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ENVIRONMENTAL CONTAMINANT SURVEYS AT NATIONAL WILDLIFE REFUGES IN WEST TENNESSEE

U.S. Fish and Wildlife Service
Ecological Services
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by

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EXECUTIVE SUMMARY

Samples were collected at six National Wildlife Refuges (NWRs) in Tennessee (Chickasaw, Cross Creeks, Hatchie, Lake Isom, Lower Hatchie and Reelfoot) from 1988 and 1990. Fish samples were obtained at each of these refuges and sediment samples were collected at three (Cross Creeks, Lower Hatchie and Reelfoot). Results are summarized below. Results for analyses of a bald eagle egg collected at Reelfoot NWR and turtles collected at Cross Creeks NWR are also included.

All fish and sediment samples were analyzed for polychlorinated biphenyls (PCBs), 22 chlorinated hydrocarbon insecticides or related compounds, and 13 metals. Sediment samples from Reelfoot NWR and Lower Hatchie NWR (Sunk Lake) were also analyzed for six chlorophenoxy herbicides, none of which were detected. Nine additional organochlorine compounds were analyzed in fish and sediment samples from Lower Hatchie (Sunk Lake), but were not detected. Ten additional metals were analyzed in fish samples from Reelfoot and Cross Creeks NWRs. Thallium was analyzed in samples from Chickasaw, Hatchie, Lake Isom and Lower Hatchie NWRs, but was not detected.

Thirty-four fish samples representing 12 species were collected. Gar specimens, either spotted or shortnose, were obtained from all refuges except Cross Creeks, where channel catfish and blue catfish were collected. Of the 34 fish samples collected, DDE was detected in all except the blue catfish from Pool 8 at Cross Creeks NWR. Gar samples contained the higher DDE concentrations at all locations where they were collected except Chisolm Lake at Chickasaw NWR, where bowfin were higher. Only one turtle sample (*Pseudemys scripta*) from Cross Creeks NWR (Pool 2) contained DDE.

Mercury (Hg) was found in all 34 fish and five turtle samples. Gar contained the higher Hg concentrations at locations where they were collected, except Champion Lake at Lower Hatchie NWR, where bowfin were higher. At the other two locations (Powell Lake and Kelso Lake at Hatchie NWR) where bowfin were collected, Hg concentrations approached that found in gar.

Average DDE concentrations in fish were greatest (0.209 ppm, wet-weight) at Reelfoot NWR and least (0.089 ppm) at Lower Hatchie NWR. The highest DDE concentration (1.3 ppm) was found at Reelfoot NWR. Average Hg concentrations were greatest (0.459 ppm) at Lower Hatchie NWR (Champion Lake) and at Hatchie NWR (0.384 ppm), and lowest (0.053 ppm) at Reelfoot NWR. The highest Hg concentration in fish (0.7 ppm) was observed in the bowfin sample from Lower Hatchie NWR, where Hg in sediment averaged 0.019 ppm.

PCBs were detected in all four fish samples from Chickasaw NWR, three gar samples from Lower Hatchie NWR, and four catfish samples and one turtle sample from Cross Creeks NWR. PCB concentrations averaged 0.580 ppm and 0.455 ppm at Lower Hatchie and Chickasaw NWR, respectively. The maximum PCB concentration (0.90 ppm) was found in a gar sample from Sunk Lake at Lower Hatchie NWR.

DDT was detected only at Hatchie NWR, where it was found in four of the five samples collected. The average concentration detected was 0.018 ppm with a maximum of 0.04 ppm. The average DDE concentration at this site was 0.122 ppm. Interestingly, DDT, DDE and DDD were all detected in four of the five fish samples collected at Hatchie NWR.

None of the pesticides, herbicides or PCBs analyzed in this study were detected in the sediment samples which were collected. Mercury concentrations in sediment averaged 0.041 and 0.038 ppm at Cross Creeks and Lower Hatchie NWRs, respectively.

The PCB residues in our fish samples were well below whole-body concentrations linked to mortality and reduced growth in adult fish of the same, or closely related, species. At several locations, total PCBs exceeded the whole-body residue (0.4 mg/kg) for Aroclor 1242 which has been associated with low egg survival and fry deformities in rainbow trout (USEPA 1980).

The total PCB concentration (5.4 ppm) in the bald eagle egg from Reelfoot NWR was in the lower ranges reported for the Columbia River and the Great Lakes. It also fell into the range of concentrations associated with production of one young per active nesting pair in the Great lakes (Kubiak and Best 1991).

DDE in the bald eagle egg from Reelfoot NWR was in the lower range of concentrations associated with reduced productivity in bald eagles and 12-15% eggshell thinning in ospreys. It was well below the egg residue associated with 10% eggshell thinning in bald eagle eggs from the Columbia River basin.

Mercury residues in fish samples were well below concentrations associated with mortality in walleye, brook trout and fathead minnows. In one sample (bowfin - Lower Hatchie NWR), the Hg concentration (0.7 ppm) approached lower concentrations associated with diminished predator avoidance behavior in mosquitofish (Kania and O'Hara 1974).

Mercury in the bald eagle egg from Reelfoot NWR was below the geometric mean in unhatched bald eagle eggs reported by Wiemeyer *et al.* (1984). It was also well below the concentration associated with decreased reproductive success by Newton and Galbraith (1991).

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INTRODUCTION

Five of the seven National Wildlife Refuges (NWRs) in Tennessee are located in the far western region of the State which is predominantly drained by the Mississippi River (Figure 1). Portions of this area may be variously referred to as: the Mississippi River Valley or Alluvial Floodplain, the West Tennessee Plain or Coastal Plain, and the Mississippian Embayment (Miller 1974). More recent ecoregion descriptions by Omernik (1987) divide the area into the Mississippi Alluvial Plain and the Mississippi Valley Loess Plain. These areas constitute an important region within the State, and on a larger scale, are part of the Middle Mississippi River watershed and the Mississippi Flyway.

Areas of the Middle Mississippi River Valley (or floodplain) along the Tennessee border extend up to 22.5 kilometers (km), or 14 miles (mi), in width. Major tributaries include the Forked Deer, Hatchie, Loosahatchie, Obion and Wolf Rivers. Typical features of the valley include oxbow lakes, meander scars, back swamps and cutoffs. The West Tennessee Plain comprises the western portion of the Coastal Plain of West Tennessee, and separates the Mississippi River Valley from the West Tennessee Uplands. The plain is delineated from the valley by low bluffs which are about 31 meters (m), or 100 feet (ft), in height. These bluffs and the broad flood plains of the meandering tributaries are prominent features of the West Tennessee Plain, and Reelfoot Lake is one of the most famous geologic features in the Middle Mississippi Valley (Miller 1974). The lateral migration of streams, frequent flooding, and generally flat terrain have produced fertile soils suitable for agricultural production and also provided numerous areas attractive to waterfowl, neotropical migratory birds, and other fish and wildlife resources.

Within this area of West Tennessee, Reelfoot, Lake Isom, Chickasaw, Lower Hatchie and Hatchie NWRs are situated in watersheds which have been heavily farmed for many years with a variety of row crops including corn, cotton and soybeans. Each of these refuges contain a variety of fish and wildlife habitat including bottomland hardwood forests and other types of wetlands. All of these refuges are used by hunters or anglers, and provide a variety of nongame-related recreational opportunities.

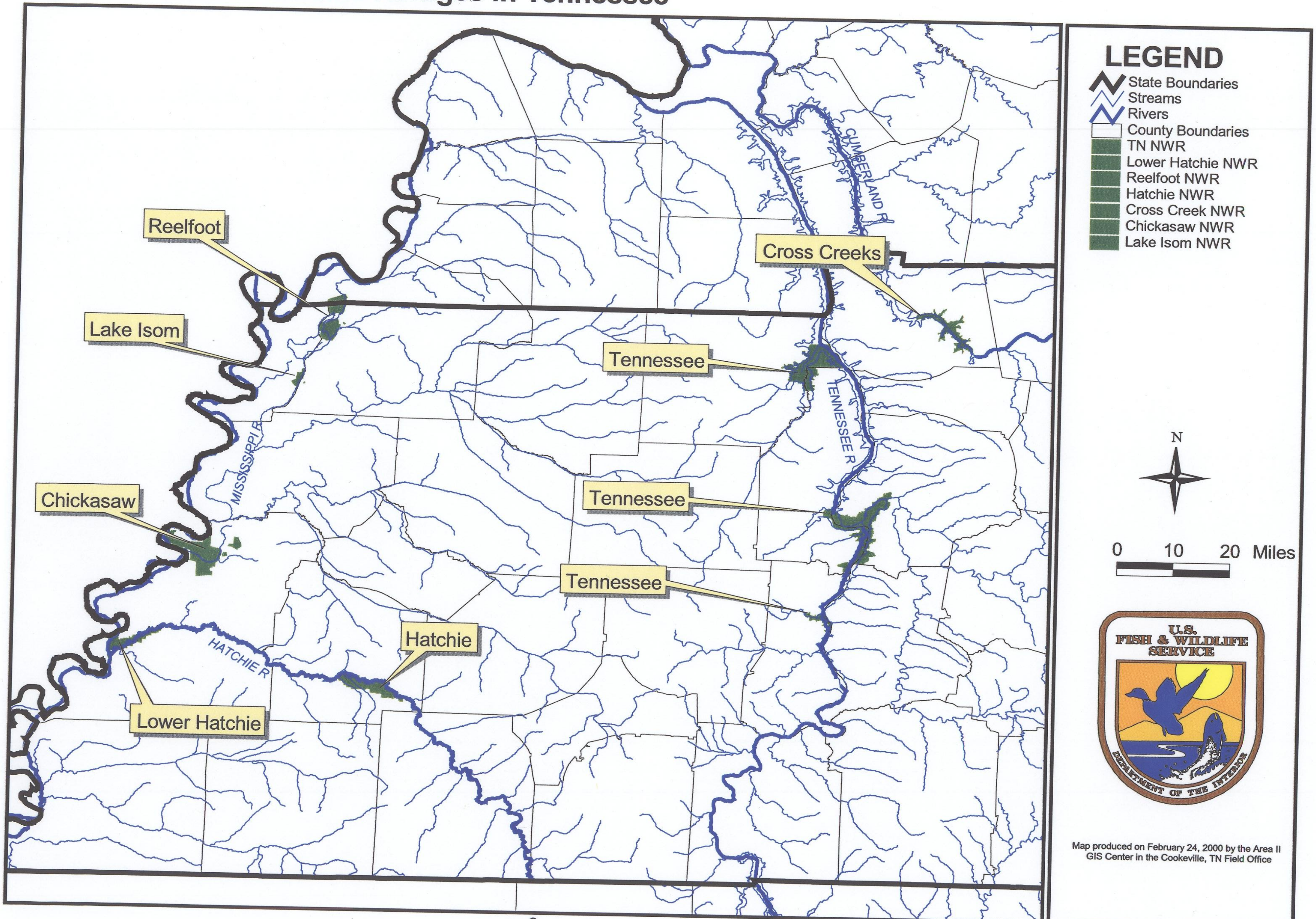
The other two NWRs in Tennessee (Cross Creeks and Tennessee) are located in the Cumberland and the Tennessee River basins, respectively. Cross Creeks NWR is located in the Western Highland Rim physiographic area (Miller 1974), and was sampled as part of this study. The three units of Tennessee NWR are located in the Western Valley physiographic area, and are being sampled in a separate investigation.

Cross Creeks NWR provides fish and wildlife habitats and recreational opportunities similar to those found at the NWRs located in the West Tennessee Plain. Cross Creeks NWR also faces many of the same types of problems. In addition to receiving runoff from agricultural lands in the surrounding watersheds, this refuge has a major, commercially navigable river flowing through it. The refuge is also located adjacent to the Tennessee Valley Authority's (TVA) Cumberland Fossil Fuel Steam Plant, and is subject to deposition of particulate matter from the TVA facility.

