Mercury Air Deposition and Selenium Levels in Tennessee Fish and Surface Water

Tennessee Department of Environment and Conservation
Division of Water Pollution Control

7th Floor L&C Annex
401 Church Street
Nashville, TN 37243-1534

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By

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December 2010

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ACKNOWLEDGMENTS

This study was funded by 2009 604(b) planning and economic stimulus money. This report was prepared in partial fulfillment of the requirements of that grant. The study was coordinated by the Planning and Standards Section, Division of Water Pollution Control, Tennessee Department of Environment and Conservation. Greg Denton is the manager of that section. Deborah Arnwine was project coordinator for the study. Linda Cartwright was responsible for sample tracking and quality assurance. Michael Graf was responsible for processing data as well as GIS mapping.

The Environmental Laboratory, Tennessee Department of Health (TDH) collected and analyzed the samples. Dr Bob Read is the director of the laboratory. Patricia Alicea is the manager of the Aquatic Biology Section, which conducted the field portion of the study including site reconnaissance, sample collection, field measurements and fillet of fish samples. The TDH Inorganic Chemistry Laboratory in Nashville analyzed the samples. Craig Edwards is the section manager.

Water Pollution Control staff from the eight Environmental Field Offices provided information for site selection. The field office managers are:

Chattanooga EFO	Dick Urban	Johnson City EFO	Jeff Horton
Columbia EFO	Ryan Owens	Knoxville EFO	Paul Schmierbach
Cookeville EFO	Rob Howard	Memphis EFO	Terry Templeton
Jackson EFO	Pat Patrick	Nashville EFO	Joe Holland

The Division of Air Pollution, under the direction of Barry Stephens, provided information on sources of air-borne mercury in Tennessee.

Cover photo of fish tissue sampling provided by Aquatic Biology Section, TDH.

EXECUTIVE SUMMARY

In summer and fall 2009, the Division of Water Pollution Control, TDEC conducted a fish tissue and water chemistry monitoring study on 33 waterbodies across the state. Since this project was funded by 604(b) planning and economic stimulus money, objectives were based on both environmental innovations and economic stimulus.

The study was designed to field test the Regional Modeling System for Aerosols and Deposition (REMSAD) model's ability to accurately predict waterbody and fish tissue contamination from air deposition of mercury in Tennessee. The model was developed in 2005 by System Application International/ICF International through an EPA contract. Thirty three sites were targeted for this study. Sites were located in areas where the model predicted various levels of mercury deposition. Additional sites were located in areas where the model did not predict elevated mercury, but where potential sources of airborne mercury were located in the vicinity. Fish tissue and water samples were collected at each site.

Mercury concentrations from the most elevated fish species at each site were mapped with the REMSAD model predictions. Results were variable, but in general, the model did not appear to be a good predictor of fish tissue contamination. Several fish taken from areas with predicted high levels of air deposition contained relatively little mercury. Fish with higher concentrations of mercury came from areas with low predicted air deposition. Six fish fillet composites had elevated mercury. None of these were in areas where the REMSAD mercury air deposition prediction was highest.

Mercury was undetected in the water samples at most sites. Five sites had mercury above Tennessee's water quality criterion for the classified use of recreation. None of the elevated water samples were collected where air deposition predictions were highest.

Selenium was also analyzed in fish and water at each site to help gain a better understanding of selenium levels throughout the state. Selenium in both fish and water was generally low. Only two sites had fish levels above the concentration suggested in EPA's 2004 draft guidance. Both are in areas of significant land disturbance due to historic mining activities. Selenium was not detected in any water samples.

1. INTRODUCTION

In summer and fall 2009, the Division of Water Pollution Control, TDEC conducted a fish tissue and water chemistry monitoring study on 33 waterbodies across the state. Since this project was funded by 604(b) planning and economic stimulus money, objectives were based on environmental innovations and economic stimulus.

Environmental innovations:

- Cooperative effort between three state divisions (air, water and health) to locate waterbodies where people and wildlife may be exposed to mercury from eating fish. This is the first time the state specifically targeted air sources that may be contributing pollutants to waterbodies.

- Field testing of a new computer model that predicts the location of mercury deposition from air sources. An accurate predictive model could be used as a tool for locating vulnerable waterbodies as well as sources that need additional environmental controls to prevent pollution.

- Use of selenium data to help refine water quality criteria (both fish and water based) as well as build a database to help protect fish-eating wildlife. Prior to this study, the state had few selenium data from whole-body fish and limited water data.

Economic Stimulus objectives:

- Partial funding of biologist and chemist positions in Department of Health Environmental Laboratories, TDH. These positions are dependent on cost recovery from the Division of Water Pollution Control, TDEC for contracted services.

- Fish tissue monitoring by TDEC is currently focused on large reservoirs with most of the monitoring conducted by federal agencies. This study expanded the state program to include smaller lakes requiring planning, monitoring and lab analyses.

- Recreational fishing is an important part of the local economy in many areas of the state. Local businesses profit from the sale of bait, supplies, beverages, food, gasoline, ramp fees, boat rentals and hotel rooms. Assuring that fish are safe to eat and improving water quality helps promote these businesses.

- This project was labor-intensive with relatively small supply costs and was implemented with existing equipment. The majority of federal dollars was spent on funding positions.

a. Mercury

Mercury is a naturally occurring element found in air, water and soil. It exists in several forms: elemental or metallic mercury, inorganic mercury compounds, and organic mercury compounds. There is a well-documented link to human health impacts. In pregnant women, ingested mercury is readily carried throughout the body by the bloodstream and easily migrates through the placenta to a developing fetus. The consumption of contaminated fish is considered to be the major pathway of mercury exposure for most people.

Natural sources of mercury include volcanoes, geysers, weathering of rocks, and forest fires. However, there are significant anthropogenic sources of mercury. Mercury is found in many rocks including coal. When coal is burned, mercury is released into the environment. According to the EPA 2005 national emissions inventory, coal-burning power plants are the largest human-caused source of mercury air emissions in the United States, accounting for over 50 percent of all domestic human-caused mercury emissions.

Air emissions can transport long distances before ultimately being deposited on watersheds and in waterbodies. Mercury deposited within state boundaries may be generated from emission sources outside the state. Atmospheric deposition of mercury is a primary route of transport of mercury to water. Once in a waterbody, mercury can form chemical compounds with organic molecules through a process known as methylation (NESCAUM 2007). Methlymercury is more toxic to humans and other animals than inorganic forms. Mercury methylation rates can be influenced by a number of factors such as acidity, dissolved sulfate, and dissolved organic carbon (Wiener et al., 2006). It is the methylated form of mercury that enters the aquatic food chain and can ultimately bioaccumulate in fish tissue to concentrations much higher than in the surrounding water. (NESCAUM 2007).

There are currently 263 stream miles and 67,562 reservoir acres assessed as impaired by mercury in Tennessee (TDEC, 2010). This is due to a variety of sources including current and legacy industrial discharges, contaminated bridges and air deposition. One percent of streams and 26 percent of reservoirs in the state are assessed as affected by air deposition.

Fossil burning plants are a leading source of air-borne mercury.

Photo courtesy of TVA

b. Selenium

Selenium is a naturally occurring chemical element that is also an essential micronutrient. Selenium is found in organic-rich shales that are source rocks formations for oil, coal, and phosphate ores. Trace amounts of selenium are required for normal cellular function in almost all animals. However, excessive amounts of selenium can have toxic effects especially to fish and birds. Mammals have a higher tolerance to selenium.

Selenium can enter surface waters through both natural and anthropogenic processes. Natural sources of selenium include volatilization of selenium in soil by plants and bacteria, weathering of selenium rich rocks, soil erosion, and volcanic activity. Sources of selenium resulting from human activities include petroleum refining, power production, and mining. Selenium can enter surface waters from a variety of agricultural activities including irrigation and the use of selenium as a dietary supplement for livestock. Manure produced in concentrated animal feeding operations may contain selenium that can enter surface waters either directly when spilled from holding lagoons, or indirectly after being applied to fields.

Atmospheric emissions of selenium originates from power plants and other facilities that burn coal or oil, refineries that process selenium for industrial users, base metal smelters and refineries, resource extraction industries, milling operations, and semiconductor manufacturers. Airborne selenium particles can settle either directly on surface waters or on soils from which selenium is deposited into waterbodies through tile drains or runoff.

Selenium is found in water as both selenite and selenate. Selenite tends to dominate in slow moving waters such as lakes and reservoirs. Selenite is more bioavailable than selenate. For the 2009 study, only total selenium was analyzed. Unless water data are speciated, fish tissue samples are probably a better predictor of selenium availability in the food chain. There are currently no waterbodies impaired due to selenium in the state. This is based on the current chronic water criterion of 5 µg/L for fish and aquatic life.

2. STUDY DESIGN

a. REMSAD Model

The study was designed to field test the Regional Modeling System for Aerosols and Deposition (REMSAD) model's ability to accurately predict waterbody and fish tissue contamination from air deposition of mercury in Tennessee. The model was developed in 2005 by System Application International/ICF International through an EPA contract. It was designed to provide information on the distribution and composition of particulate matter, the deposition of pollutants onto the surfaces of inland and coastal waterbodies, and also changes in air quality and deposition that result from changes in emissions. REMSAD estimates concentrations of pollutants for a given area by taking into account emission levels from known sources and meteorological factors, such as wind patterns, temperature, precipitation, surface pressure, specific humidity, and vertical diffusion.

The REMSAD model analyzes several different forms of mercury that are present in the atmosphere, which include HG0 (elemental mercury vapor), HG2 (mercury compounds in a gas phase), and HGP (mercury compounds in a particulate phase). The model simulates both wet and dry deposition of mercury. Wet deposition occurs as a result of precipitation scavenging, in which mercury is removed from the air by attaching to water vapors or rain/snow, which is most efficient at removing divalent mercury (a soluble form) from the air. Dry deposition is when the pollutants settle directly from the atmosphere on their own. It should be noted that not all of the forms of mercury and the processes of mercury cycling within the environment, such as bioaccumulation and methylation are simulated by the REMSAD model.

The GIS layer that was used for analysis of the REMSAD model divides the United States into a grid of cells with a 12-km horizontal resolution (Figure 1). Each cell has a value for estimated mercury deposition. The deposition is measured in grams/km²/year. In Tennessee, these values ranged from 12 g/km²/year up to 65 g/km²/year (Figure 2). The mean and median deposition values for Tennessee were similar to the southeastern states, as well as those east of the Mississippi River although maximum levels were far lower (Table 1).

The REMSAD Particle and Precursor Tagging Methodology (PPTM), referred to as "tagging," was used to track emissions from selected sources and source categories and to quantify their contribution to simulated annual mercury deposition totals. There were five tagged sources assigned in Tennessee (USEPA, 2008). The first three tags were assigned to the top three emitters of divalent gaseous mercury: the Gallatin, Johnsonville, and Kingston Fossil Plants. According to the Tennessee Division of Air Pollution Control, three other fossil plants are higher emitters of mercury including Cumberland (the largest fossil plant in Tennessee), Bull Run and John Sevier. These facilities were not tagged by the REMSAD model as a top emitter, but were probably included in the collective sources tag. The top total mercury emitter not already tagged was assigned the fourth tag for the REMSAD model, which was the Olin Corporation. Eastman Chemical Company, with emissions greater than any of the three tagged fossil plants was not tagged individually but was probably included in collective sources. The fifth tag collectively tagged all remaining emitters. An inventory of mercury emitting facilities within the state of Tennessee compiled by the Tennessee Division of Air Pollution Control is provided in Appendix A.

Table 1: Regional comparison of REMSAD mercury air deposition.

	Tennessee	**Southeastern U.S.** (EPA Region 4)	**Eastern U.S.** (east of MS River)
Min	12.0	12.0	6.3
Max	65.1	450.6	450.6
Median	25.4	26.1	23.6
Mean	26.5	27.2	23.9

Units are g/km²/year

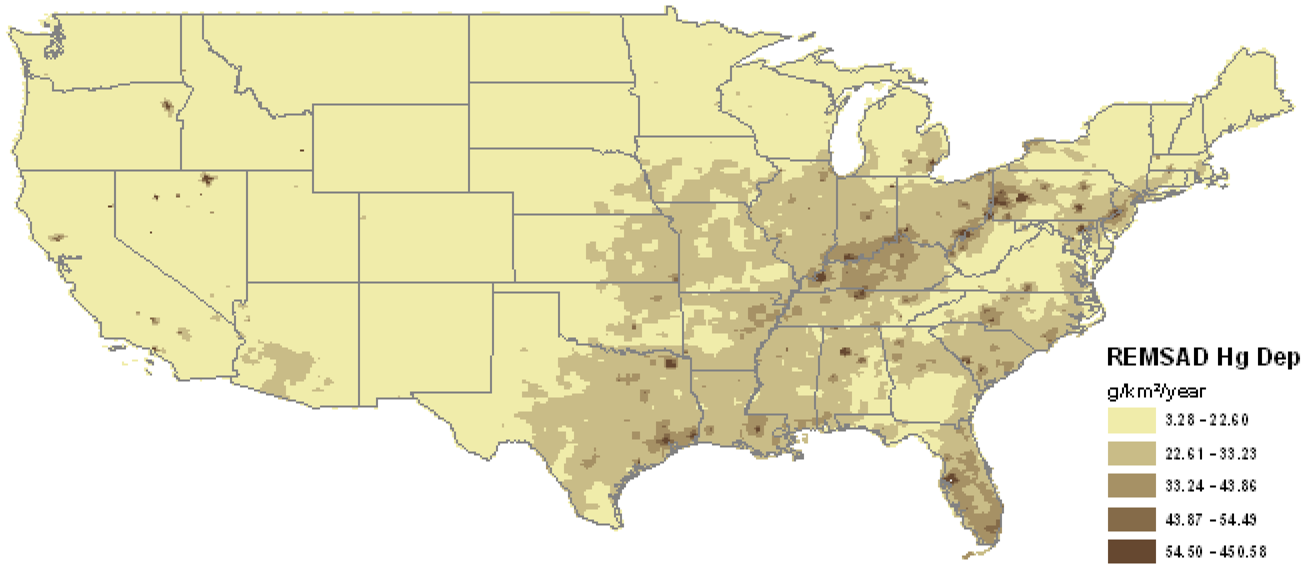

Figure 1: National REMSAD mercury deposition levels.

