback	X	.	.	.	.	.	.	.	.	1	.	1	.	1	.	.	.	.	.	.	.	.	.	1	2	.	.	.	.
Smallmouth buffalo	X	20	16	3	11	4	6	5	27	3	7	24	7	29	9	3	4	6	2	18	2	4	12	1	8	.	6	12	7
Black buffalo	X	3	.	2	.	.	2	.	3	2	.	1	3	3	3	.	.	2	2	1	.	1	.	2	3	2	.	6	1
Spotted sucker	X	14	11	18	.	15	11	52	12	30	23	10	17	64	73	15	15	16	25	32	19	23	42	19	28	17	29	47	16
Silver redhorse	X	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.
River redhorse	X	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Black redhorse	X	.	.	.	.	.	.	3	2	1	2	.	1	1	2	1	2	3	4	.	1	2	5	1	1	.	3	4	4
Golden redhorse	X	.	1	.	1	1	2	.	1	.	.	1	1	2	5	2	.	1	.	1	2	7	2	2	2	4	.	2	1
Blue catfish	X	32	15	14	7	17	17	13	24	13	17	13	35	26	6	13	21	11	12	22	8	6	12	13	16	18	21	19	14
Channel catfish	X	19	20	10	8	18	22	9	11	9	9	15	22	14	10	13	26	6	6	21	14	10	15	53	28	10	20	9	18
Flathead catfish	X	6	15	7	8	1	11	1	13	3	1	3	4	2	2	3	2	3	1	3	2	.	2	3	6	3	4	2	7

Table 6. (continued)

Common Name	Indigenous	CRM 1.5											CRM 4.4											ERM 2.5					
		2001	2003	2005	2007	2009	2010	2011	2012	2012	2013	2015	2001	2003	2005	2007	2009	2010	2011	2012	2012	2013	2015	2009	2010	2011	2012	2013	2015
		A	A	A	A	A	A	A	Su	A	A	A	A	A	A	A	A	A	A	Su	A	A	A	A	A	A	A	A	A
White bass	X	5	6	6	1	3	17	6	2	1	.	32	17	6	2	3	2	12	5	2	.	.	10	1	8	1	13	2	11
Yellow bass	X	19	22	14	5	5	32	1	30	3	8	5	38	32	9	8	28	5	20	56	13	8	2	1	22	1	41	8	3
Striped bass		14	9	18	8	3	11	5	15	3	2	11	2	18	10	9	4	22	.	7	1	4	16	1	5	.	4	6	2
Striped bass x white bass ¹		2	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Redbreast sunfish		5	1	6	1	14	5	6	8	7	9	3	3	.	.	.	2	6	2	.	1	1	.	3	2	.	4	.	.
Green sunfish	X	11	4	36	16	43	35	30	16	22	20	7	4	3	14	1	25	49	42	7	36	8	2	9	43	24	42	7	6
Warmouth	X	2	.	.	.	3	.	6	2	4	1	2	1	3	.	.	3	3	2	.	1	1	1	7	7	8	20	16	3
Bluegill	X	540	365	330	364	970	704	319	388	545	772	265	483	298	288	305	539	764	157	443	106	488	540	514	330	1012	1674	867	367
Longear sunfish	X	12	16	52	106	197	71	38	37	24	28	16	10	25	13	40	112	31	7	13	13	16	2	38	6	6	25	8	3
Redear sunfish	X	59	51	40	47	52	107	44	55	32	52	34	74	50	67	35	73	89	51	40	34	38	65	132	56	64	96	89	69
Hybrid sunfish ¹		.	.	.	.	.	.	3	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	3	.	.
Rock bass	X	.	.	.	.	3	3	1	.	2	1	1	.	.	.	.	3	.	.	3	.	.	3	.	.	.	.	.	1
Smallmouth bass	X	6	2	9	1	16	6	7	4	9	9	9	6	4	21	5	14	8	8	4	4	14	11	2	1	1	3	1	3
Spotted bass	X	25	8	14	1	8	.	1	1	2	1	3	19	18	12	4	4	1	1	4	2	1	5	7	7	.	1	9	8
Largemouth bass	X	98	37	28	21	101	57	59	26	125	70	122	86	64	83	27	96	79	54	36	50	54	114	153	120	127	171	116	111
Hybrid bass ¹		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.
White crappie	X	8	2	2	.	.	4	1	.	6	.	2	1	1	3	.	2	3	.	5	.	.	.	2	4	7	11	9	3
Black crappie	X	12	1	.	2	2	4	2	3	.	.	2	5	2	3	.	3	3	.	16	2	.	2	3	13	5	21	20	5
Greenside darter	X											1										1							1
Snubnose darter	X	.	.	.	.	.	.	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Redline Darter	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Yellow perch		3	3	.	.	2	.	.	.	1	.	1	5	2	1	1	1	4	13	1	.	4	2	5	4	2	1	9	28
Logperch	X	5	6	2	.	.	3	.	1	2	4	52	1	2	4	1	.	7	.	3	.	1	98	.	12	.	.	23	46
Sauger	X	4	4	8	.	14	5	15	.	2	3	1	9	4	6	5	12	5	6	6	4	4	2	1	4	10	2	3	.
Walleye	X	.	.	.	1	.	.	.	3	3	3	10	.	.	.	2	.	3	2	8	5	5	22	.	1	4	7	2	10
Muskellunge		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.
Freshwater drum	X	10	30	9	8	11	13	11	17	13	8	8	6	17	12	10	8	18	3	24	2	8	4	6	6	1	8	7	6
Brook silverside	X	17	34	5	11	20	21	.	1	7	6	26	14	44	18	14	40	13	.	.	.	5	4	56	29	8	39	92	13
Mississippi silverside		.	.	100	2	219	318	32	22	39	121	259	.	.	10	24	92	355	1	74	1	63	284	.	119	9	2	4	65
Chestnut lamprey	X	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.
Grass carp		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Total Fish Collected	---	1400	967	1137	858	2211	1910	938	1119	1200	1537	2285	1132	1116	1167	775	1581	1784	547	1158	412	1118	1447	1405	1672	1523	2417	1721	1657
Total Species Richness	58	36	36	34	28	32	38	30	35	38	35	41	36	37	34	32	32	38	32	35	31	37	37	35	40	30	34	40	37
Indigenous Species	51	32	32	30	24	27	34	26	31	33	31	36	32	34	30	28	27	33	27	31	27	31	33	31	34	27	28	36	33

A=Autumn; Su=Summer; *=Only young-of-year collected; 1=Hybrid fish do not contribute to total species richness or number of indigenous species

Table 7. Species collected, ecological designations, and electrofishing (EF) and gill net (GN) catch per unit effort at CRM 1.5 – Autumn 2015.

Common Name	Scientific Name	Trophic Level	Sunfish ¹ Species	Indigenous Species	Tolerance	EF Catch Per Run	EF Catch Per Hour	Total Fish EF	GN Catch Per Net	Total Fish GN	Total fish Combined	Percent Composition
Lake sturgeon	Acipenser fulvescens	IN	.	X	.	0.00	0.00	0	0.10	1	1	0.0%
Skipjack herring	Alosa chrysochloris	TC	.	X	IN	0.00	0.00	0	2.20	22	22	1.0%
Gizzard shad	Dorosoma cepedianum	OM	.	X	TO	10.60	41.19	159	0.90	9	168	7.4%
Threadfin shad	Dorosoma petenense	PK	.	X	.	70.13	272.54	1052	0.10	1	1,053	46.1%
Common carp	Cyprinus carpio	OM	.	.	TO	0.53	2.07	8	0.30	3	11	0.5%
Spotfin shiner	Cyprinella spiloptera	IN	.	X	TO	5.07	19.69	76	0.00	0	76	3.3%
Bluntnose minnow	Pimephales notatus	OM	.	X	TO	0.20	0.78	3	0.00	0	3	0.1%
Bullhead minnow	Pimephales vigilax	IN	.	X	.	0.47	1.81	7	0.00	0	7	0.3%
Northern hog sucker	Hypentelium nigricans	BI	.	X	IN	0.13	0.52	2	0.00	0	2	0.1%
Quillback	Cariodes cyprinus	OM	.	X	.	0.00	0.00	0	0.10	1	1	0.0%
Smallmouth buffalo	Ictiobus bubalus	OM	.	X	.	0.87	3.37	13	1.10	11	24	1.1%
Black buffalo	Ictiobus niger	OM	.	X	.	0.07	0.26	1	0.00	0	1	0.0%
Spotted sucker	Minytrema melanops	BI	.	X	IN	0.67	2.59	10	0.00	0	10	0.4%
Golden redbreast	Moxostoma erythrum	BI	.	X	.	0.07	0.26	1	0.00	0	1	0.0%
Blue catfish	Ictalurus furcatus	OM	.	X	.	0.00	0.00	0	1.30	13	13	0.6%
Channel catfish	Ictalurus punctatus	OM	.	X	.	0.67	2.59	10	0.50	5	15	0.7%
Flathead catfish	Pylodictis olivaris	TC	.	X	.	0.07	0.26	1	0.20	2	3	0.1%
White bass	Morone chrysops	TC	.	X	.	0.13	0.52	2	3.00	30	32	1.4%
Yellow bass	Morone mississippiensis	TC	.	X	.	0.00	0.00	0	0.50	5	5	0.2%
Striped bass	Morone saxatilis	TC	.	.	.	0.07	0.26	1	1.00	10	11	0.5%
Redbreast sunfish	Lepomis auritus	IN	.	.	TO	0.20	0.78	3	0.00	0	3	0.1%
Green sunfish	Lepomis cyanellus	IN	X	X	TO	0.47	1.81	7	0.00	0	7	0.3%
Warmouth	Lepomis gulosus	IN	X	X	.	0.13	0.52	2	0.00	0	2	0.1%
Bluegill	Lepomis macrochirus	IN	X	X	TO	17.60	68.39	264	0.10	1	265	11.6%
Longear sunfish	Lepomis megalotis	IN	X	X	IN	1.07	4.15	16	0.00	0	16	0.7%
Redear sunfish	Lepomis microlophus	IN	X	X	.	2.00	7.77	30	0.40	4	34	1.5%
Rock bass	Ambloplites rupestris	TC	.	X	IN	0.00	0.00	0	0.10	1	1	0.0%
Smallmouth bass	Micropterus dolomieu	TC	.	X	IN	0.53	2.07	8	0.10	1	9	0.4%
Spotted bass	Micropterus punctulatus	TC	.	X	.	0.00	0.00	0	0.30	3	3	0.1%
Largemouth bass	Micropterus salmoides	TC	.	X	TO	8.07	31.35	121	0.10	1	122	5.3%
White crappie	Pomoxis annularis	TC	X	X	TO	0.07	0.26	1	0.10	1	2	0.1%
Black crappie	Pomoxis nigromaculatus	TC	X	X	.	0.13	0.52	2	0.00	0	2	0.1%
Greenside darter	Etheostoma blennioides	SP	.	X	.	0.07	0.26	1	0.00	0	1	0.0%
Snubnose darter	Etheostoma simoterum	SP	.	X	.	0.13	0.52	2	0.00	0	2	0.1%
Yellow perch	Perca flavescens	IN	.	.	.	0.07	0.26	1	0.00	0	1	0.0%
Logperch	Percina caprodes	BI	.	X	.	3.47	13.47	52	0.00	0	52	2.3%
Sauger	Stizostedion canadense	TC	.	X	.	0.00	0.00	0	0.10	1	1	0.0%
Walleye	Stizostedion vitreum	TC	.	X	.	0.00	0.00	0	1.00	10	10	0.4%
Freshwater drum	Aplodinotus grunniens	BI	.	X	.	0.20	0.78	3	0.50	5	8	0.4%
Brook silverside	Labidesthes sicculus	IN	.	X	IN	1.73	6.74	26	0.00	0	26	1.1%
Mississippi silverside	Menidia audens	IN	.	.	.	17.27	67.10	259	0.00	0	259	11.3%
Total						142.96	555.46	2,144	14.10	141	2,285	100.0%
Number of Samples						15			10			
Species Collected			7	36		32			23			

1. Indigenous centrarchid species less Micropterus and hybrids

Trophic: benthic invertivore (BI), herbivore (HB), insectivore (IN), omnivore (OM), parasitic (PS), planktivore (PK), specialized insectivore (SP), top carnivore (TC);

Tolerance: tolerant (TOL), intolerant (INT).

Table 8. Species collected, ecological designations, and electrofishing (EF) and gill net (GN) catch per unit effort at CRM 4.4 – Autumn 2015.

Common Name	Scientific Name	Trophic Level	Sunfish ¹ Species	Indigenous Species	Tolerance	EF Catch Per Run	EF Catch Per Hour	Total Fish EF	GN Catch Per Net	Total Fish GN	Total fish Combined	Percent Composition
Lake sturgeon	Acipenser fulvescens	IN	.	X	.	0.00	0.00	0	0.30	3	3	0.2%
Skipjack herring	Alosa chrysochloris	TC	.	X	IN	0.00	0.00	0	0.60	6	6	0.4%
Gizzard shad	Dorosoma cepedianum	OM	.	X	TO	1.80	6.67	27	1.80	18	45	3.1%
Threadfin shad	Dorosoma petenense	PK	.	X	.	0.00	0.00	0	0.80	8	8	0.6%
Common carp	Cyprinus carpio	OM	.	.	TO	1.20	4.44	18	0.20	2	20	1.4%
Spotfin shiner	Cyprinella spiloptera	IN	.	X	TO	5.13	19.01	77	0.00	0	77	5.3%
Bluntnose minnow	Pimephales notatus	OM	.	X	TO	0.07	0.25	1	0.00	0	1	0.1%
Northern hog sucker	Hypentelium nigricans	BI	.	X	IN	0.33	1.23	5	0.00	0	5	0.3%
Smallmouth buffalo	Ictiobus bubalus	OM	.	X	.	0.27	0.99	4	0.80	8	12	0.8%
Spotted sucker	Minytrema melanops	BI	.	X	IN	2.73	10.12	41	0.10	1	42	2.9%
Black redhorse	Moxostoma duquesnei	BI	.	X	IN	0.20	0.74	3	0.20	2	5	0.3%
Golden redhorse	Moxostoma erythrurum	BI	.	X	.	0.07	0.25	1	0.10	1	2	0.1%
Blue catfish	Ictalurus furcatus	OM	.	X	.	0.07	0.25	1	1.10	11	12	0.8%
Channel catfish	Ictalurus punctatus	OM	.	X	.	0.47	1.73	7	0.80	8	15	1.0%
Flathead catfish	Pylodictis olivaris	TC	.	X	.	0.07	0.25	1	0.10	1	2	0.1%
White bass	Morone chrysops	TC	.	X	.	0.07	0.25	1	0.90	9	10	0.7%
Yellow bass	Morone mississippiensis	TC	.	X	.	0.00	0.00	0	0.20	2	2	0.1%
Striped bass	Morone saxatilis	TC	.	.	.	0.00	0.00	0	1.60	16	16	1.1%
Green sunfish	Lepomis cyanellus	IN	X	X	TO	0.13	0.49	2	0.00	0	2	0.1%
Warmouth	Lepomis gulosus	IN	X	X	.	0.07	0.25	1	0.00	0	1	0.1%
Bluegill	Lepomis macrochirus	IN	X	X	TO	35.93	133.09	539	0.10	1	540	37.3%
Longear sunfish	Lepomis megalotis	IN	X	X	IN	0.13	0.49	2	0.00	0	2	0.1%
Redear sunfish	Lepomis microlophus	IN	X	X	.	4.27	15.80	64	0.10	1	65	4.5%
Hybrid sunfish	Hybrid leporis spp.	IN	.	X	.	0.07	0.25	1	0.00	0	1	0.1%
Rock bass	Ambloplites rupestris	TC	.	X	IN	0.00	0.00	0	0.30	3	3	0.2%
Smallmouth bass	Micropterus dolomieu	TC	.	X	IN	0.73	2.72	11	0.00	0	11	0.8%
Spotted bass	Micropterus punctulatus	TC	.	X	.	0.33	1.23	5	0.00	0	5	0.3%
Largemouth bass	Micropterus salmoides	TC	.	X	TO	7.47	27.65	112	0.20	2	114	7.9%
Black crappie	Pomoxis nigromaculatus	TC	X	X	.	0.07	0.25	1	0.10	1	2	0.1%
Greenside darter	Etheostoma blennioides	SP	.	X	.	0.07	0.25	1	0.00	0	1	0.1%
Yellow perch	Perca flavescens	IN	.	.	.	0.13	0.49	2	0.00	0	2	0.1%
Logperch	Percina caprodes	BI	.	X	.	6.53	24.20	98	0.00	0	98	6.8%
Sauger	Stizostedion canadense	TC	.	X	.	0.07	0.25	1	0.10	1	2	0.1%
Walleye	Stizostedion vitreum	TC	.	X	.	0.00	0.00	0	2.20	22	22	1.5%
Freshwater drum	Aplodinotus grunniens	BI	.	X	.	0.07	0.25	1	0.30	3	4	0.3%
Brook silverside	Labidesthes sicculus	IN	.	X	IN	0.27	0.99	4	0.00	0	4	0.3%
Mississippi silverside	Menidia audens	IN	.	.	.	18.93	70.12	284	0.00	0	284	19.6%
Chestnut lamprey	Ichthyomyzon castaneus	PS	.	X	.	0.07	0.25	1	0.00	0	1	0.1%
Total						87.82	325.20	1,317	13.00	130	1,447	100.0%
Number of Samples						15			10			
Species Collected			6	33		31			23			

1. Indigenous centrarchid species less Micropterus and hybrids

Trophic: benthic invertivore (BI), herbivore (HB), insectivore (IN), omnivore (OM), parasitic (PS), planktivore (PK), specialized insectivore (SP), top carnivore (TC);

Tolerance: tolerant (TOL), intolerant (INT).

Table 9. Species collected, ecological designations, and electrofishing (EF) and gill net (GN) catch per unit effort at ERM 2.5 – Autumn 2015.

Common Name	Scientific Name	Trophic Level	Sunfish ¹ Species	Indigenous Species	Tolerance	EF Catch Per Run	EF Catch Per Hour	Total Fish EF	GN Catch Per Net	Total Fish GN	Total fish Combined	Percent Composition
Spotted gar	Lepisosteus oculatus	TC	.	X	.	0.07	0.29	1	0.10	1	2	0.1%
Skipjack herring	Alosa chrysochloris	TC	.	X	IN	0.00	0.00	0	1.30	13	13	0.8%
Gizzard shad	Dorosoma cepedianum	OM	.	X	TO	16.53	73.16	248	1.30	13	261	15.8%
Threadfin shad	Dorosoma petenense	PK	.	X	.	24.80	109.73	372	4.70	47	419	25.3%
Common carp	Cyprinus carpio	OM	.	.	TO	1.20	5.31	18	0.20	2	20	1.2%
Spotfin shiner	Cyprinella spiloptera	IN	.	X	TO	5.27	23.30	79	0.00	0	79	4.8%
Bluntnose minnow	Pimephales notatus	OM	.	X	TO	1.60	7.08	24	0.00	0	24	1.4%
Bullhead minnow	Pimephales vigilax	IN	.	X	.	0.47	2.06	7	0.00	0	7	0.4%
Smallmouth buffalo	Ictiobus bubalus	OM	.	X	.	0.33	1.47	5	0.20	2	7	0.4%
Black buffalo	Ictiobus niger	OM	.	X	.	0.00	0.00	0	0.10	1	1	0.1%
Spotted sucker	Minytrema melanops	BI	.	X	IN	0.67	2.95	10	0.60	6	16	1.0%
Black redhorse	Moxostoma duquesnei	BI	.	X	IN	0.27	1.18	4	0.00	0	4	0.2%
Golden redhorse	Moxostoma erythrurum	BI	.	X	.	0.07	0.29	1	0.00	0	1	0.1%
Blue catfish	Ictalurus furcatus	OM	.	X	.	0.00	0.00	0	1.40	14	14	0.8%
Channel catfish	Ictalurus punctatus	OM	.	X	.	0.67	2.95	10	0.80	8	18	1.1%
Flathead catfish	Pylodictis olivaris	TC	.	X	.	0.00	0.00	0	0.70	7	7	0.4%
White bass	Morone chrysops	TC	.	X	.	0.13	0.59	2	0.90	9	11	0.7%
Yellow bass	Morone mississippiensis	TC	.	X	.	0.07	0.29	1	0.20	2	3	0.2%
Striped bass	Morone saxatilis	TC	.	.	.	0.00	0.00	0	0.20	2	2	0.1%
Green sunfish	Lepomis cyanellus	IN	X	X	TO	0.40	1.77	6	0.00	0	6	0.4%
Warmouth	Lepomis gulosus	IN	X	X	.	0.20	0.88	3	0.00	0	3	0.2%
Bluegill	Lepomis macrochirus	IN	X	X	TO	24.47	108.26	367	0.00	0	367	22.1%
Longear sunfish	Lepomis megalotis	IN	X	X	IN	0.20	0.88		0.00	0	3	0.2%
Redear sunfish	Lepomis microlophus	IN	X	X	.	4.47	19.76	67	0.20	2	69	4.2%
Rock bass	Ambloplites rupestris	TC	.	X	IN	0.07	0.29	1	0.00	0	1	0.1%
Smallmouth bass	Micropterus dolomieu	TC	.	X	IN	0.20	0.88	3	0.00	0	3	0.2%
Spotted bass	Micropterus punctulatus	TC	.	X	.	0.47	2.06	7	0.10	1	8	0.5%
Largemouth bass	Micropterus salmoides	TC	.	X	TO	7.40	32.74	111	0.00	0	111	6.7%
White crappie	Pomoxis annularis	TC	X	X	TO	0.13	0.59	2	0.10	1	3	0.2%
Black crappie	Pomoxis nigromaculatus	TC	X	X	.	0.33	1.47	5	0.00	0	5	0.3%
Greenside darter	Etheostoma blennioides	SP	.	X	.	0.07	0.29	1	0.00	0	1	0.1%
Yellow perch	Perca flavescens	IN	.	.	.	1.87	8.26	28	0.00	0	28	1.7%
Logperch	Percina caprodes	BI	.	X	.	3.07	13.57	46	0.00	0	46	2.8%
Walleye	Stizostedion vitreum	TC	.	X	.	0.00	0.00	0	1.00	10	10	0.6%
Freshwater drum	Aplodinotus grunniens	BI	.	X	.	0.13	0.59	2	0.40	4	6	0.4%
Brook silverside	Labidesthes sicculus	IN	.	X	IN	0.87	3.83	13	0.00	0	13	0.8%
Mississippi silverside	Menidia audens	IN	.	.	.	4.33	19.17	65	0.00	0	65	3.9%
Total						100.83	445.94	1,512	14.50	145	1,657	100.0%
Number Samples						15			10			
Species Collected			7	33		31			19			

1. Indigenous centrarchid species less Micropterus and hybrids

Trophic: benthic invertivore (BI), herbivore (HB), insectivore (IN), omnivore (OM), parasitic (PS), planktivore (PK), specialized insectivore (SP), top carnivore (TC);

Tolerance: tolerant (TOL), intolerant (INT).

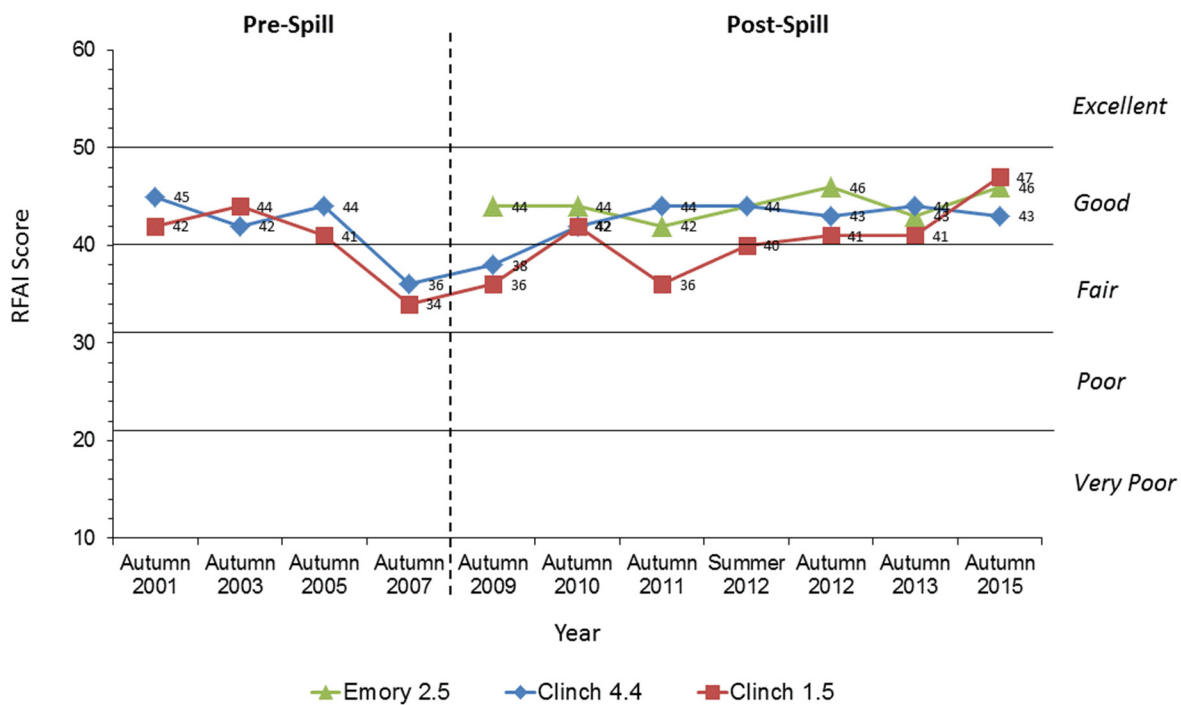


Figure 1. Reservoir Fish Assemblage Index (RFAI) ratings for fish community sampling results: 2001-2015.