The physical impacts of soil erosion and silt intrusion on NWRs are of concern to refuge managers. In addition, a variety of herbicides and insecticides (*e.g.*, chlordane, DDT, dieldrin, toxaphene) have been used within these watersheds. Some of these types of chlorinated compounds have been shown to impair the reproductive capabilities of birds (Clark and Prouty 1984; Eisler and Jacknow 1985; Eisler 1987) and other wildlife (Hoffman *et al.* 1986; Ohlendorf *et al.* 1986; O'Shea *et al.* 1980) that may utilize these refuges. Environmental pollutants or contaminants can pose serious problems for refuges utilized by resident and migratory wildlife. Fish and wildlife species, their habitats, and anglers or hunters can be affected by contaminant associated problems. To properly manage refuge habitats and wildlife resources, accurate and reliable knowledge of the presence of contaminants and their potential effects are required.

Contaminant studies were initiated by the Fish and Wildlife Service (FWS) because of concerns about the effects of agricultural activities and related chemical usage on water quality, potential impacts to fish and wildlife resources, biological impacts of sediment-associated chemicals, the presence of persistent chemicals in fish, and sediment toxicity. Our efforts, while limited, supplement earlier work by Schultz *et al.* (1985) and Winger *et al.* (1988). They also provide some additional data for comparison if future studies are conducted on these refuges.

Figure 1. National Wildlife Refuges in Tennessee



STUDY AREAS AND BASIN IMPACTS

Reelfoot NWR is located in the northwest corner of Tennessee in Lake and Obion Counties, and in southwestern Fulton County, Kentucky (Figure 2). It encompasses the northern portion of Reelfoot Lake and lies in the Obion River (Tennessee) and the Mayfield Creek (Kentucky) drainage basins. The lake was formed by a series of earthquakes in the early 1800's and is Tennessee's largest natural lake. The Refuge was established in 1941 and, through additional land purchases, now comprises 4,220 hectares (ha), or 10,428 acres (ac), of open water, cleared croplands, and palustrine-forested, scrub-shrub and emergent wetlands. Major water bodies found on Reelfoot NWR include: Reelfoot and Sandy Creeks; Running, Buzzard and Rittenhouse Sloughs; Bayou de Chien; and Reelfoot Lake.

The NWR, the nearby State Wildlife Management Area, and the surrounding lake provide a major winter migration stopover and production area for waterfowl in the southeast. This area also provides habitat for a variety of neotropical migratory birds, and supports a large population (100-200) of wintering bald eagles (Haliaeetus leucocephalus).

The predominant soils on Reelfoot NWR are the Swamp-Bowdre-Sharkey and Sharkey-Tunica associations. The former is a group of poorly and somewhat poorly drained, level clayey soils found in the Mississippi River bottoms. The latter group is also poorly drained, and almost all of it is flooded each winter and spring. The depth to seasonal water table varies from 0-91 centimeters (cm), or to 36 inches (in), and the soil pH ranges from 6.1 to 7.8 (Brown *et al.* 1969, 1973).

A contaminant survey conducted during 1983-84 at Reelfoot NWR (Schultz *et al.* 1985) found Cu, Fe, Hg and Zn in whole-body composite samples of black crappie, bluegill and gizzard shad. Lead was also found in gizzard shad at an average concentration 0.25 ppm, wet weight. Mercury concentrations ranged from 0.3 ppm (wet weight) in gizzard shad to 0.19 ppm in black crappie. Two organochlorine contaminants (α-BHC and p,p'-DDE) were detected in all three species, while bluegill also contained p,p'-DDD.

Schultz *et al.* (1985) collected 15 sediment samples from Reelfoot Lake and reported results for seven metals (As, Cd, Cu, Hg, Pb, Se and Zn). Mercury concentrations ranged from 0.06 to 0.37 ppm (wet weight) while Pb varied from 4.1 to 9.5. Average concentrations were greatest for Zn (35.7 ppm, wet weight) and Se was detected in only six of the samples. In three sediment samples, p,p'-DDD was found at concentrations from 0.4 to 4.5 ppm (wet weight). In four sediment samples, p,p'-DDE ranged from 0.9 to 11.0 ppm (wet weight). The other 15 organochlorine chemicals analyzed were not detected.

Reelfoot Lake has been classified as highly eutrophic (USEPA 1976). Although eutrophication is part of the natural aging process of a lake, human activities are accelerating this process at Reelfoot Lake. The shallow, fertile water allows for rapid growth of aquatic macrophytes and plankton (Roelle *et al.* 1986).

Nonpoint source pollution from agricultural lands and stream channelization activities in the watershed are major factors involved in the eutrophication of Reelfoot Lake (Denton 1986, 1987). Silt, pesticides and fertilizers enter the lake with most precipitation events, and result in a variety of water quality problems including nutrient loading, low oxygen, high turbidity levels and potential fish contamination. While numerous plans have been proposed to dredge or excavate channels in the lake to combat siltation problems, concern has been expressed about the potential for resuspension of contaminated sediments which could adversely affect the fish and wildlife resources of this refuge. Sampling locations for this project are shown in Figure 2.

Lake Isom NWR is located in Lake County, Tennessee, three miles south of Reelfoot Lake (Figure 2). It was established in 1938 and consists of 747 ha (1,846 ac) of open water, forested wetlands and croplands within the Obion River drainage. Major water bodies include Lake Isom and Running Reelfoot Bayou.

The fish and wildlife resources of Lake Isom NWR are similar to those at Reelfoot NWR. Sampling locations are shown in Figure 2. The predominant soils on Lake Isom NWR are the Iberia-Sharkey-Bowdre and Reelfoot-Tiptonville-Adler associations. The former are poorly drained and somewhat poorly drained, dark-colored silty and clayey soils on low broad flats. The latter are somewhat poorly drained and moderately well-drained silty, loamy soils located on the high bottoms of the Mississippi River. The depth to seasonal water table on these soils is 0 to 91 cm (to 36 in), and the soil pH ranges from 5.5 to 7.8 (Brown *et al.* 1969).

Chickasaw NWR is located completely within Lauderdale County, Tennessee, and lies south of the Obion River's confluence with the Mississippi River (Figure 3). A portion of the western refuge boundary, about 13 km (8 miles), is provided by the Mississippi River. The refuge was established in 1985 and currently consists of 6,699 ha (16,552 ac) which are under Service fee title, and 2,180 ha (5,387 ac) which are managed under a no-fee lease from Tennessee Wildlife Resources Agency (TWRA). Although the area is mostly bottomland hardwood forest, it also includes some agricultural lands, timbered bluffs, locust/osage orange upland and some small open water areas. The principal water bodies located on the refuge are the Old Fork of the Forked Deer River; Rush, Camp, and Coker Sloughs; Chisolm, Dry Arm, Grassy, Lost, Open, Right Hand Arm, and Swan Lakes; Goose, Jennings and Long Ponds; and Wardlow's Pocket. For this study, samples were collected from Chisolm Lake and Wardlow's Pocket (Figure 3).

The refuge and associated lands provide important wintering and stopover areas for a large portion of the Mississippi Flyway mallard population, and other species of waterfowl as well. Approximately 150 species of birds, including the bald eagle have been observed in the area. A bald eagle nest was constructed on Dry Arm in 1990 and three eaglets were successfully hatched and fledged in 1992.

The predominant soils on this refuge are the Open Lake, Sharkey and Commerce associations. Open Lake soils are dark-colored, poorly drained soils which are located in nearly flat or slightly depressed areas. Water percolates very slowly into the subsoil and surface runoff also occurs slowly. This often results in some standing water and extreme wetness of the surface soil layer.

The Sharkey series consists of poorly drained soils in low places on the Mississippi River bottoms. These soils developed in thick beds of clay deposited by the Mississippi River. They have a depth to seasonal ground water of 0 cm, and a pH of 6.1 to 7.8. The Commerce series consists of somewhat poorly drained soils on the Mississippi River bottoms. These soils developed in a mixture of sediments from the Mississippi River and the nearby, steep loess hills. They have a depth to seasonal ground water of 25 to 51 cm (10" to 20"), and a pH of 6.6 to 7.3 (Brown *et al.* 1973).

Lower Hatchie NWR was established in 1980 by the Migratory Bird Conservation Commission, and is located within the Hatchie River watershed in Lauderdale and Tipton Counties, Tennessee (Figure 4). It encompasses approximately 2,590 ha (6,400 ac) which include: forest (4,303 ac), cropland (1,200 ac), open water (60 ac), and old field or scrub habitat (830 ac). The principal water bodies located on this refuge are the Hatchie River, Indian Creek, Champion Lake and Little Champion Lake. The refuge provides habitat for wintering waterfowl and other migratory birds. Developed impoundment areas adjacent to the Mississippi River are managed for ducks (primarily mallards) and the Mississippi Valley population of Canada geese.

Predominant soils on the refuge are the Sharkey, Commerce and Memphis associations. The Sharkey series consists of poorly drained soils in the Mississippi River bottoms. These soils developed in thick beds of clay deposited by the Mississippi River. The depth to seasonal high water table is 0 - 20 cm (to 8") and the pH ranges from 6.6 to 7.8. The Commerce series consists of somewhat poorly drained soils on the Mississippi River bottoms. These soils developed in a mixture of sediments from the Mississippi River and the nearby, steep loess slopes. The depth to seasonal high water table is 25 - 51 cm (to 20") and the pH ranges from 6.6 to 7.3. The Memphis series consists of well-drained, silty soils. These soils are on upland areas and have slopes ranging from 2 to 50 percent. The depth to seasonal water table is greater than 183 cm (72 in), and pH values range from 5.1 to 7.3 (Brown *et al.* 1973).

Hatchie NWR is located entirely within Haywood County, Tennessee, and lies about 4.8 km (3 mi) south of Brownsville (Figure 5). The refuge occupies 4,677 ha (11,556 ac), and stretches along 39.4 km (24.5 mi) of the southern bank of the Hatchie River. This river is designated as a Class I Scenic Swamp River under Tennessee State law, and is the last major unaltered stream in West Tennessee and the Middle Mississippi River.

The refuge was established in 1964 to provide feeding, resting and wintering habitat for migrating waterfowl. Over 3,800 ha (9,400 ac) of flooded bottomland forests dominate the habitat types, possibly the best in the refuge system. These forested wetlands are a singular example of the oak-dominated forests that historically provided the principal wintering habitat for continental mallard populations in the upper Delta.

Predominant soils of the refuge are the Oaklimeter series. They consist of very deep, moderately well drained soils on floodplains. These soils were formed in alluvium. This series is often found geographically associated with the poorly drained Tichnor and Rosebloom soils (McCowen et al. 1995).

In addition to the agricultural impacts discussed previously, there are other sources of contaminants which could migrate or be transported following precipitation events into the Hatchie River and subsequently into the refuge. Small metal plating businesses, radiator shops, forestry practices, wood treatment plants, and at least one identified State Superfund site (Hardeman County Landfill) are located within the Hatchie River Watershed upstream of the refuge, and are potential sources of toxic metals and organic compounds. Samples for this project were collected from Powell Lake and Kelso Lake.

Cross C reeks NWR is located between Dover and Cumberland City in Stewart County, Tennessee (Figure 6). It lies within the West Tennessee Upland physiographic area. The 3,586 ha (8,862 ac) refuge stretches for 19.2 km (12 mi) along the rolling hills and high rocky bluffs bounding the Cumberland River bottom lands.