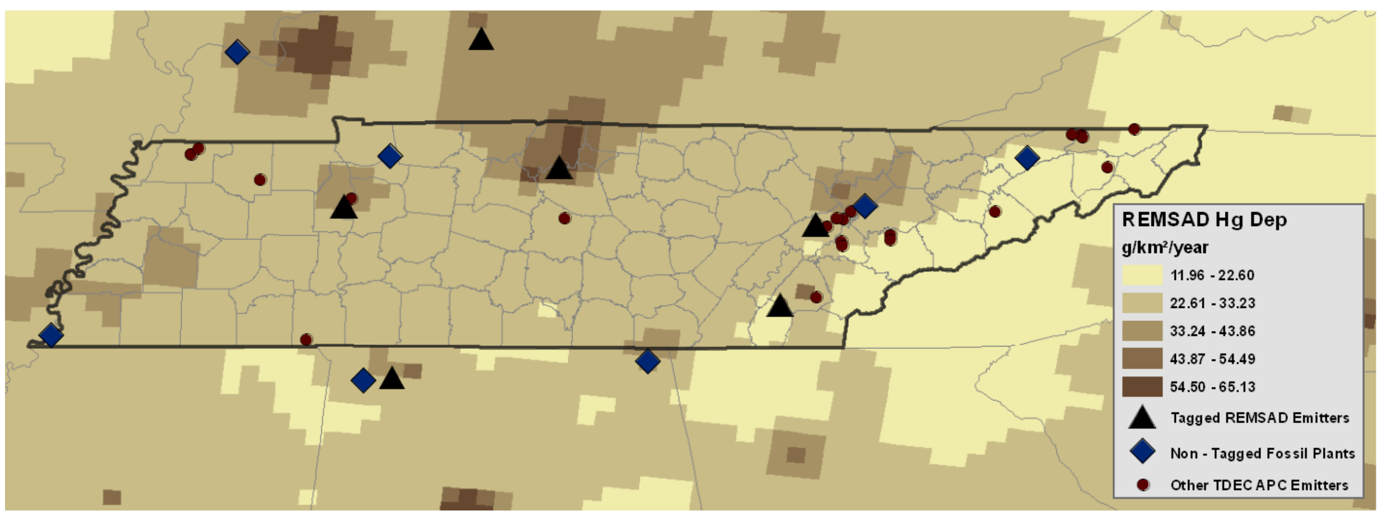

Figure 2: Tennessee REMSAD mercury deposition levels and emitters.

b. Site Selection

Thirty three monitoring sites were targeted for this study (Figure 3). A list of sites including locations is provided in appendix B. Sites were located in areas where the model predicted the highest levels of mercury deposition (Figure 3 and Table 2). Additional sites were located in areas where the model did not predict elevated mercury, but where potential sources of airborne mercury such as the Cumberland Fossil Plant were located in the vicinity.

Where possible, small isolated lakes where fish populations where not able to migrate in or out of the area were selected. Otherwise the head of embayment areas in larger reservoirs were targeted. In cases where there were no lakes within the targeted area, streams were used.

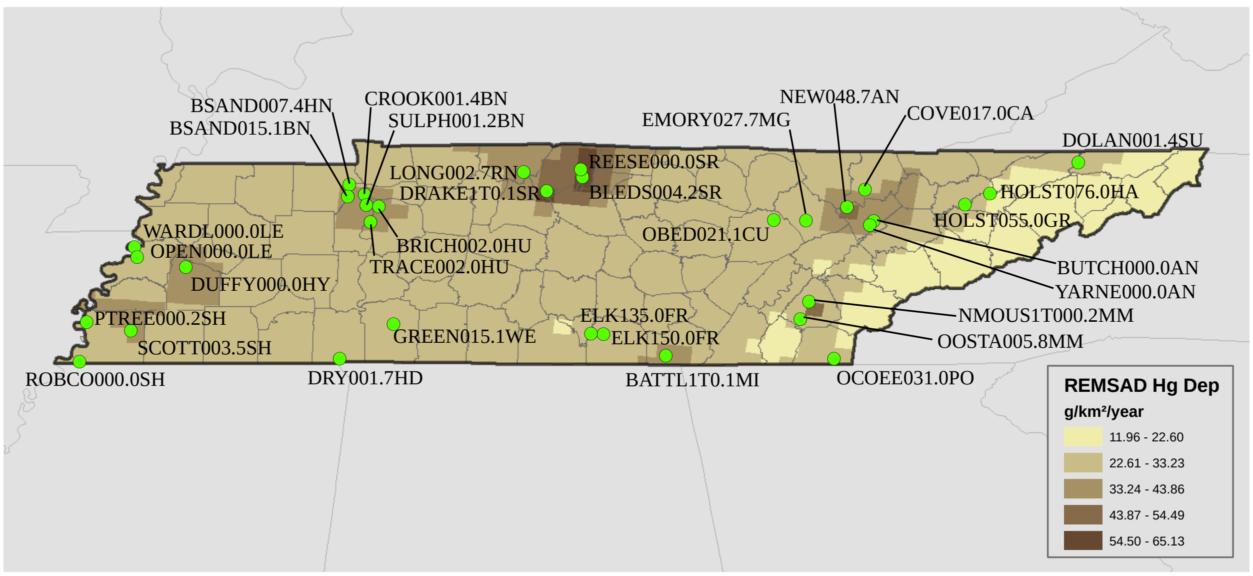

Figure 3: Location of fish tissue and water sampling sites.

Table 2: Number of sample sites located in each RAMSAD mercury deposition category.

RAMSAD Hg Deposition $g/km^2/year$	Number of Sampling Sites
11.96-22.60	1
22.61-33.23	15
33.24-43.86	12
43.87-54.49	3
54.50-65.13	2

3. SAMPLE METHODOLOGY

Fish and water chemistry samples were collected between July and November 2009. Aquatic biologists from the Tennessee Department of Health (TDH) Environmental Laboratories collected all samples. Fish were weighed, measured and filleted in the laboratory following TDEC and TDH procedures. Fish were composited and analyzed by inorganic chemists at the same laboratory following TDH standard operating procedures and quality assurance. Chain of custody was maintained on all samples.

a. Fish Tissue

Game fish are generally more likely to bioaccumulate mercury than are fatty fish. Therefore, two game fish species were targeted at each site. Selected species were representative of the most common native populations in the waterbody and did not include stocked species. Nine fish species were collected (Table 3). Largemouth bass and bluegill sunfish were the most frequently collected.

Twenty fish (10 from each of two species) were collected at each site. Fish were analyzed in 5-fish composites of similar size and same species. For each species, one composite was filleted (scaled, skin-on, include belly flap) to represent human consumption. The other composite was analyzed whole-body to represent wildlife consumption. Mercury and selenium (wet weight) were analyzed for each composite.

b. Water Chemistry

A Kemmerer discrete depth sampler was used to collect water samples in conjunction with the fish samples. The samples were collected mid-depth in the middle of the targeted waterbody. Equipment blanks, duplicates, trip blanks and field blanks were collected at ten percent of the sites. Mercury and selenium were analyzed on all water samples.

4. MERCURY RESULTS

a. Fish Tissue

Mercury concentrations from the highest fish species at each site were mapped with the REMSAD model predictions (Figures 4 and 5). Results were variable, but in general, the model did not appear to be a good predictor of fish tissue contamination. Several fish taken from areas with predicted high levels of air deposition contained relatively little mercury. Fish with higher concentrations of mercury came from areas with low predicted air deposition.

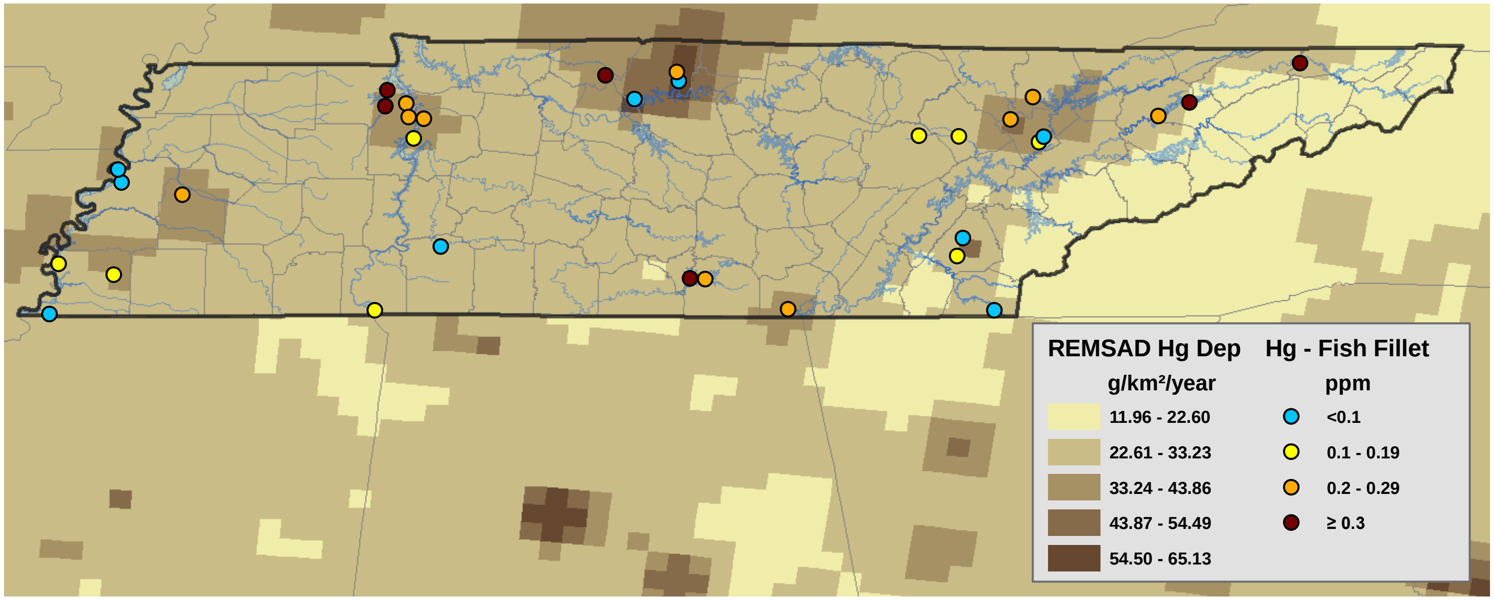

Figure 4: Fish fillet mercury concentrations by location. Values represent the highest game fish composite at each site.

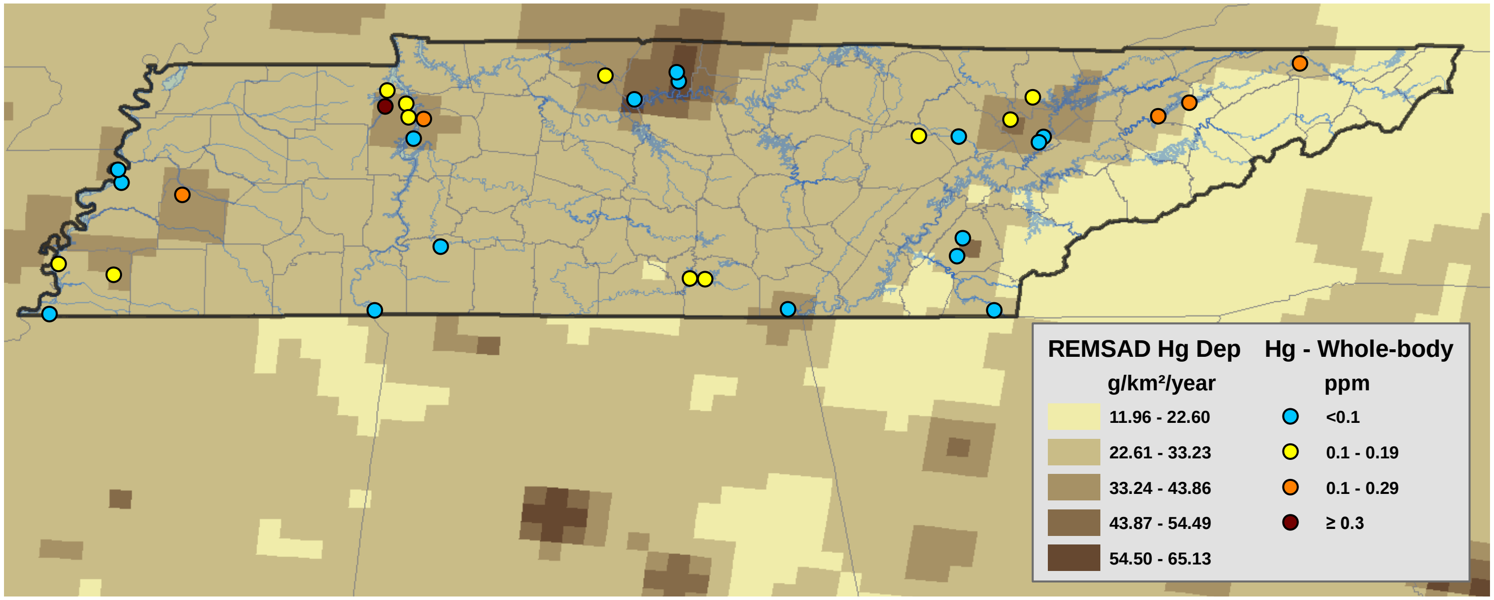

Figure 5: Whole-body fish mercury concentrations by location. Values represent the highest game fish composite at each site.

Regression analysis indicated no statistical correlation (r-square = 0.007) between the model and mercury levels in fish when the highest composite was used from each site (Figure 6). If all 66 fish samples were used, the r-square would be 0.014 still indicating no relationship. The large degree of variability between the fish fillet mercury concentrations and the REMSAD deposition is represented by the distance that the plotted values are from the regression line, which are the predicted values for a close relationship.

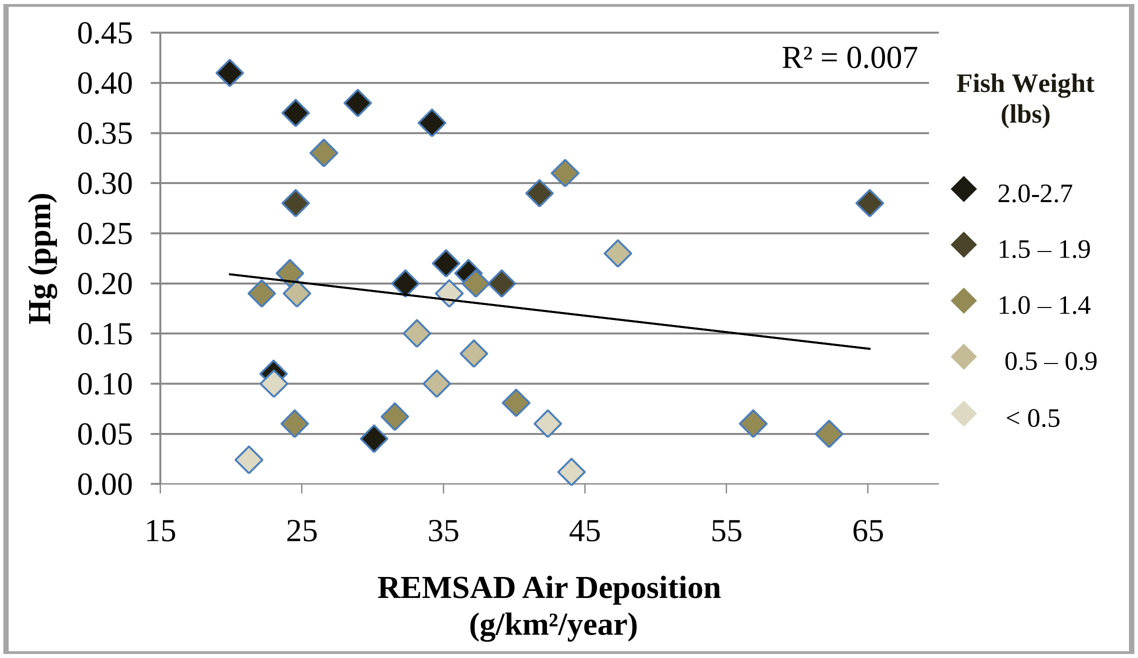

Figure 6: Relationship between mercury in fish fillets and predicted REMSAD air deposition. Species with the highest mercury concentration were plotted from each site.