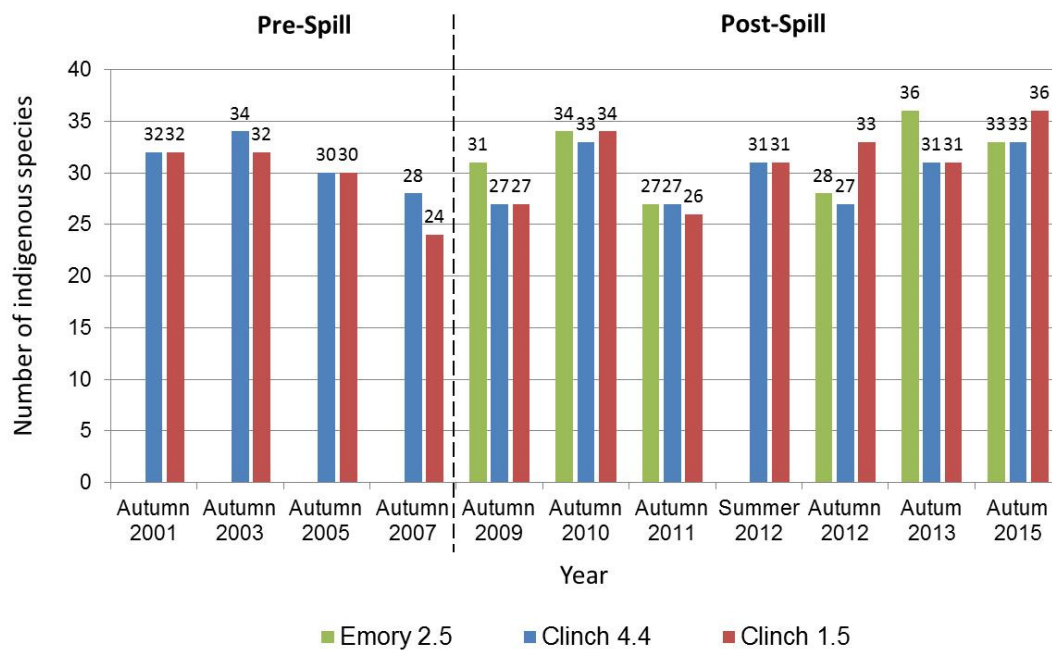


Figure 2. Number of indigenous species collect at ERM 2.5, CRM 4.4, and CRM 1.5 during fish community sampling: 2001- 2015.

APPENDIX B

2016 ORNL Progress Report for the TVA-Kingston Project



2016 ORNL Progress Report for the TVA–Kingston Project



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**Approved for public release.
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Environmental Sciences Division

2016 ORNL PROGRESS REPORT FOR THE TVA-KINGSTON PROJECT

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ACRONYMS

ANCOVA	analysis of covariance
CRM	Clinch River mile
ERM	Emory River mile
KIF	Kingston Fossil Plant
ORNL	Oak Ridge National Laboratory
TVA	Tennessee Valley Authority

1. INTRODUCTION

In December 2008, an ash dike at the Tennessee Valley Authority (TVA) Kingston Fossil Plant (KIF) ruptured and released a large quantity of coal fly ash into the Emory and Clinch Rivers. Coal ash may contain several contaminants that, if found in large enough quantities in some aquatic systems, can be a human or ecological risk concern. In the case of the Kingston spill, numerous coal ash constituents were studied for years after the event; in particular, selenium, mercury, and arsenic have been a major focus of monitoring and research because of their toxicity or tendency to bioaccumulate in aquatic food chains. To assess the potential impact of the spilled fly ash on humans and the environment, a comprehensive biological monitoring program has been in place since the event. Resident aquatic organisms are collected on a regular basis to determine contaminant exposure and evaluate the risks to humans and wildlife.

Oak Ridge National Laboratory (ORNL) scientists have supported the TVA–Kingston project’s biological monitoring and research activities since shortly after the spill. Primary project tasks include bioaccumulation sampling and analysis, including fish and invertebrates, toxicity testing studies, and fish health and reproduction evaluations. ORNL program management activities associated with the core tasks, including data management and quality assurance, have been significant because of the overall project’s large scope and the scientific rigor expected of the program. ORNL staff has provided a number of published reports as well as internal assessments and guidance over the years that were used for the project’s human and ecological risk assessments, as well as numerous presentations at project and scientific meetings. A key current ORNL effort is to disseminate TVA–Kingston research in open literature publications.

This report provides an update on the TVA–Kingston project as of September 2016; the report includes monitoring results through 2015 and progress on sampling and analysis and publication activities in 2016. The 2015 monitoring and assessment activities for the TVA–Kingston project included sampling of multiple sites and species consistent with the every-other-year more detailed surveys specified in the approved monitoring plan. In 2016, only one site near the area of the spill was sampled for fish and invertebrate bioaccumulation. The most current results are provided in Sect. 2, Fish Studies (including bioaccumulation and fish health results through 2015), and Sect. 3, Invertebrate Bioaccumulation. Sect. 4, 2016 Progress, presents ORNL sampling and analysis progress associated with the 2016 monitoring effort, as well as a list of recent presentations that offer more detailed information about ORNL staff studies of the Kingston fly ash spill.

2. FISH STUDIES

Fish studies at ORNL are divided into three tasks: (1) fish bioaccumulation, (2) fish health, and (3) fish reproduction. To assess the effects of coal ash exposure on overall and reproductive fish health, eight individuals of each of three species (largemouth bass, redear sunfish, and bluegill) were targeted for collection. In 2012, a Baseline Ecological Risk Assessment done at the Kingston site found that contaminant concentrations were not above guidelines or levels of concern, and there was no clear evidence that fish health or reproduction were impacted severely by the ash spill (Arcadis, 2012). As a result, in 2013 the Long Term Monitoring program for the KIF site proposed a biannual sampling regime for which sampling in odd-numbered years is done at five sampling locations, while in even-numbered years sampling is limited to one location (Emory River mile [ERM] 1.0). The five sampling locations included three ash-affected sites—ERM 3.0, ERM 1.0, and Clinch River mile (CRM) 1.5 (Fig. 1) and two reference sites (ERM 8.0 and CRM 8.0). The reference sites were chosen for this study because they are upstream of the coal ash release and are therefore not contaminated by coal ash, but it is important to note that both reference sites have been affected by other legacy contaminant releases. In 2016, the only site sampled was ERM 1.0, a site downstream of the spill with the highest contaminant concentrations among ash-affected sites.

Sampling for this project began in January 2009, and fish were collected twice annually in the spring and fall from 2009 until 2013, and in the spring only beginning in 2014. Spring collections occurred in April through June to coincide with the beginning of the breeding seasons of the study species and included only females to investigate possible relationships among metal exposure, fish health, and reproductive fitness. However, because sex determination in the field is not 100% accurate, sometimes more than eight individuals per site were collected. Fall collections occurred in October through November and included both male and female fish. All fish were collected by TVA and ORNL staff and/or their contractors, in most cases using TVA equipment (e.g., electrofishers, dip nets, etc.). Fish were then transported to the lab, where blood was collected for blood chemistry assessments before euthanizing fish with buffered MS-222. External and internal fish health examinations were then conducted and spleen, liver, ovary, and fillet tissue was removed for metal concentration analysis. Portions of ovaries also were removed and preserved for reproductive health assessments.

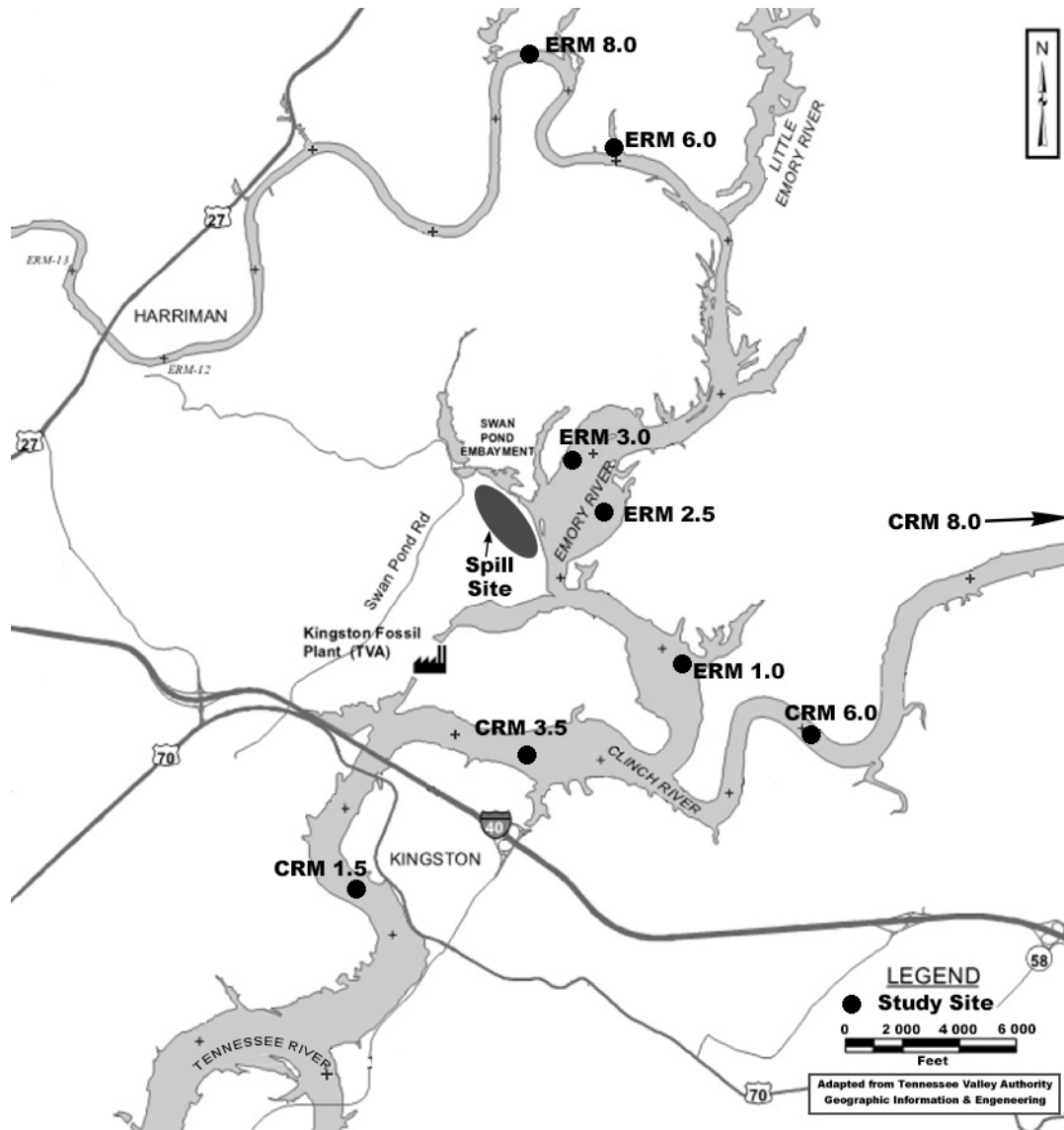


Fig. 1. Study sites for the Tennessee Valley Authority Kingston coal fly ash spill research project
 (Source: Adapted from Tennessee Valley Authority, used with permission).

2.1 FISH BIOACCUMULATION

The objective of the fish bioaccumulation task is to assess exposure to contaminants over time to infer potential risks to humans and wildlife because of the ash spill. As noted in Sect. 1, the primary contaminants of concern in terms of fish bioaccumulation are selenium, arsenic, and mercury. Selenium concentrations have historically been highest across all sites in redear fillets and lowest in largemouth bass, but in 2015, mean selenium concentrations in bluegill collected from ERM 1.0 and ERM 3.0 (0.87 and 0.72 $\mu\text{g/g}$, respectively) were higher than those in redear (0.71 and 0.63 $\mu\text{g/g}$, respectively) (Tables 1, 2, and 3). Across all species and study sites, selenium concentrations were highest in liver tissue and lowest in fillet tissue. Whereas selenium concentrations in all species and in all tissues were on average higher at ash-affected locations than at reference locations, concentrations continue to be well below toxicity and risk guidelines.

Mercury fillet concentrations were highest in largemouth bass at all sites considered but remain low and below regulatory guidelines at all ash-affected sites. In 2015, mean fillet mercury concentrations exceeded the US Environmental Protection Agency's fish tissue criterion in largemouth bass at ERM 8.0, but this site is upstream of coal ash influence and is likely due to legacy mercury inputs in the upper Emory River. In all species at all sites, mercury concentrations were highest in fillets and were generally lowest in ovary tissue. There was no clear spatial pattern in arsenic concentrations because both ash-affected and reference sites had comparable concentrations in all species and tissues. Arsenic concentrations were highest in liver tissues and lowest in fillets.

Temporal trends in selected trace element concentrations in fillets of fish collected at ERM 1.0 are shown in Fig. 2. Overall mercury concentrations in largemouth bass concentrations appear to be increasing (both at ERM 1.0 and at other monitored locations, including those not affected by the coal ash spill). These data are not shown here because ERM 1.0 is the only site monitored on an annual basis. Temporal trends in mercury in largemouth bass at other sites were presented previously. Arsenic concentrations in fillets of all species have been variable over time but show no increasing or decreasing trends. Selenium concentrations appear to have declined slightly in largemouth bass and redear over time; the most recent mean concentrations in spring of 2015 for these two species are at or near the lowest values reported to-date. Selenium concentrations in bluegill were higher by 0.24 $\mu\text{g/g}$ in spring 2015 than in spring of 2014, but the 2015 levels are within the range of variability since 2009, with no clear increasing or decreasing trend in this species. Thus, depending on the fish species selenium concentrations appear to be either not changing, or slightly decreasing, over time. The data from fish collected in 2016, which are still pending, will be useful in assessing these temporal trends.

Table 1. Arsenic, mercury, and selenium concentrations ($\mu\text{g/g}$ wet wt) in tissues of bluegill sunfish collected in 2015.

Tissue type	ARSENIC				MERCURY				SELENIUM			
	Number of samples	Number of detects	Mean concentration	St. dev	Number of samples	Number of detects	Mean concentration	St. dev	Number of samples	Number of detects	Mean concentration	St. dev
CRM 1.5												
Fillet	6	5	0.050	0.009	6	6	0.083	0.021	6	6	0.655	0.055
Liver	1	1	0.400	NA	1	1	0.079	NA	1	1	1.900	NA
Ovary	6	6	0.102	0.035	6	0	0.008	0.001	6	6	0.905	0.128
CRM 8.0												
Fillet	6	6	0.080	0.015	6	6	0.142	0.047	6	6	0.433	0.040
Liver	1	1	0.410	NA	1	1	0.062	NA	1	1	1.400	NA
Ovary	6	6	0.154	0.062	6	0	0.015	0.005	6	6	0.760	0.054
ERM 1.0												
Fillet	6	6	0.054	0.029	6	6	0.097	0.013	6	6	0.865	0.128
Liver	1	1	0.430	NA	1	1	0.052	NA	1	1	1.800	NA
Ovary	6	6	0.126	0.036	6	0	0.010	0.003	6	6	1.023	0.178
ERM 3.0												
Fillet	6	6	0.075	0.017	6	5	0.128	0.047	6	6	0.720	0.070
Liver	1	1	0.510	NA	1	0	0.056	NA	1	1	1.600	NA
Ovary	6	5	0.188	0.053	2	0	0.014	0.001	6	6	0.997	0.181
ERM 8.0												
Fillet	6	5	0.047	0.054	6	6	0.125	0.019	6	6	0.368	0.050
Liver	1	1	0.340	NA	1	1	0.069	NA	1	1	1.600	NA
Ovary	6	6	0.124	0.098	6	0	0.012	0.006	6	6	0.802	0.157

Table 2. Arsenic, mercury, and selenium concentrations ($\mu\text{g/g}$ wet wt) in tissues of redear sunfish collected in 2015.

Tissue type	ARSENIC				MERCURY				SELENIUM			
	Number of samples	Number of detects	Mean concentration	St. dev	Number of samples	Number of detects	Mean concentration	St. dev	Number of samples	Number of detects	Mean concentration	St. dev
CRM 1.5												
Fillet	6	6	0.182	0.042	6	6	0.111	0.062	6	6	0.772	0.161
Liver	1	1	1.400	NA	1	0	0.049	NA	1	1	2.000	NA
Ovary	6	6	0.568	0.229	6	0	0.015	0.011	6	6	1.250	0.217
CRM 8.0												
Fillet	6	6	0.215	0.031	6	6	0.195	0.103	6	6	0.553	0.115
Liver	1	1	2.000	NA	1	1	0.089	NA	1	1	2.200	NA
Ovary	6	6	0.888	0.177	6	1	0.019	0.017	6	6	0.973	0.076
ERM 1.0												
Fillet	6	6	0.240	0.065	6	4	0.073	0.031	6	6	0.705	0.052
Liver	1	1	2.400	NA	1	1	0.083	NA	1	1	2.500	NA
Ovary	6	6	1.117	0.242	6	2	0.005	0.003	6	6	1.350	0.187
ERM 3.0												
Fillet	6	6	0.143	0.080	6	6	0.124	0.042	6	6	0.628	0.132
Liver	1	1	1.200	NA	1	0	0.068	NA	1	1	1.600	NA
Ovary	6	6	0.444	0.236	6	0	0.007	0.002	6	6	0.997	0.220
ERM 8.0												
Fillet	6	6	0.050	0.011	6	6	0.160	0.028	6	6	0.548	0.120
Liver	1	1	0.740	NA	1	1	0.078	NA	1	1	2.700	NA
Ovary	6	6	0.127	0.041	6	0	0.010	0.003	6	6	1.137	0.248

Table 3. Arsenic, mercury, and selenium concentrations ($\mu\text{g/g}$ wet wt) in tissues of largemouth bass collected in 2015.

Tissue type	ARSENIC				MERCURY				SELENIUM			
	Number of samples	Number of detects	Mean concentration	St. dev	Number of samples	Number of detects	Mean concentration	St. dev	Number of samples	Number of detects	Mean concentration	St. dev
CRM 1.5												
Fillet	6	6	0.235	0.062	6	6	0.233	0.102	6	6	0.415	0.099
Liver	6	6	0.402	0.050	6	5	0.106	0.074	6	6	1.382	0.274
Ovary	6	6	0.342	0.167	6	1	0.031	0.035	6	6	1.062	0.248
CRM 8.0												
Fillet	6	6	0.245	0.073	6	6	0.218	0.045	6	6	0.392	0.062
Liver	6	6	0.565	0.171	6	6	0.136	0.041	6	6	1.417	0.319
Ovary	6	6	0.392	0.108	6	0	0.016	0.003	6	6	0.978	0.185
ERM 1.0												
Fillet	6	6	0.178	0.031	6	6	0.258	0.070	6	6	0.443	0.096
Liver	6	6	0.463	0.116	6	6	0.152	0.039	6	6	1.683	0.240
Ovary	6	6	0.322	0.068	6	0	0.023	0.007	6	6	1.072	0.113
ERM 3.0												
Fillet	6	6	0.123	0.032	6	6	0.242	0.068	6	6	0.498	0.099
Liver	6	6	0.455	0.245	6	6	0.172	0.080	6	6	2.300	0.460
Ovary	6	6	0.224	0.092	6	0	0.019	0.004	6	6	1.048	0.215
ERM 8.0												
Fillet	6	6	0.119	0.053	6	6	0.312	0.159	6	6	0.355	0.041
Liver	6	6	0.292	0.095	6	5	0.164	0.103	6	6	1.283	0.349
Ovary	6	6	0.227	0.095	6	0	0.025	0.013	6	6	1.032	0.151

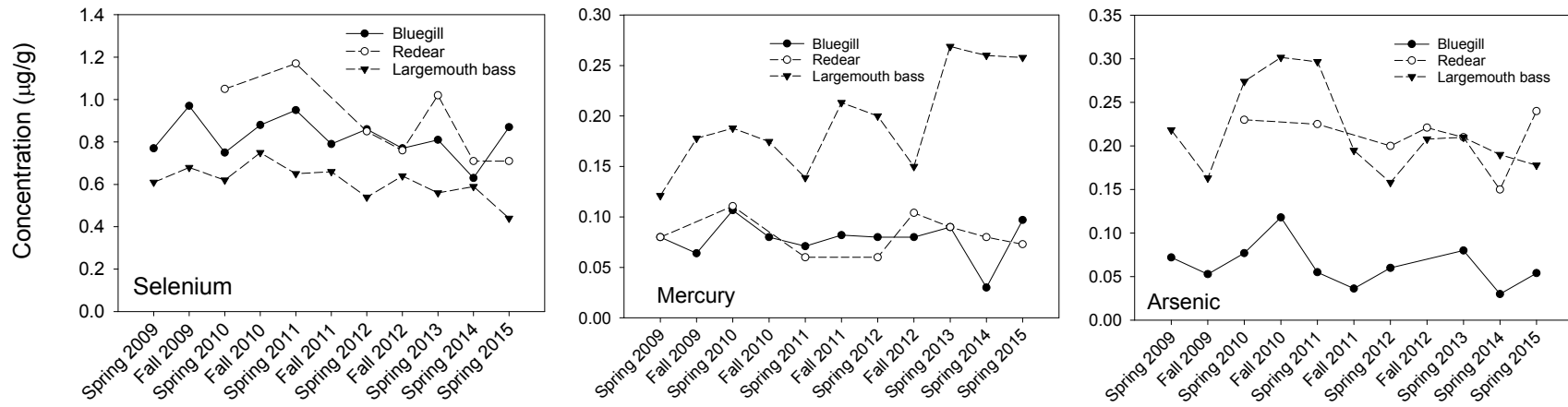


Fig. 2. Mean trace element concentrations in fish fillets (redeer, bluegill, and largemouth bass) collected from ERM 1.0, from spring 2009 to spring 2015.

Because many contaminants are accumulated in fish through dietary exposure, contaminant concentrations throughout the food chain have been examined to help explain bioaccumulation patterns seen in fish. For example, the invertebrate bioaccumulation task has examined metal concentrations in mayfly nymphs and snails both before and after depuration. From these data, assimilation efficiencies were calculated and related to both exposure concentrations and trophic transfer to fish (see Sect. 3).

Because mercury and selenium are accumulated primarily through dietary exposure, the trophic transfer of these two elements is of particular interest. Selenium has been recognized to mitigate mercury toxicity, and concentrations of these two elements have been shown to be correlated inversely in fish fillets. However, the mechanisms controlling this inverse relationship remain unknown. Selenium can affect mercury bioaccumulation at multiple steps in the food chain, leading to the observed trends in selenium and mercury levels in fish. Very few studies address the effects of selenium on the bioaccumulation and toxicity of mercury in freshwater primary producers or invertebrates, although this likely is a critical link in the understanding of mercury/selenium interactions observed in fish. Over the past 5 years, bioaccumulation monitoring for the TVA–Kingston project has included organisms at multiple trophic levels. Figure 3 shows that there is a negative relationship between the molar ratios of selenium:mercury and mercury concentrations throughout the food chain.

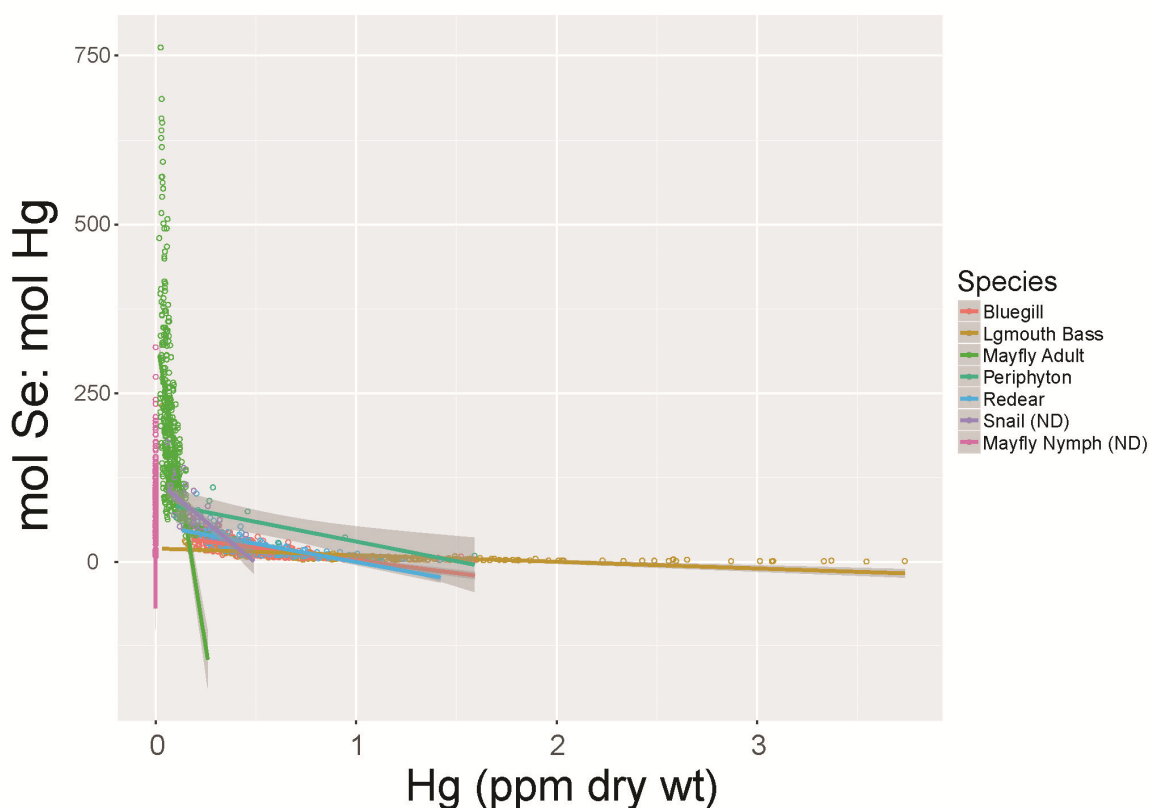


Fig. 3. The relationship between mercury and selenium molar ratios and mercury concentrations in organisms collected around the Kingston ash spill site (2009–2014). *Note:* (D) refers to “depurated” for mayfly nymphs and snails.