The refuge was established in 1962 to mitigate for the inundation of the Kentucky Woodlands Refuge by the creation of Lake Barkley. The refuge provides feeding and resting habitat for migrating waterfowl in the Mississippi Flyway and provides suitable habitat for more than 245 other species of birds and numerous species of mammals, reptiles, amphibians and insects. In addition, the bald eagle and the peregrine falcon (*Falco peregrinus*) occur on the refuge while endangered species, such as the gray bat (*Myotis grisescens*) and the Indiana bat (*Myotis sodalis*), occur within the surrounding county.

Predominant soils on the refuge are the Arrington-Lindside-Beason association. These soils formed in sediment deposited by the Cumberland River. They consist of level, well-drained to somewhat poorly drained soils on the floodplain of the Cumberland River.

About one-third of the refuge consists of hardwood forests in various successional stages. Other terrestrial habitats include marsh, cultivated lands and grasslands. In addition, the refuge has about 1000 ac of cropland which is used for growing corn, soybeans, milo, millet and buckwheat. Aquatic habitats consist of the Cumberland River, many small streams and 16 impoundments of various sizes. Refuge impoundments are managed by moist soil management techniques, which involves raising and lowering water levels to promote food production for waterfowl and other wildlife. The samples collected in this study came from the following refuge impoundments: Pool 2, Lower Pool 4, Upper Pool 4, Pool 8 and Elk Reservoir (Figure 6).

Concerns have been raised that value of this refuge as wildlife habitat and as a recreational area may be impaired due to activities occurring in and around the Cumberland River watershed. The refuge is located immediately adjacent to the Cumberland Fossil Fuel Steam Plant, which is operated by TVA. Cross Creeks NWR is subject to receiving particulate deposition from the TVA facility. The refuge impoundments also receive runoff from surrounding agricultural lands, where persistent organochlorine pesticides have been utilized.