Fish weight appeared to have more influence on mercury levels. The concentrations of mercury in fish fillets were generally higher in the larger fish (Figure 7). Some of the highest concentrations were in fish that were 2.0 - 2.7 pounds (no fish composites exceeded 2.7 pounds). Although some large fish composites had little mercury, those with higher mercury concentrations were in areas predicted to have medium to low air deposition. Regression analysis of mercury concentrations vs. fish weight had an r-square value of 0.500 when all 66 fish (two species from each site) were used (Figure 8). The weight may have a greater correlation with contamination than geographic location relative to predicted mercury deposition areas. Within a given waterbody, it is likely that the larger fish of any one species are older and have had more exposure to mercury than the smaller ones. Biomagnification also increases the potential for the larger and piscivorous fish to have higher levels of mercury.

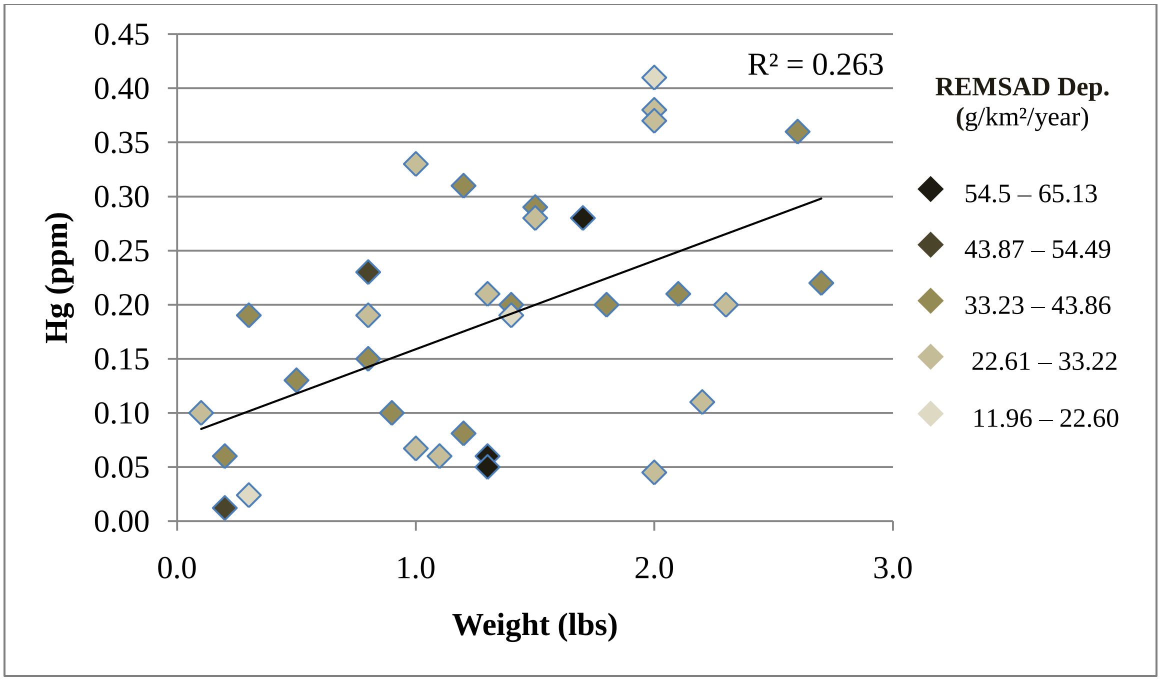

Figure 7: Relationship between fish weight, mercury concentration in fillets and REMSAD air deposition. Data set includes 33 samples (the fish species with the highest mercury level in from each site).

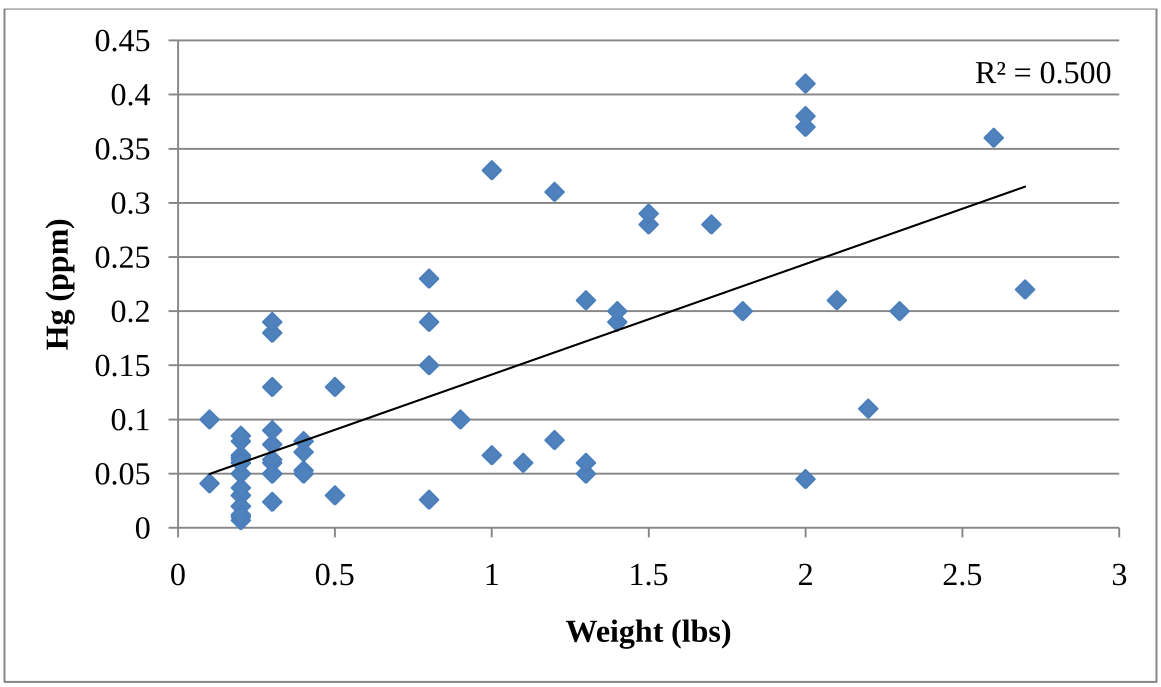

Figure 8: Relationship between fish weight and mercury concentrations in fillets. Data set includes all 66 fish samples collected (2 species from each site).

Fish species appears to be another influence in mercury contamination. Of the species sampled, the largemouth bass had the highest mean mercury concentrations and also the most variability (Table 3 and Figure 9). Largemouth bass are top predators and generally larger than other native game species. These factors result in higher levels of mercury bioaccumulation. Sunfish species, which are smaller and have a more varied diet, were generally lower in mercury when collected from the same site.

Table 3: Summary of mercury results by fish species.

Species of Fish	Number of Samples Analyzed	Mean Hg Concentration - Fillet (ppm)	Mean Hg Concentration - Whole (ppm)	Mean Fish Weight (lbs)
Largemouth Bass	24	0.214	0.136	1.6
Bluegill Sunfish	23	0.058	0.036	0.3
Redear Sunfish	6	0.044	0.022	0.3
Rockbass	3	0.100	0.042	0.4
Redbreast Sunfish	3	0.076	0.066	0.2
White Crappie	3	0.066	0.042	0.8
Smallmouth Bass	2	0.210	0.105	0.6
Longear Sunfish	1	0.041	0.024	0.1
Yellow Perch	1	0.024	0.016	0.3

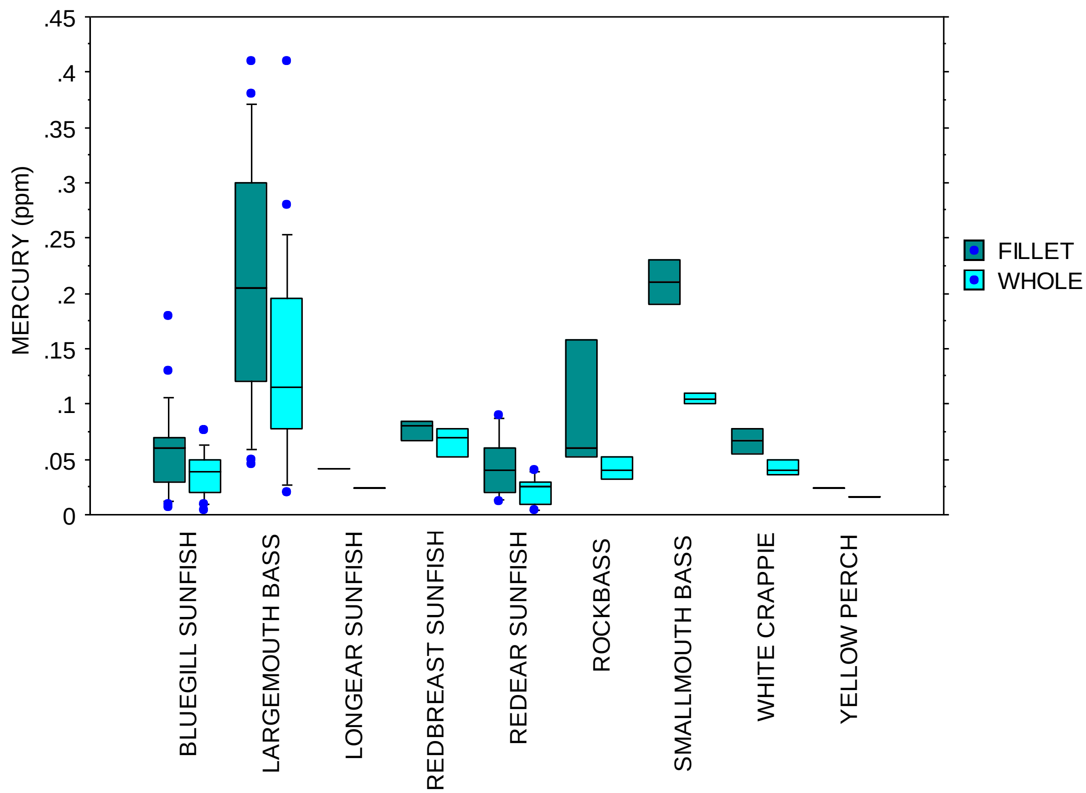

Figure 9: Range of mercury concentrations by fish species.

The areas with the highest predicted mercury air deposition were in Sumner County in the Old Hickory Watershed (Figure10). This is probably because the model used Gallatin Fossil Plant as one of the top emitters. Largemouth bass and bluegill were collected from three waterbodies in this area. Fish were similar in size at all three locations with largemouth bass averaging between 1.3 and 1.7 pounds.

Reese Lake is an isolated farm pond. According to the owner, fish are not stocked so would have been exposed to any contaminants throughout their life cycle. This was the only one of the three sites where mercury levels in fish approached the 0.3 ppm precautionary advisory level. Largemouth bass fillets were 0.28 ppm.

Bledsoe Creek and Drakes Creek tributary are embayments of Old Hickory Lake. Both are almost completely separated by causeway from the main waterbody limiting fish movement in and out of the target area. Mercury levels in largemouth fillets were among the lowest in the study, 0.05 and 0.06 ppm.

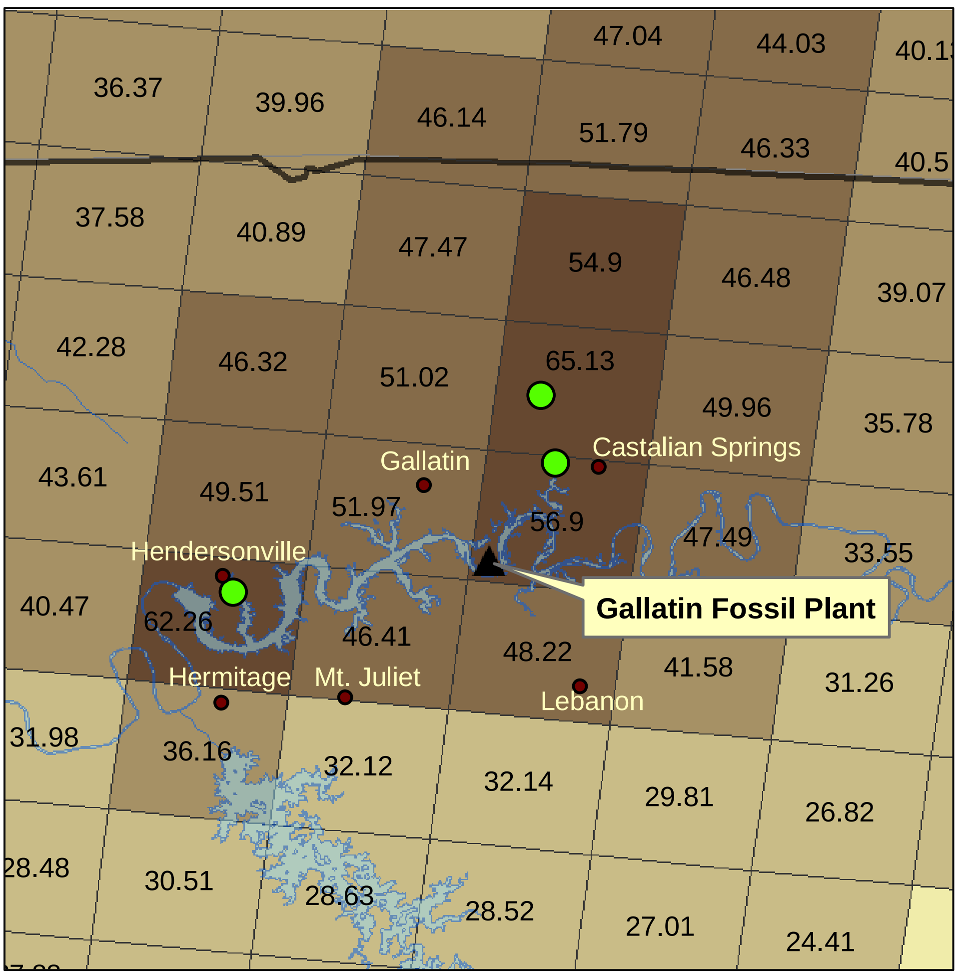

Figure 10: Area of Tennessee with highest predicted mercury air deposition. Green dots represent sampling locations. Numbers are REMSAD deposition units (g/km^2/year).

Reese Lake is in the area of highest predicted mercury deposition. *Photo provided by Aquatic Biology Section, TDH.*

There were six fish fillet composites above the precautionary advisory level of 0.3 ppm (Figure 11). When advisories are issued in Tennessee, they are based on data that is averaged for a given location over time, and are never issued based on a single sampling event. However, samples above the advisory level may warrant further sampling to determine if the fish are potentially unsafe for human consumption in waterbodies with public access. None of the elevated fish were in areas where the REMSAD model predicted elevated mercury deposition. One site is on the Holston River in the upper Cherokee Reservoir (HOLSRO076.0HA), which is already assessed as impaired for a combination of air deposition and legacy point source outside of Tennessee (TDEC, 2010). This site was within the lowest range in Tennessee of predicted air deposition according to the REMSAD model (19.9 g/km^2/year).