2.2 FISH HEALTH

The objective of the fish health task is to assess the long-term health effects of the coal ash spill on aquatic communities. This task assessed the health of all bluegill sunfish, largemouth bass, and redear sunfish that were collected during April and May 2015 for the three fish-based ORNL tasks. Fish health assessments were conducted at ORNL. This report section presents fish health findings from 2015.

Given the large number of possible pathways of effects (e.g., toxicological effect of exposure to multiple metals, physical effects from ash exposure, and food web effects), measurement of only a few health metrics is not likely to give a complete picture of fish health effects from a coal ash spill. For this study, 24 metrics were used to assess fish health from two reference (ERM8.0, CRM 8.0) and three ash-affected (ERM3.0, ERM1.0, CRM1.5) sites for all three fish species collected. Metrics used to assess fish health for each fish along with brief descriptions of what the metric is measuring are provided in Table 4, but were selected, in general, to measure a wide range of physiological and energetic responses.

Comparison of means and standard errors of fish health metrics collected in 2015 showed some differences between and among sites (Tables 5-7), although as in prior years, there were no broad spatial or temporal patterns outside of the years immediately following the spill or dredging. Furthermore, t-tests conducted on 2015 data showed no significant differences between means of reference and ash-affected sites for any fish health metric once Bonferroni corrections were applied ($N_{\text{comparisons}}=24$, $\alpha_{\text{old}}=0.05$, $\alpha_{\text{new}}=0.002$). This finding of no significant differences between reference and spill sites is consistent with findings from the Pracheil et al. (2016) study that additionally showed few linkages between fish health and ash-associated metals.

Histopathology samples are undergoing additional evaluation to resolve some data discrepancies and the results will be reported in the CY2016 report.

Table 4. Description of the physiologic relevance of bioindicator metrics (abbreviation) of fish health and condition bioindicators by functional response group

Functional Response Group	Bioindicator	Physiologic Relevance
Bioenergetics	Amylase (AMY)	Converts starch into sugars
Blood Composition	Hematocrit (HCT)	Ratio of red blood cells to total blood volume
	Leucocrit (LCT)	Ratio of white blood cells to total blood volume
Organ Function	Alanine transferase (ALT)	Liver function
	Blood urea nitrogen (BUN)	Kidney and gill function
	Creatinine (CREAT)	Kidney function
	Total bilirubin (TBIL)	Liver function
	Alkaline phosphatase (ALP)	Bone formation

Table 4. (continued)

Carbohydrate-protein metabolism	Glucose (GLU)	Metabolic efficiency
	Blood protein (BPRO)	Liver and general inflammation
	Globulin (GLOB)	Liver and kidney function
	Albumin (ALB)	Liver and kidney function
	Phosphorus (PHOS)	Indicator of kidney, liver, bone disease
Electrolyte homeostasis	Calcium (CA), Sodium (NA)	Function of most organs including liver and kidney
Fish Condition	Condition factor (CF)	Index of plumpness
	Lipids (LIP)	Index of mesentery lipids
	Visceral weight (VSWT)	Weight of entire visceral mass including organs where a higher value indicates greater energy reserves
	Stomach fullness (PSTO)	Index of stomach fullness (values 1-4) where a higher value indicates a fuller stomach
	Intestinal fullness (PINT)	Index of intestinal fullness (values 1-4) where a higher value indicates fuller intestines
	Gonadosomatic index (GSI)	Index of reproductive potential
	Hepatosomatic index (LSI)	Index of energy reserves
	Spleen somatic index (SSI)	Index of immune response
	Visceral somatic index (VSI)	Index of overall condition

Table 5. Mean $\pm$ standard error for bluegill collected in 2015 by collection site. Abbreviations are as follows: CRM—Clinch River mile, ERM—Emory River mile. Metric abbreviations are as reported in Table 4.

Metric	CRM1.5	CRM8.0	ERM1.0	ERM3.0	ERM8.0
Bluegill					
LIP	1.00 $\pm$ 0.00	1.33 $\pm$ 0.17	1.20 $\pm$ 0.20	0.80 $\pm$ 0.13	1.14 $\pm$ 0.14
VSWT	1.20 $\pm$ 0.10	1.48 $\pm$ 0.18	1.40 $\pm$ 0.16	0.85 $\pm$ 0.07	1.45 $\pm$ 0.11
PSTO	3.55 $\pm$ 0.21	3.78 $\pm$ 0.15	2.70 $\pm$ 0.45	3.00 $\pm$ 0.52	3.86 $\pm$ 0.14
PINT	3.09 $\pm$ 0.25	3.22 $\pm$ 0.32	2.10 $\pm$ 0.23	3.40 $\pm$ 0.31	2.29 $\pm$ 0.36
ALB	26.78 $\pm$ 1.66	26.75 $\pm$ 1.77	24.75 $\pm$ 2.23	22.88 $\pm$ 0.74	29.14 $\pm$ 1.50
ALP	51.67 $\pm$ 8.53	55.38 $\pm$ 9.46	48.75 $\pm$ 7.25	36.13 $\pm$ 4.06	49.43 $\pm$ 9.53
ALT	41.78 $\pm$ 7.61	25.00 $\pm$ 3.70	54.63 $\pm$ 9.04	46.38 $\pm$ 2.91	55.71 $\pm$ 4.77
AMY	57.11 $\pm$ 5.70	61.50 $\pm$ 7.50	51.13 $\pm$ 4.94	50.63 $\pm$ 2.80	41.86 $\pm$ 5.66
TBIL	0.46 $\pm$ 0.03	0.61 $\pm$ 0.04	0.38 $\pm$ 0.03	0.63 $\pm$ 0.07	0.63 $\pm$ 0.05
BUN	1.44 $\pm$ 0.24	2.63 $\pm$ 0.26	2.00 $\pm$ 0.33	0.88 $\pm$ 0.23	1.71 $\pm$ 0.42
CA	19.81 $\pm$ 0.11	19.89 $\pm$ 0.11	19.64 $\pm$ 0.19	19.93 $\pm$ 0.06	20.00 $\pm$ 0.00
PHOS	15.67 $\pm$ 1.82	13.36 $\pm$ 0.97	18.03 $\pm$ 0.85	16.70 $\pm$ 0.85	19.18 $\pm$ 1.55
CRE	0.16 $\pm$ 0.05	0.16 $\pm$ 0.04	0.24 $\pm$ 0.06	0.25 $\pm$ 0.07	0.14 $\pm$ 0.07
GLU	51.56 $\pm$ 9.61	79.50 $\pm$ 18.18	74.75 $\pm$ 23.32	183.38 $\pm$ 30.20	70.00 $\pm$ 20.43
NA	145.33 $\pm$ 1.94	148.88 $\pm$ 2.29	141.38 $\pm$ 1.78	139.63 $\pm$ 1.73	144.14 $\pm$ 1.60
K	5.23 $\pm$ 0.32	3.12 $\pm$ 0.33	5.30 $\pm$ 0.54	5.40 $\pm$ 0.33	5.19 $\pm$ 0.62
P	48.22 $\pm$ 2.78	47.13 $\pm$ 2.68	45.13 $\pm$ 3.32	41.63 $\pm$ 0.98	52.14 $\pm$ 2.18
GLOB	21.44 $\pm$ 1.16	20.63 $\pm$ 1.07	20.50 $\pm$ 1.48	18.88 $\pm$ 0.40	22.71 $\pm$ 1.21
HCT	32.33 $\pm$ 2.01	29 $\pm$ 0.96	34.13 $\pm$ 1.41	30.25 $\pm$ 1.96	33.83 $\pm$ 1.87
LCT	1.00 $\pm$ 0.08	1.11 $\pm$ 0.11	1.13 $\pm$ 0.13	1.125 $\pm$ 0.125	1.42 $\pm$ 0.35
CF	1.59 $\pm$ 0.02	1.68 $\pm$ 0.03	1.53 $\pm$ 0.03	1.53 $\pm$ 0.05	1.51 $\pm$ 0.09
GSI	8.96 $\pm$ 0.67	6.30 $\pm$ 0.60	5.31 $\pm$ 1.14	4.16 $\pm$ 0.49	6.11 $\pm$ 1.16
LSI	1.42 $\pm$ 0.09	1.80 $\pm$ 0.10	1.57 $\pm$ 0.07	1.42 $\pm$ 0.062	1.56 $\pm$ 0.11
SSI	0.07 $\pm$ 0.01	0.06 $\pm$ 0.01	0.08 $\pm$ 0.01	0.06 $\pm$ 0.01	0.08 $\pm$ 0.01

Table 6. Mean $\pm$ standard error for redear sunfish collected in 2015 by collection site. Abbreviations: CRM = Clinch River mile, ERM = Emory River mile. Metric abbreviations are as reported in Table 4.

Metric	CRM1.5	CRM8.0	ERM1.0	ERM3.0	ERM8.0
Redear Sunfish					
LIP	2.13 $\pm$ 0.35	2.38 $\pm$ 0.26	1.86 $\pm$ 0.46	2.00 $\pm$ 0.42	2.25 $\pm$ 0.31
VSWT	58.32 $\pm$ 6.97	48.26 $\pm$ 7.05	49.85 $\pm$ 7.17	42.29 $\pm$ 7.07	59.02 $\pm$ 8.23
PSTO	1.75 $\pm$ 0.67	0.13 $\pm$ 0.13	0.14 $\pm$ 0.14	1.00 $\pm$ 0.58	1.75 $\pm$ 0.62
PINT	0.63 $\pm$ 0.26	0.50 $\pm$ 0.27	0.29 $\pm$ 0.18	0.38 $\pm$ 0.26	1.13 $\pm$ 0.35
ALB	24.86 $\pm$ 1.01	24.00 $\pm$ 1.24	30.29 $\pm$ 0.68	20.57 $\pm$ 3.68	25.13 $\pm$ 1.26
ALP	22.86 $\pm$ 2.36	17.67 $\pm$ 1.26	15.43 $\pm$ 1.46	18.57 $\pm$ 3.54	22.13 $\pm$ 2.26
ALT	74.86 $\pm$ 49.42	36.67 $\pm$ 9.15	85.86 $\pm$ 34.07	19.14 $\pm$ 2.56	30.88 $\pm$ 6.89
AMY	104.43 $\pm$ 6.78	105.83 $\pm$ 14.84	119.00 $\pm$ 6.49	76.29 $\pm$ 13.10	94.88 $\pm$ 8.61
TBIL	0.29 $\pm$ 0.01	0.32 $\pm$ 0.02	0.27 $\pm$ 0.02	0.31 $\pm$ 0.03	0.33 $\pm$ 0.02
BUN	1.43 $\pm$ 0.20	1.33 $\pm$ 0.42	2.71 $\pm$ 0.29	1.43 $\pm$ 0.48	0.88 $\pm$ 0.13
CA	18.16 $\pm$ 0.62	16.43 $\pm$ 0.85	20.00 $\pm$ 0.00	15.49 $\pm$ 2.31	18.11 $\pm$ 0.56
PHOS	10.44 $\pm$ 1.06	9.70 $\pm$ 0.88	16.16 $\pm$ 1.01	7.31 $\pm$ 1.56	10.54 $\pm$ 0.98
CRE	0.14 $\pm$ 0.07	0.12 $\pm$ 0.03	0.00 $\pm$ 0.00	0.14 $\pm$ 0.06	0.1625 $\pm$ 0.08
GLU	85.14 $\pm$ 17.61	88.83 $\pm$ 23.86	148.14 $\pm$ 17.60	85.43 $\pm$ 17.92	93.75 $\pm$ 15.01
NA	152.00 $\pm$ 2.06	155.67 $\pm$ 2.03	157.57 $\pm$ 1.15	134.14 $\pm$ 22.37	155.50 $\pm$ 2.14
K	4.06 $\pm$ 0.74	3.17 $\pm$ 0.69	1.42 $\pm$ 0.52	1.76 $\pm$ 0.45	2.14 $\pm$ 0.39
P	49.00 $\pm$ 1.77	49.17 $\pm$ 2.70	60.00 $\pm$ 1.41	43.43 $\pm$ 7.38	50.00 $\pm$ 2.26
GLOB	24.14 $\pm$ 1.01	25.17 $\pm$ 1.62	29.86 $\pm$ 0.96	22.57 $\pm$ 4.01	24.88 $\pm$ 1.59
HCT	32.88 $\pm$ 1.46	30.38 $\pm$ 2.12	36.43 $\pm$ 0.90	32.38 $\pm$ 1.90	33.25 $\pm$ 2.76
LCT	1.31 $\pm$ 0.13	1.00 $\pm$ 0.09	1.21 $\pm$ 0.21	1.25 $\pm$ 0.13	1.19 $\pm$ 0.16
CF	1.50 $\pm$ 0.05	1.44 $\pm$ 0.04	1.46 $\pm$ 0.03	1.28 $\pm$ 0.04	1.43 $\pm$ 0.03
GSI	5.87 $\pm$ 0.50	6.52 $\pm$ 0.70	6.04 $\pm$ 0.48	5.35 $\pm$ 0.76	4.30 $\pm$ 0.43
LSI	1.40 $\pm$ 0.04	1.30 $\pm$ 0.06	1.38 $\pm$ 0.09	1.18 $\pm$ 0.07	1.33 $\pm$ 0.12
SSI	0.12 $\pm$ 0.01	0.11 $\pm$ 0.02	0.12 $\pm$ 0.02	0.16 $\pm$ 0.02	0.14 $\pm$ 0.02

Table 7. Mean $\pm$ standard error for largemouth bass collected in 2015 by collection site. Abbreviations: CRM—Clinch River mile, ERM—Emory River mile. Metric abbreviations are as reported in Table 4.

Metric	CRM1.5	CRM8.0	ERM1.0	ERM3.0	ERM8.0
Largemouth bass					
LIP	2.13 $\pm$ 0.35	2.38 $\pm$ 0.26	1.86 $\pm$ 0.46	2.00 $\pm$ 0.42	2.25 $\pm$ 0.31
VSWT	58.32 $\pm$ 6.97	48.26 $\pm$ 7.05	49.85 $\pm$ 7.17	42.29 $\pm$ 7.07	59.02 $\pm$ 8.23
PSTO	1.75 $\pm$ 0.67	0.13 $\pm$ 0.13	0.14 $\pm$ 0.14	1.00 $\pm$ 0.58	1.75 $\pm$ 0.62
PINT	0.63 $\pm$ 0.26	0.50 $\pm$ 0.27	0.29 $\pm$ 0.18	0.38 $\pm$ 0.26	1.13 $\pm$ 0.35
ALB	24.86 $\pm$ 1.01	24.00 $\pm$ 1.24	30.29 $\pm$ 0.68	20.57 $\pm$ 3.68	25.13 $\pm$ 1.26
ALP	22.86 $\pm$ 2.36	17.67 $\pm$ 1.26	15.43 $\pm$ 1.46	18.57 $\pm$ 3.54	22.13 $\pm$ 2.26
ALT	74.86 $\pm$ 49.42	36.67 $\pm$ 9.15	85.86 $\pm$ 34.07	19.14 $\pm$ 2.56	30.88 $\pm$ 6.89
AMY	104.43 $\pm$ 6.78	105.83 $\pm$ 14.84	119.00 $\pm$ 6.49	76.29 $\pm$ 13.10	94.88 $\pm$ 8.61
TBIL	0.29 $\pm$ 0.01	0.32 $\pm$ 0.02	0.27 $\pm$ 0.02	0.31 $\pm$ 0.03	0.33 $\pm$ 0.02
BUN	1.43 $\pm$ 0.20	1.33 $\pm$ 0.42	2.71 $\pm$ 0.29	1.43 $\pm$ 0.48	0.88 $\pm$ 0.13
CA	18.16 $\pm$ 0.62	16.43 $\pm$ 0.85	20.00 $\pm$ 0.00	15.49 $\pm$ 2.31	18.11 $\pm$ 0.56
PHOS	10.44 $\pm$ 1.06	9.70 $\pm$ 0.88	16.16 $\pm$ 1.01	7.31 $\pm$ 1.56	10.54 $\pm$ 0.98
CRE	0.14 $\pm$ 0.07	0.12 $\pm$ 0.03	0.00 $\pm$ 0.00	0.14 $\pm$ 0.06	0.16 $\pm$ 0.08
GLU	85.14 $\pm$ 17.61	88.83 $\pm$ 23.86	148.14 $\pm$ 17.60	85.43 $\pm$ 17.92	93.75 $\pm$ 15.01
NA	152.00 $\pm$ 2.05	155.67 $\pm$ 2.03	157.57 $\pm$ 1.15	134.14 $\pm$ 22.37	155.50 $\pm$ 2.14
K	4.06 $\pm$ 0.74	3.17 $\pm$ 0.69	1.43 $\pm$ 0.52	1.76 $\pm$ 0.45	2.14 $\pm$ 0.39
P	49.00 $\pm$ 1.77	49.17 $\pm$ 2.70	60.00 $\pm$ 1.41	43.43 $\pm$ 7.38	50.00 $\pm$ 2.26
GLOB	24.14 $\pm$ 1.01	25.17 $\pm$ 1.62	29.86 $\pm$ 0.96	22.57 $\pm$ 4.01	24.88 $\pm$ 1.59
HCT	32.88 $\pm$ 1.46	30.38 $\pm$ 2.12	36.43 $\pm$ 0.90	32.38 $\pm$ 1.90	33.25 $\pm$ 2.76
LCT	1.31 $\pm$ 0.13	1.00 $\pm$ 0.09	1.21 $\pm$ 0.21	1.25 $\pm$ 0.13	1.19 $\pm$ 0.16
CF	1.50 $\pm$ 0.05	1.45 $\pm$ 0.04	1.46 $\pm$ 0.03	1.28 $\pm$ 0.04	1.43 $\pm$ 0.0
GSI	5.87 $\pm$ 0.50	6.52 $\pm$ 0.70	6.04 $\pm$ 0.48	5.35 $\pm$ 0.76	4.30 $\pm$ 0.44
LSI	1.40 $\pm$ 0.04	1.30 $\pm$ 0.06	1.38 $\pm$ 0.09	1.18 $\pm$ 0.07	1.33 $\pm$ 0.12
SSI	0.12 $\pm$ 0.01	0.11 $\pm$ 0.02	0.12 $\pm$ 0.02	0.16 $\pm$ 0.02	0.14 $\pm$ 0.02

2.3 FISH REPRODUCTION

Reproduction is a key link between the potential effects of environmental contaminants on individual fish and potential adverse consequences to fish populations and communities. In the case of coal ash, several metals enriched in the ash—including selenium, mercury, and arsenic—are known from either laboratory or field-based studies to be capable of negatively affecting one aspect or another of fish development or reproduction under certain exposure conditions. Selenium, in particular, has been associated with the reproductive failure and even local extinction of fish populations at environmentally relevant concentrations. Therefore, the objectives of the fish reproduction task include assessing and evaluating the possible effects of the Kingston coal ash release and residual ash remaining in the system on fish reproduction in affected reaches of the Emory and Clinch Rivers.

As part of this effort, female fish of three sentinel species (bluegill, largemouth bass, and redear sunfish) were sampled at the onset of the 1999–2013 and 2015 spring breeding seasons from five sites in the Emory and Clinch Rivers (ERM 8.0, ERM 3.0, ERM 1.0, CRM 8.0, and CRM 1.5) to assess their reproductive status, metal bioaccumulation (Sect. 2.1), and fish health (Sect. 2.2), as previously discussed. One site only (ERM 1.0) was sampled in 2014 and 2016, each primarily for the purposes of assessing bioaccumulation. Patterns and trends in fish reproductive status at the various study sites from the spill through 2013 were presented in the previous 2015 annual report and thus will not be repeated here. However, in summary, a few statistically significant differences or trends between study sites were noted in a select few of the reproductive parameters evaluated during this 5-year post-spill monitoring effort. But for the most part, comparisons with fish collected from reference sites, coupled with consideration of the weather and river conditions immediately before each sample collection, suggest that the ash spill had little obvious real impact on fish reproduction in areas affected by the release, other than possibly in the initial breeding season after the spill at locations nearest the spill site.

In 2016, field-related activities associated with the fish reproduction task consisted solely of choosing and saving in fixative a small representative piece of ovary of each fish sampled from ERM 1.0 for bioaccumulation assessment and archival purposes. Other than this limited 2016 fish processing activity, efforts during fiscal year (FY) 2016 for the fish reproduction task focused on the completion of detailed morphometric analyses of ovary samples from fish collected during the 2015 comprehensive sampling event and publication of task findings. The fish collected during 2015 demonstrated no obvious signs of reproductive dysfunction, although the average ovary sizes relative to body sizes (or gonadosomatic indices) did vary considerably between study sites (Fig. 4). However, ovary sizes can change rapidly even within a single study site during the immediate reproductive condition build-up to a breeding season, or from site to site if fish were collected from one site or another after spawning has begun; therefore, more intensive ovary morphometric analyses are needed. Analyses conducted during 2016 on eight fish of each species per study site (with the exception of bluegill from ERM 8.0, where only seven reproductive females were able to be collected before the end of the primary portion of the 2015 breeding season) included developmental staging and sizing of all vitellogenic (yolk-accumulating) and maturation-phase oocytes. In addition, if present, analysis included the enumeration of shed follicles (the supporting cell layers that encompass the developing oocytes before their ovulation and release into the ovarian lumen prior to spawning) and/or ovulated eggs in a pre-weighed portion of each ovary. Processing of the data is ongoing and will be followed by statistical analysis of the data and comparisons between reference and ash-exposed sites and previous results. Data processing includes determination of the abundance of vitellogenic oocytes per ovary, calculation of various measures of fecundity (“batch” and/or “annual,” as appropriate for each species’ respective reproductive strategies) from the data, and analysis of the frequency of atresia (the presence of dead or dying oocytes that are in the process of being reabsorbed by an ovary) as a potential measure of oocyte quality.

In summary, results from the fish reproduction task suggest to date that the residual ash remaining in the watershed following remediation appears unlikely to pose significant long-term risks to the reproductive success of exposed fish populations in the upper Watts Bar system, pending the results of ongoing evaluations of data from recently completed analyses of the 2015 fish ovary samples. Journal articles directly related to the fish reproduction task that were published in FY 2016 include Greeley et al 2016 and Pracheil et al 2016 (Section 4.3).

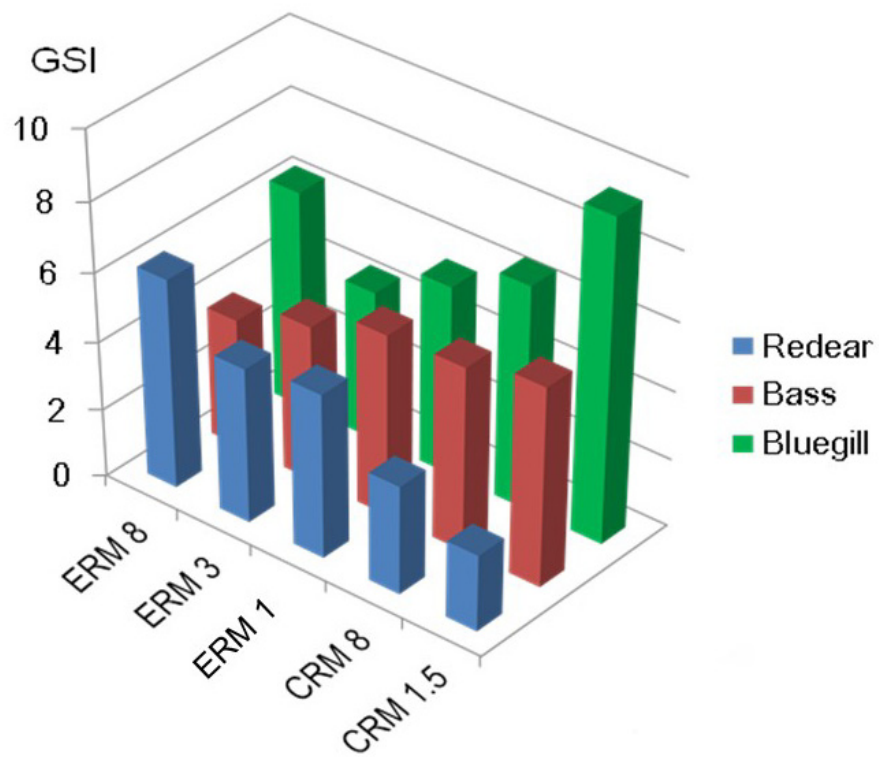


Fig. 4. Gonadosomatic indices (GSIs) of female fish collected at or near the onset of the spring 2015 breeding season. $GSI = (\text{gonad weight/body weight}) \times 100$.

3. INVERTEBRATE BIOACCUMULATION

In fiscal year 2016, samples of mayfly (*Hexagenia bilineata*) nymphs and adults for bioaccumulation assessment were collected from one site (ERM 1.0), per the requirements in the TVA long-term monitoring sampling and analysis plan for KIF (TVA 2013). As in FY 2015, samples were not submitted to the analytical laboratory in time to have results available for inclusion in this summary. Therefore, this summary includes only results from samples collected in 2015. Samples of mayfly nymphs and adults were collected from seven sites in 2015, and as has been the case in past years, not all four adult developmental stages were collected at every site, although multiple trips were made during their collection (Table 8). Samples from 2015 were analyzed by PACE Analytical for a suite of 13 metals: arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), mercury (Hg), selenium (Se), strontium (Sr), thallium (Tl), vanadium (V), and zinc (Zn).