Figure 2. Reelfoot and Lake National Wildlife Refuges

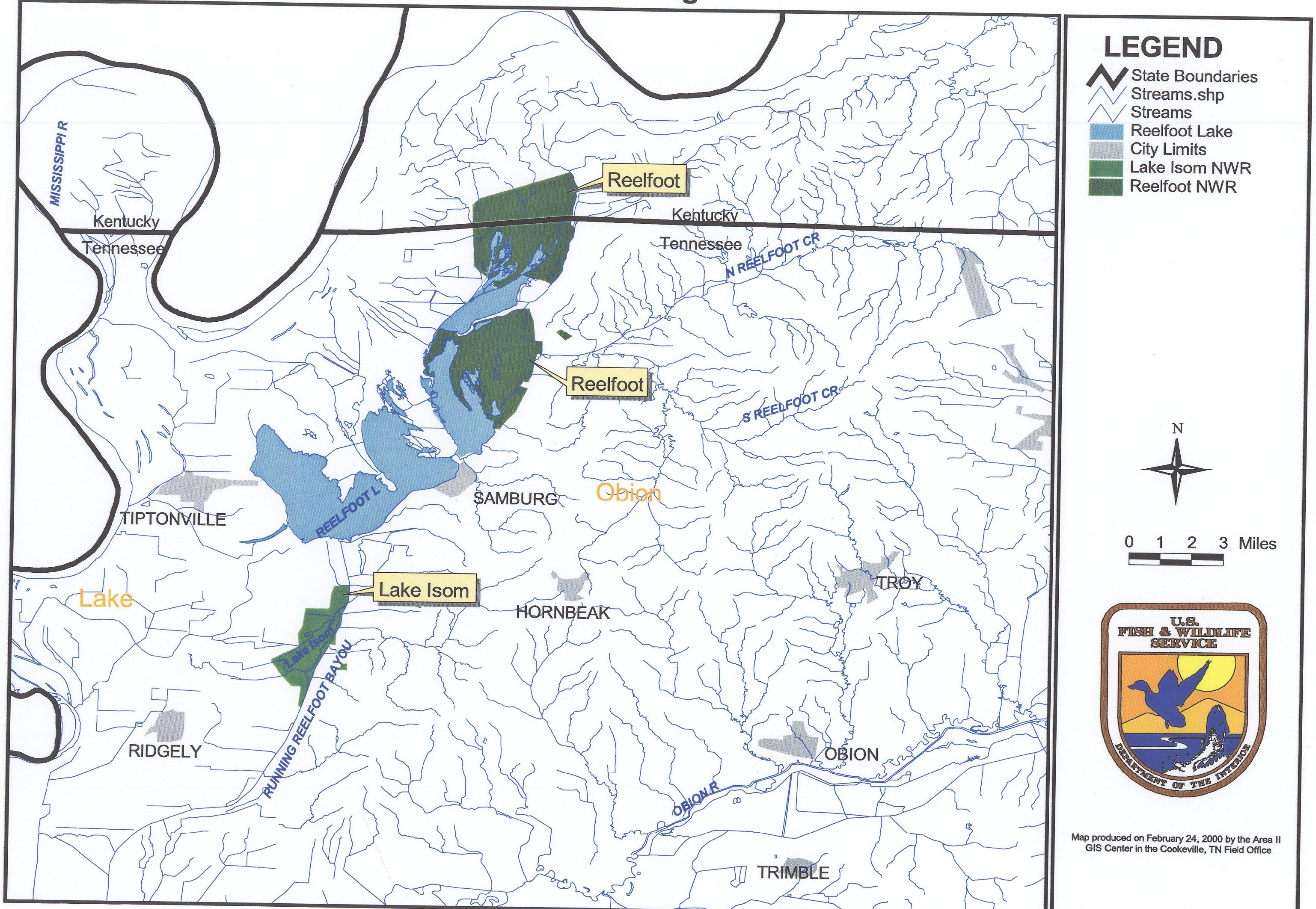


Figure 3. Chickasaw National Wildlife Refuge

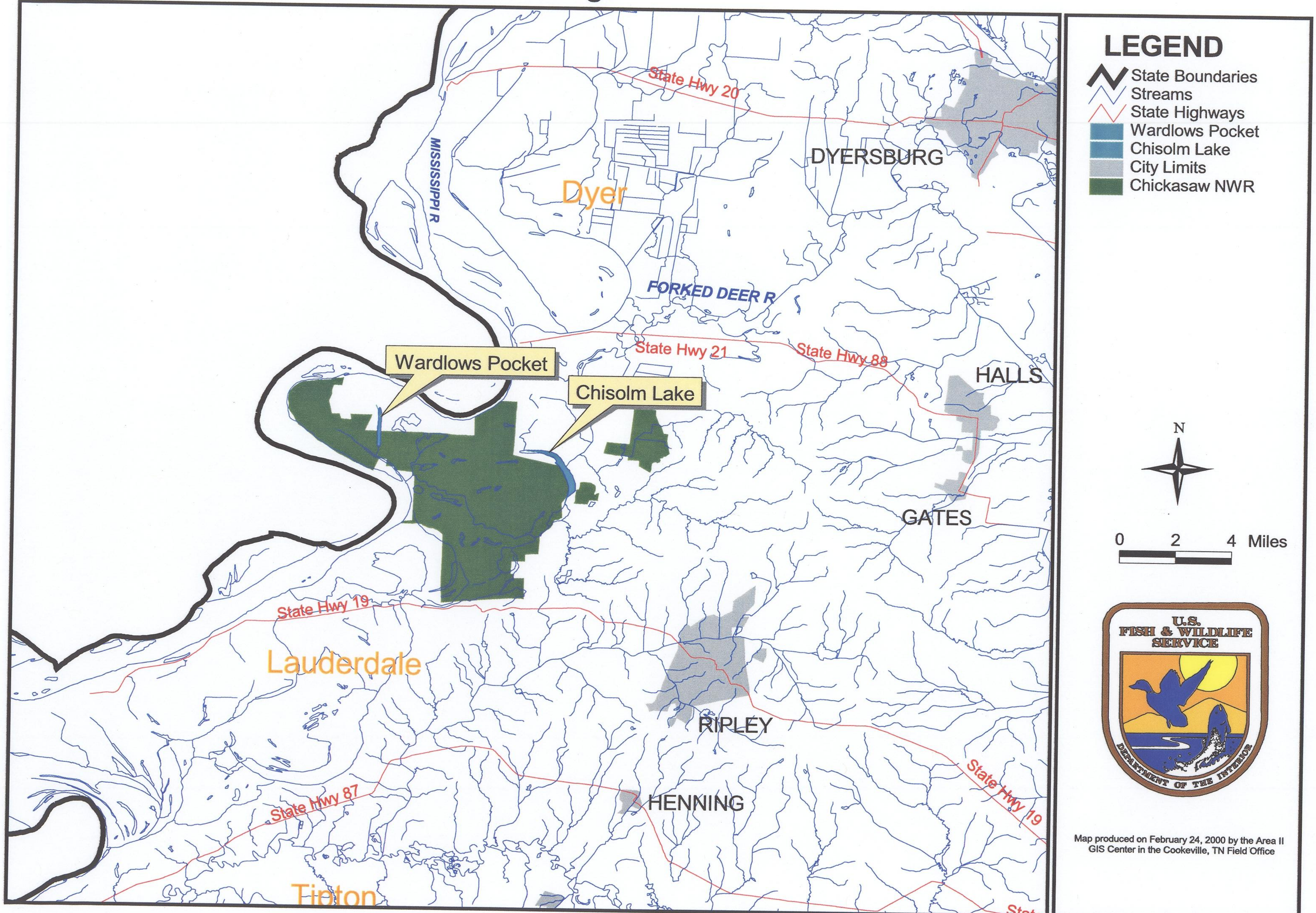


Figure 4. Lower Hatchie National Wildlife Refuge

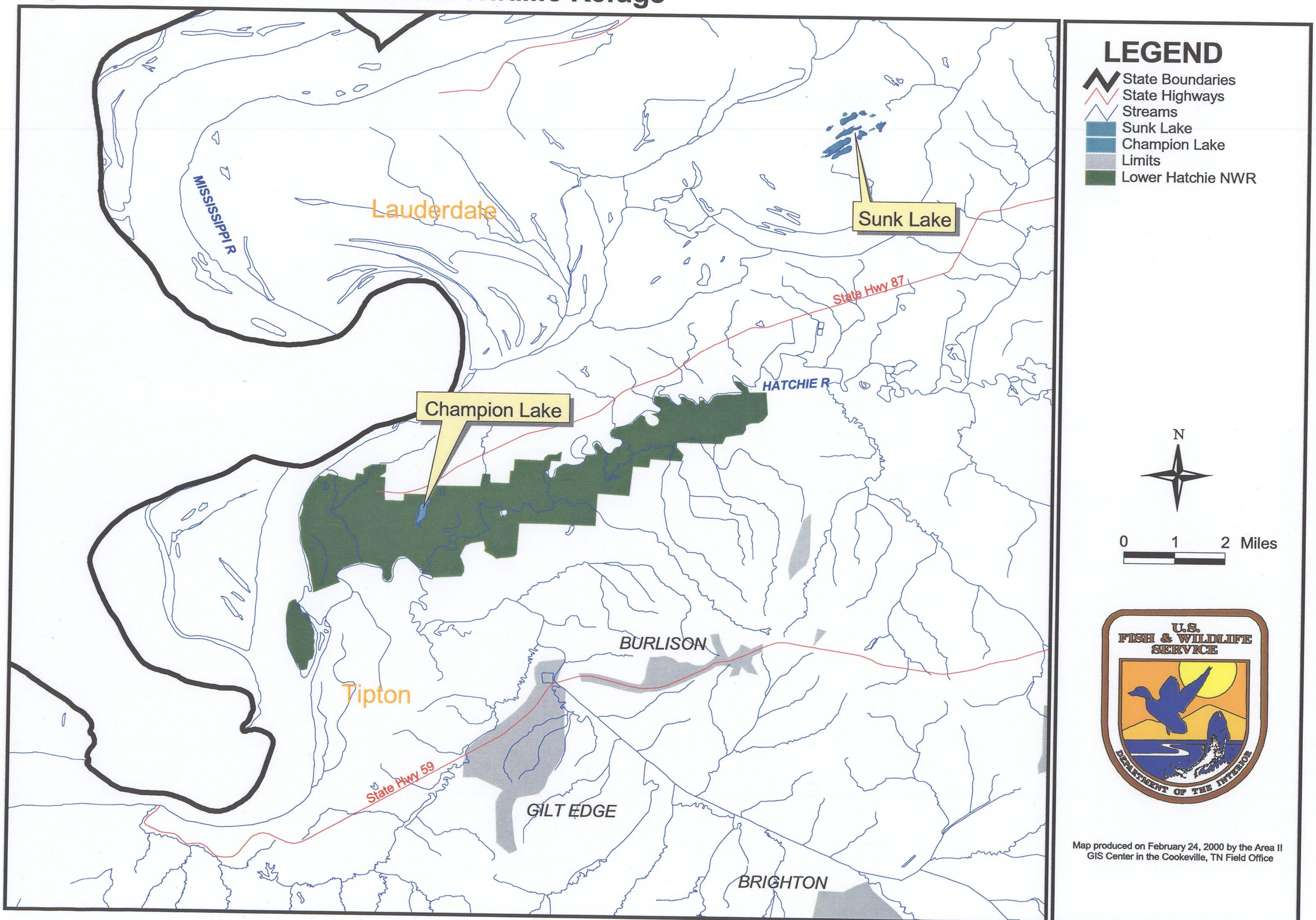


Figure 5. Hatchie National Wildlife Refuge

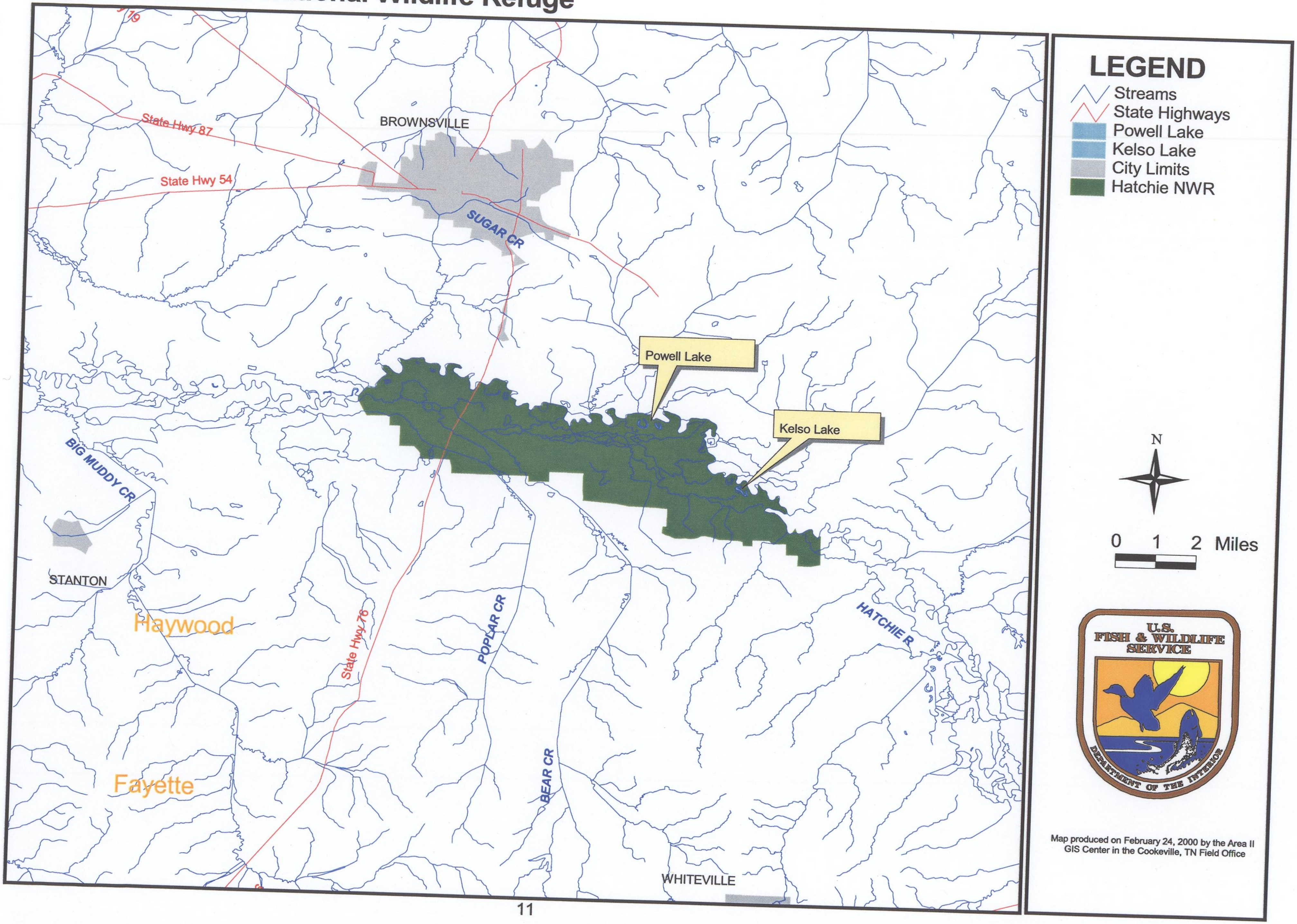
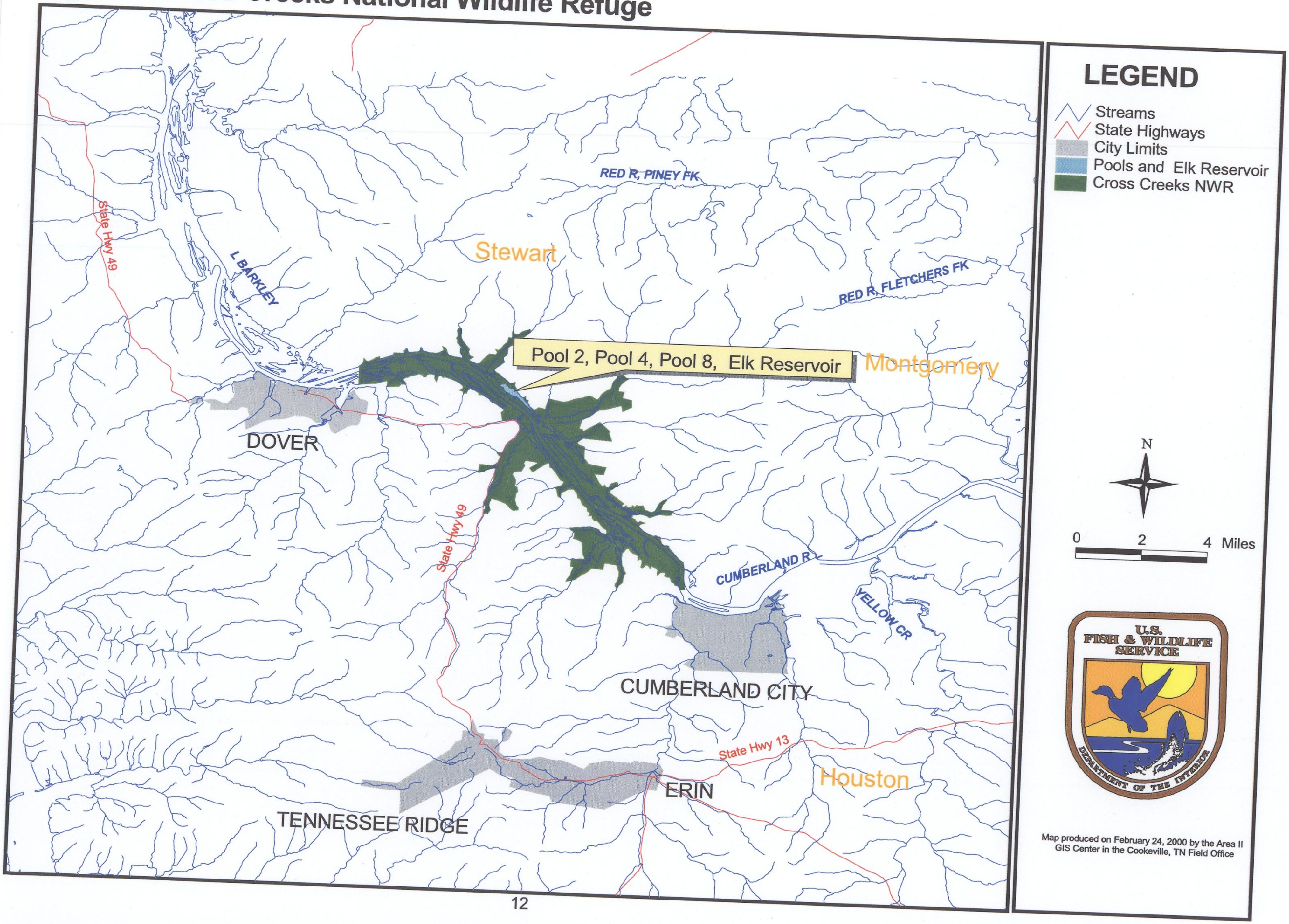


Figure 6. Cross Creeks National Wildlife Refuge



METHODS AND MATERIALS

Sample Collection. Fish specimens were collected by Service and TWRA personnel using standard boat-electrofishing techniques. Samples were kept in the boat's live-well until collecting efforts were completed. Fish were sorted by species, and those retained for analysis were weighed and measured (total length). Specimens for the composite samples were then wrapped in clean aluminum foil, labeled and sealed in plastic bags. The samples were held on wet ice during transport, frozen and shipped to the analytical laboratory.

Sediment samples were collected by Service and USGS personnel using a Wildco hand corer with a two-inch stainless steel tube and cellulose acetate butyrate tube-liners. Samples were collected in areas where fine-grained, silty, depositional substrate was overlain by relatively shallow water. The corer tube was inserted as far as possible into the bottom and withdrawn. The tube-liner was carefully removed and the overlying water slowly drained away. At least three core samples were collected at each site. Sediment cores were retained in a vertical position on wet ice and frozen after collections were completed. Frozen core samples were then sectioned into vertical segments 10-14" in length, and a matched set used for inorganic analyses, elutriate tests, and pesticide/herbicide analyses.

Sample Analysis. Fish samples were prepared for chlorinated hydrocarbon pesticides and PCB analyses by taking a five-gram (g) aliquot from a well-mixed composite sample and combining with up to 150 g of anhydrous sodium sulfate. These samples were then extracted with hexane for seven hours in a Soxhlet extractor and concentrated using a rotary evaporator. The extract was then air-dried to a constant weight (usually 4 days) for lipid determinations. After weighing, the lipid sample was dissolved in petroleum ether (12 ml) saturated with acetonitrile and extracted four times each with 30 ml of acetonitrile saturated with petroleum ether. Residues were partitioned into petroleum ether, washed, concentrated to 5 ml, and transferred to a glass elution column containing 20 g of Florisil.

The Florisil column was eluted with a 200 ml mixture of 6% diethyl ether and 94% petroleum ether (Fraction I), followed by 200 ml of 15% diethyl ether and 85% petroleum ether (Fraction II). Fraction II was then concentrated for quantification of chemical residues using capillary or megabore columns and electron capture gas chromatography. Fraction I was concentrated to 5 ml and transferred to a silicic acid chromatographic column for additional cleanup and separation of PCBs. Three elutriate fractions were obtained and concentrated to 10 ml for quantification using capillary or megabore columns and electron capture gas chromatography. Elution profiles for the separation columns are shown in Appendix A.