The other five sites where elevated mercury was found in fish fillets had no other known sources of mercury contamination other than air deposition. Three were in the second lowest range of the model's prediction. These included the lower portion of the Big Sandy embayment of Kentucky Lake, Tims Ford Lake, and a small lake within a nature preserve – Bays Mountain Lake. Two sites, one on the upper end of the Big Sandy embayment and the other on Greenbrier Lake, a small lake in middle Tennessee, were in the middle range of predicted mercury deposition.

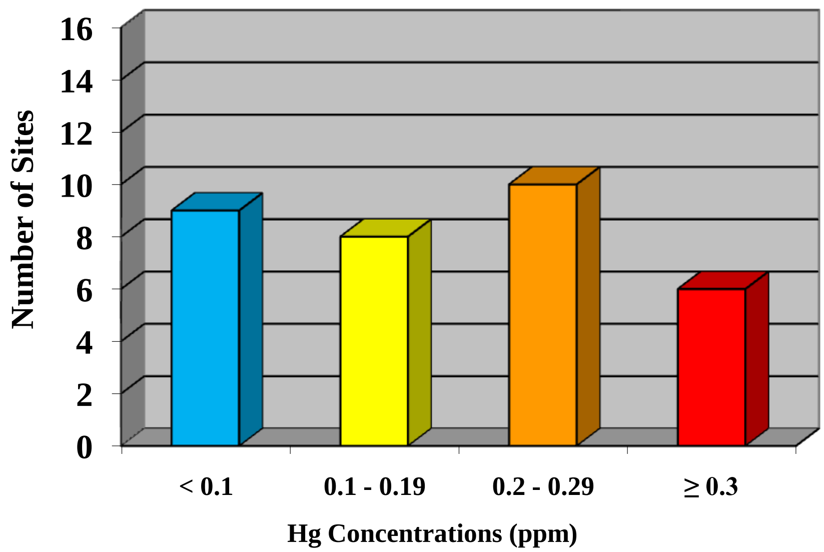

Figure 11: Distribution of sample sites by mercury level in fillets. Data represent species with highest mercury level at each site.

Elevated mercury was found in bass fillets where mercury air deposition prediction was low such as Bays Mountain Lake near Kingsport. *Photo provided by Aquatic Biology Section, TDH.*

Mercury concentrations were lower in the whole-body composites than in the fillets (Figure 9). Nearly half of the whole-body fish had less than 0.1 ppm of mercury detected (Figure 12). Only one, from the upper end of the Big Sandy embayment, was above 0.3 ppm. However, mercury is more of a problem for human consumption than it is for wildlife, so contamination of fillets is a bigger concern.

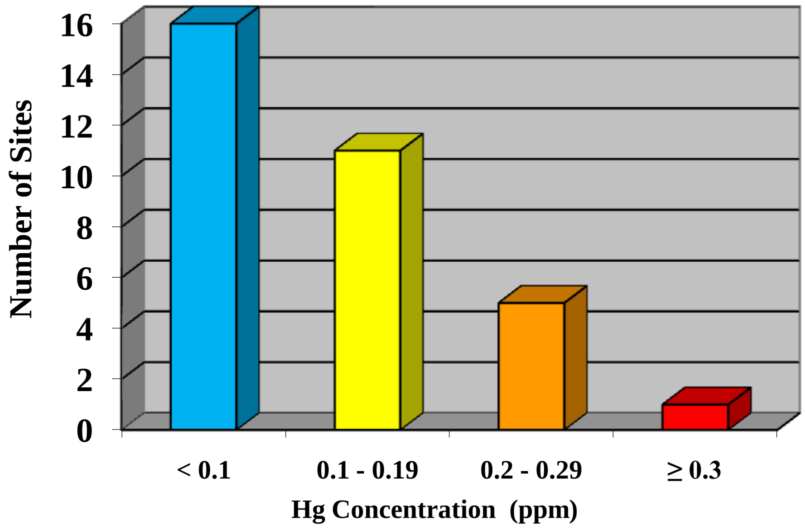

Figure 12: Distribution of sample sites by mercury level in whole-body fish. Data represent species with highest mercury level at each site.

b. Water Chemistry

The majority of the water samples (24) had mercury concentrations that were below detection levels. Mercury was detected in the water samples at nine sites, seven in west Tennessee and two in east Tennessee (Figure 13). Five sites had mercury levels that were above Tennessee's water quality criterion for the classified uses of recreation and domestic water supply, 0.05 µg/l. The highest water sample, 0.145 µg/L was from the Holston River (Cherokee Reservoir), which has legacy point source as well as air deposition sources (TDEC, 2010). The next highest 0.12 µg/L was from Duffy Lake in Haywood County. This is a small privately owned lake with no other known sources of mercury. Largemouth bass fillets from this site had 0.22 ppm mercury which is below the advisory level. This site was located in a moderate level of predicted air deposition (35.2 g/km^2/year). None of the elevated water samples were collected where air deposition predictions were highest. Regression analysis of mercury in the water vs. the REMSAD air deposition had an r-squared value of 0.016, indicating no correlation (Figure 14).

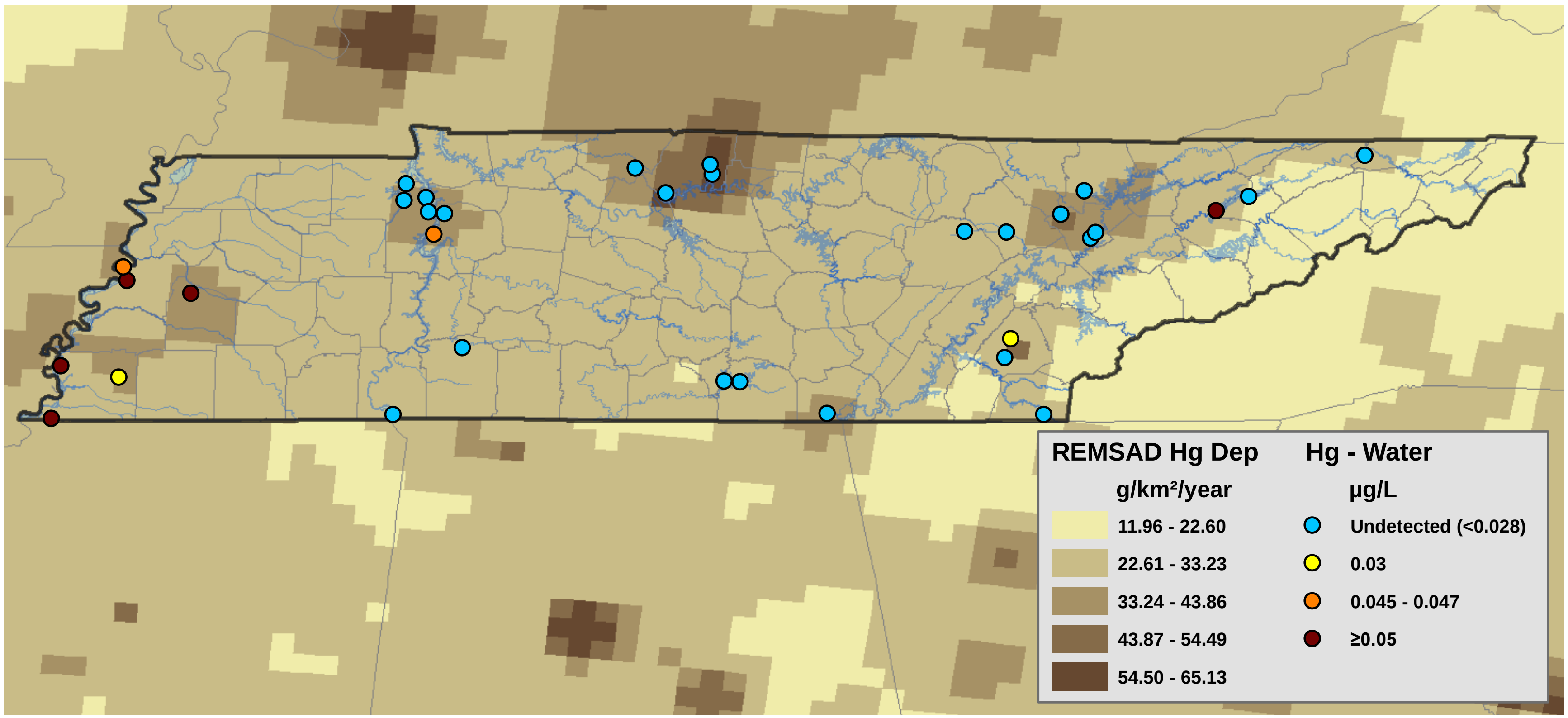

Figure 13: Water sample mercury concentrations by location.

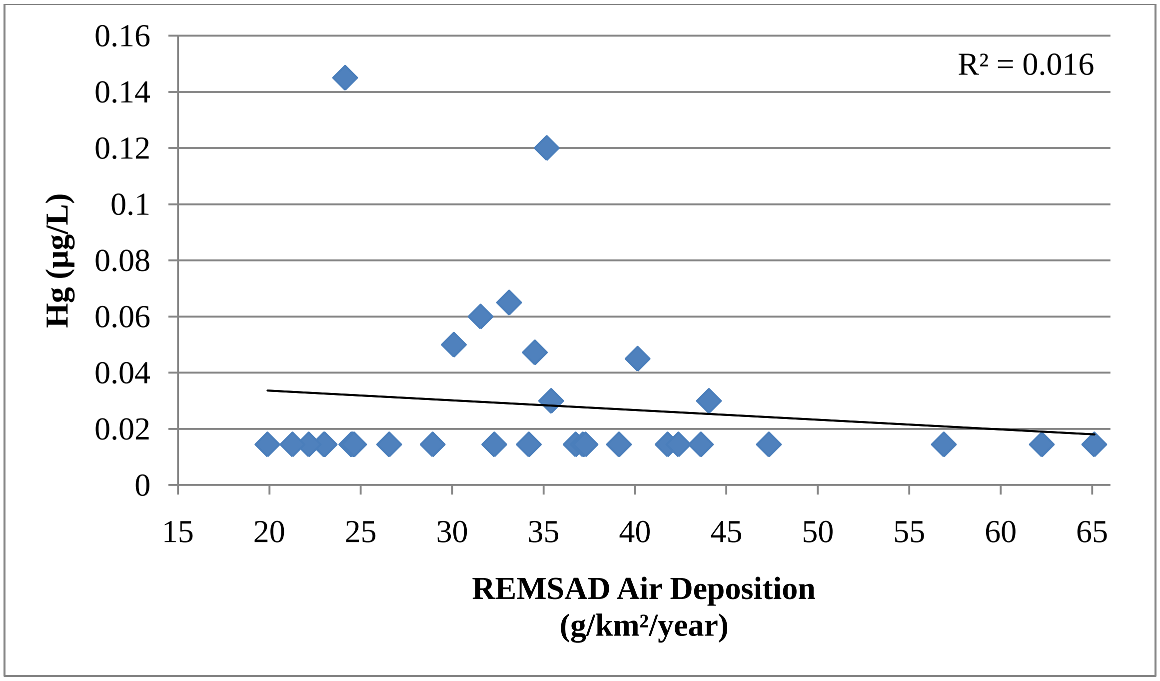

Figure 14: Relationship between water sample mercury concentrations and REMSAD air deposition model.

5. SELENIUM RESULTS

a. Fish Tissue

The wet weight concentrations of selenium found in the whole-body fish composites ranged from levels that were undetectable (<0.13 ppm) up to 1.5 ppm. The average concentration for each species of fish is shown in Table 4. Unlike mercury, selenium concentrations were similar in the fillet and whole-body fish (Table 4 and Figure 15).

Table 4: Selenium results by fish species.

Fish Species	Number of composites	Mean Se – Fillet (ppm)	Mean Se – Whole-body (ppm)	Average Weight (lbs)
Largemouth Bass	24	0.369	0.366	1.6
Bluegill Sunfish	23	0.419	0.352	0.3
Redear Sunfish	6	0.417	0.413	0.3
Rockbass	3	0.293	0.35	0.4
Redbreast Sunfish	3	0.423	0.4	0.2
White Crappie	3	0.537	0.383	0.8
Smallmouth Bass	2	0.605	0.855	0.6
Longear Sunfish	1	0.83	0.63	0.1
Yellow Perch	1	1.4	1.5	0.3

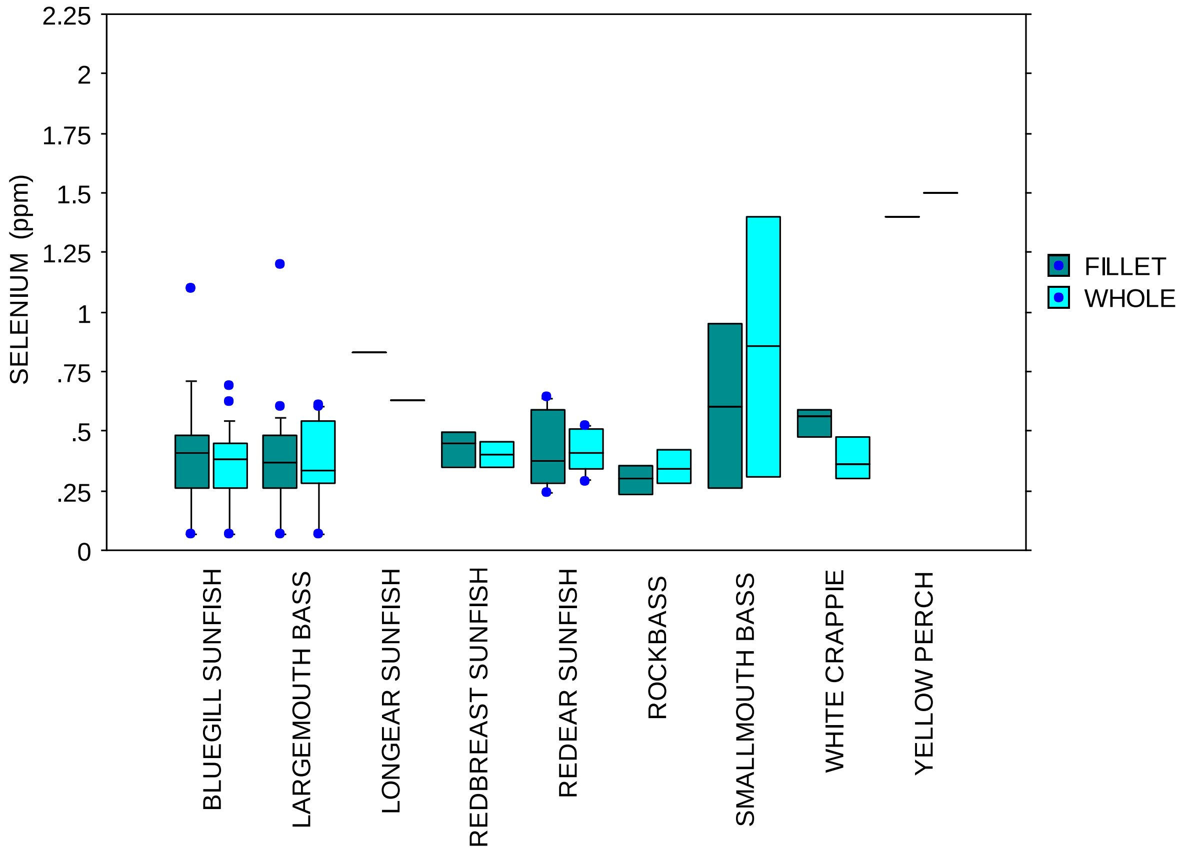

Figure 15: Ranges for selenium concentrations by fish species.