Table 8. Invertebrates collected and sites sampled in 2015

Site	Mayfly nymphs		Adult mayflies			
	Not depurated	Depurated	Female subimagos	Female imagos	Male subimagos	Male imagos
ERM 6.0	X	X				X
ERM 4.0	X		X		X	X
ERM 3.0	X		X	X	X	X
ERM 2.5	X	X	X	X	X	X
ERM 1.0	X	X	X	X	X	X
CRM 6.0	X		X		X	X
CRM 3.5	X	X	X	X	X	X

Notes: ERM = Emory River mile; CRM = Clinch River mile.

Summary descriptive statistics for mayfly nymph samples (non-depurated and depurated) collected in 2015 are presented in Appendix A, Table A.1, and summary plots for As, Hg, Se, Sr, Cu, Fe, and Zn are provided in Fig. 5. In general, metals continued a trend of either a further decrease or no change compared with previous years, although increases in Cd appeared to have occurred in 2015 in non-depurated nymphs at ERM 1.0 and CRM 3.5 and depurated nymphs at ERM 1.0. Even though As and Se remained elevated above background at ERM 1.0 and CRM 3.5, concentrations of both elements were distinctly lower than their respective remediation goals established for KIF (remediation goals shown in Fig. 5). Mercury remains elevated at CRM 3.5 and possibly slightly elevated at ERM 1.0, but results from CRM 6.0 continue to indicate that the primary source of Hg at CRM 3.5 is from the Clinch River and not the ash spill. The slightly elevated concentrations of Hg at ERM 1.0 are associated with particles carried upstream in the Emory River during periods when some of the flow from the Clinch River is diverted during high demands for cooling water at KIF and when operations at Watts Bar and Melton Hill dams force flow to be diverted into the Emory River. Differences in concentrations of most metals between non-depurated and depurated nymphs indicate that most metals are particle bound and, thus, exhibit little bioaccumulation. Metals with concentrations that continue to be similar between non-depurated and depurated nymphs include Cd, Cu, Hg, Se, and Zn. Copper, Se, and Zn are essential elements that occur naturally in animals, whereas Cd and Hg have no known physiological function.

Summary descriptive statistics for adult mayfly samples (subimagos and imagos of males and females) collected in 2015 are presented in Appendix A, Table A.2, and summary plots for As, Hg, Se, Sr, Cu, Fe, and Zn are provided in Fig. 6. Results for adult mayflies in 2015 continue to indicate that some metals (Ba, Cd, Cr, Cu, Se, and V) remain above background in some adult groups and some sites, primarily

ERM 1.0 and CRM 3.5. However, except for Se, concentrations continue to be much lower (1.5 to > 50× lower) in the adults than in the nymphs. Even though Se was above background at some sites, the concentrations at all sites were well below the KIF goal of 7.0 µg/g. Selenium is the only metal assessed for which concentrations remain similar among all adult and nymph groups. Apparent or clear sex differences in concentrations continue to be evident. Zinc is the only metal found in higher concentrations in the females than males (~2× higher). Barium, Cr, Cu, Fe, Hg, and Sr were slightly to modestly higher in males than in females. Thallium continues to be present at concentrations close to the analytical detection limits. Since 2009, Tl has been detected in only 34% of the 317 adult mayfly samples that have been analyzed.

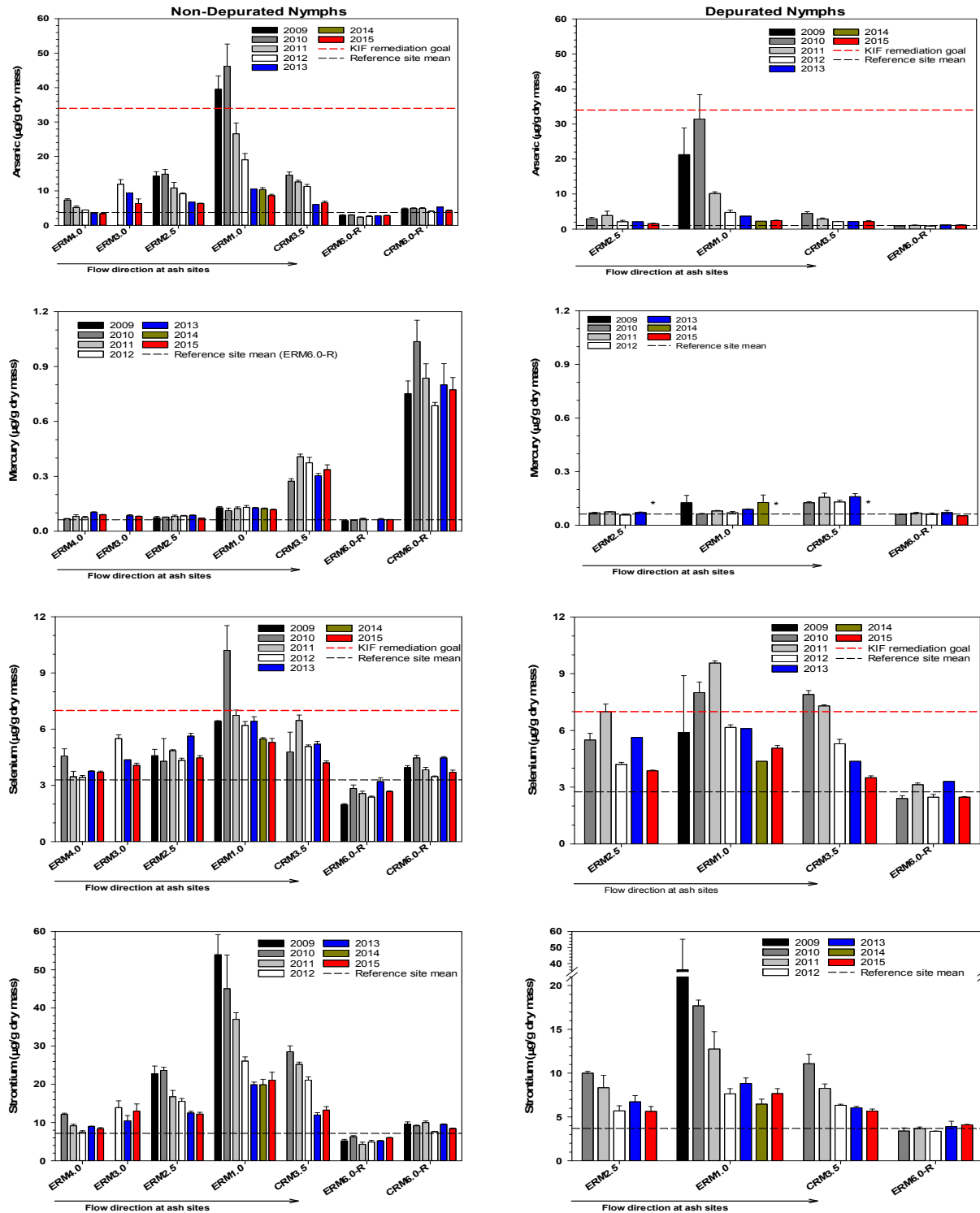


Fig. 5. Mean (error bars $\pm$ standard error) concentrations of arsenic, mercury, selenium, strontium, copper, iron, and zinc in non-depurated (left panel) and depurated (right panel) mayfly nymphs (*Hexagenia bilineata*), 2009–2015. Note that in 2014 samples were collected only from ERM 1.0. Note: *Insufficient tissue available in 2015 for analysis of mercury in depurated nymphs from ERM 2.5, ERM 1.0, and CRM 3.5.

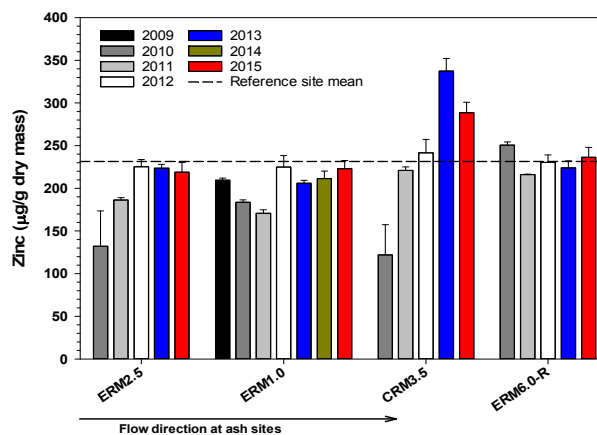
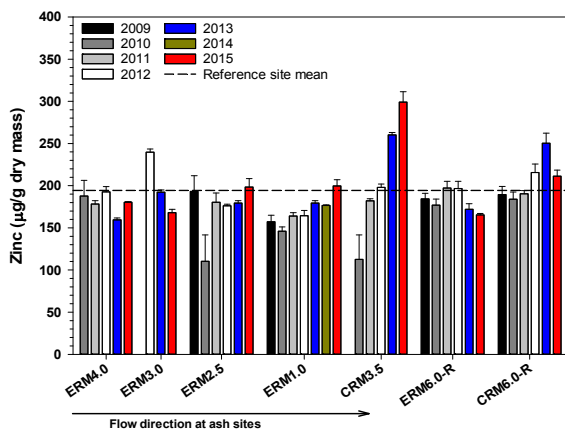
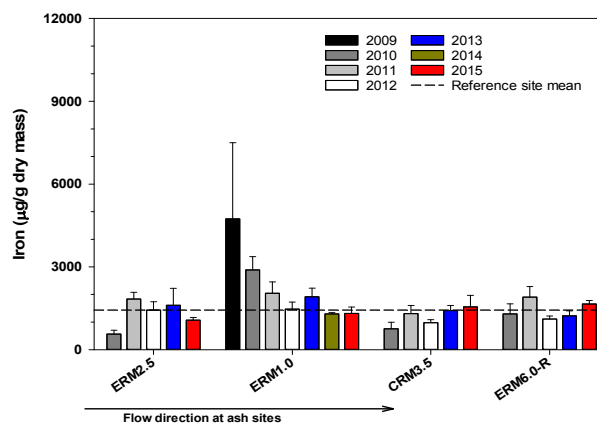
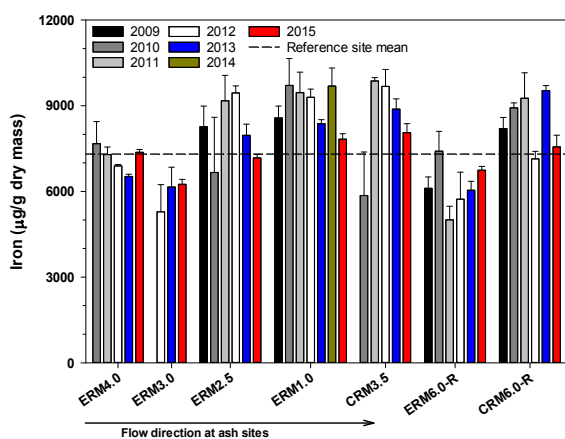
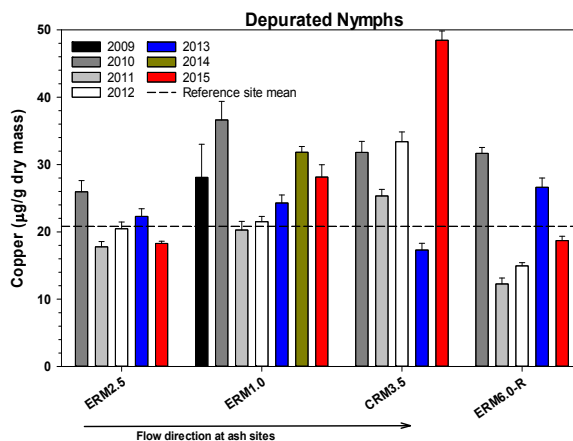
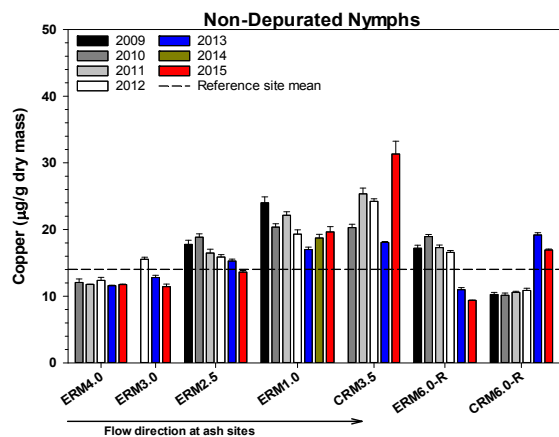


Fig. 5. Continued.

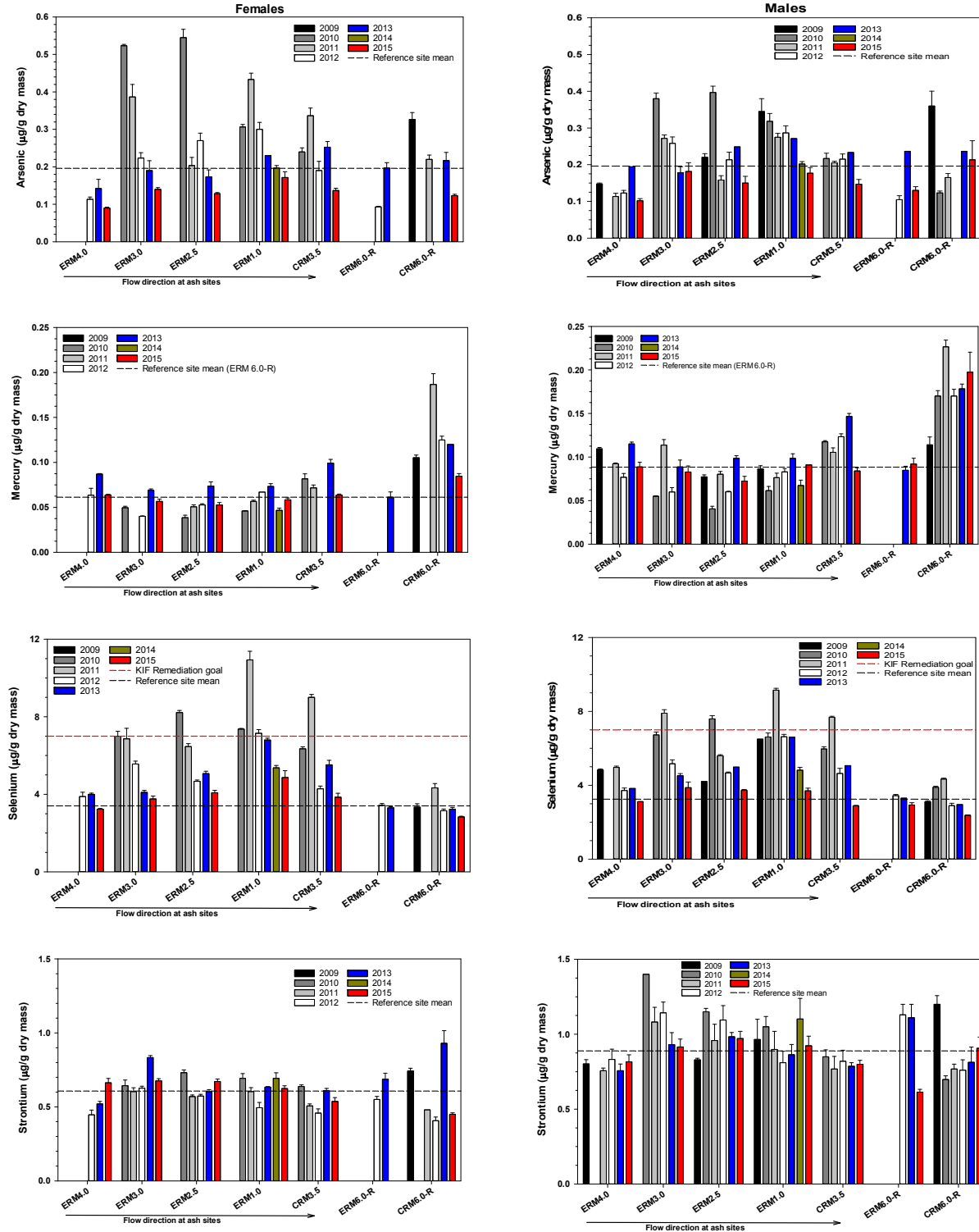


Fig. 6. Mean (error bars $\pm$ standard error) concentrations of arsenic, mercury, selenium, strontium, copper, iron, and zinc in adult female (left panel) and male (right panel) mayflies (*Hexagenia bilineata*), 2009–2015.

Note that in 2014 samples were collected only from ERM 1.0.

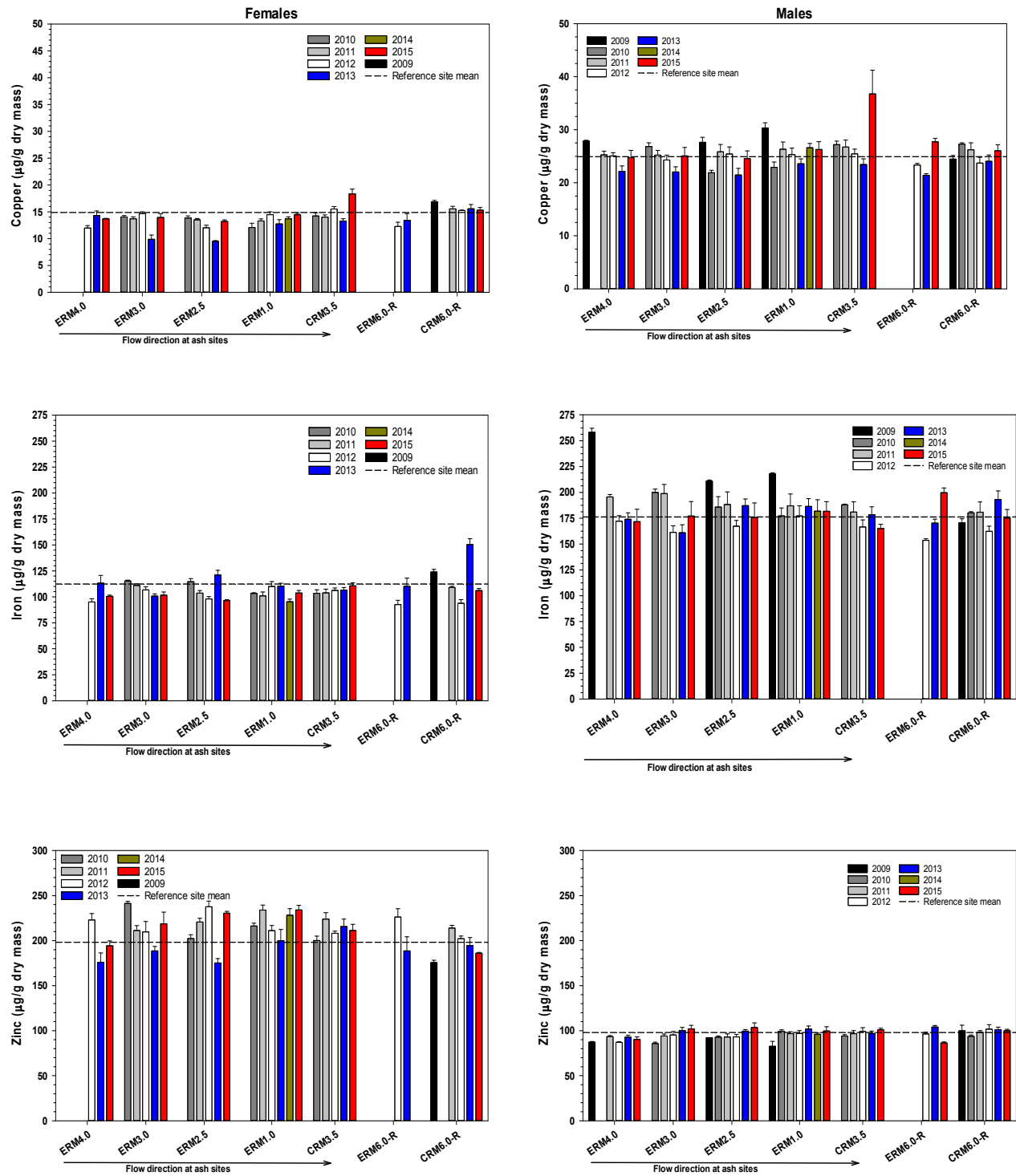


Fig. 6. Continued.

4. 2016 PROGRESS

4.1 FISH

Fish were sampled from the Emory River at ERM 1.0 in April and May 2016 for analysis of metal bioaccumulation, fish health, and fish reproductive fitness. The objective was to collect fish at or near the beginning of their respective breeding seasons to investigate possible relationships among metal bioaccumulation, fish health, and reproductive fitness. ERM 1.0 represents an ash-affected area adjacent to the site of the Kingston coal ash release. Target sample sizes for fish health and reproductive fitness analyses were eight adult females of each of three fish species—largemouth bass, redear sunfish, and bluegill—that represent different trophic levels and home ranges, but at least six fish were processed at ORNL for each task. Actual numbers of fish collected from the site (Table 9) varied in certain cases because of fish availability or the need to resample to better standardize fish sizes or status within the respective breeding seasons.

The normal annual fish health assessment, which includes blood analysis, was not performed on 2016 fish per the monitoring plan. Select observational measures and tissues were taken for potential future fish health and reproduction evaluation if deemed needed in the future. The visual inspection showed no evidence of unusual internal or external anomalies. Six of the sampled fish of each species were filleted for each site, and muscle tissue, ovaries, and livers will be processed and submitted for metals analysis in September 2016.

Table 9. Fish sampling summary for spring 2016

Site	Species	Total samples	Bioaccumulation	Fish health	Fish reproduction
ERM 1.0	Bluegill	8	6	8	8
	Largemouth bass	8	6	8	8
	Redear sunfish	7	6	7	7
Totals		23	18	23	23

4.2 INVERTEBRATES

As in 2014, invertebrates (nymph and adult stages of the mayfly [*Hexagenia bilineata*]) were collected only from ERM 1.0. Sample collection began in early May and was completed by late-June. Processing of all samples were completed by the end of August, and samples will be sent to PACE Analytical for analysis in September 2016.

4.3 SELECT ORNL STAFF PUBLICATIONS

- Greeley, M. S. Jr., S. M. Adams, L. R. Elmore, and M. K. McCracken. 2016. Influence of metal(loid) bioaccumulation and maternal transfer on embryo–larval development in fish exposed to a major coal ash spill. *Aquatic Toxicology* 173:165–177.
- Smith, J. G., T. F. Baker, C. A. Murphy, and R. T. Jett. 2016. “Spatial and Temporal Trends in Contaminant Concentrations in *Hexagenia* Nymphs Following a Coal Ash Spill at the Tennessee Valley Authority’s Kingston Fossil Plant.” *Environmental Toxicology and Chemistry* 35:1159-1171.

- Pracheil, B. M., Adams, S. M., Bevelhimer, M. S., Fortner, A. M., Greeley Jr, M. S., Murphy, C. A. and Peterson, M. J. 2016. “Relating fish health and reproductive metrics to contaminant bioaccumulation at the Tennessee Valley Authority Kingston coal ash spill site.” *Ecotoxicology*, 1–14.
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- Sherrard, R. M., N. E. Carriker, and M. S. Greeley Jr. 2015. “How Toxic Is Coal Ash? A Laboratory Toxicity Case Study.” *Integrated Assessment and Management* 11 (5–9). doi: 10.1002/ieam.1587.
- Bevelhimer, M. S., S. M. Adams, A. M. Fortner, M. S. Greeley, and C. C. Brandt. 2014. “Using Ordination and Clustering Techniques to Assess Multi-Metric Fish Health Response Following a Coal Ash Spill.” *Environmental Toxicology and Chemistry* 33:1903–1913.
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- Greeley, M. S., L. R. Elmore, M. K. McCracken, and R. M. Sherrard. 2014. “Effects of Sediment Containing Coal Ash from the Kingston Ash Release on Embryo–Larval Development in the Fathead Minnow, *Pimephales promelas* (Rafinesque, 1820).” *Bulletin of Environmental Contamination and Toxicology* 92:154–159.
- Mathews, T., A. Fortner, R. T. Jett, J. G. Morris, J. Gable, M. Peterson, and N. Carriker. 2014. “Selenium Bioaccumulation in Fish Exposed to Coal Ash at the Tennessee Valley Authority Kingston Spill Site.” *Env. Toxicol. Chem.* 33:2273–2279.
- Pracheil, Brenda, and Terry Mathews. 2014. “Assessing Bioaccumulation at Kingston Site,” podcast audio, <http://www.ornl.gov/ornl/news/features/2014/lasers-fish-ears-and-environmental-change>.

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Arcadis 2012. Kingston Ash Recovery Project Non-Time Critical Removal Action River System Baseline Ecological Risk Assessment (BERA). Document No. EPA-AO-50. Tennessee Valley Authority, Knoxville, TN.

TVA 2013. May 23, 2013 (EPA approval). Non-Time-Critical Removal Action for the River System LongTerm Monitoring Sampling and Analysis Plan. Document No. EPA-AO-059.

**APPENDIX A. SUMMARY STATISTICS FOR 2015 INVERTEBRATE
BIOACCUMULATION SAMPLES**

APPENDIX A. SUMMARY STATISTICS FOR 2015 INVERTEBRATE BIOACCUMULATION SAMPLES

Table A.1. Descriptive statistics for mayfly nymph (*Hexagenia bilineata*) samples collected for the KIF Coal Ash Project in 2015.

Metal concentrations are reported in µg/g, dry weight.