Fish samples were prepared for metal analyses by freeze-drying aliquots of well-homogenized composite samples. After moisture content was determined, a 0.25 to 0.5 g aliquot of freeze-dried tissue was digested with nitric acid. Specific procedures are included in Appendix B.

Sediment samples were prepared for analysis of insecticides, PCBs and chlorophenoxy herbicides by taking a 20 g aliquot and mixing with sulfuric acid, acetone, and a 1:1 mixture of petroleum ether and ethyl ether. Detailed procedures are included in Appendix C.

Except for the 1988 samples from Cross Creeks NWR, pesticide, PCB and herbicide (sediment only) assays on fish and sediment samples were performed by the Hand Chemical Laboratory at Mississippi State University, Starkville. The 1988 Cross Creeks NWR samples (fish, turtles, sediment) were analyzed for organochlorine pesticides and PCBs by the Geochemical and Environmental Research Group at Texas A&M University, College Station, Texas. The bald eagle egg sample collected at Reelfoot NWR in 1987 was analyzed by the Patuxent National Wildlife Research Center in Laurel, Maryland. Analyses were conducted for the organic compounds listed in Table 1M and for the metals shown in Table 2M. Chlorophenoxy acid herbicide assays were performed at Reelfoot NWR.

Samples (fish, turtle, sediment) collected from Cross Creeks NWR in 1988 and fish samples collected from Reelfoot NWR in 1989 were analyzed for metals by Research Triangle Institute, Research Triangle Park, North Carolina. The U. S. Geological Survey (USGS) soils laboratory analyzed the 1988 sediment cores from Reelfoot Lake for inorganic constituents and also performed elutriate tests on these samples. All other metal analyses on fish and sediment samples were performed by the Environmental Trace Substances Research Center, Columbia, Missouri. Arsenic and Se were analyzed using atomic absorption (AA) spectrophotometry. Mercury was analyzed using a standard cold vapor AA technique. All other metals were analyzed using inductively coupled plasma (ICP) emission spectrometry.

Metals detection limits for samples analyzed by Research Triangle Institute are shown in Table 3M (Reelfoot NWR) and Table 4M (Cross Creeks NWR). Detection limits for samples analyzed by the Environmental Trace Substances Research Center are shown in Table 5M. Both laboratories reported detection limits and results in micrograms per gram (µg/g) dry weight. Thus, the detection limits shown in the Appendix D tables are those reported for each sample.

Results are initially given in wet weight values to provide comparisons with other studies. Dry weight values are provided in Appendix D. Conversion between wet weight and dry weight values was accomplished using the following formulas:

Dry weight concentration = wet weight concentration/(1-(%Moisture÷100))
Wet weight concentration = dry weight concentration*(1-(%Moisture÷100))

Both wet and dry weight values are provided to ease comparisons with data reported from previous or future studies by other investigators.

Quality Assurance/Quality Control

Laboratory quality control was verified by the Patuxent Analytical Control Facility at the Patuxent National Wildlife Research Center in Laurel, Maryland. The precision and accuracy of the analytical results were confirmed with matrix and reagent blanks, duplicate analysis of randomly selected samples, recoveries of spiked analytes, and analysis of samples from the National Institute of Standards and Technology, the U.S. Environmental Protection Agency (USEPA), and the use of FWS reference materials.

With only a few exceptions, all analytical results were considered to be acceptable. The laboratories which analyzed the 1988 samples (fish, turtles and sediment) from Cross Creeks NWR and the 1989 fish samples from Reelfoot NWR noted that recoveries of antimony (Sb), silver (Ag) and tin (Sn) by ICP analysis were usually low. None of these metals were detected in any samples analyzed for this report.

Concerns regarding high variability of aluminum data were expressed by the laboratory which analyzed the 1989 fish samples from Reelfoot NWR. These results are included in this report to allow some comparisons between refuges. Any subsequent statistical analysis involving Al data would likely include some type of data transformation to help address this variability.

Some concern was expressed by reviewers regarding the pre-wetted column technique used for extracting samples for chlorophenoxy acid herbicide analysis. The main concern was that the absence of these contaminants could be a result of the procedure used. Recovery data supplied by the laboratory indicated 95-100 percent recoveries for these compounds.

The laboratories used in these investigations completed a considerable amount of QA/QC analyses. This included analyzing several samples in duplicate. Although other detailed QA/QC information is not included in this report, it is available upon request.

Table 1M. Chlorinated Hydrocarbon Insecticides and Chlorophenoxy Herbicides Analyzed in Samples From National Wildlife Refuges in Tennessee*.

Insecticides and PCBs	Herbicides
HCB (hexachlorobezene) *aka* perchlorobenzene	Dicamba (3,6-dichloro-*o*-anisic acid)
BHC (benzene hexachloride) *aka* hexachlorocyclohexane alpha, beta, gamma, delta isomers	Dichlorprop (2,4-dichlorophenoxy propionic acid)
Oxychlordane	2,4-D (2,4-dichlorophenoxy acetic acid)
Chlordane (alpha, gamma)	2,4-DB [4-(2,4-dichlorophenoxy) butyric acid]
Nonachlor (trans, cis)	2,4,5-T (2,4,5-trichlorophenol)
Heptachlor epoxide	Silvex [2-(2,4,5-trichlorophenoxy) propionic acid] aka 2,4,5-TP
DDT (*o,p'* and *p,p'*)	Supplemental Organochlorine Parameters**
DDE (*o,p'* and *p,p'*)	Dicofol
DDD (*o,p'* and *p,p'*)	Endosulfan I and II
	8-monohydromirex
Endrin	10-monohydromirex
Dieldrin	2,8-dihydromirex
Mirex	5,10-dihydromirex (cis and trans)
Toxaphene	Octochlorostyrene
Polychlorinated biphenyls (PCBs)	

* At Cross Creeks NWR, aldrin and lindane (99% gamma-BHC) were also analyzed, but not detected. Chlorophenoxy acid herbicides were analyzed in sediment samples from Reelfoot NWR and Lower Hatchie NWR (Sunk Lake), but none were detected.

** Analyzed in 1990 fish and sediment samples from Lower Hatchie NWR (Sunk Lake), but not detected.

Table 2M. Metals Analyzed in Samples from Six National Wildlife Refuges in Tennessee.

Aluminum	(Al)[1]	Chromium	(Cr)[1]	Nickel	(Ni)[1]
Antimony	(Sb)[2]	Copper	(Cu)[1]	Selenium	(Se)[1]
Arsenic	(As)[1]	Iron	(Fe)[1]	Silver	(Ag)
Barium	(Ba)	Lead	(Pb)[1]	Strontium	(Sr)
Beryllium	(Be)[1]	Magnesium	(Mg)	Thallium	(Tl)[3]
Boron	(B)	Manganese	(Mn)[1]	Tin	(Sn)
Cadmium	(Cd)[1]	Mercury	(Hg)[1]	Vanadium	(Vn)
Cobalt	(Co)[2]	Molybdenum	(Mo)	Zinc	(Zn)[1]

[1]Metals analyzed in samples from all six NWRs.

[2]Metals analyzed only in samples from Reelfoot and Cross Creeks NWRs.

[3]Analyzed only in samples from Lake Isom, Chickasaw, Lower Hatchie and Hatchie NWRs.

Table 3M. Detection Limits for the ICP and AA Methods (µg/g, dry weight) Used on the 1989 Fish Samples From Reelfoot NWR.[1]

ICP Detection Limits		AA Detection Limits	
Element	Tissue	Element	Tissue
Al	20	As	0.3
Sb	20	Hg (CVAA[2])	0.02
Ba	2.0	Se	0.3
Be	0.1		
B	2.0		
Cd	0.4		
Co	3.0		
Cr	2.0		
Cu	2.0		
Fe	10		
Pb	5.0		
Mg	10		
Mn	0.3		
Mo	3.5		
Ni	3.5		
Ag	5.0		
Sr	2.0		
Sn	20		
V	1.5		
Zn	3.0		

[1]Analyses by Research Triangle Institute. Detection limits provided as dry weight values.
[2]Cold vapor atomic absorption.

Table 4M. Detection Limits for the ICP and AA Methods (µg/g, dry weight) Used on the 1988 Samples From Cross Creeks NWR.[1]

ICP Detection Limits			AA Detection Limits	
Element	Sediment	Tissue [2]	Sediment	Tissue
Al	50	2.5		
Sb	50	4.5		
As			0.20	0.20
Ba	1.5	0.15		
Be	0.20	0.02		
B	1.0	0.40		
Cd	0.70	0.07		
Co	4.3	0.60		
Cr	1.0	0.35		
Cu	3.3	0.25		
Fe	60	5.0		
Pb	15	1.2		
Mg	50	4.0		
Mn	1.7	0.15		
Hg (CV)[3]			0.02	0.02
Mo	16	2.0		
Ni	6.0	0.30		
Se			0.30	0.30
Ag	12	2.0		
Sr	10	0.60		
Sn	40	6.0		
V	0.90	0.07		
Zn	16	3.0		

[1]Analyses by Research Triangle Institute. Detection limits provided as dry weight values.
[2] Pre-concentration done using microwave technique.
[3]Cold vapor method.

Table 5M. Detection Limits for the ICP and AA Methods (ug/g, dry wt.) Used on the 1988 Fish Samples From Lake Isom, Chickasaw, Lower Hatchie and Hatchie NWRs[1].

ICP Detection Limits[2]		AA Detection Limits[3]	
Element	Tissue	Element	Tissue
Al	0.3	As	0.100
Be	0.01	Hg (CVAA[4])	0.012
Cd	0.03	Se	0.090
Cr	0.1		
Cu	0.02		
Fe	0.1		
Pb	0.5		
Mn	0.03		
Ni	0.2		
Tl	0.5		
Zn	0.02		

[1] Analyses by Environmental Trace Substances Research Center. Detection limits provided as dry weight values.
[2] The lowest detection limit reported for each analyte is shown.
[3] Detection limits are values from analysis of blanks.
[4] Cold vapor atomic absorption.

RESULTS

Reelfoot NWR

Fish. Nine composite samples representing five fish species were collected from Reelfoot NWR in June 1989 (Table 1R). Duplicate composite samples were collected for each species except crappie. The crappie composite consisted of two white crappie (*Pomoxis annularis*) specimens and one black crappie (*Pomoxis nigromaculatus*) specimen. Although the gar specimens were not identified to species, they were likely spotted (*Lepisosteus oculatus*), longnose (*L. osseus*) or shortnose (*L. platostomus*) specimens.

Two chlordane-related compounds (α-chlordane and trans-nonachlor), two DDT-related compounds (*p,p'*-DDD and -DDE), dieldrin, and toxaphene were detected in the fish samples (Table 2R). DDE was detected in all samples at concentrations ranging from 0.02 in catfish and crappie to 1.3 ppm in gar. Dieldrin was found in one sample at 0.03 ppm. DDD, α-chlordane and trans-nonachlor were each detected only in one gar sample. The highest concentrations for all insecticides were present in the same gar sample (RFL-8). Dry-weight concentrations (Appendix D) were generally three-four times higher than the wet-weight concentrations.

Twelve metals were detected in the fish samples (Table 3R). Mercury concentrations were highest (0.166 ppm) in the gar samples and lowest (0.007 and 0.013 ppm, respectively) in the yellow bass (*Morone mississippiensis*) and channel catfish (*Ictalurus punctatus*) samples.