EPA's draft criterion for selenium in fish is expressed as a wet weight concentration in whole-body fish tissue of 7.91 ppm (1.7 dry weight), and says if fish tissue samples exceed 5.85 ppm (1.26 dry weight) during summer or fall, fish should be monitored during the winter to determine if selenium exceeds 7.91 ppm. The increase in the concentration of selenium in whole body tissue at colder temperatures is apparently due to reductions in lipid and body weight caused by decreased feeding, resulting in a higher concentration of selenium (EPA, 2004). It should be noted that this draft, which is based on environmental toxicity rather than human health effects, is under revision and may be focused on reproductive organs in the future. Current criteria are based only on water. The dry weight conversion is based on an average 78.5% moisture content for all fish composites: wet weight = dry weight x (1 – moisture content)/100 (USEPA, 1999).

All of the fish tissue samples had selenium concentrations below 1.7 ppm (dry weight), and all but two fish were below 1.26 ppm (dry weight). One of these was a yellow perch (both whole-body and fillets) from Ocoee Lake #3 in Polk County, and the other was smallmouth bass whole-body composite from the New River in Anderson County (Figures 18 and 19). Both of these sites are within watersheds that have had significant amounts of land disturbance as a result of decades of mining activity.

The New River site is in an area intensively mined for coal through surface and underground mines. The Ocoee Lake site is immediately downstream from the historic Copper Basin mining site, which was used for copper mining for over 150 years. In addition to extensive mining, the ground was denuded due to wood cutting and sulfuric acid fumes (acid rain). This large degree of deforestation caused severe erosion and massive amounts of sediment runoff. Much of this contaminated sediment is now trapped by dams within the Ocoee River Gorge.

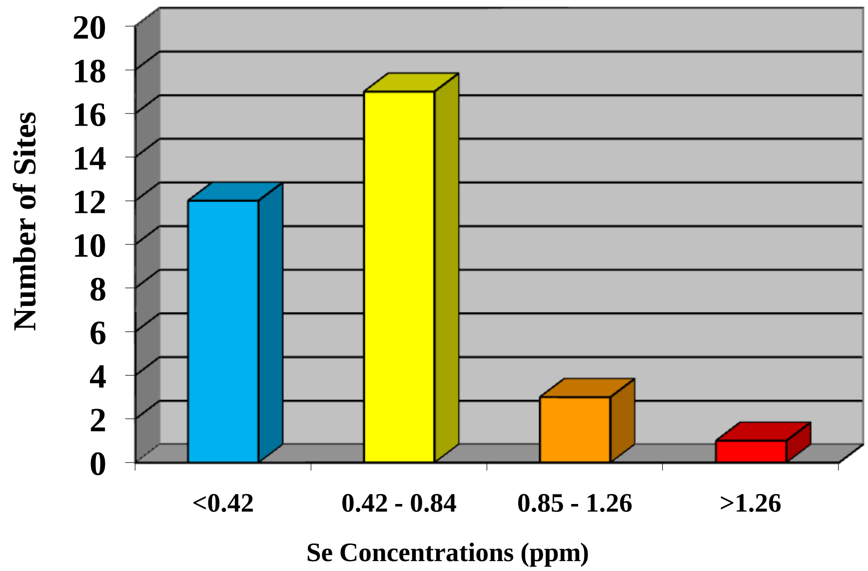

Figure 16: Distribution of sample sites by selenium level in fillets. Data represent species with highest selenium concentration at each site.

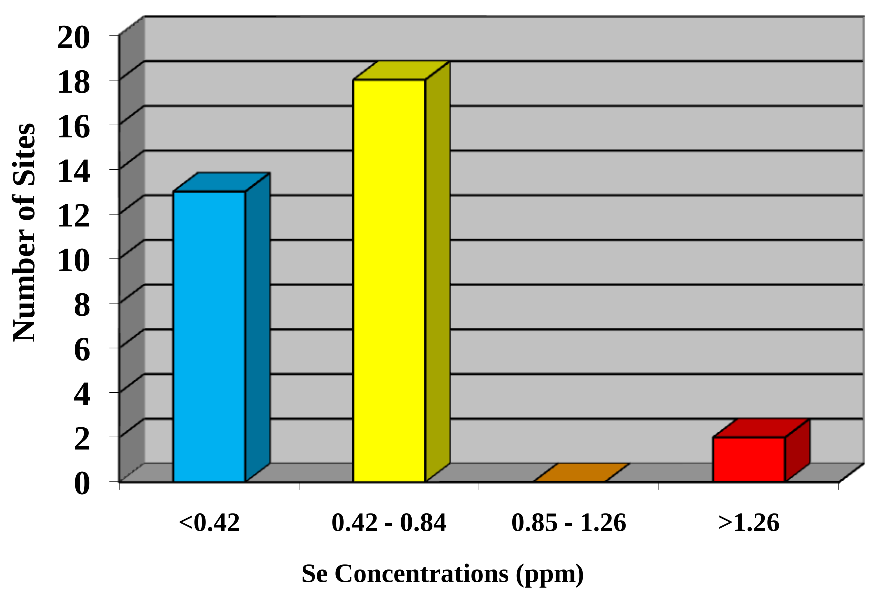

Figure 17: Distribution of sample sites by selenium level in whole-body fish. Data represent species with highest selenium concentration at each site.

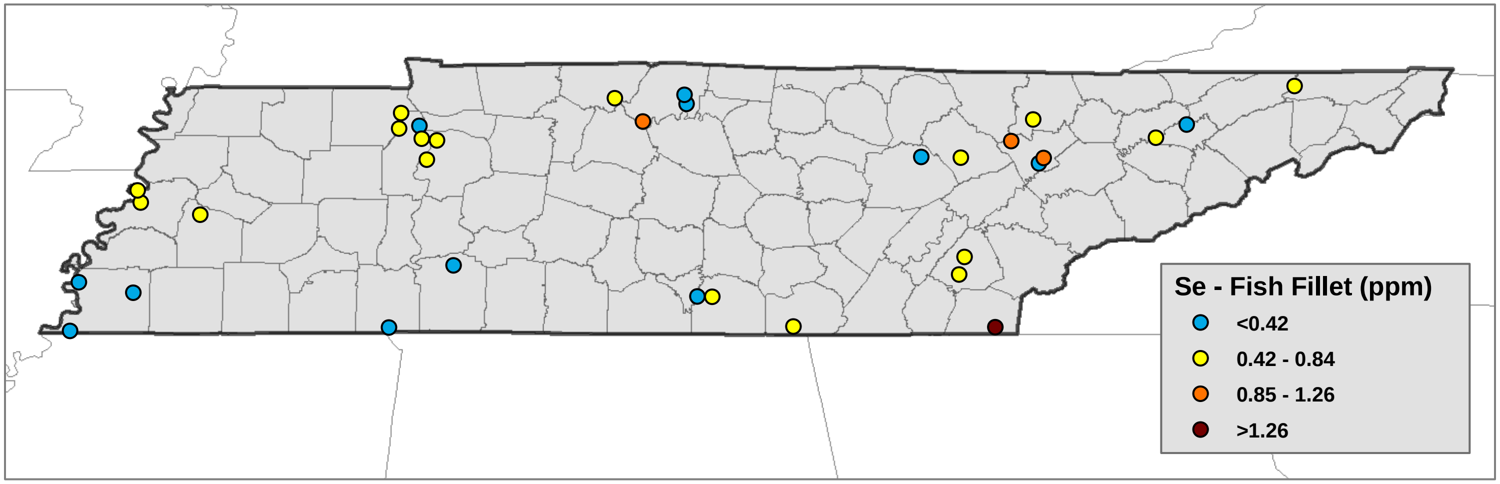

Figure 18: Fish fillet selenium concentrations by location. Values represent the highest game fish composite at each site.

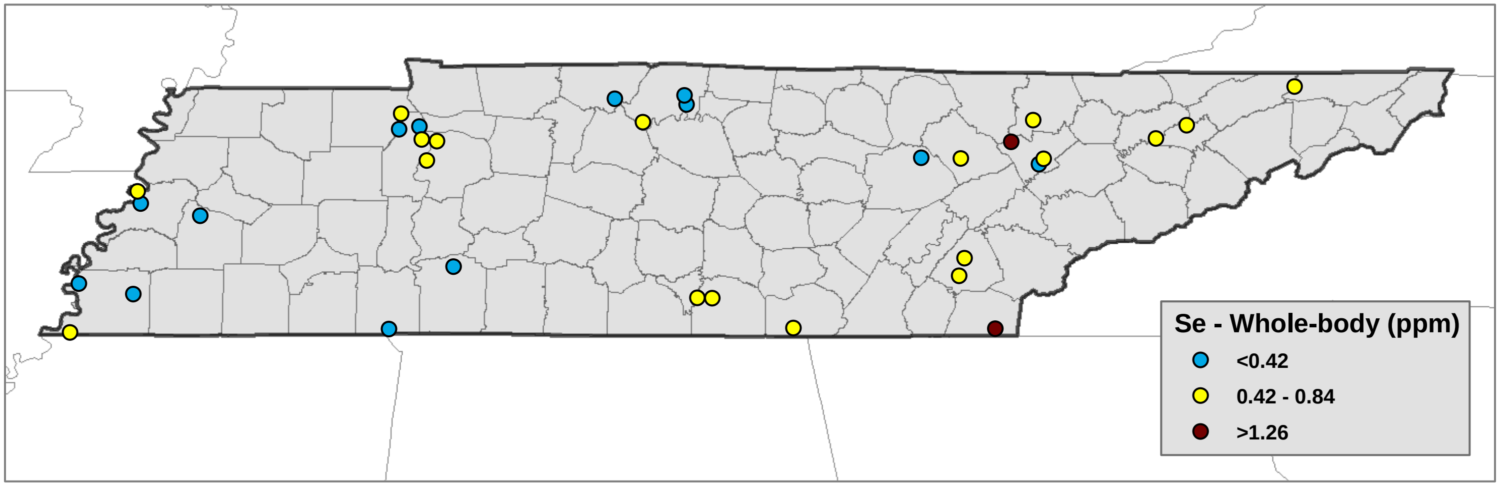

Figure 19: Whole-body fish selenium concentrations by location. Values represent the highest game fish composite at each site.

Fish weight did not seem to influence the selenium concentrations in the whole-body or fillet composites. Some of the fish samples with the highest selenium were composed of smaller fish (Figures 20 and 21). Sunfish species collected at same locations as largemouth often had higher levels of selenium (Figure 22 and Appendix C).

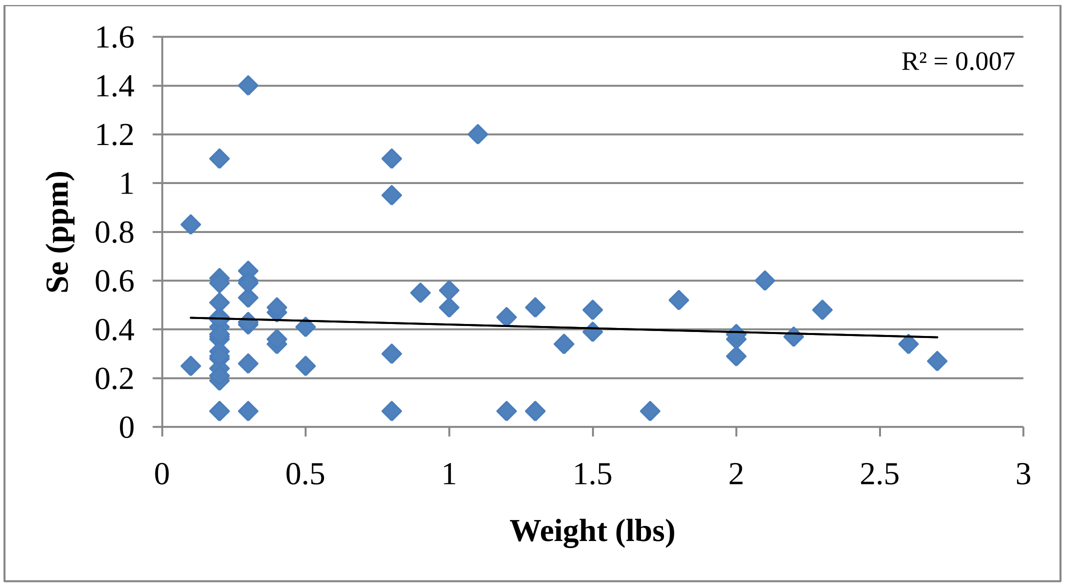

Figure 20: Relationship between fish weight and selenium concentrations in fillets.

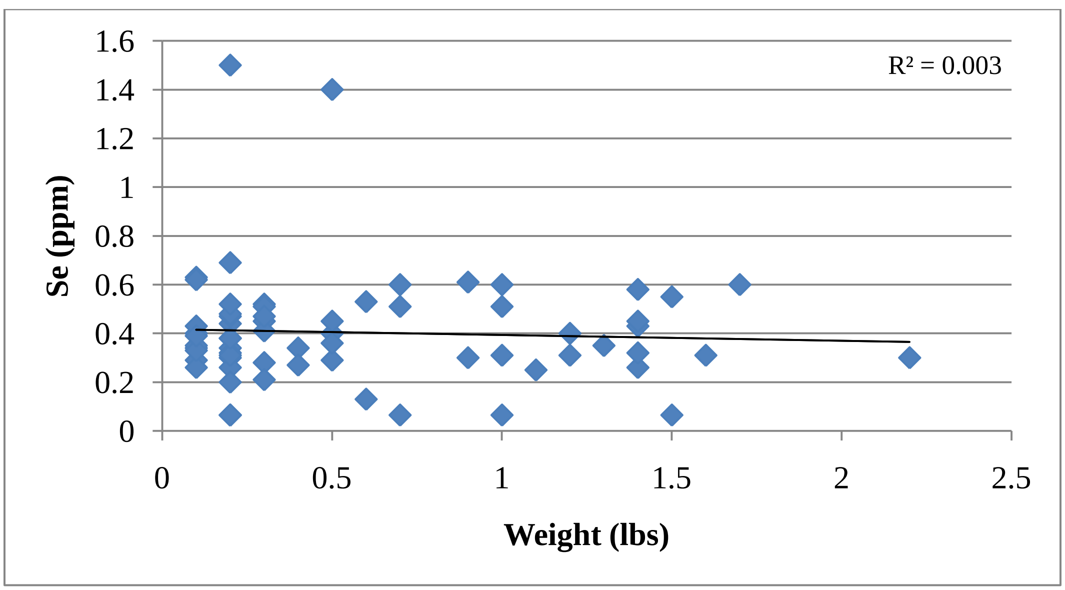

Figure 21: Relationship between fish weight and selenium concentrations in whole-body fish.