River/site	Depurated	Statistic ^a	As	Ba	Cd	Cr	Cu	Fe	Mn	Hg	Se	Sr	Tl	V	Zn
<u>Clinch River</u>															
CRM3.5	No	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	3	3	3
		Mean	6.6	60.7	2.70	7.9	31.3	8060	1156.7	0.337	4.20	13.27	0.137	11.4	299
		Med.	7	62.7	2.6	8.2	32.8	8310	1160	0.34	4.1	14.1	0.14	11.9	288
		Min.	5.6	54.4	2.4	7.3	27.5	7440	1080	0.29	4.1	11.4	0.12	10.2	285
		Max.	7.1	65	3.1	8.2	33.7	8430	1230	0.38	4.4	14.3	0.15	12	324
		SD	0.839	5.576	0.361	0.520	3.350	540.3	75.1	0.0451	0.17	1.620	0.015	1.012	21
		SE	0.484	3.219	0.208	0.300	1.934	312	43.3	0.0260	0.10	0.935	0.009	0.584	12
CRM3.5	Yes	N	3	3	3	3	3	3	3	. ^b	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	.	3	3	3	3	3
		Mean	2.2	16.9	2.43	1.6	48.5	1553.0	566.3	.	3.50	5.67	0.041	2.3	288
		Med.	2.1	15.4	2.4	1.4	48.9	1300	561	.	3.4	5.8	0.041	2	286
		Min.	1.8	13.9	2.1	1.1	45.9	999	511	.	3.4	5.2	0.035	1.6	269
		Max.	2.6	21.4	2.8	2.4	50.6	2360	627	.	3.7	6	0.048	3.3	311
		SD	0.404	3.969	0.351	0.681	2.380	714.9	58.2	.	0.17	0.416	0.006	0.889	21
		SE	0.233	2.291	0.203	0.393	1.374	412.7	33.6	.	0.10	0.240	0.004	0.513	12.2
CRM6.0	No	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	3	3	3
		Mean	4.3	48.7	0.98	7.1	16.9	7560.0	1017.0	0.773	3.70	8.43	0.076	8.9	211
		Med.	4.3	46.6	1	6.9	16.8	7270	994	0.77	3.7	8.4	0.076	8.5	217
		Min.	4.1	46.1	0.75	6.8	16.8	7040	957	0.66	3.5	8.2	0.074	8.4	197
		Max.	4.6	53.5	1.2	7.7	17.2	8370	1100	0.89	3.9	8.7	0.079	9.8	220
		SD	0.252	4.136	0.225	0.493	0.231	710.8	74.2	0.115	0.20	0.252	0.002	0.781	12.5
		SE	0.145	2.388	0.130	0.285	0.133	410.4	42.9	0.066	0.12	0.145	0.001	0.451	7.2

Table A.1. (continued)

River/site	Depurated	Statistic ^a	As	Ba	Cd	Cr	Cu	Fe	Mn	Hg	Se	Sr	Tl	V	Zn
<u>Emory River</u>															
ERM1.0	No	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	3	3	3
		Mean	8.7	63.3	1.83	7.7	19.6	7830.0	633.0	0.117	5.30	21.10	0.160	12.7	199.7
		Med.	8.7	63.8	1.5	7.7	19.1	7930	627	0.12	5.2	20.9	0.15	12.6	196
		Min.	8	59.3	1.2	7.4	18.6	7460	602	0.11	5	17.6	0.14	11.8	189
		Max.	9.3	66.8	2.8	8.1	21.2	8100	670	0.12	5.7	24.8	0.19	13.8	214
		SD	0.651	3.775	0.850	0.351	1.380	331.5	34.4	0.0058	0.36	3.604	0.026	1.007	12.9
		SE	0.376	2.179	0.491	0.203	0.797	191.4	19.9	0.0033	0.21	2.081	0.015	0.581	7.4
ERM1.0	Yes	N	3	3	3	3	3	3	3	2 ^c	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	0	3	3	3	3	3
		Mean	2.5	15.3	2.13	1.2	28.1	1313.3	169.3	.	5.07	7.67	0.051	2.0	223
		Med.	2.5	15.7	2.5	0.97	28.2	1080	133		5.2	7.6	0.054	1.7	230
		Min.	2.3	12.4	1.3	0.89	24.9	1080	121		4.8	6.7	0.029	1.4	204
		Max.	2.6	17.9	2.6	1.8	31.3	1780	254		5.2	8.7	0.07	3	235
		SD	0.153	2.768	0.723	0.504	3.201	404.1	73.6		0.23	1.002	0.021	0.850	17
		SE	0.088	1.598	0.418	0.291	1.848	233.3	42.5		0.13	0.578	0.012	0.491	9
ERM2.5	No	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	3	3	3
		Mean	6.4	56.5	1.47	6.9	13.6	7173.3	456.0	0.071	4.47	12.23	0.127	10.4	198
		Med.	6.4	56.8	1.3	6.9	13.4	7270	454	0.071	4.4	12.4	0.13	10.5	196
		Min.	6.2	54.3	1.3	6.7	13.3	6940	424	0.068	4.3	11.4	0.12	10	182
		Max.	6.5	58.5	1.8	7	14.1	7310	490	0.073	4.7	12.9	0.13	10.6	217
		SD	0.153	2.113	0.289	0.153	0.436	203.1	33.0	0.0025	0.21	0.764	0.006	0.321	17
		SE	0.088	1.220	0.167	0.088	0.252	117.2	19.1	0.0015	0.12	0.441	0.003	0.186	10
ERM2.5	Yes	N	3	3	3	3	3	3	3	^b	3	3	3	3	3
		Detects	3	3	3	3	3	3	3		3	3	3	3	3
		Mean	1.6	12.6	1.93	1.1	18.3	1071.0	69.3		3.87	5.63	0.036	1.5	219
		Med.	1.5	13.1	2	1	18.1	997	72.2		3.9	6.1	0.036	1.4	227
		Min.	1.4	10.6	1.8	0.92	17.8	956	62.3		3.8	4.5	0.032	1.4	197
		Max.	1.8	14.2	2	1.4	18.9	1260	73.5		3.9	6.3	0.039	1.8	233
		SD	0.208	1.845	0.115	0.257	0.569	165.0	6.1		0.06	0.987	0.003	0.231	19
		SE	0.120	1.065	0.067	0.148	0.328	95.2	3.5		0.03	0.570	0.002	0.133	11

Table A.1. (continued)

River/site	Depurated	Statistic ^a	As	Ba	Cd	Cr	Cu	Fe	Mn	Hg	Se	Sr	Tl	V	Zn
ERM3.0	No	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	3	3	3
		Mean	6.4	53.5	0.33	5.6	11.4	6253.3	333.7	0.081	4.07	13.00	0.106	8.9	169
		Med.	5.2	53.7	0.27	5.7	11.7	6220	328	0.082	4	11.6	0.1	8.8	168
		Min.	4.9	49.2	0.23	5.3	10.7	5970	304	0.078	3.9	10.7	0.087	8.2	161
		Max.	9	57.6	0.48	5.8	11.9	6570	369	0.083	4.3	16.7	0.13	9.6	175
		SD	2.285	4.204	0.134	0.265	0.643	301.4	32.9	0.0026	0.21	3.236	0.022	0.702	77
		SE	1.320	2.427	0.078	0.153	0.371	174.0	19.0	0.0015	0.12	1.868	0.013	0.406	47
ERM4.0	No	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	3	3	3
		Mean	3.4	52.8	0.29	6.1	11.7	7373.3	369.0	0.089	3.70	8.40	0.084	8.9	180
		Med.	3.4	53.9	0.28	6.1	11.7	7320	372	0.087	3.7	8.4	0.085	8.9	180
		Min.	3.2	49.5	0.25	5.9	11.6	7240	341	0.086	3.6	7.9	0.079	8.4	179
		Max.	3.6	54.9	0.35	6.4	11.9	7560	394	0.094	3.8	8.9	0.087	9.3	182
		SD	0.200	2.873	0.051	0.252	0.153	166.5	26.6	0.0044	0.10	0.500	0.0042	0.451	1.5
		SE	0.115	1.659	0.030	0.145	0.088	96.1	15.4	0.0025	0.06	0.289	0.0024	0.260	0.9
ERM6.0	No	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	3	3	3
		Mean	2.8	43.5	0.87	5.0	9.4	6746.7	361.3	0.063	2.67	5.97	0.064	7.3	165
		Med.	2.8	43.9	0.92	4.9	9.4	6660	359	0.062	2.7	6	0.063	7.1	164
		Min.	2.7	41.9	0.74	4.8	9.3	6580	351	0.06	2.6	5.7	0.062	7	163
		Max.	3	44.6	0.94	5.3	9.4	7000	374	0.066	2.7	6.2	0.066	7.8	169
		SD	0.153	1.401	0.110	0.265	0.058	223.0	11.7	0.0031	0.06	0.252	0.0021	0.436	3
		SE	0.088	0.809	0.064	0.153	0.033	128.8	6.7	0.0018	0.03	0.145	0.0012	0.252	2
ERM6.0	Yes	N	3	3	3	3	3	3	3	1 ^d	3	3	3	3	3
		Detects	3	3	3	3	3	3	3		3	3	3	3	3
		Mean	1.2	13.5	1.07	1.2	18.7	1653.3	96.4	0.053	2.47	4.10	0.020	1.7	236
		Med.	1.2	13.5	1.3	1.2	18.5	1620	94.8		2.5	4.1	0.02	1.7	235
		Min.	0.99	13.3	0.61	1.1	17.7	1450	92.3		2.4	4	0.017	1.5	217
		Max.	1.3	13.8	1.3	1.3	19.9	1890	102		2.5	4.2	0.022	1.8	257
		SD	0.158	0.252	0.398	0.100	1.114	221.9	5.0		0.06	0.100	0.0025	0.153	20
		SE	0.091	0.145	0.230	0.058	0.643	128.1	2.9		0.03	0.058	0.0015	0.088	12

^aAbbreviations for statistics: N = number of samples analyzed; Detects = number of samples the metal was detected in; Med. = Median; Min. = minimum concentration detected; Max. = maximum concentration detected; SD = standard deviation; and SE = standard error of the mean.

^bNot enough tissue for depurated nymph samples from CRM 3.5 to complete analysis of mercury.

^cEnough tissue for only two depurated nymph samples from ERM 1.0 to complete mercury analysis.

^dEnough tissue for only one depurated nymph sample from ERM 6.0 to complete mercury analysis.

Table A.2. Descriptive statistics for adult mayfly (*Hexagenia bilineata*) samples collected for the KIF Coal Ash Project in 2015

River/site	Sex/adult life stage ^a	Statistic ^b	As	Ba	Cd	Cr	Cu	Fe	Mn	Hg	Se	Sr	Tl	V	Zn
<u>Clinch River</u>															
CRM3.5	FI	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	0	3	3
		Mean	0.15	0.59	0.131	0.094	16.8	112.0	3.1	0.062	4.30	0.59		0.093	218.3
		Med.	0.15	0.58	0.14	0.096	17.1	117	3	0.062	4.3	0.61	.	0.087	209
		Min.	0.15	0.57	0.094	0.087	15.1	102	3	0.06	4.2	0.55	.	0.083	208
		Max.	0.15	0.62	0.16	0.1	18.1	117	3.3	0.064	4.4	0.61	.	0.110	238
		SD	0.000	0.026	0.034	0.007	1.528	8.66	0.17	0.002	0.10	0.035	.	0.0146	17.04
		SE	0.000	0.015	0.020	0.004	0.882	5.00	0.10	0.001	0.06	0.020	.	0.0084	9.84
CRM3.5	FS	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	1	3	3
		Mean	0.12	0.91	0.400	0.193	19.9	109.3	4.1	0.065	3.4	0.48	0.014	0.099	204.3
		Med.	0.12	0.9	0.44	0.19	20.5	112	4.2	0.067	3.4	0.49	.	0.100	196
		Min.	0.12	0.73	0.31	0.18	18.3	103	3.5	0.062	3.3	0.47	.	0.087	194
		Max.	0.13	1.1	0.45	0.21	20.9	113	4.5	0.067	3.5	0.49	.	0.110	223
		SD	0.006	0.185	0.078	0.015	1.400	5.51	0.51	0.003	0.10	0.012	.	0.0115	16.20
		SE	0.003	0.107	0.045	0.009	0.808	3.18	0.30	0.002	0.06	0.007	.	0.0067	9.35
CRM3.5	MI	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	3	3	3
		Mean	0.17	0.58	1.933	0.303	46.7	174.0	2.8	0.092	2.9	0.81	0.029	0.260	97.8
		Med.	0.16	0.6	2	0.3	46.5	175	2.7	0.092	2.9	0.79	0.029	0.270	98.8
		Min.	0.15	0.55	1.8	0.29	44.7	171	2.7	0.09	2.9	0.74	0.027	0.240	93.7
		Max.	0.2	0.6	2	0.32	48.9	176	3.1	0.093	2.9	0.91	0.031	0.270	101
		SD	0.026	0.029	0.115	0.015	2.107	2.65	0.23	0.002	0.00	0.087	0.0020	0.0173	3.74
		SE	0.015	0.017	0.067	0.009	1.217	1.53	0.13	0.001	0.00	0.050	0.0012	0.0100	2.16
CRM3.5	MS	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	3	3	3
		Mean	0.12	1.10	0.447	0.203	26.8	156.0	2.4	0.076	2.87	0.79	0.018	0.120	104.0
		Med.	0.12	1.1	0.45	0.2	26.5	156	2.3	0.075	2.8	0.76	0.018	0.110	104
		Min.	0.11	1.1	0.44	0.19	26.1	155	2.3	0.074	2.8	0.76	0.015	0.110	102
		Max.	0.14	1.1	0.45	0.22	27.9	157	2.6	0.08	3	0.84	0.022	0.140	106
		SD	0.015	0.000	0.006	0.015	0.945	1.00	0.17	0.003	0.12	0.046	0.0035	0.0173	2.00
		SE	0.009	0.000	0.003	0.009	0.546	0.58	0.10	0.002	0.07	0.027	0.0020	0.0100	1.15

Table A.2. (continued)

River/site	Sex/adult life stage ^a	Statistic ^b	As	Ba	Cd	Cr	Cu	Fe	Mn	Hg	Se	Sr	Tl	V	Zn	
CRM6.0	FS	N	3	3	3	3	3	3	3	3	3	3	3	3	3	
		Detects	3	3	3	3	3	3	3	3	3	3	0	3	3	
		Mean	0.12	0.42	0.323	0.163	15.3	106.0	3.3	0.085	2.83	0.45		0.076	186.0	
		Med.	0.12	0.42	0.34	0.16	14.9	107	3.1	0.086	2.8	0.46		0.075	187	
		Min.	0.12	0.37	0.28	0.15	14.7	102	3	0.079	2.8	0.43		0.069	184	
		Max.	0.13	0.47	0.35	0.18	16.3	109	3.7	0.089	2.9	0.46		0.084	187	
		SD	0.006	0.050	0.038	0.015	0.872	3.61	0.38	0.005	0.06	0.017		0.0075	1.73	
		SE	0.003	0.029	0.022	0.009	0.503	2.08	0.22	0.003	0.03	0.010		0.0044	1.00	
CRM6.0	MI	N	3	3	3	3	3	3	3	3	3	3	3	3	3	
		Detects	3	3	3	3	3	3	3	3	3	3	0	3	3	
		Mean	0.16	0.78	0.627	0.183	28.5	193.7	2.1	0.220	2.33	1.07		0.117	101.2	
		Med.	0.17	0.82	0.65	0.18	28.3	194	2.1	0.22	2.3	1.1		0.120	103	
		Min.	0.14	0.7	0.57	0.18	27.9	192	2	0.21	2.3	1		0.110	96.5	
		Max.	0.17	0.82	0.66	0.19	29.3	195	2.1	0.23	2.4	1.1		0.120	104	
		SD	0.017	0.069	0.049	0.006	0.721	1.53	0.06	0.010	0.06	0.058		0.0058	4.07	
		SE	0.010	0.040	0.028	0.003	0.416	0.88	0.03	0.006	0.03	0.033		0.0033	2.35	
CRM6.0	MS	N	3	3	3	3	3	3	3	3	3	3	3	3	3	
		Detects	3	3	3	3	3	3	3	3	1	3	3	0	3	3
		Mean	0.27	0.79	0.390	0.223	23.6	156.7	2.7	0.130	2.40	0.75		0.098	98.6	
		Med.	0.23	0.75	0.4	0.23	23.8	157	2.4	.	2.4	0.75		0.099	98	
		Min.	0.11	0.74	0.36	0.19	22.7	156	2	.	2.4	0.7		0.095	94.9	
		Max.	0.46	0.87	0.41	0.25	24.3	157	3.6	.	2.4	0.79		0.100	103	
		SD	0.178	0.072	0.026	0.031	0.819	0.58	0.83	.	0.00	0.045		0.0026	4.09	
		SE	0.103	0.042	0.015	0.018	0.473	0.33	0.48	.	0.00	0.026		0.0015	2.36	
<u>Emory River</u>																
ERM1.0	FI	N	3	3	3	3	3	3	3	3	3	3	3	3	3	
		Detects	3	3	3	3	3	3	3	3	3	3	1	3	3	
		Mean	0.20	0.83	0.056	0.079	14.7	103.9	4.0	0.060	5.63	0.66	0.011	0.079	236.7	
		Med.	0.21	0.83	0.047	0.082	14.7	104	4.1	0.06	5.7	0.65	.	0.081	233	
		Min.	0.18	0.77	0.041	0.069	14.1	95.7	3.6	0.06	5.5	0.62	.	0.075	227	
		Max.	0.22	0.9	0.079	0.085	15.4	112	4.2	0.061	5.7	0.7	.	0.082	250	
		SD	0.021	0.065	0.020	0.009	0.651	8.15	0.32	0.001	0.12	0.040	.	0.0038	11.93	
		SE	0.012	0.038	0.012	0.005	0.376	4.71	0.19	0.000	0.07	0.023	.	0.0022	6.89	

Table A.2. (continued)

River/site	Sex/adult life stage ^a	Statistic ^b	As	Ba	Cd	Cr	Cu	Fe	Mn	Hg	Se	Sr	Tl	V	Zn
ERM1.0	FS	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	2	3	3
		Mean	0.14	0.78	0.099	0.123	14.2	103.7	3.9	0.056	4.10	0.59	0.013	0.079	231.7
		Med.	0.14	0.75	0.095	0.12	13.9	101	3.9	0.055	4	0.58	0.013	0.081	239
		Min.	0.13	0.75	0.092	0.12	13.8	101	3.7	0.05	4	0.57	0.011	0.071	214
		Max.	0.15	0.84	0.11	0.13	14.8	109	4.1	0.064	4.3	0.62	0.014	0.084	242
		SD	0.010	0.052	0.010	0.006	0.551	4.62	0.20	0.007	0.17	0.026	0.0015	0.0068	15.37
		SE	0.006	0.030	0.006	0.003	0.318	2.67	0.12	0.004	0.10	0.015	0.0009	0.0039	8.88
ERM1.0	MI	N	3	3	3	3	3	3	3	2	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	1	3	3	3	3	3
		Mean	0.20	1.17	0.740	0.263	29.5	202.3	3.5	0.091	4.00	0.86	0.026	0.190	91.6
		Med.	0.21	1.1	0.72	0.26	29.9	204	3.4	.	4	0.83	0.024	0.190	89.7
		Min.	0.18	1.1	0.66	0.25	28.7	198	3.4	.	3.9	0.8	0.023	0.160	87.9
		Max.	0.21	1.3	0.84	0.28	30	205	3.8	.	4.1	0.95	0.030	0.220	97.2
		SD	0.017	0.115	0.092	0.015	0.723	3.79	0.23	.	0.10	0.079	0.0038	0.0300	4.93
		SE	0.010	0.067	0.053	0.009	0.418	2.19	0.13	.	0.06	0.046	0.0022	0.0173	2.85
ERM1.0	MS	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	0	3	3	3	3	3
		Mean	0.15	1.57	0.120	0.167	23.0	161.0	2.2		3.40	0.99	0.015	0.094	107.7
		Med.	0.14	1.6	0.11	0.16	23.2	160	2.2		3.4	0.97	0.015	0.083	108
		Min.	0.12	1.3	0.1	0.14	22.5	160	2		3.3	0.79	0.013	0.080	97.1
		Max.	0.2	1.8	0.15	0.2	23.4	163	2.5		3.5	1.2	0.016	0.120	118
		SD	0.042	0.252	0.026	0.031	0.473	1.73	0.25		0.10	0.206	0.0015	0.0223	10.45
		SE	0.024	0.145	0.015	0.018	0.273	1.00	0.15		0.06	0.119	0.0009	0.0129	6.04
ERM2.5	FI ^c	N	3	3	3	3	3	3	3	2	3	3	3	3	3
		Detects	3	3	3	1	3	3	3	0	3	3	0	3	3
		Mean	0.13	0.85	0.030	0.210	13.5	95.4	3.8		4.30	0.70		0.055	231.7
		Med.	0.13	0.87	0.026		13.8	96.4	3.8		4.2	0.7		0.057	231
		Min.	0.12	0.82	0.025		12.6	93.2	3.6		4.1	0.66		0.047	230
		Max.	0.13	0.87	0.039		14.1	96.7	3.9		4.6	0.73		0.060	234
		SD	0.006	0.029	0.008		0.794	1.94	0.15		0.26	0.035		0.0068	2.08
		SE	0.003	0.017	0.005		0.458	1.12	0.09		0.15	0.020		0.0039	1.20

Table A.2. (continued)

River/site	Sex/adult life stage ^a	Statistic ^b	As	Ba	Cd	Cr	Cu	Fe	Mn	Hg	Se	Sr	Tl	V	Zn
ERM2.5	FS	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	0	3	3
		Mean	0.13	0.85	0.025	0.083	12.9	97.4	3.6	0.053	3.87	0.65		0.051	229.3
		Med.	0.13	0.83	0.026	0.085	12.8	96.7	3.6	0.053	3.9	0.63		0.051	233
		Min.	0.12	0.81	0.018	0.069	12.3	95.6	3.6	0.048	3.8	0.62		0.044	221
		Max.	0.14	0.92	0.03	0.094	13.6	100	3.7	0.057	3.9	0.69		0.058	234
		SD	0.010	0.059	0.006	0.013	0.656	2.29	0.06	0.005	0.06	0.038		0.0070	7.23
		SE	0.006	0.034	0.004	0.007	0.379	1.32	0.03	0.003	0.03	0.022		0.0040	4.18
ERM2.5	MI	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	3	3	3
		Mean	0.18	1.10	0.463	0.177	27.8	207.0	4.3	0.084	3.73	0.88	0.018	0.083	93.3
		Med.	0.17	1.1	0.44	0.17	27.8	207	2.4	0.086	3.7	0.85	0.019	0.083	92.9
		Min.	0.14	1	0.42	0.17	27.6	200	2.3	0.079	3.7	0.83	0.017	0.080	90.5
		Max.	0.23	1.2	0.53	0.19	28	214	8.3	0.087	3.8	0.95	0.019	0.086	96.5
		SD	0.046	0.100	0.059	0.012	0.200	7.00	3.44	0.004	0.06	0.064	0.0012	0.0030	3.02
		SE	0.026	0.058	0.034	0.007	0.115	4.04	1.98	0.003	0.03	0.037	0.0007	0.0017	1.74
ERM2.5	MS	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	3	3	3
		Mean	0.12	1.53	0.043	0.097	21.3	144.3	2.2	0.061	3.70	1.07	0.012	0.069	113.7
		Med.	0.12	1.6	0.044	0.096	21.1	146	2.2	0.059	3.7	1.1	0.012	0.067	112
		Min.	0.11	1.4	0.041	0.096	21.1	141	2	0.059	3.5	1	0.012	0.064	106
		Max.	0.13	1.6	0.044	0.1	21.8	146	2.4	0.064	3.9	1.1	0.013	0.077	123
		SD	0.010	0.115	0.002	0.002	0.404	2.89	0.20	0.003	0.20	0.058	0.0006	0.0068	8.62
		SE	0.006	0.067	0.001	0.001	0.233	1.67	0.12	0.002	0.12	0.033	0.0003	0.0039	4.98
ERM3.0	FI ^b	N	2	2	2	2	2	2	2	2	2	2	2	2	2
		Detects	2	2	2	2	2	2	2	0	2	2	0	2	2
		Mean	0.14	0.99	0.015	0.085	12.5	95.1	3.8		4.10	0.68		0.057	245.5
		Med.	0.14	0.99	0.015	0.0845	12.45	95.1	3.8		4.1	0.68		0.057	245.5
		Min.	0.13	0.88	0.013	0.077	12.1	94.4	3.5		4	0.64		0.055	236
		Max.	0.15	1.1	0.017	0.092	12.8	95.8	4.1		4.2	0.72		0.058	255
		SD	0.014	0.156	0.003	0.011	0.495	0.99	0.42		0.14	0.057		0.0021	13.44
		SE	0.010	0.110	0.002	0.008	0.350	0.70	0.30		0.10	0.040		0.0015	9.50

Table A.2. (continued)