Sediment. Nine sediment core samples collected in November 1998, and held frozen, were analyzed along with the fish samples collected in June 1989. None of the 22 pesticides or six chlorophenoxy acid herbicides analyzed in this study were detected in our sediment samples from Reelfoot Lake. Other results for water and sediment samples were reported by Broshears (1991) and are briefly summarized here. Concentrations of inorganic constituents in the water and sediments did not vary significantly among the five sampling sites. The concentrations of trace elements in the sediments were similar to values found in surface soils, and there were no significant changes in the concentrations of inorganic constituents with depth. Trace elements and nutrients in the water were associated with particulate matter, and did not exceed water-quality criteria for the protection of aquatic life. Although water quality criteria for the protection of aquatic life were exceeded for copper, lead, and zinc in several of the elutriate tests, 48-hour toxicity tests of the elutriate with *Cerodaphnia dubia* resulted in mortality rates less than 10 percent. Additional information can be found in the USGS report by Broshears (1991).

Other. One unhatched bald eagle egg was collected from a nest at Reelfoot NWR in 1987. The egg was incubated by the parents for 58 days and then abandoned. The eggshell thickness was measured at 0.46 mm, however, this did not include the membrane because it had deteriorated. Twelve chlorinated hydrocarbon insecticides (or related compounds), three PCB Aroclors, and three metals were detected in the egg (Table 4R). Insecticide concentrations ranged from 0.0098 ppm (endrin) to 3.8 ppm (DDE). For PCBs, Aroclor 1260 occurred at the greatest concentration

(5.2 ppm). Six chlordane-related compounds were also detected at concentrations ranging from 0.013 ppm (trans-chlordane) to 0.24 ppm (trans-nonachlor). Mercury was present at 0.23 ppm.

Lake Isom NWR

Fish. Duplicate composite samples of spotted gar (*Lepisosteus oculatus*) and smallmouth buffalo (*Ictiobus cyprinellus*) were collected. Two DDT-related compounds (p,p'-DDD and -DDE) were detected in all four samples at concentrations ranging from 0.02 to 0.23 ppm (Table 5R). The higher DDE concentrations were present in the gar samples.

Twelve metals were detected in at least one of the samples (Table 6R). Both the greatest (0.5 ppm) and the least (0.04 ppm) mercury concentrations were found in the gar whole-body samples. In smallmouth buffalo, the average mercury concentration was 0.095 ppm.

Chickasaw NWR

Fish. Composite samples of spotted gar and smallmouth buffalo were collected from Chisolm Lake while bigmouth buffalo (*Ictiobus bubalus*), spotted gar and shortnose gar (*Lepisosteus platostomus*) were obtained from Wardlow's Pocket. Polychlorinated biphenyls (PCBs) and p,p'-DDE were detected in all samples. Four chlordane-related compounds and hexachlorobenzene (HCB) were also present in the gar sample from Wardlow's Pocket (Table 7R). Only a trace amount of trans-nonachlor was detected in the smallmouth buffalo from Chisolm Lake.

Thirteen metals were detected in at least one fish sample (Table 8R). An unusually high lead concentration (1181 ppm) was reported for the spotted gar sample from Chisolm Lake. Mercury concentrations were higher in the gar samples, with the highest (0.203 ppm) present in the Chisolm Lake sample.

Lower Hatchie NWR

Fish. Composite samples of spotted gar and bowfin (*Amia calva*) were collected from Champion Lake in 1988 (Table 9R) while gar, gizzard shad (*Dorosoma cepedianum*) and quillback (*Carpiodes cyprinus*) were collected from Sunk Lake in 1990 (Table 10R). Analyses indicated that p,p'-DDE was present in all samples at concentrations ranging from 0.03-0.19 ppm, with the greater concentrations found in the gar samples. PCBs, dieldrin, alpha-chlordane and trans-nonachlor were detected only in the gar samples (Tables 9R and 10R).

Ten metals were detected in the bowfin samples and nine in the spotted gar samples collected from Champion Lake in 1988 (Table 11R). These same ten metals were also detected in at least one of the five fish samples collected from Sunk Lake in 1990 (Table 12R). Of the additional eight metals (Ba, B, Mg, Mo, Ag, Sr, Sn and V) analyzed in 1990, four (Ba, Mg, Sr and V) were detected. Mercury concentrations ranged from 0.28 ppm in the Sunk Lake quillback sample to 0.7 ppm in the bowfin sample from Champion Lake. In the gar samples, mercury concentrations averaged 0.25 ppm, and were slightly higher for those collected from Sunk Lake.

Sediment. Nineteen metals were detected in the sediment samples collected from Sunk Lake in 1990 (Table 13R). Five of these (Ag, B, Be, Cd, Pb) were not found in the 1990 fish samples and three (Ba, Cd and Pb) were not detected in the 1988 fish samples. Detected concentrations for these five metals ranged from 0.1 ppm (Be, Cd) to 18 ppm (Pb). Mercury concentrations averaged 0.019 ppm.

Hatchie NWR

Fish. Composite samples of spotted sucker (*Minytrema melanops*), spotted gar and bowfin were collected from Powell Lake while spotted gar and bowfin samples were obtained from Kelso Lake. Both p,p'-DDD and -DDE were present in all five samples, and p,p'-DDT was detected in both Powell and Kelso Lakes (Table 14R). Trace amounts of dieldrin were found in the bowfin sample and the spotted sucker sample from Powell Lake.

Twelve metals were detected in the fish samples (Table 15R). Mercury concentrations ranged from 0.222 ppm in spotted sucker to 0.5 ppm in spotted gar. Mercury was slightly higher in the spotted gar sample from Powell Lake.

Cross Creeks NWR

Fish. Thirty fish, turtle and sediment samples were collected from five locations on Cross Creeks NWR (Table 16R). Three channel catfish and two blue catfish (*Ictalurus furcatus*) samples were analyzed for chlorinated hydrocarbon pesticides and PCBs (Table 17R). Both DDE and PCBs were detected in fish from all locations except Pool 8 (blue catfish). Concentrations of DDE ranged from 0.09 - 0.15 ppm while PCBs varied from 0.06 - 0.31 ppm. Hexa- and penta-chlorobiphenyls were the predominant PCB congener groups (Table 17R).

Turtle. Ten turtle samples representing two species were trapped from the same areas where the fish were collected. Common snapping turtle (*Chelydra serpentina serpentina*) specimens were trapped at Pool 8 while red-eared turtles (*Chrysemys scripta elegans*) were obtained at the other four locations. Both DDE and PCBs were detected only in the samples from Pool 2 (Table 17R). Concentrations ranged from 0.05 ppm (tetrachlorobipheny) to 0.15 ppm (trichlorobiphenyl).

Sediment. Two sediment samples were collected at each location. One set was analyzed for pesticides and PCBs, and the other set used for metals analyses. None of the 31 pesticides or PCB compounds analyzed were detected in the sediment samples.

Metals. Twenty of the 23 metals analyzed (87%) were detected in at least one fish, turtle or sediment sample (Tables 18R and 19R). Silver, Sb and Sn were not detected in any samples. Cobalt was not found in the fish samples and Pb was not detected in the turtle samples. Beryllium was not detected in either fish or turtle samples, and Mo was not detected in the sediment or fish samples. Selenium was notably higher in the turtle samples as compared to fish.

Eleven metals (i.e., Al, Ba, B, Cr, Cu, Fe, Mg, Mn, Se, V, Zn) were detected in all fish, turtle and sediment samples. Strontium was present in all samples except the turtle sample from Pool 8. Mercury and Se were each present in all but one sediment sample (Pool 2 and Elk Reservoir, respectively). The remaining metals (Cd, Ni and As) were present in at least 8 of the 15 samples.

Summary of Results

During 1988-1990, 34 fish samples representing 12 species were collected from six NWRs in Tennessee. Eighteen sediment samples were also collected from three of these NWRs. Eleven organochlorine contaminants were detected in at least one fish sample (Table 20R). Except for the blue catfish sample from Pool 8 at Cross Creeks NWR, DDE (p,p') was found in all fish samples (Table 21R).

Gar specimens were collected from all locations except Cross Creeks NWR and almost always had greater concentrations of DDE, PCBs, toxaphene and Hg than other species collected at the same locations. Three exceptions noted were: 1) Chisholm Lake at Chickasaw NWR, where smallmouth buffalo had higher concentrations of DDE and PCBs; 2) Lake Isom NWR, where smallmouth buffalo had a higher Hg concentration; and 3) Champion Lake at Lower Hatchie NWR, where bowfin had a greater Hg concentration than spotted gar.

Nineteen metals were detected in at least one fish sample while Hg was found in all fish samples (Table 22R), along with five other metals (Cu, Fe, Mn, Se and Zn). Other than the two exceptions noted previously, Hg concentrations were greater in the gar samples as compared to other species collected at the same locations (Table 23R). Average Hg concentrations in fish were higher at Champion Lake on Lower Hatchie NWR (0.459 ppm, wet weight) and at Hatchie NWR (0.384 ppm, wet weight). Average Hg concentrations in fish were lowest at Reelfoot NWR (0.053 ppm, wet weight) and almost as low (0.059 ppm, wet weight) at Cross Creeks NWR. The highest Hg concentration in an individual fish sample (0.7 ppm, wet weight) occurred in the bowfin sample from Champion Lake at Lower Hatchie NWR.

Five turtle samples representing two species were collected at Cross Creeks NWR. Both DDE (p,p') and PCBs (total) were detected in the *Pseudemys scripta* sample from Pool 2. Concentrations were similar to those found in the channel catfish sample from the same location. No organochlorines were detected in the *Chelydra serpentina* samples collected from Pool 8.

Eighteen metals were detected in at least one turtle sample from Cross Creeks NWR. Two metals (Co and Mo) were detected only in turtles and were not detected in any fish samples. Three metals (Be, Pb, Sn) were detected only in fish samples and not found in the turtle samples. This was particularly the case for Pb at Cross Creeks NWR. Mercury was found in all five turtle samples at concentrations ranging from 0.083 to 3.4 ppm, wet weight. The highest value was in turtles collected from Pool 2.

One unhatched bald eagle egg was collected from Reelfoot NWR in 1987. Three metals (As, Se and Hg), three DDT isomers, three PCB Aroclor mixtures (1248, 1254 and 1260), and nine other organochlorine contaminants were detected. Of these, the Aroclor 1260 concentration was greatest (5.2 ppm, wet weight). The eggshell thickness was measured (0.46 mm), but did not include the membrane due to deterioration of the egg.

A total of 18 sediment samples were collected from Reelfoot NWR, Lower Hatchie NWR (Sunk Lake), and Cross Creeks NWR. Of the 31 organochlorine contaminants and six chlorophenoxy acid herbicides analyzed, none were detected in any sediment samples.

Eighteen metals were analyzed in all 18 sediment samples collected. Of these, 16 metals were detected at all three refuges. Cadmium and Mn were not found by USGS (Broshears 1991) in the 1988 samples from Reelfoot NWR. The dry weight Hg concentrations reported by Broshears (1991) average 0.12 ppm in the upper 14-inch layer of sediment. Values ranged from 0.06 ppm at Donaldson Ditch to 0.16 ppm at Buck Basin.

At Sunk Lake on Lower Hatchie NWR, sediment Hg concentrations averaged 0.098 ppm (dry weight), however, the maximum value observed (0.16 ppm) was the same as for Reelfoot NWR. At Cross Creeks NWR, Hg was detected in four of the five samples collected and ranged from <0.02 ppm, dry weight at Pool 2 to 0.095 ppm at Pool 8. The average detected Hg concentration was 0.064 ppm, dry weight.

Total organic carbon (TOC) and volatile sulfide (TVS) were determined only for the sediment samples from Sunk Lake at Lower Hatchie NWR. Values for TOC varied from 0.8% to 5.9% while those for TVS ranged from 6.1% to 19.2%. Individual results are included in Table D-11.