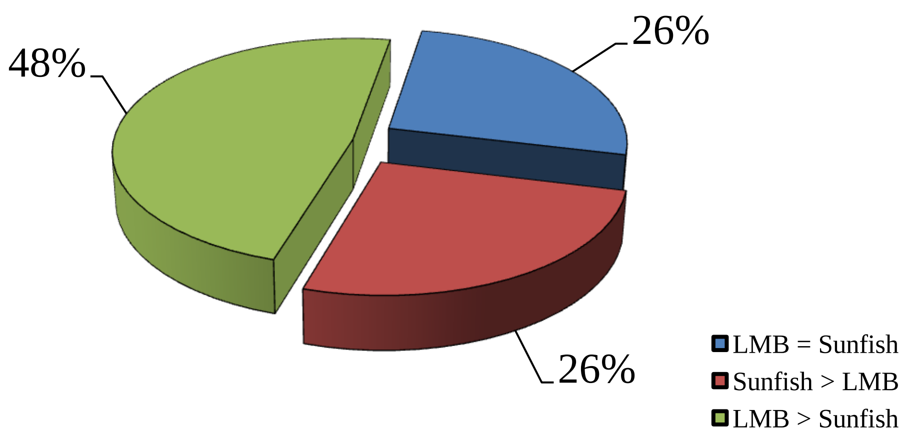

Figure 22: Comparison of selenium concentrations in largemouth bass and sunfish collected at the same locations. (Data represent 23 sample sites).

b. Water Chemistry

There was no selenium detected in the water samples from any of the sampling sites. All of the water samples were well below the chronic water criterion of 5 µg/L for fish and aquatic life (Tennessee Water Quality Control Board, 2008).

Historic deforestation and erosion in the Copper Basin area circa 1960. Widespread land disturbance contributed to elevated selenium in fish samples from the Ocoee.

Photo courtesy of Ducktown Basin Museum.

SUMMARY

Sampling results indicate the REMSAD model for air deposition of mercury does not appear to be a useful tool for predicting mercury contamination in Tennessee waterbodies. The mercury levels found in fish tissue did not correlate with the air deposition model. Several fish taken from areas with predicted high levels of mercury air deposition contained relatively low levels of contamination. Other fish that had higher concentrations of mercury came from areas with low predicted depositional mercury.

Several variables may account for the discrepancy between predicted air deposition and mercury concentrations in fish tissue. This may be in part because the top emitters according to the Tennessee Division of Air Pollution were not tagged as top emitters by the model, although they were probably included in the collective sources. Another factor is that the REMSAD model does not simulate all of the processes that occur as part of the mercury cycle, such as methylation and bioaccumulation. There may also be unknown sources of non-depositional mercury contributing to elevated levels in some areas.

The study does demonstrate that smaller waterbodies in isolated areas should be checked for mercury contamination particularly if largemouth bass are routinely consumed by the public.

The study also indicates that selenium levels in water and fish throughout the state are generally low. Fish concentrations were slightly elevated at two sites according to 2004 EPA draft guidance which is currently under revision. Both sites have large scale land disturbance through historic mining activities. Selenium was not detected in any of the water samples. The existing selenium criterion is based on water.

Water samples were collected mid-depth.

Electroshocking was used to collect fish samples.

Photos provided by Aquatic Biology Section, TDH.

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APPENDIX A

MERCURY EMITTERS IN TENNESSEE

Table A-1: Mercury Air Emitters in Tennessee. Data provided by Division of Air Pollution, TDEC.

FACILITY NAME	SITE DESCRIPTION	COUNTY	EMISSION VALUE (Tons / Year)
OLIN CORPORATION*	INORGANIC CHEMICAL PRODUCTION	BRADLEY	0.071
TVA CUMBERLAND FOSSIL PLANT	ELECTRIC POWER GENERATION	STEWART	0.0215
TVA BULL RUN FOSSIL PLANT	ELECTRIC POWER GENERATION	ANDERSON	0.0198
TVA JOHN SEVIER FOSSIL PLANT	ELECTRIC POWER GENERATION	HAWKINS	0.0194
EASTMAN CHEMICAL COMPANY	ALL OTHER BASIC ORGANIC CHEMICAL MFG.	SULLIVAN	0.015105
TVA KINGSTON FOSSIL PLANT*	ELECTRIC POWER GENERATION	ROANE	0.0133
TVA GALLATIN FOSSIL PLANT*	ELECTRIC POWER GENERATION	SUMNER	0.00613
TVA JOHNSONVILLE FOSSIL PLANT*	ELECTRIC POWER GENERATION	HUMPHREYS	0.005
U.S. DEPARTMENT OF ENERGY, K-25	R & D, HAZARDOUS WASTE INCINERATION	ROANE	0.00286045
DOMTAR PAPER COMPANY, LLC - KINGSPORT MILL	PAPER & ALLIED PRODUCTS	SULLIVAN	0.0019
U.S. DEPARTMENT OF ENERGY, Y-12 PLANT NATIONAL SECURITY COMPLEX	FABRICATED METAL PRODUCTS	ANDERSON	0.00056
DIVERSIFIED SCIENTIFIC SERVICES	MIXED WASTE TSD	ROANE	0.000508487
SONOCO PRODUCTS COMPANY	PAPER AND ALLIED PRODUCTS	COCKE	0.00046
TATE & LYLE, Loudon	CORN SYRUP & ALCOHOL	LOUDON	0.00031
KIMBERLY CLARK CORPORATION	MANUFACTURE OF SANITARY PAPER PRODUCTS	LOUDON	0.000237
PACKAGING CORPORATION OF AMERICA	PAPER & ALLIED PRODUCTS	HARDIN	0.0000816
HOLSTON ARMY AMMUNITION PLANT (HSAAP)	EXPLOSIVES MANUFACTURING	HAWKINS	0.0000691
ALCOA INC. - SOUTH PLANT	PRIMARY & SECONDARY ALUMINUM INDUSTRIES	CARROLL	0.0000686
ALCOA INC. - NORTH PLANT	ALUMINUM FABRICATION	CARROLL	0.0000677

Table A-1 Cont.

FACILITY NAME	SITE DESCRIPTION	COUNTY	EMISSION VALUE (Tons / Year)
NORTHWEST TENNESSEE DISPOSAL CORPORATION	SANITARY SERVICES-REFUSE SYSTEMS	OBION	0.0000415
TEMPLE - INLAND	PAPERBOARD MILLS	HUMPHREYS	0.0000399
NORTHWEST TENNESSEE DISPOSAL CORPORATION	SANITARY SERVICES-REFUSE SYSTEMS	OBION	0.0000277
MOUNTAIN HOME ENERGY	STEAM AND ELECTRICITY GENERATION FACILITY	WASHINGTON	0.0000259
BFI WASTE SYSTEMS OF TENNESSEE, LLC – MIDDLE POINT LANDFILL	SOLID WASTE LANDFILL	RUTHERFORD	0.0000246
THE GOODYEAR TIRE & RUBBER COMPANY	MANUFACTURING OF TIRES	OBION	0.0000186
U.S. DEPARTMENT OF ENERGY, (ORNL)	RESEARCH & DEVELOPMENT LABS	ROANE	0.000015
THYSSEN KRUPP WAUPACA, INC	IRON CASTING FOUNDRY	MCMINN	0.00000230
KING PHARMACEUTICALS, INC.	PHARMACEUTICAL MANUFACTURING OPERATIONS	SULLIVAN	0.0000003
TVA GLEASON COMBUSTION TURBINE PLANT	POWER GENERATION	WEAKLEY	0.0000000476

* Sources tagged as top emitters for REMSAD model.

APPENDIX B

AIR DEPOSITION STUDY MONITORING STATIONS

Table B-1: Study Sites

Station ID	Lake/Stream	Location	County	Lat	Long
BATTL1T0.1MI	Unnamed Lake off Battle Creek	Between Sequatchie Valley Golf and Country Club and Battle Creek.	Marion	35.05236	-85.71555
BLEDS004.2SR	Bledsoe Creek Embayment of Old Hickory Lake	U/S Hwy 25	Sumner	36.39859	-86.34297
BRICH002.0HU	Big Richland Creek embayment of Ky Lake.	Upper end of embayment	Humphreys	36.17370	-87.87346
BSAND007.4HN	Big Sandy Embayment of Kentucky Lake	D/S Poplar Creek	Henry	36.3434	-88.0938
BSAND015.1BN	Big Sandy Embayment of Kentucky Lake	Downstream of Levee at Dewatering Area.	Benton	36.248	-88.105
BUTCH000.0AN	Butcher Lake	Off Old Emory Rd near Clinch River Mile 50, Oak Ridge	Anderson	36.03439	-84.18141
COVE017.0CA	Cove Lake	Cove Lake State Park	Campbell	36.3031	-84.218
CROOK001.4BN	Bass Bay of Ky Lake	Upper end of embayment	Benton	36.26480	-87.98049
DOLAN001.4SU	Kingsport (Bays Mountain) Reservoir	Bays Mountain Park	Sullivan	36.50757	-82.61444
DRAKE1T0.1SR	Drakes Creek Embayment of Old Hickory Reservoir	Saunders Ferry Road in Hendersonville	Sumner	36.29119	-86.6103
DRY001.7HD	Dry Creek embayment of Pickwick Reservoir	Dry Creek Rd.	Hardin	35.02690	-88.16809
DUFFY000.0HY	Duffy Lake	Off Eubanks Road	Haywood	35.71930	-89.32385
ELK135.0FR	Tims Ford Reservoir	Marble Plains	Franklin	35.2169	-86.2773
ELK150.0FR	Tims Ford Reservoir	Maple Bend	Franklin	35.2139	-86.1849
EMORY027.7MG	Emory River	Nemo Bridge	Morgan	36.0689	-84.6623
GREEN004.8WE	Green River	Off HWY 13	Wayne	35.28750	-87.76306
HOLST055.0GR	Cherokee Reservoir	At dam	Grainger	36.1911	-83.4646
HOLST076.0HA	Cherokee Reservoir	At Hwy 25e	Hamblen	36.2713	-83.2771
LONG002.7RN	Greenbrier Lake	Off Main Street (Distillery Rd) outside of Greenbrier community.	Robertson	36.43358	-86.78324
NEW048.7AN	New River	Upstream Double Camp Creek near Rosedale	Anderson	36.17048	-84.35208
NMOUS1T000.2MM	Athens Regional Park Fishing Lake	Athens Regional Park	McMinn	35.45919	-84.63915
OBED021.1CU	Obed River	Potters Bridge	Cumberland	36.0729	-84.90308
OCOEE031.0PO	Ocoee Lake #3	Near Tumbling Creek	Polk	35.0271	-84.4499
OOSTA011.6MM	Oostanaula Mill Dam	Near USGS stream gauge	McMinn	35.32780	-84.70502
OPEN000.0LE	Open Lake	Adjacent to Chickasaw National Wildlife Refuge	Lauderdale	35.79317	-89.68998
PTREE000.2SH	Poplar Tree Lake	Meeman Shelby Forest State Park	Shelby	35.3046	-90.0681
REESE000.0SR	Reese Farm Lake	Off South Dry Fork Rd	Sumner	36.45439	-86.35499
ROBCO000.0SH	Robco Lake	Off West Holmes Rd in Memphis	Shelby	35.00448	-90.12179
SCOTT003.6SH	Garner (Lakeland) Lake	Lakeland community NE of Memphis	Shelby	35.24029	-89.73598
SULPH001.2BN	Sulphur Creek embayment of Ky Lake	Upper end of embayment	Benton	36.18500	-87.96650
TRACE002.0HU	Trace Creek embayment of Ky Lake	Upper end of embayment	Humphreys	36.05618	-87.93569
WARDL000.0LE	Wardlow Pocket	Chickasaw National Wildlife Refuge	Lauderdale	35.86867	-89.70903
YARNE000.0AN	Yarnell Branch Pond	Off Ridge View Drive near Clinch River Mile 55, SW of Clinton	Anderson	36.06664	-84.15278

APPENDIX C

FISH TISSUE DATA

Table C-1: Fish Tissue Data **-** All results represent 5 fish composite, weight and length are average.

STATION ID	NAME	RESERVOIR	DATE	FISH SPECIES	FISH WEIGHT (lbs)	FISH LENGTH (in)	SAMPLE TYPE	Hg (ppm)	Se (ppm wet weight)	REMSAD Dep (g/km²/yr)
BATTL001.2MI	BATTLE CREEK		08-19-2009	REDBREAST SUNFISH	0.2	6.4	FILLET	0.085	0.51	36.76
BATTL001.2MI	BATTLE CREEK		08-19-2009	LARGEMOUTH BASS	2.1	15.8	FILLET	0.21	0.6	36.76
BATTL001.2MI	BATTLE CREEK		08-19-2009	REDBREAST SUNFISH	0.1	5.4	WHOLE	0.046	0.4	36.76
BATTL001.2MI	BATTLE CREEK		08-19-2009	LARGEMOUTH BASS	1.4	13.7	WHOLE	0.075	0.43	36.76
BLEDS004.2SR	BLEDSOE CREEK EMBAYMENT OF OLD HICKORY LAKE	OLD HICKORY	06-30-2009	BLUEGILL SUNFISH	0.3	6.7	FILLET	0.05	0.065	56.9
BLEDS004.2SR	BLEDSOE CREEK EMBAYMENT OF OLD HICKORY LAKE	OLD HICKORY	06-30-2009	LARGEMOUTH BASS	1.3	13.1	FILLET	0.06	0.065	56.9
BLEDS004.2SR	BLEDSOE CREEK EMBAYMENT OF OLD HICKORY LAKE	OLD HICKORY	06-30-2009	BLUEGILL SUNFISH	0.2	6.7	WHOLE	0.02	0.065	56.9
BLEDS004.2SR	BLEDSOE CREEK EMBAYMENT OF OLD HICKORY LAKE	OLD HICKORY	06-30-2009	LARGEMOUTH BASS	1.4	13.5	WHOLE	0.02	0.26	56.9
BRICH002.0HU	BIG RICHLAND CREEK EMBAYMENT OF KY LAKE	KENTUCKY	07-07-2009	LARGEMOUTH BASS	1.8	14.4	FILLET	0.2	0.52	39.13
BRICH002.0HU	BIG RICHLAND CREEK EMBAYMENT OF KY LAKE	KENTUCKY	07-07-2009	BLUEGILL SUNFISH	0.3	7	FILLET	0.06	0.42	39.13
BRICH002.0HU	BIG RICHLAND CREEK EMBAYMENT OF KY LAKE	KENTUCKY	07-07-2009	LARGEMOUTH BASS	1.4	13.8	WHOLE	0.22	0.58	39.13
BRICH002.0HU	BIG RICHLAND CREEK EMBAYMENT OF KY LAKE	KENTUCKY	07-07-2009	BLUEGILL SUNFISH	0.2	7	WHOLE	0.04	0.38	39.13

Table C-1 Cont.