River/site	Sex/adult life stage ^a	Statistic ^b	As	Ba	Cd	Cr	Cu	Fe	Mn	Hg	Se	Sr	Tl	V	Zn
ERM3.0	FS	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	0	3	3
		Mean	0.14	0.99	0.016	0.066	14.9	106.0	3.3	0.057	3.53	0.67		0.043	201.0
		Med.	0.14	1	0.015	0.065	14.6	105	3.2	0.057	3.5	0.67		0.044	190
		Min.	0.13	0.96	0.014	0.064	14.1	102	3.2	0.052	3.4	0.65		0.040	190
		Max.	0.15	1	0.019	0.068	16.1	111	3.4	0.061	3.7	0.7		0.046	223
		SD	0.010	0.023	0.003	0.002	1.041	4.58	0.12	0.005	0.15	0.025		0.0031	19.05
		SE	0.006	0.013	0.002	0.001	0.601	2.65	0.07	0.003	0.09	0.015		0.0018	11.00
ERM3.0	MI	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	3	3	3
		Mean	0.17	1.13	0.187	0.143	28.6	208.3	3.0	0.094	4.47	0.83	0.016	0.077	96.8
		Med.	0.18	1.1	0.2	0.14	29.1	208	2.8	0.091	4.2	0.85	0.016	0.080	94.6
		Min.	0.15	1	0.16	0.14	27.1	206	2.8	0.09	4.1	0.72	0.015	0.065	89.7
		Max.	0.19	1.3	0.2	0.15	29.5	211	3.3	0.1	5.1	0.91	0.017	0.087	106
		SD	0.021	0.153	0.023	0.006	1.286	2.52	0.29	0.006	0.55	0.097	0.0010	0.0112	8.36
		SE	0.012	0.088	0.013	0.003	0.742	1.45	0.17	0.003	0.32	0.056	0.0006	0.0065	4.83
ERM3.0	MS	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	2	3	3	0	3	3
		Mean	0.19	1.70	0.018	0.083	21.6	146.0	2.1	0.064	3.27	1.00		0.052	107.1
		Med.	0.16	1.7	0.019	0.087	21.8	146	2.1	0.063	3.3	1		0.054	111
		Min.	0.12	1.6	0.015	0.075	21.2	144	2.1	0.059	3.1	0.91		0.039	96.2
		Max.	0.29	1.8	0.021	0.088	21.8	148	2.2	0.07	3.4	1.1		0.064	114
		SD	0.089	0.100	0.003	0.007	0.346	2.00	0.06	0.006	0.15	0.095		0.0126	9.53
		SE	0.051	0.058	0.002	0.004	0.200	1.15	0.03	0.003	0.09	0.055		0.0073	5.50
ERM4.0	FS	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	0	3	3
		Mean	0.09	1.10	0.011	0.059	13.7	100.5	3.6	0.064	3.23	0.66		0.038	194.3
		Med.	0.088	1.1	0.011	0.058	13.7	101	3.6	0.064	3.2	0.67		0.038	194
		Min.	0.087	1	0.0088	0.054	13.6	98.4	3.4	0.062	3.2	0.61		0.031	185
		Max.	0.095	1.2	0.012	0.065	13.8	102	3.7	0.065	3.3	0.71		0.045	204
		SD	0.004	0.100	0.002	0.006	0.100	1.86	0.15	0.002	0.06	0.050		0.0070	9.50
		SE	0.003	0.058	0.001	0.003	0.058	1.07	0.09	0.001	0.03	0.029		0.0040	5.49

Table A.2. (continued)

River/site	Sex/adult life stage ^a	Statistic ^b	As	Ba	Cd	Cr	Cu	Fe	Mn	Hg	Se	Sr	Tl	V	Zn
ERM4.0	MI	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	0	3	3
		Mean	0.11	1.01	0.099	0.123	27.8	198.7	2.2	0.100	3.13	0.74		0.038	84.9
		Med.	0.11	1	0.097	0.12	27.9	199	2.3	0.1	3.1	0.79		0.038	87
		Min.	0.11	0.92	0.091	0.11	26.9	197	2.1	0.1	3.1	0.61		0.035	79.2
		Max.	0.12	1.1	0.11	0.14	28.6	200	2.3	0.1	3.2	0.82		0.040	88.5
		SD	0.006	0.090	0.010	0.015	0.854	1.53	0.12	0.000	0.06	0.114		0.0025	4.99
		SE	0.003	0.052	0.006	0.009	0.493	0.88	0.07	0.000	0.03	0.066		0.0015	2.88
ERM4.0	MS	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	0	3	3
		Mean	0.09	1.73	0.017	0.065	21.7	144.7	2.1	0.077	3.07	0.89		0.033	95.7
		Med.	0.088	1.7	0.016	0.065	21.6	144	2.1	0.077	3.1	0.89		0.032	95.6
		Min.	0.083	1.7	0.015	0.061	21.5	142	2	0.072	3	0.86		0.028	94.3
		Max.	0.099	1.8	0.019	0.07	21.9	148	2.1	0.083	3.1	0.93		0.039	97.2
		SD	0.008	0.058	0.002	0.005	0.208	3.06	0.06	0.006	0.06	0.035		0.0056	1.45
		SE	0.005	0.033	0.001	0.003	0.120	1.76	0.03	0.003	0.03	0.020		0.0032	0.84
ERM6.0	MI	N	3	3	3	3	3	3	3	3	3	3	3	3	3
		Detects	3	3	3	3	3	3	3	3	3	3	0	3	3
		Mean	0.13	0.93	0.170	0.103	27.7	199.7	2.9	0.092	2.93	0.61		0.030	86.4
		Med.	0.12	0.97	0.14	0.1	27.6	201	2.5	0.097	3	0.6		0.030	86.4
		Min.	0.12	0.83	0.14	0.1	26.7	191	2.2	0.079	2.7	0.59		0.029	84.3
		Max.	0.15	0.98	0.23	0.11	28.9	207	4	0.1	3.1	0.65		0.030	88.4
		SD	0.017	0.084	0.052	0.006	1.106	8.08	0.96	0.011	0.21	0.032		0.0006	2.05
		SE	0.010	0.048	0.030	0.003	0.639	4.67	0.56	0.007	0.12	0.019		0.0003	1.18

^a FI = female subimago; FS = female subimago; MI = male imago; MS = male subimago.

^b Abbreviations for statistics: N = number of samples analyzed; Detects = number of samples the metal was detected in; Med. = Median; Min. = minimum concentration detected; Max. = maximum concentration detected; SD = standard deviation; and SE = standard error of the mean.

^c Enough female imagos were collected for only two samples.

APPENDIX C

2015 TVA Benthic Invertebrate Community Survey



Benthic Invertebrate Community

Benthic invertebrate community evaluations in November 2015 were conducted on the Emory and Clinch Rivers. Sites included nine ash-impacted sites—six on the Emory River (ERM 4.1, ERM 3.0, ERM 2.6, ERM 2.2, ERM 1.0, and ERM 0.7) and three on the Clinch River (CRM 4.0, CRM 3.0, and CRM 1.5)—and two reference sites (ERM 6.0 and CRM 6.0).

Monitoring continues to be performed annually at the two sites located on the lower Emory River (ERM 1.0 and ERM 0.7) as part of the long-term monitoring plan because they are within the river reach with the highest potential for aquatic life exposure to residual ash. Annual monitoring was reduced to biennial in 2013 at the nine additional locations (Table 1). All locations will be evaluated again in autumn 2017.

As in previous years, 10 equally-spaced Ponar grab samples were collected along each transect and submitted for laboratory processing and identification of organisms to the lowest practical taxonomic level. The total number of each taxa was tallied and used to generate benthic invertebrate community metrics in order to assess the status/response of the community. Water depth also was recorded for each sample along with estimates of proportions of substrate types. In addition, a sample of sediment co-located with each benthic community sample was collected and analyzed for percent ash. A detailed description of the sampling locations and collection methods can be found in *Evaluation of Benthic Macroinvertebrate Communities in the Vicinity of TVA's Kingston Fossil Plant, 2009-2010* (Baker 2011b).

The 2015 benthic community results are consistent with previous years as the community metrics do not show substantial impacts attributable to the ash release. Invertebrate population density and taxa richness at sites were similar to previous years as were the dominant taxa groups and proportions among feeding guilds and organism habits (Tables 2 and 3; Figures 1-6). Similarly, results for ash-impacted sites in both the Emory and Clinch Rivers over the 2009-2015 period do not indicate a trend of decreasing invertebrate abundance or decreasing richness and the temporal variations seen at these sites are also evident at reference sites. Additionally, the most recent analysis (ANCOVA) examining the effects of site, sampling period (2012-2015), and substrate types on benthic community metrics did not indicate a significant negative relationship with percentage ash composition (Table 4). Combined, these results indicate that the structure and function of the benthic community has not been substantially altered and that any adverse effects of the residual ash in the river system are apparently small enough that the long-term viability of the population is not impacted.

Percent ash in sediments co-located with benthic community samples in 2015 ranged from less than one to 56% (mean 12.1%) in the Emory River and ranged from less than one to 28% (mean 8.9%) in the Clinch River (Figure 7). Laboratory sediment toxicity tests indicate that only river sediments containing greater than 40% ash are likely to cause toxicity to benthic fauna (ARCADIS 2012¹). Only two samples exceeded this threshold in 2015; one (56%) at ERM 2.6 and one (48%) at ERM 1.0. For the 10 co-located sediment samples collected at ERM 1.0 and ERM 0.7 annually from 2012 through 2015, the frequency of samples with ash composition equal to or greater than 40% ash declined from 7 and 6 samples respectively at ERM 0.7 and ERM 1.0 in 2012 to two or less samples at each location in 2013, 2014, and 2015. As residual

¹ ARCADIS. 2012. River system baseline ecological risk assessment, Tennessee Valley Authority, Kingston Ash Recovery Project. EPA-AO-050. May.

ash is distributed unevenly through the system, these results suggest that ash and natural sediments are becoming more intermixed within the upper 6 inches of sediment.

Table 1. Benthic invertebrate community and co-located sediment sampling sites, 2009-2015.
(X-Benthic invertebrate sampling; XX-Benthic invertebrate and co-located sediment sampling)

Sampling Period	1 January 2009	2 December 2009	3 December 2010 - January 2011	4 December 2011 - January 2012	5 November- December 2012	6 December 2013	7 November 2014	8 November 2015
River Mile								
ERM 6.0*	X	X	X	XX	XX	XX	.	XX
ERM 5.0	X	X	X	XX	XX	.	.	.
ERM 4.1	.	X	X	XX	XX	XX	.	XX
ERM 3.5	.	.	.	XX	XX	.	.	.
ERM 3.0	.	.	X	XX	XX	XX	.	XX
ERM 2.6	.	.	X	XX	XX	XX	.	XX
ERM 2.2	.	X	X	XX	XX	XX	.	XX
ERM 1.0	X	X	X	XX	XX	XX	XX	XX
ERM 0.7	.	.	.	XX	XX	XX	XX	XX
CRM 8.7*	X	X	X	X	X	.	.	.
CRM 6.0*	X	X	X	X	X	XX	.	XX
CRM 4.0	X	X	X	X	X	XX	.	XX
CRM 3.0	X	X	X	X	X	XX	.	XX
CRM 1.5	X	X	X	X	X	XX	.	XX
CRM 0.5	X	X	X	X	X	.	.	.
TRM 573.9*	X	X	X	X	.	.	.	.
TRM 566.3	X	X	X	X	.	.	.	.
TRM 560.8 ¹	X	X	X	X	X	.	.	.

* - Reference Site.

1 - TRM 560.8 is sampled as part of TVA's Valley-wide monitoring program. Samples were collected at this site in November 2008, 2009 and 2010; December 2011; and October 2012.

Table 2. Benthic invertebrate community metric results for long-term monitoring locations on the Emory River, 2009-2015

Transect Sample Period Sample Period Number of Samples		ERM 6.0							ERM 4.1						ERM 3.0					ERM 2.6				
		1	2	3	4	5	6	8	2	3	4	5	6	8	3	4	5	6	8	3	4	5	6	8
		Jan-09	Dec-09	Dec-10	Dec-11	Dec-12	Dec-13	Dec-15	Dec-09	Dec-10	Dec-11	Dec-12	Dec-13	Dec-15	Dec-10	Dec-11	Dec-12	Dec-13	Dec-15	Dec-10	Dec-11	Dec-12	Dec-13	Dec-15
		10	10	10	10	10	10	10	10	10	10	10	10	10	20	10	10	10	10	20	10	10	10	10
Average Abundance (# / m ²)	Population	752	737	452	707	1612	1135	1930	988	2142	1300	1547	1748	1608	2433	2258	1558	3390	1608	2093	2157	2175	3690	2165
	Oligochaetes	273	110	48	402	335	317	238	255	507	592	517	722	610	1108	1407	332	1668	443	628	743	735	1995	502
	Chironomids	375	415	227	247	987	557	287	552	1107	422	645	747	403	1056	697	518	1053	312	1219	948	662	993	500
	Hexagenia	9	12	5	3	5	12	3	10	35	37	28	52	53	20	13	33	40	32	55	55	58	65	75
	Sphaeriidae	0	0	0	0	0	0	3	5	0	22	80	15	118	94	40	415	337	260	53	255	402	423	835
Average Composition	% Oligochaetes	35	15	19	55	19	24	15	23	26	41	30	34	39	41	61	19	39	27	23	33	31	41	26
	% Chironomids	50	57	48	35	59	48	19	56	48	36	40	44	29	47	31	34	35	17	56	43	33	32	24
Taxa Richness	Total Richness	26	23	23	28	27	42	21	45	41	57	26	37	31	47	43	32	43	27	39.5	41	30	36	26
	Average Richness	8.6	7.7	5.9	8.0	7.6	11.9	7.1	11.5	11.3	12.3	11.4	12.6	10.2	13.5	12.8	11.7	15.8	10.1	13.9	13.9	12.2	12.3	10.9
	Total EPT Richness	2	2	3	1	2	5	2	6	5	5	2	3	3	3	2	2	4	2	3	1	2	2	1
	Average EPT Richness	0.5	0.5	0.4	0.2	0.3	1.1	0.2	1.0	1.1	0.8	0.8	1.1	1	0.7	0.3	1.0	1.5	0.8	1.0	0.7	0.8	0.9	0.9
Feeding	% Filterer	2	10	7	5	5	5	1	20	7	11	8	6	9	8	10	26	16	23	7	21	20	16	35
	% Gatherer	76	57	53	65	69	57	28	54	63	56	60	68	59	57	71	42	56	37	53	52	52	59	37
	% Predator	20	32	29	17	22	31	67	20	25	28	27	24	27	27	10	23	25	33	29	21	24	23	23
	% Scraper	0	1	0	5	1	0	--	1	0	2	0	0	--	1	1	0	0	0	2	0	0	0	--
	% Shredder	0	0	5	7	1	3	2	1	1	2	2	1	1	5	7	1	1	0	5	3	0	--	1
	% Parasite	1	--	5	0	2	2	1	0	3	1	1	1	1	0	1	6	1	4	0	0	2	1	0
	% Omnivore	1	0	0	1	0	1	1	3	1	1	2	1	3	1	0	2	2	2	3	2	2	2	4

Transect Sample Period Sample Period Number of Samples		ERM 2.2						ERM 1.0								ERM 0.7				
		2	3	4	5	6	8	1	2	3	4	5	6	7	8	4	5	6	7	8
		Dec-09	Dec-10	Dec-11	Dec-12	Dec-13	Dec-15	Jan-09	Dec-09	Dec-10	Dec-11	Dec-12	Dec-13	Nov-14	Nov-15	Dec-11	Dec-12	Dec-13	Nov-14	Nov-15
		10	20	10	10	10	10	10	10	20	10	10	10	10	10	10	10	10	10	10
Average Abundance (# / m ²)	Population	1315	2073	1823	3203	4483	2335	967	1108	1577	2832	1462	1155	1857	1957	2648	2182	2333	2667	2353
	Oligochaetes	260	543	1190	1335	2520	425	373	465	689	1025	277	210	892	540	847	590	1083	1328	908
	Chironomids	378	1026	508	893	1417	767	320	318	718	1230	632	507	475	528	1347	1153	853	940	750
	Hexagenia	168	126	23	63	73	230	35	115	39	168	77	143	63	328	193	128	177	97	143
	Sphaeriidae	360	104	42	657	32	462	163	128	64	242	372	205	287	393	145	70	130	160	297
Average Composition	% Oligochaetes	12	14	46	30	49	14	33	47	36	36	20	21	50	33	35	23	41	51	41
	% Chironomids	27	50	43	34	35	32	37	28	49	41	45	45	25	24	47	48	36	34	29
Taxa Richness	Total Richness	47	40.5	48	32	44	31	23	24	39.5	55	40	29	41	45	43	41	33	40	44
	Average Richness	11.0	12.5	13.4	12.7	15.1	13.9	9.0	9.2	11.2	17.6	12.6	11.9	12.8	15.2	15.1	16.0	13.0	13.5	15.4
	Total EPT Richness	4	2.5	3	2	3	2	1	3	3.5	3	2	2	3	2	2	3	2	2	2
	Average EPT Richness	1.5	1.0	0.6	1.0	1.1	1.1	0.6	0.9	0.9	1.1	1.1	0.9	0.9	1.1	0.6	1.5	1.0	0.9	1.2
Feeding	% Filterer	32	13	12	24	5	24	19	8	6	15	29	16	19	21	10	16	7	11	16
	% Gatherer	43	41	59	51	67	41	50	68	65	54	46	55	65	58	56	62	72	76	67
	% Predator	20	37	22	21	25	26	25	21	23	17	17	22	12	13	17	13	16	9	9
	% Scraper	0	0	3	0	1	--	0	--	0	0	1	1	0	1	1	4	0	1	6
	% Shredder	1	2	2	1	1	1	1	0	4	11	3	1	1	1	12	2	1	1	1
	% Parasite	0	2	0	1	1	1	1	--	1	0	2	1	1	1	0	1	1	0	1
	% Omnivore	3	4	2	2	1	8	4	3	2	2	2	3	2	5	4	2	4	3	2

Sample periods are defined as follows: 1=January 2009; 2=December 2009; 3= December 2010-January 2011; 4=December 2011-January 2012; 5=December 2012; 6=December 2013; 7=November 2014; 8=November 2015. Abbreviations: EPT = Ephemeroptera, Plecoptera, and Trichoptera; ERM = Emory River Mile

Table 3. Benthic invertebrate community metric results for long-term monitoring locations on the Clinch River, 2009-2015

Transect		CRM 6.0							CRM 4.0						
Sample Period		1	2	3	4	5	6	8	1	2	3	4	5	6	8
Sample Period		Jan-09	Dec-09	Dec-10	Dec-11	Dec-12	Dec-13	Nov-15	Jan-09	Dec-09	Dec-10	Dec-11	Dec-12	Dec-13	Nov-15
Number of Samples		10	10	20	10	10	10	10	10	10	10	10	10	10	10
Average Abundance (# / m ²)	Population	3013	972	2478	1602	3203	2185	2655	1652	1300	1643	2638	2047	2385	2348
	Oligochaetes	1838	345	1005	242	462	188	667	550	57	527	417	237	255	237
	Chironomids	790	238	1040	487	1105	773	1003	393	325	702	695	557	817	430
	Hexagenia	145	88	91	445	335	388	292	150	278	188	470	458	560	543
	Sphaeriidae	90	30	22	3	225	53	218	477	352	143	195	453	458	847
Average Composition	% Oligochaetes	62	30	38	22	17	10	27	47	7	29	18	11	10	11
	% Chironomids	25	18	42	28.8	29	33	36	23	30	46	26	28	35	18
Taxa Richness	Total Richness	36	34	48	46	53	45	41	35	21	53	56	47	51	38
	Average Richness	15.1	8.8	16.9	14.7	20.2	19.8	16.6	10.2	8.7	16.4	16.9	16.3	17.8	16.2
	Total EPT Richness	2	4	5	2	5	5	4	2	2	4	7	3	3	2
	Average EPT Richness	1.1	0.9	1.2	1.0	1.7	1.9	1.5	0.7	1.0	1.2	1.8	1.3	1.5	1.0
Feeding	% Filterer	3	25	12	18	15	13	30	19	34	12	23	29	22	34
	% Gatherer	75	40	60	47	34	45	46	59	37	65	54	43	53	39
	% Predator	14	11	19	22	32	21	17	13	16	14	8	18	15	13
	% Scraper	1	11	2	4	13	14	3	0	0	1	2	4	3	8
	% Shredder	3	9	5	6	2	2	2	3	0	2	6	2	1	1
	% Parasite	0	--	0	0	1	2	0	1	--	0	0	2	2	1
	% Omnivore	3	3	1	2	2	4	1	5	13	5	6	2	4	3

Transect		CRM 3.0							CRM 1.5						
Sample Period		1	2	3	4	5	6	8	1	2	3	4	5	6	8
Sample Period		Jan-09	Dec-09	Dec-10	Dec-11	Dec-12	Dec-13	Nov-15	Jan-09	Dec-09	Dec-10	Dec-11	Dec-12	Dec-13	Nov-15
Number of Samples		10	10	10	10	10	10	10	10	10	7	9	10	10	10
Average Abundance (# / m ²)	Population	1587	947	1207	1320	2338	2568	2338	1380	1230	981	1826	1757	2797	2000
	Oligochaetes	190	70	160	303	372	365	212	150	333	217	526	217	382	168
	Chironomids	575	318	573	370	433	638	370	420	380	488	469	412	587	365
	Hexagenia	345	140	245	402	392	538	877	292	252	176	404	387	363	940
	Sphaeriidae	388	392	150	103	855	782	580	402	188	10	215	493	1203	292
Average Composition	% Oligochaetes	9	12	12	26	15	14	9	15	25	15	28	12	14	7.6
	% Chironomids	35	33	46	28	17	24	15	31	33	43	26	23	19	17
Taxa Richness	Total Richness	25	19	27	41	39	33	38	17	20	26	41	32	50	33
	Average Richness	9.9	8.6	11.2	14.2	14.6	15.2	15.4	10.0	10.1	9.6	14.8	13.5	18.1	13.7
	Total EPT Richness	2	1	2	4	3	3	2	2	1	2	3	2	3	3
	Average EPT Richness	1.1	1.0	1.2	1.4	1.1	1.5	1.4	1.1	1.0	0.7	1.0	1.1	1.3	1.4
Feeding	% Filterer	24	39	15	14	43	33	28	25	20	25	21	34	45	20
	% Gatherer	43	42	50	60	36	42	53	41	57	41	51	38	34	63
	% Predator	20	11	26	15	12	16	11	24	15	30	20	21	11	11
	% Scraper	0	--	1	1	2	1	1	--	0	0	1	0	1	1
	% Shredder	0	0	0	4	1	1	1	0	0	--	3	1	3	0
	% Parasite	0	0	1	1	2	1	2	0	0	--	0	1	3	1
	% Omnivore	12	7	7	4	4	6	4	10	7	4	4	4	5	4

Sample periods are defined as follows: 1=January 2009; 2=December 2009; 3= December 2010-January 2011; 4=December 2011-January 2012; 5=December 2012; 6=December 2013; 7=November 2014; 8=November 2015. Abbreviations: EPT = Ephemeroptera, Plecoptera, and Trichoptera; ERM = Emory River Mile.

Table 4. Summary of ANCOVA results examining effects of predominate substrate types, site, and sampling period on benthic invertebrate community metrics for ash-affected sites in the Emory River, 2012-2015. Overall model results are shown for each response metric as $F_{\text{num d.f., denom d.f.}}$ and P-value. Significant P-values ($\alpha=0.05$) for each covariate from type III sum-of-squares are shown.

Response Metric	Site Group	Model Results	Ash	Detritus	Fines	Sand	Gravel	Site	Sampling Period	Site*Period
Population Density	Group 1	$F_{9,70}=9.13$, $P<0.0001$	--	0.0003 (+)	0.0061 (+)	0.0406 (–)	0.0063 (+)	0.0135	--	--
	Group 2	$F_{9,78}=11.27$, $P<0.0001$	--	<0.0001 (+)	0.0012 (+)	--	--	--	<0.0001	--
Oligochaete Density	Group 1	$F_{9,70}=14.47$, $P<0.0001$	--	<0.0001 (+)	--	0.0001 (+)	0.0492 (+)	0.0064	--	--
	Group 2	$F_{9,78}=24.42$, $P<0.0001$	--	<0.0001 (+)	--	0.0163 (+)	--	--	<0.0001	--
Chironomid Density	Group 1	$F_{9,70}=8.51$, $P<0.0001$	--	0.0001 (+)	0.0172 (+)	0.0216 (–)	0.0173 (+)	--	0.0003	--
	Group 2	$F_{9,78}=10.81$, $P<0.0001$	--	<0.0001 (+)	0.0138 (+)	--	--	0.0188	<0.0001	--
Hexagenia Density	Group 1	$F_{9,70}=7.03$, $P<0.0001$	--	0.0002 (–)	--	<0.0001 (–)	--	--	0.0087	--
	Group 2	$F_{13,74}=4.77$, $P<0.0001$	--	--	0.0144 (+)	--	--	0.0014	--	0.0134
Sphaeriid Density	Group 1	$F_{9,70}=9.71$, $P<0.0001$	--	0.0101 (–)	0.0003 (+)	<0.0001 (–)	--	0.0124	--	--
	Group 2	$F_{9,78}=10.19$, $P<0.0001$	--	--	<0.0001 (+)	--	--	--	--	--
Total Richness	Group 1	$F_{9,70}=4.31$, $P=0.0002$	--	--	0.0351 (+)	--	<0.0001 (+)	--	0.0284	--
	Group 2	$F_{9,78}=2.95$, $P=0.0046$	--	--	0.0102 (+)	--	0.0487 (+)	--	0.0042	--
Gatherer Density	Group 1	$F_{9,70}=9.93$, $P<0.0001$	--	<0.0001 (+)	--	--	0.0435 (+)	0.0004	--	--
	Group 2	$F_{9,78}=22.66$, $P<0.0001$	--	<0.0001 (+)	--	0.0237 (+)	--	--	<0.001	--
Predator Density	Group 1	$F_{9,70}=3.28$, $P=0.0022$	--	0.0130 (+)	0.0066 (+)	--	0.0149 (+)	--	0.0335	--
	Group 2	$F_{9,78}=4.21$, $P=0.0002$	0.0121 (+)	0.0273 (+)	0.0044 (+)	--	--	--	0.0123	--
Filterer Density	Group 1	$F_{9,70}=7.79$, $P<0.0001$	--	--	0.0040 (+)	<0.0001 (–)	--	--	0.0008	--
	Group 2	$F_{9,78}=7.16$, $P<0.0001$	--	--	<0.0001 (+)	--	--	--	--	--
Burrower Density	Group 1	$F_{9,70}=8.52$, $P<0.0001$	--	0.0019 (+)	0.0083 (+)	0.0547 (–)	--	0.0035	--	--
	Group 2	$F_{9,78}=10.03$, $P<0.0001$	--	<0.0001 (+)	0.0021 (+)	--	--	--	0.0001	--

Group 1: ERM 1.0 and ERM 0.7 sampled annually from 2012 through 2015; Group 2: ERM 3.0, 2.6, and 2.2 sampled in 2012, 2013, and 2015

(+) positive correlation; (–) negative correlation

Analysis was performed on the 2012 to 2015 dataset for long-term monitoring sites in the Emory River. These data include results for co-located sediments for each benthic community sample (i.e., 10 samples per transect). ERM 6.0 and ERM 4.1 were excluded from the analysis because few samples had detectable ash and detection yielded low ash content. Given the complex nature of the river system, the remaining five sites were grouped based on proximity of sampling locations, similarities of river cross-sections, and estimated risk for exposure to residual ash. Two site-groups were formed, one consisting of ERM 3.0, 2.6, and 2.2 and one consisting of ERM 1.0 and ERM 0.7.