Table 1R. Information for 1989 Fish Samples Collected at Reelfoot NWR.

Sample Number[1]	Species	No. in Composite Sample	Average Weight (g)	Average Length (cm)	% Moisture (organics)	% Moisture (metals)	% Lipids
RFL-1	Common carp	4	1521	45.6	70.0	69.6	9.82
RFL-2	Common carp	3	1533	46.2	66.0	63.0	13.70
RFL-3	Channel catfish	3	1145	49.2	72.5	71.9	7.48
RFL-4	Channel catfish	3	1111	47.7	73.5	71.6	5.90
RFL-5	Crappie [2]	3	212	24.1	76.5	76.0	2.38
RFL-7	Gar [3]	3	680	57.5	63.0	61.1	10.00
RFL-8	Gar [3]	3	782	56.4	68.0	65.3	4.80
RFL-9	Yellow bass	3	168	23.1	76.5	75.6	1.72
RFL-10	Yellow bass	3	133	21.0	70.0	73.8	3.44

[1] A second sample of crappie (RFL-6) was not collected.
[2] Two white crappie specimens and one black crappie specimen.
[3] Specimens not identified to species, but were most likely spotted, shortnose or longnose species.

Table 2R. Chlorinated Hydrocarbon Insecticides Detected (ppm, wet weight) in 1989 Fish Samples Collected From Reelfoot NWR.

Samples	Toxaphene	p,p'-DDE	p,p'-DDD	alpha-Chlordane	trans-Nonachlor	Dieldrin
RFL-1 (Common carp)	0.21	0.10	<0.01	<0.01	<0.01	0.03
RFL-2 (Common carp)	0.05	0.06	<0.01	<0.01	<0.01	<0.01
RFL-3 (Channel catfish)	<0.05	0.02	<0.01	<0.01	<0.01	<0.01
RFL-4 (Channel catfish)	<0.05	0.03	<0.01	<0.01	<0.01	<0.01
RFL-5 (Crappie)[1]	<0.05	0.02	<0.01	<0.01	<0.01	<0.01
RFL-7 (Gar)[2]	<0.05	0.26*	<0.01	<0.01	<0.01	<0.01
RFL-8 (Gar)[2]	0.30	1.3*	0.06	0.02	0.03	<0.01
RFL-9 (Yellow bass)	<0.05	0.03	<0.01	<0.01	<0.01	<0.01
RFL-10 (Yellow bass)	<0.05	0.06	<0.01	<0.01	<0.01	<0.01

* Confirmed by GC/MS.
[1] Two white crappie specimens and one black crappie specimen.
[2] Specimens not identified to species, but were most likely spotted, shortnose or longnose species.

Table 3R. Metals Detected (ppm, wet weight) in 1989 Fish Samples From Reelfoot NWR.

Samples	RFL-1	RFL-2	RFL-3	RFL-4	RFL-5	RFL-7	RFL-8	RFL-9	RFL-10
Species	Carp	Carp	Catfish	Catfish	Crappie	Gar	Gar	Yellow Bass	Yellow Bass
Al	16.0	<7.0	9.30	6.6	<5.0	<8.0	<7.0	<5.0	<5.0
Ba	1.80	3.12	2.74	<0.057	1.48	1.77	2.11	2.27	2.38
Cu	0.96	<0.74	0.80	0.721	0.492	<0.80	0.89	2.26	3.35
Fe	81	50	51	46	16.5	47	32.5	24.4	38.8
Mg	276	377	289	271	362	2750	2741	417	406
Mn	13.9	8.4	42	7.0	4.5	14.9	4.7	13.4	16.3
Sr	5.2	12.8	5.6	3.7	15.5	26.4	25.7	13.5	12.5
Sn	<14	<13	<14	<14	<15	19.2	13.6	<15	<15
Zn	69	86	15.8	17.1	17.7	26.2	20.6	25.4	25.8
As	<0.09	<0.111	0.08	<0.08	<0.07	<0.117	<0.105	<0.07	<0.08
Hg	0.082	0.51	0.016	0.013	0.027	0.103	0.166	0.014	0.007
Se	0.44	0.341	0.31	0.219	0.203	0.231	0.269	0.366	0.393
% Moisture	69.6	63.0	71.9	71.6	76.0	61.1	65.3	75.6	73.8

Table 4R. Contaminants Detected (ppm, wet weight) in Bald Eagle Egg* Collected in 1987 From Reelfoot NWR.

Analyte	ppm
Se	0.34
As	0.098
Hg	0.23
PCB 1248	0.098
PCB 1254	0.098
PCB 1260	5.2
Total PCBs	5.396
DDE	3.8
DDD	0.97
DDT	0.014
Total DDT	4.784
Toxaphene	0.49
Dieldrin	0.31
Endrin	0.0098
Heptachlor epoxide	0.044
Oxychlordane	0.034
Trans-chlordane	0.013
Cis-chlordane	0.15
Trans-nonachlor	0.24
Cis-nonachlor	0.088
Total Chlordane	0.569

*Eggshell thickness was 0.46 mm (does not include membrane).

Table 5R. DDT-related Compounds Detected (ppm, wet weight) in 1988 Fish Samples From Lake Isom NWR.

Species	Spotted Gar (1)	Spotted Gar (2)	Smallmouth Buffalo (1)	Smallmouth Buffalo (2)
Sample No.	LISG-1	LISG-2	LIBU-1	LIBU-2
p,p'-DDE	0.12	0.23	0.08	0.08
p,p'-DDD	0.02	0.02	0.02	0.02
% Moisture	65.0	68.2	69.4	67.6
% Lipids	3.30	1.04	10.1	12.2
Average Length (cm)	50.0	62.0	43.2	43.8
Average Weight (g)	431	744	1293	1349
No. in Composite	3	4	5	5

Table 6R. Metals Detected (ppm, wet weight) in 1988 Fish Samples From Lake Isom NWR.

	Spotted Gar (1)	Spotted Gar (2)	Smallmouth Buffalo (1)	Smallmouth Buffalo (2)
Sample No.	LISG-1	LISG-2	LIBU-1	LIBU-2
ICP Analyses				
Al	6	24.6	13.9	58
Be	<0.003 [a]	0.01	<0.003	0.01
Cd	0.02	<0.010	0.01	<0.010
Cr	2.6	6.9	0.17	0.1
Cu	0.6	0.4	1.39	0.91
Fe	42	76	91	112
Mn	40	37	16.1	29.9
Ni	1.3	3.2	0.1	0.1
Zn	18.1	21.4	19.3	18.6
AA Analyses				
As	<0.062	<0.065	<0.003	0.1
Hg	0.37	0.5	0.11	0.08
Se	0.23	0.2	0.23	0.22
% Moisture	69.1	67.3	68.3	65.5

[a] Detection limits were calculated from dry weight values provided by the laboratory.

Table 7R. Chlorinated Hydrocarbon Insecticides and PCBs Detected (ppm, wet weight) in 1988 Fish Samples From Chickasaw NWR.

Location	Wardlow's Pocket		Chisolm Lake	
Species	Spotted and Shortnose Gar[a]	Bigmouth Buffalo	Spotted Gar	Smallmouth Buffalo
Sample Id.	CHWP-SG	CHWP-BBU	CHCL-SG	CHCL-SBU
HCB	0.01	<0.01	<0.01	<0.01
Γ-Chlordane	0.01	<0.01	<0.01	<0.01
α-Chlordane	0.03	<0.01	<0.01	<0.01
t-Nonachlor	0.01	<0.01	<0.01	0.01
cis-Nonachlor	0.02	<0.01	<0.01	<0.01
PCB's (total)	0.71*	0.42	0.24	0.45
p,p'-DDE	0.18*	0.06	0.06	0.11
p,p'-DDD	0.03	<0.01	<0.01	<0.01
Average Weight (g)	620	1293	267	743
% Moisture	64.4	71	68	71.8
% Lipids	8.65	7.91	0.341	6.57
Average Length (cm)	53.5	43.6	47.6	36.6
No. in Composite	4	5	5	5

[a] Spotted and shortnose gar specimens combined.
* Confirmed by GC/MS.

Table 8R. Metals Detected (ppm, wet weight) in 1988 Fish Samples From Chickasaw NWR.

Location	Wardlow's Pocket		Chisolm Lake	
Species	Spotted and Shortnose Gar[a]	Bigmouth Buffalo	Spotted Gar	Smallmouth Buffalo
Sample Id.	CHWP-SG	CHWP-BBU	CHCL-SG	CHCL-SBU
ICP Analyses				
Al	8	28.9	7	64
Be	<0.004 [b]	<0.003	0.01	<0.003
Cd	<0.012	0.02	0.02	0.02
Cr	7.0	0.23	3	0.4
Cu	0.6	0.98	0.7	0.69
Fe	62	46	42	88
Mn	14.0	8.8	30	31
Ni	3.2	0.1	1.5	0.3
Pb	<0.192	<0.121	1181	<0.134
Zn	22.4	18.6	23.8	15.9
AA Analyses				
As	<0.077	0.2	1.9	0.1
Hg	0.10	0.028	0.203	0.09
Se	0.4	0.4	0.29	0.4
% Moisture	61.5	69.8	70.9	73.2

[a] Spotted and shortnose gar specimens combined.
[b] Detection limits were calculated from dry weight values provided by the laboratory.

Table 9R. Chlorinated Hydrocarbon Insecticides and PCBs Detected (ppm, wet weight) in 1988 Fish Samples From Lower Hatchie NWR.

	Champion Lake	
Species	Spotted Gar	Bowfin
Sample Id.	LHCL-SG	LHCL-BF
t-Nonachlor	0.01	<0.01
PCBs (total)	0.51	<0.05
p,p'-DDE	0.19	0.05
p,p'-DDD	0.04	<0.01
Average Weight (g)	536	933
% Moisture	65.6	74.8
% Lipids	4.8	1.98
Average Length (cm)	51.4	47.8
No. in Composite	5	5

Table 10R. Chlorinated Hydrocarbon Insecticides and PCBs Detected in 1990 Fish Samples From Sunk Lake on Lower Hatchie NWR (ppm, wet weight).

Sample Number	SLFSH-1	SLFSH-2	SLFSH-3	SLFSH-4	SLFSH-5
Species	Gar	Gar	Gizzard Shad	Gizzard Shad	Quillback
α-Chlordane	0.01	0.02	<0.01	<0.01	<0.01
t-Nonachlor	0.01	0.01	<0.01	<0.01	<0.01
Dieldrin	<0.01	0.01	<0.01	<0.01	<0.01
PCBs (total)	0.33	0.9*	<0.05	<0.05	<0.05
p,p'-DDE	0.14	0.18*	0.03	0.03	0.04
p,p'-DDD	0.03	0.04	<0.01	<0.01	0.02
Average Weight (g)	605	661	212	66	454
% Moisture	63.5	68	79.5	81	67
% Lipids	8.82	7.98	1.6	1.06	13.9
Average Length (cm)	57.6	60.0	31.1	24.6	30.5
No. in Composite	3	3	2	3	1

* Confirmed by GC/MS

Table 11R. Metals Detected in 1988 Fish Samples From Champion Lake on Lower Hatchie NWR (ppm, wet weight).

	Champion Lake	
Species	Spotted Gar	Bowfin
Sample Id.	LHCL-SG	LHCL-BF
ICP Analyses		
Al	10	9
Cr	1.9	0.09
Cu	0.5	0.68
Fe	44	60
Mn	57	8.5
Ni	1.3	0.21
Zn	19	12.4
AA Analyses		
As	<0.066 [a]	0.1
Hg	0.219	0.7
Se	0.29	0.4
% Moisture	67.2	75

[a] Detection limits were calculated from dry weight values provided by the laboratory.