STATION ID	NAME	RESERVOIR	DATE	FISH SPECIES	FISH WEIGHT (lbs)	FISH LENGTH (in)	SAMPLE TYPE	Hg (ppm)	Se (ppm wet weight)	REMSAD Dep (g/km²/yr)
BSAND007.4HN	BIG SANDY EMBAYMENT	KENTUCKY	07-13-2009	LARGEMOUTH BASS	2	15	FILLET	0.38	0.36	28.94
BSAND007.4HN	BIG SANDY EMBAYMENT	KENTUCKY	07-13-2009	BLUEGILL SUNFISH	0.3	7.6	FILLET	0.13	0.43	28.94
BSAND007.4HN	BIG SANDY EMBAYMENT	KENTUCKY	07-13-2009	BLUEGILL SUNFISH	0.3	7.4	WHOLE	0.05	0.52	28.94
BSAND007.4HN	BIG SANDY EMBAYMENT	KENTUCKY	07-13-2009	LARGEMOUTH BASS	1.3	13.3	WHOLE	0.13	0.35	28.94
BSAND015.1BN	BIG SANDY EMBAYMENT	KENTUCKY	07-13-2009	BLUEGILL SUNFISH	0.3	7.1	FILLET	0.18	0.53	34.2
BSAND015.1BN	BIG SANDY EMBAYMENT	KENTUCKY	07-13-2009	LARGEMOUTH BASS	2.6	16.7	FILLET	0.36	0.34	34.2
BSAND015.1BN	BIG SANDY EMBAYMENT	KENTUCKY	07-13-2009	BLUEGILL SUNFISH	0.2	7	WHOLE	0.06	0.3	34.2
BSAND015.1BN	BIG SANDY EMBAYMENT	KENTUCKY	07-13-2009	LARGEMOUTH BASS	1.6	14.4	WHOLE	0.41	0.31	34.2
BUTCH000.0AN	BUTCHER LAKE	BUTCHER	08-05-2009	LARGEMOUTH BASS	0.5	11.1	FILLET	0.13	0.25	37.15
BUTCH000.0AN	BUTCHER LAKE	BUTCHER	08-05-2009	REDEAR SUNFISH	0.2	7.4	FILLET	0.06	0.28	37.15
BUTCH000.0AN	BUTCHER LAKE	BUTCHER	08-05-2009	REDEAR SUNFISH	0.2	6.9	WHOLE	0.03	0.34	37.15
BUTCH000.0AN	BUTCHER LAKE	BUTCHER	08-05-2009	LARGEMOUTH BASS	0.5	10.9	WHOLE	0.08	0.4	37.15

Table C-1 Cont.

STATION ID	NAME	RESERVOIR	DATE	FISH SPECIES	FISH WEIGHT (lbs)	FISH LENGTH (in)	SAMPLE TYPE	Hg (ppm)	Se (ppm wet weight)	REMSAD Dep (g/km²/yr)
COVE017.0CA	COVE LAKE	COVE LAKE	07-16-2009	WHITE CRAPPIE	0.3	8.9	FILLET	0.05	0.6	32.31
COVE017.0CA	COVE LAKE	COVE LAKE	07-16-2009	LARGEMOUTH BASS	2.3	15.5	FILLET	0.2	0.48	32.31
COVE017.0CA	COVE LAKE	COVE LAKE	07-16-2009	WHITE CRAPPIE	0.3	8.3	WHOLE	0.04	0.28	32.31
COVE017.0CA	COVE LAKE	COVE LAKE	07-16-2009	LARGEMOUTH BASS	1.4	13.5	WHOLE	0.11	0.45	32.31
CROOK001.4BN	CROOKED CREEK	KENTUCKY	07-14-2009	LARGEMOUTH BASS	1.4	14.1	FILLET	0.2	0.34	37.3
CROOK001.4BN	CROOKED CREEK	KENTUCKY	07-14-2009	REDEAR SUNFISH	0.4	8.5	FILLET	0.05	0.34	37.3
CROOK001.4BN	CROOKED CREEK	KENTUCKY	07-14-2009	LARGEMOUTH BASS	1.2	13.4	WHOLE	0.11	0.31	37.3
CROOK001.4BN	CROOKED CREEK	KENTUCKY	07-14-2009	REDEAR SUNFISH	0.4	8.3	WHOLE	0.03	0.34	37.3
DOLAN002.6SU	BAYS MOUNTAIN (KINGSPORT) LAKE ON DOLAN CREEK	BAYS MT (KINGSPORT)	07-15-2009	BLUEGILL SUNFISH	0.4	8.2	FILLET	0.07	0.36	26.56
DOLAN002.6SU	BAYS MOUNTAIN (KINGSPORT) LAKE ON DOLAN CREEK	BAYS MT (KINGSPORT)	07-15-2009	LARGEMOUTH BASS	1	12.1	FILLET	0.33	0.49	26.56
DOLAN002.6SU	BAYS MOUNTAIN (KINGSPORT) LAKE ON DOLAN CREEK	BAYS MT (KINGSPORT)	07-15-2009	LARGEMOUTH BASS	0.6	9.8	WHOLE	0.21	0.53	26.56
DOLAN002.6SU	BAYS MOUNTAIN (KINGSPORT) LAKE ON DOLAN CREEK	BAYS MT (KINGSPORT)	07-15-2009	BLUEGILL SUNFISH	0.3	7.7	WHOLE	0.05	0.45	26.56

Table C-1 Cont

STATION ID	NAME	RESERVOIR	DATE	FISH SPECIES	FISH WEIGHT (lbs)	FISH LENGTH (in)	SAMPLE TYPE	Hg (ppm)	Se (ppm wet weight)	REMSAD Dep (g/km²/yr)
DRAKE1T0.1SR	DRAKES CREEK UT 1 - MALLARD POINT PARK	OLD HICKORY	07-06-2009	BLUEGILL SUNFISH	0.2	6.1	FILLET	0.01	1.1	62.26
DRAKE1T0.1SR	DRAKES CREEK UT 1 - MALLARD POINT PARK	OLD HICKORY	07-06-2009	LARGEMOUTH BASS	1.3	13.4	FILLET	0.05	0.065	62.26
DRAKE1T0.1SR	DRAKES CREEK UT 1 - MALLARD POINT PARK	OLD HICKORY	07-06-2009	LARGEMOUTH BASS	1	12.4	WHOLE	0.02	0.6	62.26
DRAKE1T0.1SR	DRAKES CREEK UT 1 - MALLARD POINT PARK	OLD HICKORY	07-06-2009	BLUEGILL SUNFISH	0.2	6	WHOLE	0.01	0.065	62.26
DRY001.7HD	DRY CREEK	PICKWICK	08-10-2009	LARGEMOUTH BASS	2.2	15.3	FILLET	0.11	0.37	22.99
DRY001.7HD	DRY CREEK	PICKWICK	08-10-2009	REDEAR SUNFISH	0.5	9.1	FILLET	0.03	0.41	22.99
DRY001.7HD	DRY CREEK	PICKWICK	08-10-2009	LARGEMOUTH BASS	1.1	12.8	WHOLE	0.09	0.25	22.99
DRY001.7HD	DRY CREEK	PICKWICK	08-10-2009	REDEAR SUNFISH	0.5	8.6	WHOLE	0.02	0.29	22.99
DUFFY000.0HY	DUFFY LAKE	DUFFY LAKE	10-19-2009	LARGEMOUTH BASS	2.7	16.4	FILLET	0.22	0.27	35.18
DUFFY000.0HY	DUFFY LAKE	DUFFY LAKE	10-19-2009	BLUEGILL SUNFISH	0.4	7.8	FILLET	0.053	0.47	35.18
DUFFY000.0HY	DUFFY LAKE	DUFFY LAKE	10-19-2009	BLUEGILL SUNFISH	0.3	7.7	WHOLE	0.02	0.21	35.18
DUFFY000.0HY	DUFFY LAKE	DUFFY LAKE	10-19-2009	LARGEMOUTH BASS	2.2	15.4	WHOLE	0.28	0.3	35.18

Table C-1 Cont.

STATION ID	NAME	RESERVOIR	DATE	FISH SPECIES	FISH WEIGHT (lbs)	FISH LENGTH (in)	SAMPLE TYPE	Hg (ppm)	Se (ppm wet weight)	REMSAD Dep (g/km²/yr)
ELK135.0FR	ELK RIVER	TIMS FORD	07-28-2009	LARGEMOUTH BASS	2	16.1	FILLET	0.37	0.29	24.56
ELK135.0FR	ELK RIVER	TIMS FORD	07-28-2009	BLUEGILL SUNFISH	0.2	6.3	FILLET	0.03	0.36	24.56
ELK135.0FR	ELK RIVER	TIMS FORD	07-28-2009	LARGEMOUTH BASS	1.5	14.1	WHOLE	0.11	0.55	24.56
ELK135.0FR	ELK RIVER	TIMS FORD	07-28-2009	BLUEGILL SUNFISH	0.2	6	WHOLE	0.02	0.32	24.56
ELK150.0FR	ELK RIVER	TIMS FORD	07-27-2009	BLUEGILL SUNFISH	0.2	7	FILLET	0.05	0.38	24.56
ELK150.0FR	ELK RIVER	TIMS FORD	07-27-2009	LARGEMOUTH BASS	1.5	14.1	FILLET	0.28	0.48	24.56
ELK150.0FR	ELK RIVER	TIMS FORD	07-27-2009	LARGEMOUTH BASS	1.2	13.1	WHOLE	0.18	0.4	24.56
ELK150.0FR	ELK RIVER	TIMS FORD	07-27-2009	BLUEGILL SUNFISH	0.2	6.7	WHOLE	0.03	0.44	24.56
EMORY027.7MG	EMORY RIVER		09-15-2009	BLUEGILL SUNFISH	0.1	5.6	FILLET	0.1	0.25	23.03
EMORY027.7MG	EMORY RIVER		09-15-2009	REDBREAST SUNFISH	0.2	7	FILLET	0.063	0.45	23.03
EMORY027.7MG	EMORY RIVER		09-15-2009	BLUEGILL SUNFISH	0.1	5.3	WHOLE	0.077	0.29	23.03
EMORY027.7MG	EMORY RIVER		09-15-2009	REDBREAST SUNFISH	0.2	6.2	WHOLE	0.081	0.47	23.03

Table C-1 Cont.

STATION ID	NAME	RESERVOIR	DATE	FISH SPECIES	FISH WEIGHT (lbs)	FISH LENGTH (in)	SAMPLE TYPE	Hg (ppm)	Se (ppm wet weight)	REMSAD Dep (g/km²/yr)
GREEN004.8WE	GREEN RIVER		08-12-2009	ROCKBASS	0.2	6.1	FILLET	0.05	0.21	24.49
GREEN004.8WE	GREEN RIVER		08-12-2009	ROCKBASS	0.2	6.1	FILLET	0.06	0.37	24.49
GREEN004.8WE	GREEN RIVER		08-12-2009	ROCKBASS	0.1	5.8	WHOLE	0.03	0.26	24.49
GREEN004.8WE	GREEN RIVER		08-12-2009	ROCKBASS	0.1	5.8	WHOLE	0.04	0.34	24.49
HOLST055.0GR	HOLSTON RIVER	CHEROKEE	08-18-2009	BLUEGILL SUNFISH	0.2	6.3	FILLET	0.06	0.41	24.15
HOLST055.0GR	HOLSTON RIVER	CHEROKEE	08-18-2009	LARGEMOUTH BASS	1.3	13.4	FILLET	0.21	0.49	24.15
HOLST055.0GR	HOLSTON RIVER	CHEROKEE	08-18-2009	LARGEMOUTH BASS	0.9	11.6	WHOLE	0.25	0.61	24.15
HOLST055.0GR	HOLSTON RIVER	CHEROKEE	08-18-2009	BLUEGILL SUNFISH	0.1	5.9	WHOLE	0.046	0.35	24.15
HOLST076.0HA	HOLSTON RIVER	CHEROKEE	08-19-2009	BLUEGILL SUNFISH	0.2	6.2	FILLET	0.065	0.19	19.9
HOLST076.0HA	HOLSTON RIVER	CHEROKEE	08-19-2009	LARGEMOUTH BASS	2	15.9	FILLET	0.41	0.38	19.9
HOLST076.0HA	HOLSTON RIVER	CHEROKEE	08-19-2009	LARGEMOUTH BASS	1.4	14.2	WHOLE	0.23	0.32	19.9
HOLST076.0HA	HOLSTON RIVER	CHEROKEE	08-19-2009	BLUEGILL SUNFISH	0.1	6	WHOLE	0.039	0.43	19.9

Table C-1 Cont.

STATION ID	NAME	RESERVOIR	DATE	FISH SPECIES	FISH WEIGHT (lbs)	FISH LENGTH (in)	SAMPLE TYPE	Hg (ppm)	Se (ppm wet weight)	REMSAD Dep (g/km²/yr)
LONG002.7RN	GREENBRIER LAKE ON LONG CREEK	GREENBRIER LAKE	07-01-2009	LARGEMOUTH BASS	1.2	12.1	FILLET	0.31	0.065	43.61
LONG002.7RN	GREENBRIER LAKE ON LONG CREEK	GREENBRIER LAKE	07-01-2009	BLUEGILL SUNFISH	0.4	7.9	FILLET	0.08	0.49	43.61
LONG002.7RN	GREENBRIER LAKE ON LONG CREEK	GREENBRIER LAKE	07-01-2009	LARGEMOUTH BASS	0.7	10.9	WHOLE	0.12	0.065	43.61
LONG002.7RN	GREENBRIER LAKE ON LONG CREEK	GREENBRIER LAKE	07-01-2009	BLUEGILL SUNFISH	0.4	7.5	WHOLE	0.04	0.27	43.61
NEW048.7AN	NEW RIVER		09-14-2009	LONGEAR SUNFISH	0.1	5.2	FILLET	0.041	0.83	47.33
NEW048.7AN	NEW RIVER		09-14-2009	SMALLMOUTH BASS	0.8	10.8	FILLET	0.23	0.95	47.33
NEW048.7AN	NEW RIVER		09-14-2009	LONGEAR SUNFISH	0.1	5.1	WHOLE	0.024	0.63	47.33
NEW048.7AN	NEW RIVER		09-14-2009	SMALLMOUTH BASS	0.5	9.9	WHOLE	0.11	1.4	47.33
NMOUS1T0.2MM	ATHENS REGIONAL PARK FISHING LAKE	ATHENS REG PARK FISH	09-30-2009	REDEAR SUNFISH	0.2	7.3	FILLET	0.012	0.24	44.05
NMOUS1T0.2MM	ATHENS REGIONAL PARK FISHING LAKE	ATHENS REG PARK FISH	09-30-2009	BLUEGILL SUNFISH	0.2	6.3	FILLET	0.012	0.44	44.05
NMOUS1T0.2MM	ATHENS REGIONAL PARK FISHING LAKE	ATHENS REG PARK FISH	09-30-2009	BLUEGILL SUNFISH	0.2	6.4	WHOLE	0.009	0.26	44.05
NMOUS1T0.2MM	ATHENS REGIONAL PARK FISHING LAKE	ATHENS REG PARK FISH	09-30-2009	REDEAR SUNFISH	0.2	7	WHOLE	0.004	0.48	44.05

Table C-1 Cont.