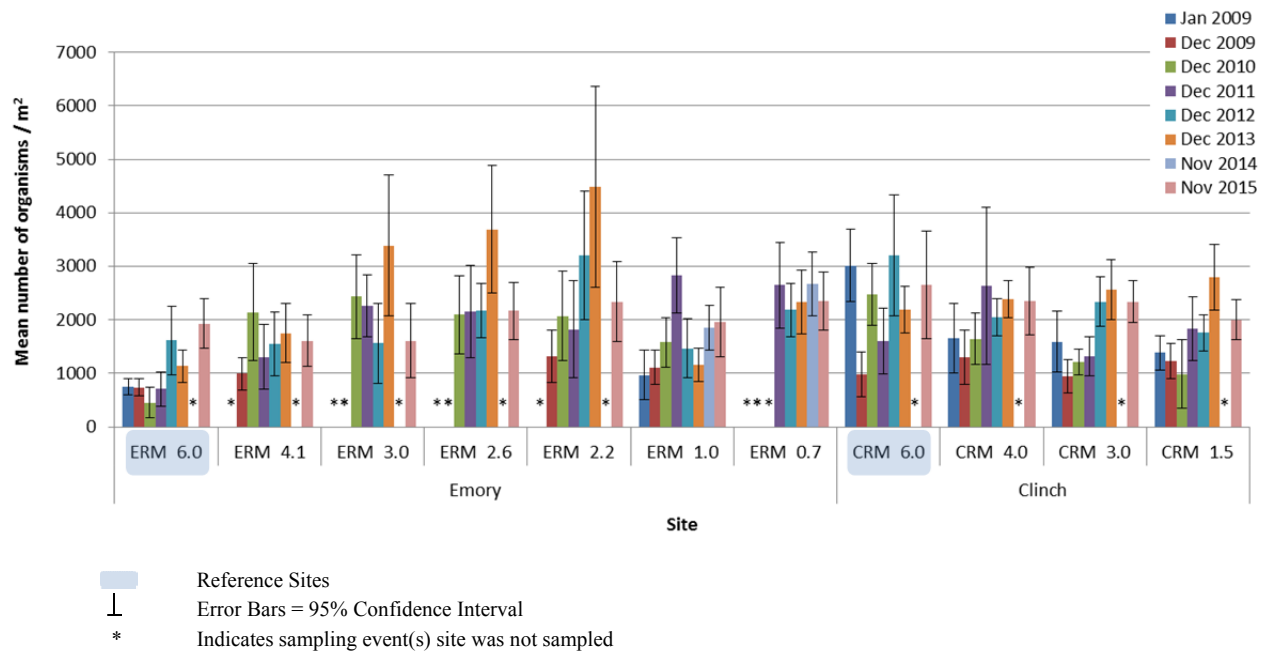


Figure 1. Mean benthic invertebrate population densities at long-term monitoring locations in the Emory and Clinch Rivers, 2009-2015; only Emory River Miles (ERM) 1.0 and 0.7 were sampled in 2014.

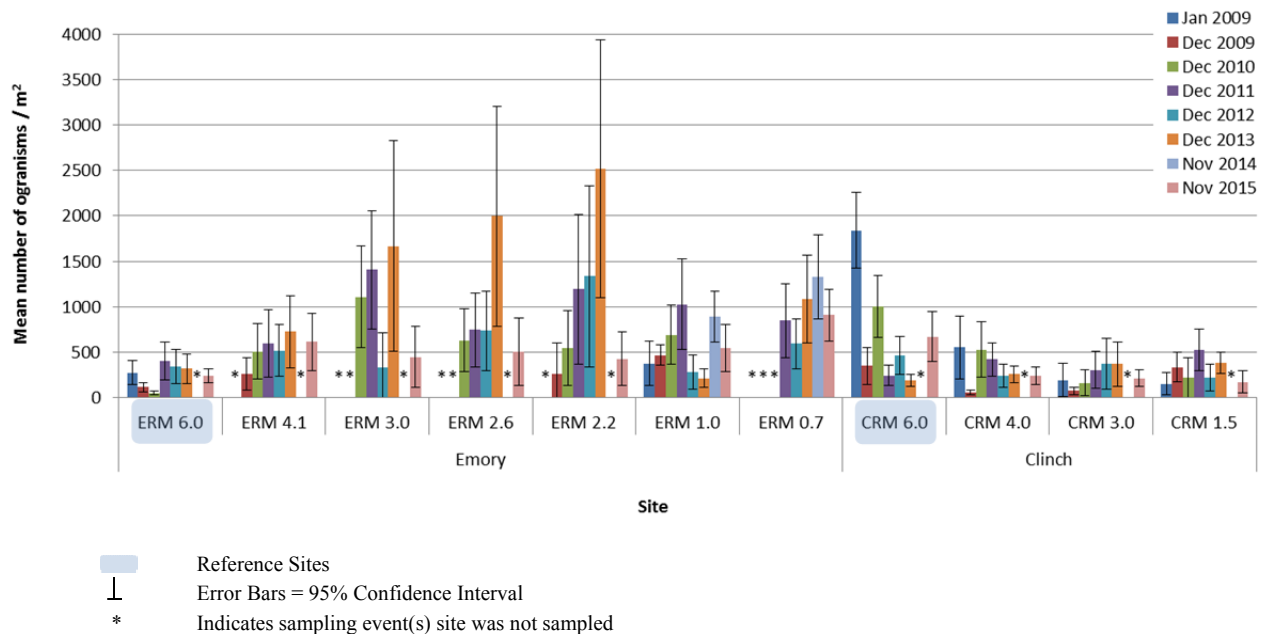


Figure 2. Mean densities of oligochaetes at long-term monitoring locations in the Emory and Clinch Rivers, 2009-2015; only Emory River Miles (ERM) 1.0 and 0.7 were sampled in 2014.

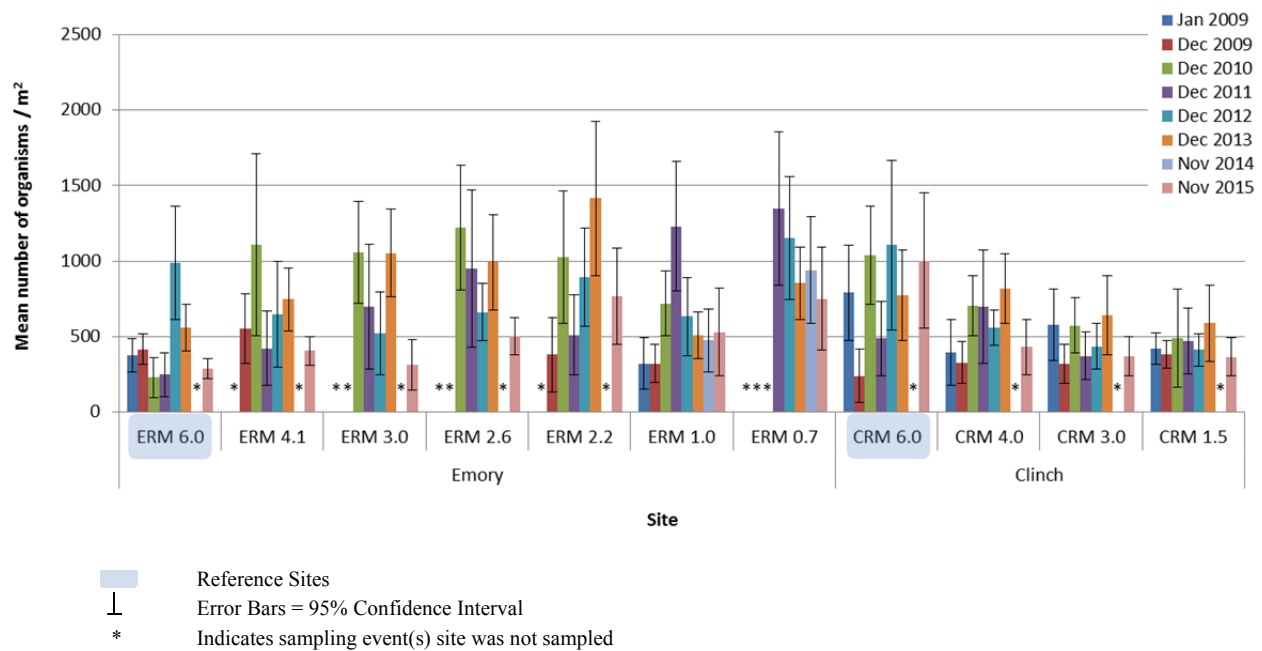


Figure 3. Mean densities of chironomids at long-term monitoring locations in the Emory and Clinch Rivers, 2009-2015; only Emory River Miles (ERM) 1.0 and 0.7 were sampled in 2014.

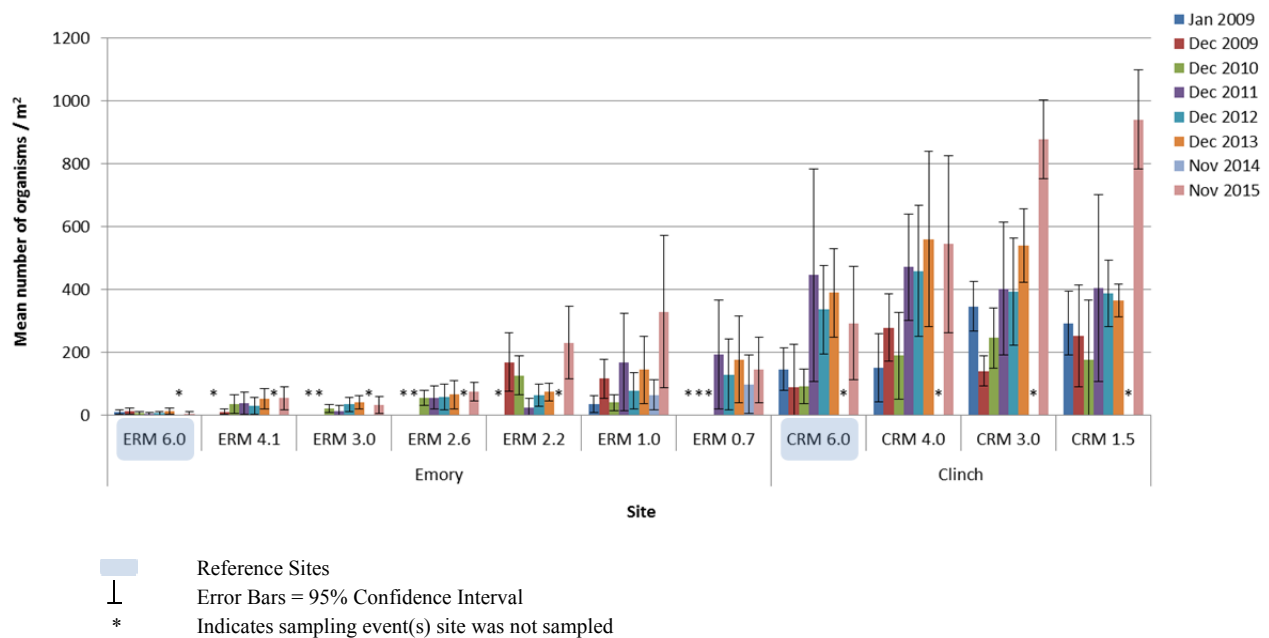


Figure 4. Mean densities of *Hexagenia* at long-term monitoring locations in the Emory and Clinch Rivers, 2009-2015; only Emory River Miles (ERM) 1.0 and 0.7 were sampled in 2014.

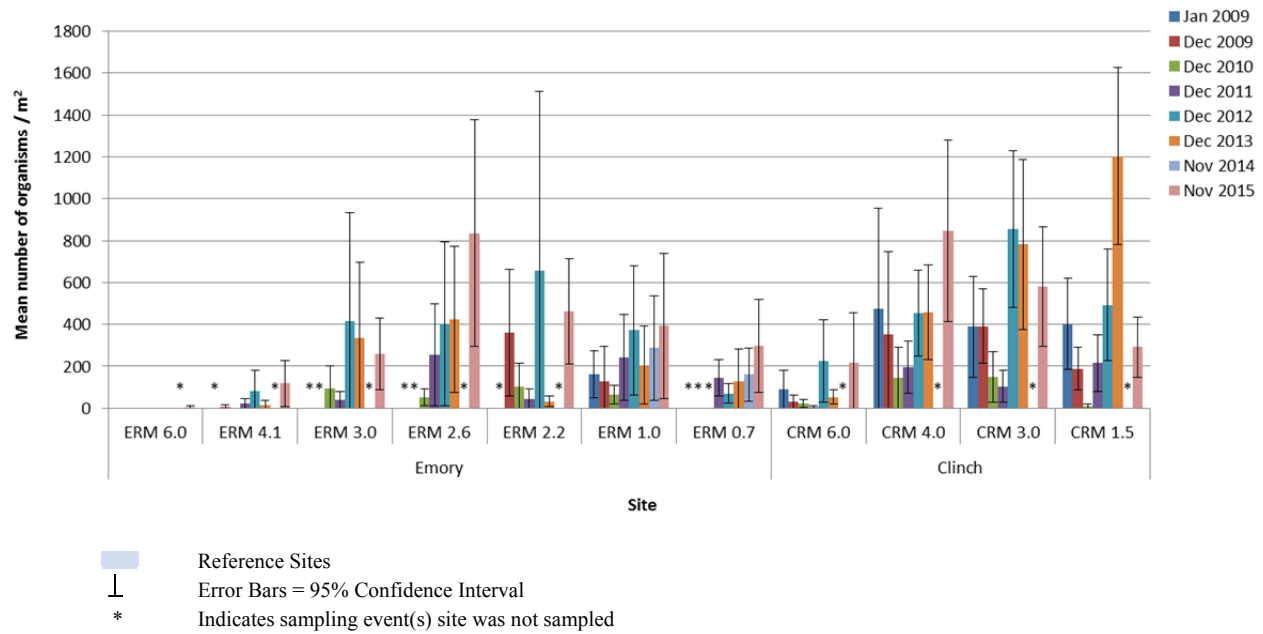


Figure 5. Mean densities of sphaeriid clams at long-term monitoring locations in the Emory and Clinch Rivers, 2009-2015; only Emory River Miles (ERM) 1.0 and 0.7 were sampled in 2014.

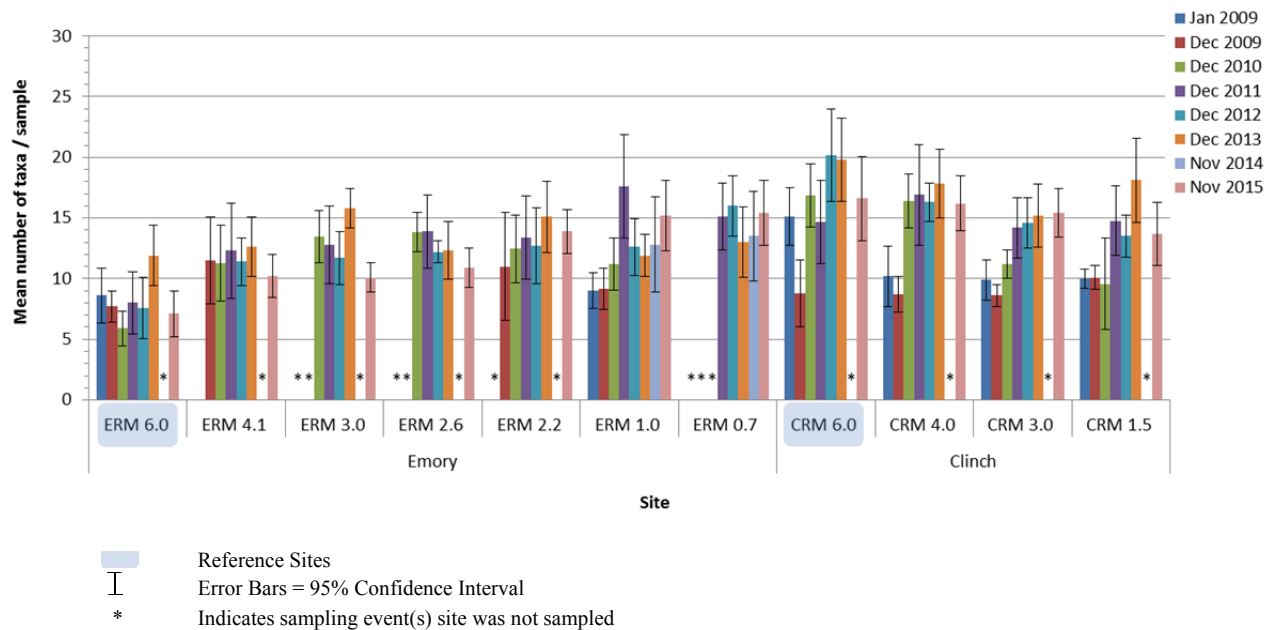
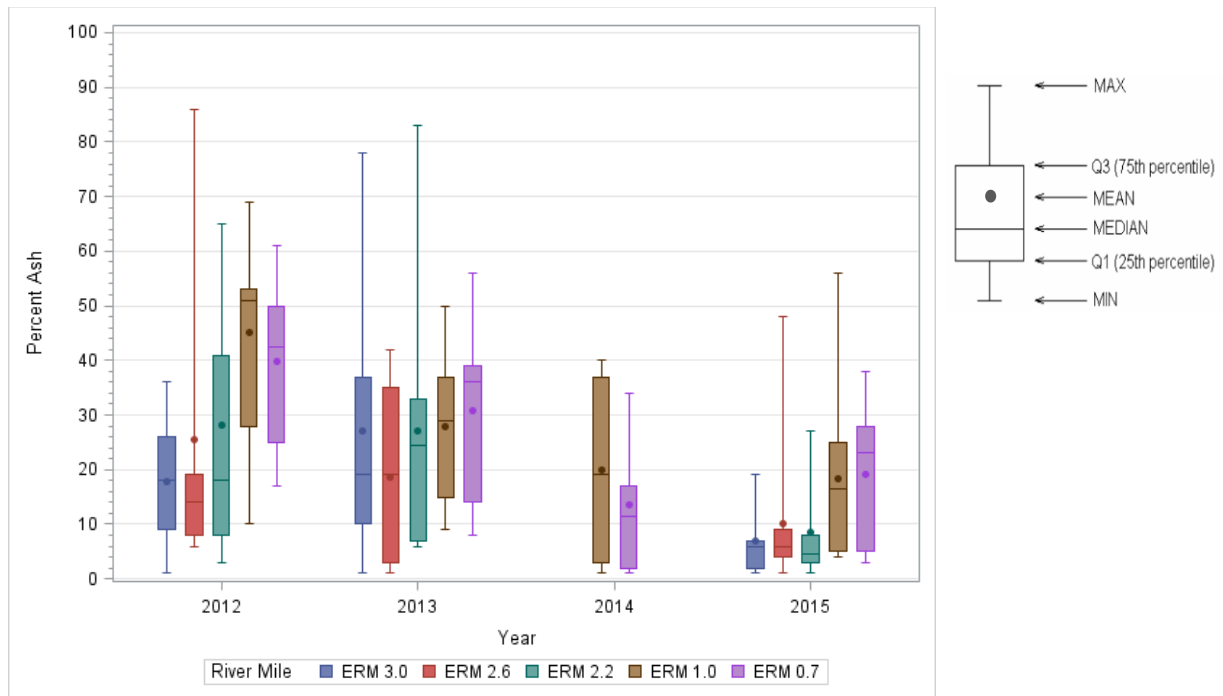
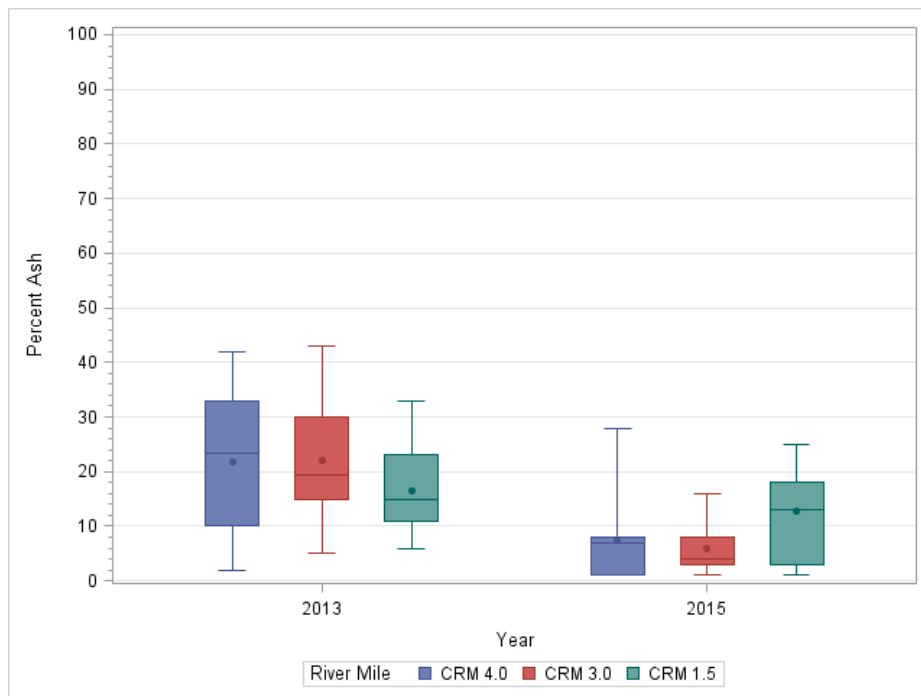


Figure 6. Mean number of benthic invertebrate taxa at long-term monitoring locations in the Emory and Clinch Rivers, 2009-2015; only Emory River Miles (ERM) 1.0 and 0.7 were sampled in 2014.



a. Emory River



b. Clinch River

Figure 7. Percentage ash composition in sediment samples collected co-located with benthic invertebrate community samples in the Emory (a) and Clinch (b) Rivers, 2012-2015.

APPENDIX D

2015 Arcadis Tree Swallow Data Analysis Memorandum





2015 TREE SWALLOW DATA ANALYSIS MEMORANDUM

Kingston, Roane County, Tennessee

March 2016

**2015 TREE SWALLOW
DATA ANALYSIS
MEMORANDUM**

Kingston, Tennessee



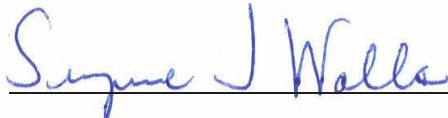
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Figure 4. Historical Trends in Selenium Concentrations in Tree Swallow Eggs

ACRONYMS AND ABBREVIATIONS

COPECs	Constituents of Potential Ecological Concern
ERM	Emory River Mile
mg/kg dw	milligrams per kilogram dry weight
TRM	Tennessee River Mile
site	Tennessee Valley Authority Kingston Fossil Plant

1 TREE SWALLOWS

Tree swallows (*Tachycineta bicolor*) were selected as a representative aerial-feeding insectivorous bird species for Tennessee Valley Authority Kingston Fossil Plant (the site). Tree swallows are a breeding migratory resident in Tennessee, inhabiting standing cavities of dead trees, bluebird boxes, or other artificial structures (Nicholson 1997; Robinson 1990), and foraging 100 to 200 meters around their nest during the breeding season. They commonly prey on a variety of insects, and when nest boxes are placed along aquatic areas, they feed primarily on emergent aquatic insects (U.S. Geological Survey 2003; Blancher and McNicol 1991; Quinney and Ankney 1985). As a result, tree swallow tissue residues often reflect the local sediment contamination for those chemicals that transfer into the aquatic emergent insects (McCarty and Winkler 1999; Froese et al. 1998). Tree swallows serve as a useful receptor in order to understand exposure and potential effects of these constituents on the aerial-feeding insectivorous bird and mammal communities.

In 2015, tree swallow colonies were erected at two locations along the Emory River at Emory River Mile (ERM) 1.4 and ERM 3.0, and at one reference location, Tennessee River Mile (TRM) 572.0 (Figure 1). Boxes were monitored daily at colony from April through July. A detailed description of the collection methods can be found in *Trace Element Concentrations and Productivity in Tree Swallows: 2009-2010* (Appendix Z, Arcadis 2012).

The main study objectives were to 1) determine the extent of maternal transfer of metals and metalloids to the eggs between locations and across years; 2) evaluate tree swallow reproductive success among locations and years; and 3) assess impacts to tree swallows by comparing concentrations measured at the study sites with literature-derived effects values, when available.

1.1 Tree Swallow Reproduction

The total number of eggs (clutch size), the number of eggs that hatched (hatching success), the number of young that survived to day 15 (fledgling success), and the number of females fledglings produced per nesting female (fecundity) were recorded in 2015 at ERM 1.4, ERM 3.0, and TRM 572.0 colonies. In addition, egg mass and volume were recorded, as well as morphological measures (egg length and width) (Table 1).