STATION ID	NAME	RESERVOIR	DATE	FISH SPECIES	FISH WEIGHT (lbs)	FISH LENGTH (in)	SAMPLE TYPE	Hg (ppm)	Se (ppm wet weight)	REMSAD Dep (g/km²/yr)
OBED021.1CU	OBED RIVER		09-16-2009	SMALLMOUTH BASS	0.3	7.9	FILLET	0.19	0.26	22.16
OBED021.1CU	OBED RIVER		09-16-2009	REDBREAST SUNFISH	0.2	6	FILLET	0.08	0.31	22.16
OBED021.1CU	OBED RIVER		09-16-2009	SMALLMOUTH BASS	0.2	7.2	WHOLE	0.1	0.31	22.16
OBED021.1CU	OBED RIVER		09-16-2009	REDBREAST SUNFISH	0.1	5.8	WHOLE	0.07	0.33	22.16
OCOEE031.0PO	OCOEE RIVER	OCOEE # 3	10-28-2009	BLUEGILL SUNFISH	0.8	9.5	FILLET	0.026	1.1	21.27
OCOEE031.0PO	OCOEE RIVER	OCOEE # 3	10-28-2009	YELLOW PERCH	0.3	9.3	FILLET	0.024	1.4	21.27
OCOEE031.0PO	OCOEE RIVER	OCOEE # 3	10-28-2009	BLUEGILL SUNFISH	0.7	9.2	WHOLE	0.026	0.51	21.27
OCOEE031.0PO	OCOEE RIVER	OCOEE # 3	10-28-2009	YELLOW PERCH	0.2	9.1	WHOLE	0.016	1.5	21.27
OOSTA011.6MM	OOSTANAULA CREEK		11-05-2009	BLUEGILL SUNFISH	0.2	6.5	FILLET	0.037	0.61	24.64
OOSTA011.6MM	OOSTANAULA CREEK		11-5-2009	ROCKBASS	0.8	9.8	FILLET	0.19	0.3	24.64
OOSTA011.6MM	OOSTANAULA CREEK		11-5-2009	BLUEGILL SUNFISH	0.1	6.1	WHOLE	0.023	0.62	24.64
OOSTA011.6MM	OOSTANAULA CREEK		11-5-2009	ROCKBASS	0.5	9	WHOLE	0.057	0.45	24.64

Table C-1 Cont.

STATION ID	NAME	RESERVOIR	DATE	FISH SPECIES	FISH WEIGHT (lbs)	FISH LENGTH (in)	SAMPLE TYPE	Hg (ppm)	Se (ppm wet weight)	REMSAD Dep (g/km²/yr)
OPEN000.0LE	OPEN LAKE	OPEN LAKE	10-20-2009	WHITE CRAPPIE	1	10.9	FILLET	0.067	0.56	31.56
OPEN000.0LE	OPEN LAKE	OPEN LAKE	10-20-2009	BLUEGILL SUNFISH	0.3	7.1	FILLET	0.063	0.43	31.56
OPEN000.0LE	OPEN LAKE	OPEN LAKE	10-20-2009	WHITE CRAPPIE	0.5	8.4	WHOLE	0.053	0.36	31.56
OPEN000.0LE	OPEN LAKE	OPEN LAKE	10-20-2009	BLUEGILL SUNFISH	0.3	6.9	WHOLE	0.049	0.41	31.56
PTREE000.2SH	POPLAR TREE LAKE	POPLAR TREE	10-21-2009	LARGEMOUTH BASS	0.8	11.7	FILLET	0.15	0.065	33.12
PTREE000.2SH	POPLAR TREE LAKE	POPLAR TREE	10-21-2009	BLUEGILL SUNFISH	0.2	7	FILLET	0.067	0.21	33.12
PTREE000.2SH	POPLAR TREE LAKE	POPLAR TREE	10-21-2009	LARGEMOUTH BASS	0.6	10.7	WHOLE	0.15	0.13	33.12
PTREE000.2SH	POPLAR TREE LAKE	POPLAR TREE	10-21-2009	BLUEGILL SUNFISH	0.2	6.6	WHOLE	0.052	0.065	33.12
REESE000.0SR	REESE FARM LAKE	REESE FARM LAKE	07-07-2009	BLUEGILL SUNFISH	0.2	6.1	FILLET	0.02	0.065	65.13
REESE000.0SR	REESE FARM LAKE	REESE FARM LAKE	07-07-2009	LARGEMOUTH BASS	1.7	14.3	FILLET	0.28	0.065	65.13
REESE000.0SR	REESE FARM LAKE	REESE FARM LAKE	07-07-2009	LARGEMOUTH BASS	1.5	13.6	WHOLE	0.08	0.065	65.13
REESE000.0SR	REESE FARM LAKE	REESE FARM LAKE	07-07-2009	BLUEGILL SUNFISH	0.1	6	WHOLE	0.01	0.39	65.13

Table C-1 Cont.

STATION ID	NAME	RESERVOIR	DATE	FISH SPECIES	FISH WEIGHT (lbs)	FISH LENGTH (in)	SAMPLE TYPE	Hg (ppm)	Se (ppm wet weight)	REMSAD Dep (g/km²/yr)
ROBCO000.0SH	ROBCO LAKE	ROBCO LAKE	10-19-2009	BLUEGILL SUNFISH	0.2	6.4	FILLET	0.007	0.29	30.1
ROBCO000.0SH	ROBCO LAKE	ROBCO LAKE	10-19-2009	LARGEMOUTH BASS	2	14.9	FILLET	0.045	0.38	30.1
ROBCO000.0SH	ROBCO LAKE	ROBCO LAKE	10-19-2009	LARGEMOUTH BASS	1.7	14.7	WHOLE	0.028	0.6	30.1
ROBCO000.0SH	ROBCO LAKE	ROBCO LAKE	10-19-2009	BLUEGILL SUNFISH	0.2	6.3	WHOLE	0.004	0.2	30.1
SCOTT003.6SH	SCOTTS CREEK - GARNER/LAKELAND LAKE	GARNER LAKE	10-20-2009	LARGEMOUTH BASS	1.4	13.2	FILLET	0.19	0.34	35.42
SCOTT003.6SH	SCOTTS CREEK - GARNER/LAKELAND LAKE	GARNER LAKE	10-20-2009	BLUEGILL SUNFISH	0.2	7	FILLET	0.065	0.38	35.42
SCOTT003.6SH	SCOTTS CREEK - GARNER/LAKELAND LAKE	GARNER LAKE	10-20-2009	LARGEMOUTH BASS	0.9	11.6	WHOLE	0.12	0.3	35.42
SCOTT003.6SH	SCOTTS CREEK - GARNER/LAKELAND LAKE	GARNER LAKE	10-20-2009	BLUEGILL SUNFISH	0.2	7.1	WHOLE	0.055	0.38	35.42
SULPH001.2BN	SULPHUR CREEK EMBAYMENT OF KY LAKE	KENTUCKY	07-15-2009	REDEAR SUNFISH	0.3	7.6	FILLET	0.09	0.64	41.79
SULPH001.2BN	SULPHUR CREEK EMBAYMENT OF KY LAKE	KENTUCKY	07-15-2009	LARGEMOUTH BASS	1.5	14.1	FILLET	0.29	0.39	41.79
SULPH001.2BN	SULPHUR CREEK EMBAYMENT OF KY LAKE	KENTUCKY	07-15-2009	REDEAR SUNFISH	0.3	7.3	WHOLE	0.04	0.51	41.79
SULPH001.2BN	SULPHUR CREEK EMBAYMENT OF KY LAKE	KENTUCKY	07-15-2009	LARGEMOUTH BASS	1	12.8	WHOLE	0.13	0.31	41.79

Table C-1 Cont.

STATION ID	NAME	RESERVOIR	DATE	FISH SPECIES	FISH WEIGHT (lbs)	FISH LENGTH (in)	SAMPLE TYPE	Hg (ppm)	Se (ppm wet weight)	REMSAD Dep (g/km²/yr)
TRACE002.0HU	TRACE CREEK EMBAYMENT OF KY LAKE	KENTUCKY	07-06-2009	LARGEMOUTH BASS	0.9	12.9	FILLET	0.1	0.55	34.53
TRACE002.0HU	TRACE CREEK EMBAYMENT OF KY LAKE	KENTUCKY	07-06-2009	BLUEGILL SUNFISH	0.2	6.5	FILLET	0.03	0.065	34.53
TRACE002.0HU	TRACE CREEK EMBAYMENT OF KY LAKE	KENTUCKY	07-06-2009	BLUEGILL SUNFISH	0.2	6.3	WHOLE	0.02	0.69	34.53
TRACE002.0HU	TRACE CREEK EMBAYMENT OF KY LAKE	KENTUCKY	07-06-2009	LARGEMOUTH BASS	1	12.4	WHOLE	0.07	0.065	34.53
WARDL000.0LE	WARDLOW POCKET	WARDLOW POCKET	10-20-2009	BLUEGILL SUNFISH	0.3	7	FILLET	0.077	0.59	40.15
WARDL000.0LE	WARDLOW POCKET	WARDLOW POCKET	10-20-2009	WHITE CRAPPIE	1.2	11.7	FILLET	0.081	0.45	40.15
WARDL000.0LE	WARDLOW POCKET	WARDLOW POCKET	10-20-2009	WHITE CRAPPIE	1	11.4	WHOLE	0.034	0.51	40.15
WARDL000.0LE	WARDLOW POCKET	WARDLOW POCKET	10-20-2009	BLUEGILL SUNFISH	0.3	6.9	WHOLE	0.077	0.47	40.15
YARNE000.0AN	YARNELL BRANCH	YARNELL POND	08-04-2009	REDEAR SUNFISH	0.2	7.3	FILLET	0.02	0.59	42.38
YARNE000.0AN	YARNELL BRANCH	YARNELL POND	08-04-2009	LARGEMOUTH BASS	1.1	12.6	FILLET	0.06	1.2	42.38
YARNE000.0AN	YARNELL BRANCH	YARNELL POND	08-04-2009	REDEAR SUNFISH	0.2	7.1	WHOLE	0.01	0.52	42.38
YARNE000.0AN	YARNELL BRANCH	YARNELL POND	08-04-2009	LARGEMOUTH BASS	0.7	11.5	WHOLE	0.05	0.6	42.38

APPENDIX D

WATER CHEMISTRY

Table D-1: Mercury and Selenium in the Water Samples.

STATION ID	NAME	RESERVOIR	DATE	MERCURY (µg/l)	SELENIUM (µg/l)
BATTL001.2MI	BATTLE CREEK		08-19-2009	0.015U	1.3U
BLEDS004.2SR	BLEDSOE CREEK EMBAYMENT OF OLD HICKORY LAKE	OLD HICKORY	06-30-2009	0.015U	1.3U
BRICH002.0HU	BIG RICHLAND CREEK EMBAYMENT OF KY LAKE	KENTUCKY	07-07-2009	0.015U	1.3U
BSAND007.4HN	BIG SANDY EMBAYMENT	KENTUCKY	07-13-2009	0.015U	1.3U
BSAND015.1BN	BIG SANDY EMBAYMENT	KENTUCKY	07-13-2009	0.015U	1.3U
BUTCH000.0AN	BUTCHER LAKE	BUTCHER	08-05-2009	0.015U	1.3U
COVE017.0CA	COVE LAKE	COVE LAKE	09-14-2009	0.015U	1.3U
CROOK001.4BN	CROOKED CREEK	KENTUCKY	07-14-2009	0.015U	1.3U
DOLAN002.6SU	BAYS MOUNTAIN (KINGSPORT) LAKE ON DOLAN CREEK	BAYS MT (KINGSPORT)	09-05-09	0.015U	1.3U
DRAKE1T0.1SR	DRAKES CREEK UT 1 - MALLARD POINT PARK	OLD HICKORY LAKE	07-06-2009	0.015U	NA
DRY001.7HD	DRY CREEK	PICKWICK	08-10-2009	0.015U	1.3U
DUFFY000.0HY	DUFFY LAKE	DUFFY LAKE	10-19-2009	0.12	1.3U
ELK135.0FR	ELK RIVER	TIMS FORD	07-28-2009	0.015U	1.3U
ELK150.0FR	ELK RIVER	TIMS FORD	07-28-2009	0.015U	1.3U
EMORY027.7MG	EMORY RIVER		09-15-2009	0.015U	1.3U
GREEN004.8WE	GREEN RIVER		08-12-2009	0.015U	1.3U
HOLST055.0GR	HOLSTON RIVER	CHEROKEE	08-17-2009	0.145	1.3U
HOLST076.0HA	HOLSTON RIVER	CHEROKEE	08-19-2009	0.015U	1.3U
LONG002.7RN	GREENBRIER LAKE ON LONG CREEK	GREENBRIER LAKE	07-01-2009	0.015U	1.3U

Table D-1: Cont.

STATION ID	NAME	RESERVOIR	DATE	MERCURY (µg/l)	SELENIUM (µg/l)
NEW048.7AN	NEW RIVER		09-14-2009	0.015U	1.3U
NMOUS1T0.2MM	ATHENS REGIONAL PARK FISHING LAKE	ATHENS REG PARK FISH	09-30-2009	0.03	1.3U
OBED021.1CU	OBED RIVER		09-16-2009	0.015U	1.3U
OCOEE031.0PO	OCOEE RIVER	OCOEE # 3	10-27-2009	0.015U	1.3U
OOSTA011.6MM	OOSTANAULA CREEK		11-06-2009	0.015U	1.3U
OPEN000.0LE	OPEN LAKE	OPEN LAKE	10-20-2009	0.06	1.3U
PTREE000.2SH	POPLAR TREE LAKE	POPLAR TREE	10-21-2009	0.065	1.3U
REESE000.0SR	REESE FARM LAKE	REESE FARM LAKE	07-07-2009	0.015U	1.3U
ROBCO000.0SH	ROBCO LAKE	ROBCO LAKE	10-19-2009	0.05	1.3U
SCOTT003.6SH	SCOTTS CREEK - GARNER/LAKELAND LAKE	GARNER LAKE	10-20-2009	0.03	1.3U
SULPH001.2BN	SULPHUR CREEK EMBAYMENT OF KY LAKE	KENTUCKY	07-15-2009	0.015U	1.3U
TRACE002.0HU	TRACE CREEK EMBAYMENT OF KY LAKE	KENTUCKY	07-06-2009	0.047	NA
WARDL000.0LE	WARDLOW POCKET	WARDLOW POCKET	11-23-2009	0.045	1.3U
YARNE000.0AN	YARNELL BRANCH	YARNELL POND	08-04-2009	0.015U	1.3U

NOTE: The mercury values of 0.015U were below the detection limit.
The selenium values of 1.3U were below the detection limit.
NA = Not analyzed due to lab error.