In 2015, there were no apparent differences identified in clutch size, hatching success, fledgling success, or fecundity among colonies ($p > 0.05$). Further, no differences were observed for egg volume, egg mass, egg length, or egg width ($p > 0.05$). Temporal comparisons of hatching success at ERM 1.4 and TRM 572.0 were conducted using data from 2013, 2014, and 2015 (Figure 2). While this evaluation indicated statistically lower hatching success at ERM 1.4 compared to the reference at TRM 572.0 ($p = 0.02$), there were no differences in fledgling success or fecundity over time ($p > 0.05$). There were insufficient reproductive data at ERM 3.0 for temporal comparisons; however, the lack of differences in 2015 metrics indicate that reproductive success has not been significantly impacted at ERM 3.0.

1.2 Tree Swallow Bioaccumulation

In 2015, tree swallow eggs were collected to evaluate exposure of tree swallows to ash-related constituents of potential ecological concern (COPECs). Eggs were of particular interest as some ash-related COPECs can be maternally transferred from the adult female to her young. When possible, the first egg laid from each available nest was collected within 3 days of clutch completion. A total of 25 eggs were collected from each colony. Eggs were frozen and prepared for trace element analysis. Concentrations of arsenic and selenium in egg tissue collected in 2015 are presented in Table 2 and Figure 3. Arsenic was detected in only two of 25 samples from ERM 1.4 and was below the detection limit in all samples from ERM 3.0 and TRM 572.0. Both detections from ERM 1.4 were within the range of detection limits and were considered estimated (J-flagged). Consequently, arsenic concentrations were not significantly different between locations and are not discussed further.

A nonparametric analysis of variance was used to compare selenium concentrations in eggs among colonies, and post hoc Dunnetts tests were used to further identify difference between selenium concentrations at each impacted colony compared to the reference colony. The results showed a statistically significant difference among the colonies ($p < 0.0001$), with higher average concentration at ERM 1.4 and ERM 3.0 (3.86 milligrams per kilogram dry weight [mg/kg dw] and 4.03 mg/kg dw, respectively) compared to TRM 572.0 (3.50 mg/kg dw) ($p < 0.0001$). When compared to previous years of data, 2015 selenium concentrations at ERM 1.4 were higher than concentrations in 2014, but were similar to 2013 data and were within the range of concentrations from the reference site in 2015 (Figure 3). Selenium concentrations at ERM 3.0 were not available in 2014 or 2013 for comparison, but were within the range of concentrations from the reference site in 2015 (Figure 3).

Literature studies of selenium in eggs of other species have recently been reviewed and suggest threshold effects (EC_{10}) concentrations ranging from 7.7 to 60 mg/kg dw in various species of avian eggs (Janz et al. 2010). Similar to previous years, selenium concentrations in eggs collected from ERM 1.4 and ERM 3.0 in 2015 were below the most conservative of these literature values (Figure 4). While one egg collected in 2015 had a selenium concentration above the conservative EC_{10} (8.69 mg/kg dw), this egg was from the reference colony at TRM 572.0 and does not reflect potential impacts from the ash release (Figure 3).

Correlations between reproductive metrics and selenium were conducted using data from 2011 through 2015. These evaluations identified a weak statistically significant negative relationship between selenium concentrations and fledgling success ($r = -0.16$, $p = 0.04$); however, no relationship was identified between selenium concentrations and overall fecundity, indicating that the correlation between selenium and fledgling success was not strong enough to adversely impact the tree swallow population.

1.3 Summary

Overall, the results of the 2015 tree swallow data collections indicate that some differences in reproductive metrics and selenium concentrations in eggs are occurring between impacted colonies and the reference colony. These differences are likely not significant enough to adversely affect the tree swallow population. Based on these results, no further tree swallow monitoring is recommended for upcoming years at this time.

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TABLES



Table 1
Tree Swallow Reproduction Metrics Summary for 2015
Tennessee Valley Authority
Kingston, Tennessee

Metric	Location	Number of Samples	Mean $\pm$ SD	Range	SE
Clutch Size (Number of Eggs)	Emory River				
	ERM 1.4	49	5.08 $\pm$ 0.89	2 - 7	0.13
	ERM 3.0	56	5.04 $\pm$ 0.95	3 - 7	0.13
	Tennessee River				
	TRM 572.0	44	5.20 $\pm$ 0.88	3 - 7	0.13
Fecundity (Number of Fledglings)	Emory River				
	ERM 1.4	40	2.15 $\pm$ 0.72	0 - 3.0	0.11
	ERM 3.0	43	1.87 $\pm$ 1.01	0 - 3.5	0.15
	Tennessee River				
	TRM 572.0	21	2.28 $\pm$ 0.61	0.5 - 3.0	0.13
Hatching Success (%)	Emory River				
	ERM 1.4	44	91% $\pm$ 12%	60% - 100%	2%
	ERM 3.0	56	87% $\pm$ 25%	0% - 100%	3%
	Tennessee River				
	TRM 572.0	31	94% $\pm$ 15%	25% - 100%	3%
Fledgling Success (%)	Emory River				
	ERM 1.4	40	90% $\pm$ 24%	0% - 100%	4%
	ERM 3.0	43	80% $\pm$ 35%	0% - 100%	5%
	Tennessee River				
	TRM 572.0	21	95% $\pm$ 10%	75% - 100%	2%
Egg Length (cm)	Emory River				
	ERM 1.4	25	1.87 $\pm$ 0.07	1.74 - 2.01	0.01
	ERM 3.0	29	1.88 $\pm$ 0.09	1.65 - 2.04	0.02
	Tennessee River				
	TRM 572.0	25	1.89 $\pm$ 0.09	1.69 - 2.05	0.02
Egg Width (cm)	Emory River				
	ERM 1.4	25	1.33 $\pm$ 0.07	1.24 - 1.54	0.01
	ERM 3.0	29	1.32 $\pm$ 0.05	1.22 - 1.40	0.01
	Tennessee River				
	TRM 572.0	25	1.32 $\pm$ 0.04	1.21 - 1.40	0.01
Egg Weight (g)	Emory River				
	ERM 1.4	25	1.73 $\pm$ 0.16	1.41 - 2.21	0.03
	ERM 3.0	29	1.64 $\pm$ 0.25	0.57 - 2.04	0.05
	Tennessee River				
	TRM 572.0	25	1.69 $\pm$ 0.14	1.42 - 1.90	0.03
Egg Volume (cm ³)	Emory River				
	ERM 1.4	25	1.70 $\pm$ 0.19	1.42 - 2.28	0.04
	ERM 3.0	29	1.67 $\pm$ 0.16	1.40 - 1.98	0.03
	Tennessee River				
	TRM 572.0	25	1.68 $\pm$ 0.13	1.42 - 1.88	0.03

Acronyms and Abbreviations:

cm = centimeter

ERM = Emory River Mile

g = gram

mg/kg dw = milligrams per kilogram dry weight

SD = standard deviation

SE = standard error

TRM = Tennessee River Mile

Table 2
Tree Swallow Egg Summary Statistics for 2015
Tennessee Valley Authority
Kingston, Tennessee

Analyte	Location	Number of Detects	Number of Samples	Mean ^a ± SD	Range	SE
Arsenic	Emory River					
	ERM 1.4	2	25	0.103 ± 0.04	0.065 - 0.19	0.008
	ERM 3.0	0	25	0.102 ± 0.045	0.06 - 0.223	0.009
	Tennessee River					
	TRM 572.0	0	25	0.187 ± 0.126	0.06 - 0.505	0.025
Selenium	Emory River					
	ERM 1.4	25	25	3.86 ± 0.93	2.39 - 6.52	0.19
	ERM 3.0	25	25	4.03 ± 1.19	2.44 - 7.06	0.24
	Tennessee River					
	TRM 572.0	25	25	3.5 ± 1.48	1.79 - 8.69	0.3

Footnotes:

a. Mean calculations include reporting limits substituted for non-detects; concentrations presented in mg/kg dw.

Acronyms and Abbreviations:

ERM = Emory River Mile

mg/kg dw = milligrams per kilogram dry weight

NC = Not calculated because all samples were non-detects; range represents reporting limits only

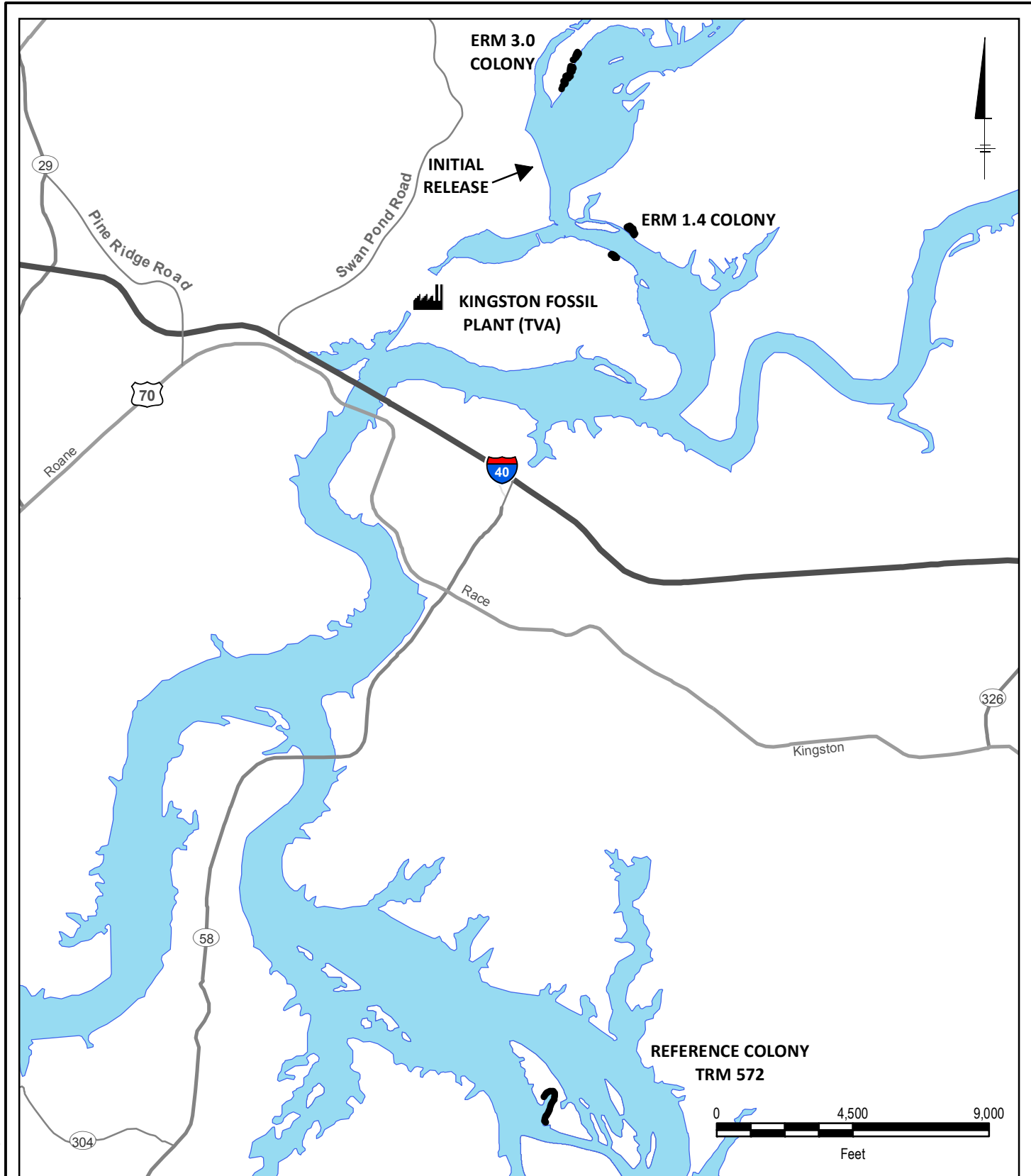
SD = standard deviation

SE = standard error

TRM = Tennessee River Mile

FIGURES





Service Layer Credits:

Legend

- 2015 Tree Swallow Box Location

TENNESSEE VALLEY AUTHORITY
 KINGSTON, TENNESSEE
2015 TREE SWALLOW DATA ANALYSIS MEMORANDUM

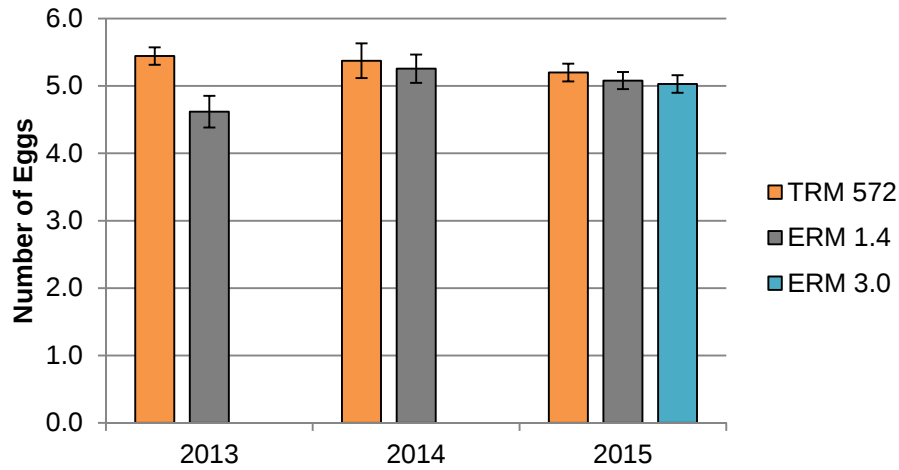
2015 Tree Swallow Box Locations



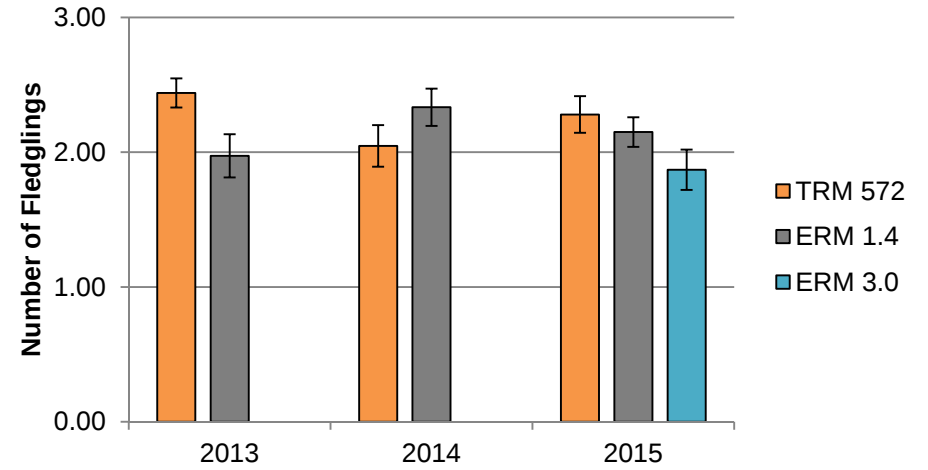
FIGURE

1

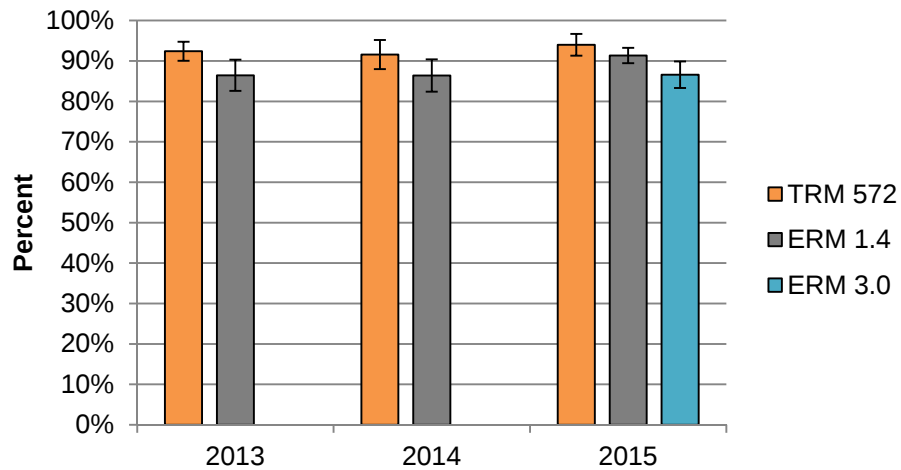
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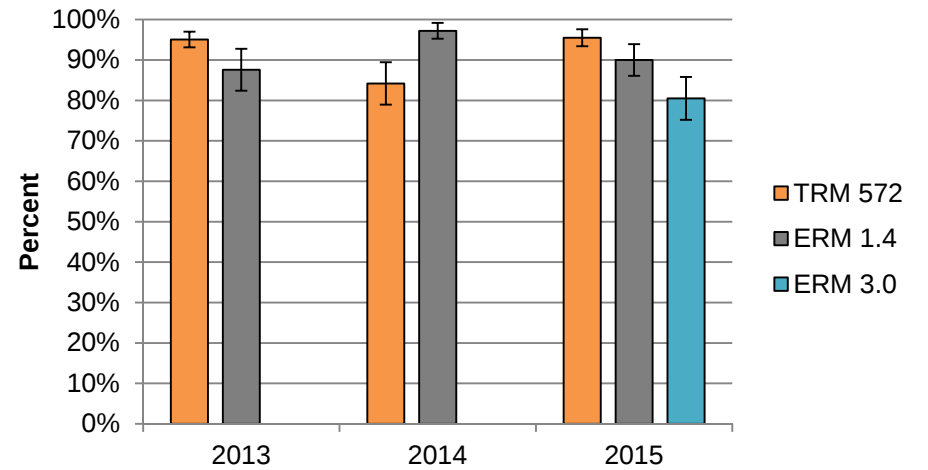
Fecundity



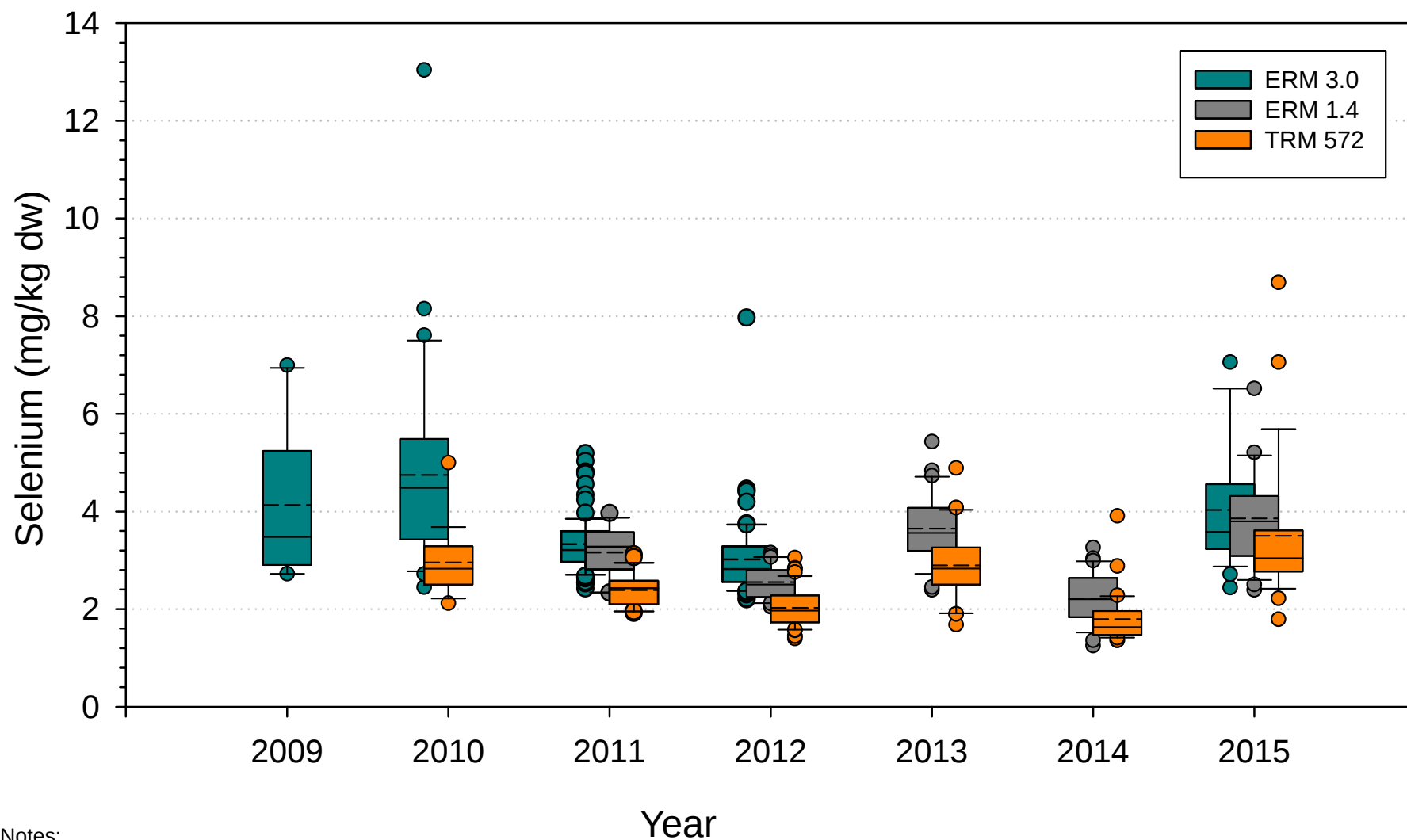
Hatching Success



Fledgling Success

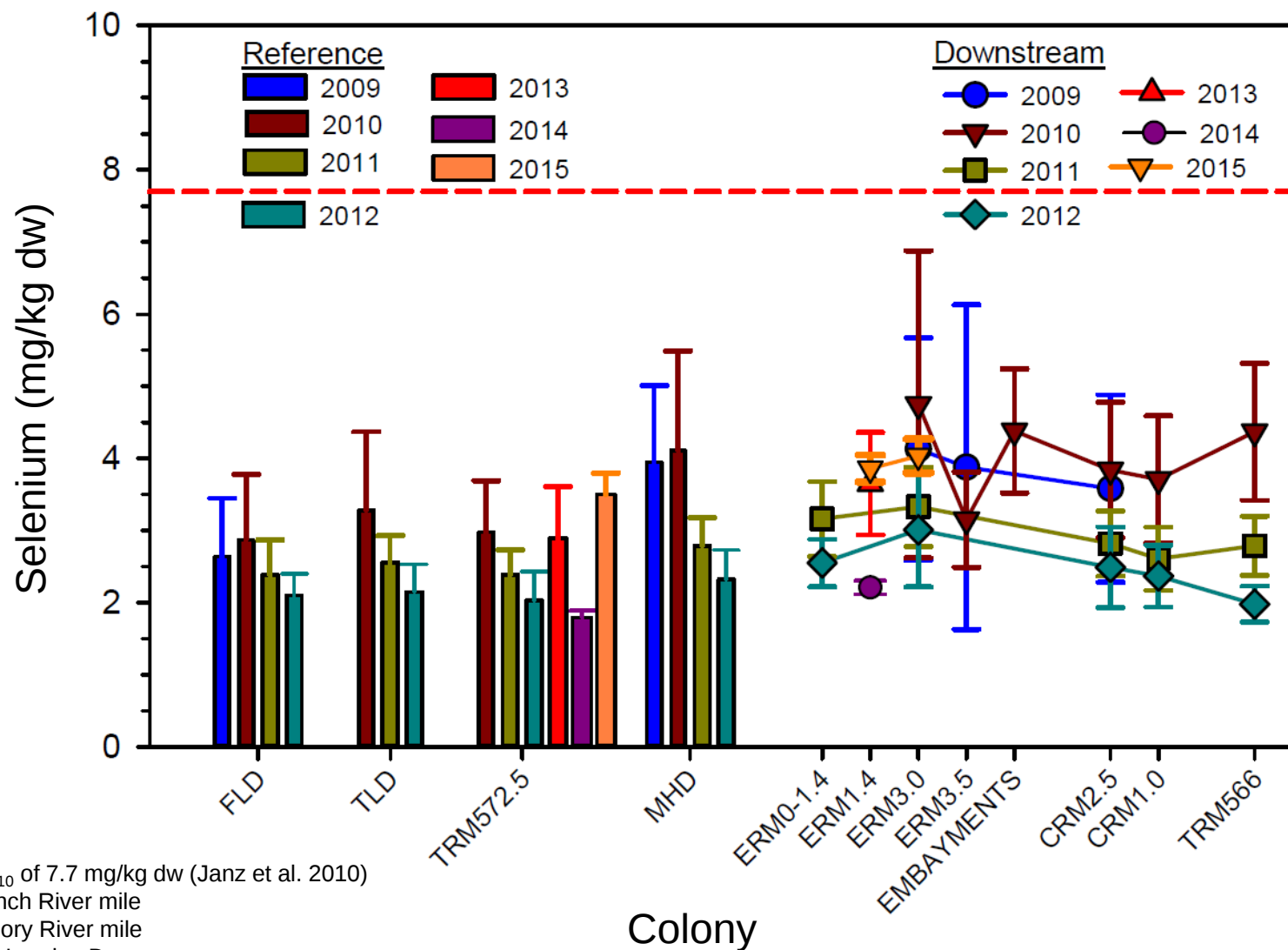


Notes:
ERM = Emory River mile
TRM = Tennessee River mile (Reference)



Notes:
 ERM = Emory River mile
 TRM = Tennessee River mile (Reference)

Selenium Concentrations in Tree Swallow Eggs: 2009 – 2015
 2015 Tree Swallow Data Analysis Memorandum
 TENNESSEE VALLEY AUTHORITY
 KINGSTON, TENNESSEE



Historical Trends in Selenium Concentrations in Tree Swallow Eggs
 2015 Tree Swallow Data Analysis Memorandum
 TENNESSEE VALLEY AUTHORITY
 KINGSTON, TENNESSEE

FIGURE

4

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A decorative graphic consisting of three thin orange lines. One line is horizontal, extending from the left edge of the page towards the right. Two other lines are diagonal, starting from the bottom left and extending towards the top right, intersecting the horizontal line.

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