Table 12R. Metals Detected (ppm, wet weight) in 1990 Fish Samples From Sunk Lake on Lower Hatchie NWR .

Sample Number	SLFSH-1	SLFSH-2	SLFSH-3	SLFSH-4	SLFSH-5
Species	Gar	Gar	Gizzard Shad	Gizzard Shad	Quillback
ICP Analyses					
Al	12	9	62	76	46
Ba	4	3.3	3.3	2.9	3
Cr	5	2.8	<0.104 [a]	<0.096	1
Cu	0.9	0.7	0.7	0.7	0.6
Fe	64	54	147	120	88
Mg	2573	1992	304	304	345
Mn	26.4	20.5	29	34	9.3
Ni	2.5	1	<0.416	<0.382	<0.664
Sr	27.3	22.2	5.1	5.9	9.9
V	<0.112	<0.103	0.2	0.2	<0.066
Zn	21.5	19.3	14.1	14.6	12.7
AA Analyses					
As	0.1	<0.138	0.1	0.2	0.2
Hg*	0.25	0.27	0.05	0.07	0.028
Se	0.29	0.29	0.4	0.3	0.4
Weight (g)	170.6	168.6	93.76	46.9	30.77
% Moisture	62.6	65.6	79.2	80.9	66.8

[a] Detection limits were calculated from dry weight values provided by the laboratory.

Table 13R. Metals Detected (ppm, wet weight) in 1990 Sediment Samples From Sunk Lake on Lower Hatchie NWR.

	Sample #	SLSED-1	SLSED-2	SLSED-3	SLSED-4
Ag		1	<0.053 [a]	<0.014	4
Al		19264	7484	1567	17279
B		4	2	<0.014	4
Ba		115	47	11	162
Be		0.7	0.3	0.1	0.8
Cd		0.3	0.1	<0.003	0.4
Cr	ICP Analyses	14	4	1	14
Cu		11.8	4.5	1	12
Fe		18735	7313	1622	16294
Mg		2251	879	216	3173
Mn		480	207	60	683
Ni		16	6	2	17
Pb		18	7	2	18
Sr		17	6.9	1.8	25.8
V		26.9	9.7	3	31
Zn		53	20	6	53.3
As	AA Analyses	4.9	2	1	5.5
Hg		0.033	0.01	0.01	0.022
Se		0.4	0.11	<0.002	0.3
Weight (g)		39.3	59.92	39.51	70.67
% Moisture		66.9	86.8	96.6	34.3
% Total Volatile Solids		16.2	16.2	19.2	6.1
% Total Organic Carbon		4.3	4.1	5.9	0.8

[a] Detection limits were calculated from dry weight values provided by the laboratory.

Table 14R. Chlorinated Hydrocarbon Insecticides Detected in 1988 Fish Samples From Hatchie NWR (ppm, wet weight).

Location	Powell Lake #1			Kelso Lake	
Species	Spotted Sucker	Spotted Gar	Bowfin	Spotted Gar	Bowfin
Sample Id.	HPL-SSU	HPL-SG	HPL-BF	HKL-SG	HKL-BF
Dieldrin	0.01	<0.01	0.01	<0.01	<0.01
p,p'-DDE	0.15	0.2	0.05	0.14	0.07
p,p'-DDD	0.05	0.03	0.01	0.02	0.01
p,p'-DDT	0.04	0.01	0.01	<0.01	0.01
% Moisture	69.8	68.2	75.4	67.2	74.8
% Lipids	9.58	2.71	2.48	1.75	2.58
Average Weight (g)	740	442	803	536	933
Average Length (cm)	38.9	51.8	45.2	51.4	47.8
No. in Composite	5	5	3	5	5

Table 15R. Metals Detected in 1988 Fish Samples From Hatchie NWR (ppm, wet weight).

Location	Powell Lake #1			Kelso Lake	
Species	Spotted Sucker	Spotted Gar	Bowfin	Spotted Gar	Bowfin
Sample Id.	HPL-SSU	HPL-SG	HPL-BF	HKL-SG	HKL-BF
ICP Analyses					
Al	7	10	15.2	13	36
Cd	0.01	0.02	0.01	0.02	0.02
Cr	<0.031	5.3	0.18	3	0.3
Cu	0.87	0.8	1.14	0.5	0.82
Fe	53	57	70	49	80
Mn	22.5	156	13.3	117	10.4
Ni	0.1	2.5	0.14	1.7	0.3
Pb	<0.154	0.3	<0.118	0.3	<0.122
Zn	17.3	20.2	11.3	18.4	12.5
AA Analyses					
As	<0.062	<0.063	0.19	<0.061	0.17
Hg	0.222	0.5	0.4	0.4	0.4
Se	0.4	0.29	0.3	0.27	0.3
% Moisture	69.2	68.4	76.4	69.6	75.5

[a] Detection limits were calculated from dry weight values provided by the laboratory.

Table 16R. 1988 Biological and Sediment Samples Collected From Cross Creeks NWR.

Sample ID	Location	Type/Species	Weight (g)	% Moisture	% Lipid
CC2A°	Pool 2	Channel catfish	493	80.93	0.77
CCL4A°	Lower Pool 4	Channel catfish	957	75.32	2.02
CCU4A°	Upper Pool 4	Channel catfish	880	76.66	2.72
CCEA°	Elk Reservoir	Blue catfish	3100	74.27	4.23
CC8A°	Pool 8	Blue catfish	2500	67.35	0.38
CC2B°	Pool 2	Sediment	100	38.92	---
CCL4B°	Lower Pool 4	Sediment	100	46.15	---
CCU4B°	Upper Pool 4	Sediment	100	39.41	---
CCEB°	Elk Reservoir	Sediment	100	52.00	---
CC8B°	Pool 8	Sediment	100	41.08	---
CC2C°	Pool 2	Turtle Fat *(Pseudemys scripta)*	54	62.89	11.04
CCL4C°	Lower Pool 4	Turtle Fat *(Pseudemys scripta)*	57	61.86	0.06
CCU4C°	Upper Pool 4	Turtle Fat *(Pseudemys scripta)*	50	59.94	0.64
CCEC°	Elk Reservoir	Turtle Fat *(Pseudemys scripta)*	52	60.51	0.05
CC8C°	Pool 8	Turtle Fat (*Chelydra serpentina*)	62	40.78	0.01

Table 16R, Continued.

Sample ID	Location	Type/Species	Weight (g)	% Moisture	% Lipid
CC2A[m]	Pool 2	Channel catfish	203	78.1	---
CCL4A[m]	Lower Pool 4	Channel catfish	1031	78.4	---
CCU4A[m]	Upper Pool 4	Channel catfish	822	73.8	---
CCEA[m]	Elk Reservoir	Blue catfish	2700	78.1	---
CC8A[m]	Pool 8	Blue catfish	2500	67.8	---
CC2B[m]	Pool 2	Sediment	100	45.3	---
CCL4B[m]	Lower Pool 4	Sediment	100	39.7	---
CCU4B[m]	Upper Pool 4	Sediment	100	36.7	---
CCEB[m]	Elk Reservoir	Sediment	100	52	---
CC8B[m]	Pool 8	Sediment	100	41.3	---
CC2C[m]	Pool 2	Turtle Liver *(Pseudemys scripta)*	60	73.8	---
CCL4C[m]	Lower Pool 4	Turtle Liver *(Pseudemys scripta)*	100	71	---
CCU4C[m]	Upper Pool 4	Turtle Liver *(Pseudemys scripta)*	61	69.2	---
CCEC[m]	Elk Reservoir	Turtle Liver *(Pseudemys scripta)*	62	73.7	---
CC8C[m]	Pool 8	Turtle Liver (*Chelydra serpentina*)	95	73.3	---

[o] Samples for pesticide and PCB analyses. [m] Samples for metals analyses.

Table 17R. DDE and PCB Results (ppm, wet weight) for 1988 Fish and Turtle Samples From Cross Creeks NWR.

Analytes	Pool 2		Lower Pool 4	Upper Pool 4	Elk Reservoir	Pool 8
	Fish	Turtle	Fish	Fish	Fish	Fish
p,p' DDE	0.11	0.12	0.12	0.15	0.09	<0.01
Tri-Chlorobiphenyls	<0.05	0.15	<0.05	<0.05	<0.05	<0.05
Tetra-Chlorobiphenyls	<0.05	0.05	<0.05	0.14	<0.05	<0.05
Penta-Chlorobiphenyls	0.13	0.09	0.08	0.24	<0.05	<0.05
Hexa-Chlorobiphenyls	0.18	0.14	0.16	0.31	0.11	<0.05
Hepta-Chlorobiphenyls	0.1	<0.05	0.09	0.07	0.06	<0.05
Octa-Chlorobiphenyls	0.1	<0.05	0.06	0.06	<0.05	<0.05
Deca-Chlorobiphenyl	0.1	<0.05	<0.05	<0.05	<0.05	<0.05
Total PCBs*	0.55	0.43	0.39	0.82	0.17	<0.5

* Sum of detected values.

Table 18R. Metals Detected in Sediment, Fish and Turtle Samples From Pools 2 and 4 on Cross Creeks NWR (ppm, wet weight).

	Pool 2			Lower Pool 4			Upper Pool 4		
	Sediment	Fish	Turtle	Sediment	Fish	Turtle	Sediment	Fish	Turtle
Al	3393	333	23.4	4565	98	28.4	5355	125	19.3
As	1.47	<0.044	<0.052	2.33	<0.043	<0.058	1.93	0.059	0.114
Ba	154	2.9	0.46	171	1.08	0.255	149	1.03	0.75
Be	0.55	<0.004	<0.005	1.01	<0.004	<0.006	0.73	<0.005	<0.006
B	22.9	0.60	2.52	24.6	0.33	3.0	20.2	0.60	1.53
Cd	0.475	0.056	0.190	0.514	<0.015	0.210	<0.044	0.168	0.069
Co	7.2	<0.131	<0.157	9.5	<0.130	<0.174	7.2	<0.157	<0.185
Cr	20.4	0.45	0.170	25.3	0.24	0.170	20.6	0.30	0.138
Cu	3.18	0.38	2.7	3.81	0.212	2.38	3.74	0.37	1.12
Fe	10831	247	1954	13628	128	2456	11014	125	1386
Pb	14.3	0.49	<0.314	21.8	0.41	<0.348	15.4	0.56	<0.370
Mg	457	318	136	443	307	135	547	288	134
Mn	476	35	2.58	868	15.5	2.02	480	17.0	7.9
Hg	<0.011	0.078	3.4	0.046	0.074	0.91	0.034	0.057	0.083
Mo	<1.09	<0.44	0.78	<1.21	<0.43	0.70	<1.27	<0.52	<0.62
Ni	12.4	0.67	0.208	16.6	0.26	0.229	13.2	0.254	0.228

Table 18R, Continued.

	Pool 2			Lower Pool 4			Upper Pool 4		
	Sediment	Fish	Turtle	Sediment	Fish	Turtle	Sediment	Fish	Turtle
Se	0.259	0.34	3.4	0.298	0.35	1.41	0.228	0.4	0.59
Sr	11.7	2.9	0.32	14.3	1.46	0.245	13.5	0.91	1.07
V	34	0.62	0.73	41.1	0.25	0.67	31.3	0.29	0.48
Zn	37.7	16.2	11.8	46.6	13.8	13.5	41.2	17	10.4

* Detection limits were calculated from dry weight values provided by the laboratory.

Table 19R. Metals Detected in Sediment, Fish and Turtle Samples From Elk Reservoir and Pool 8 on Cross Creeks NWR (ppm, wet weight).

	Elk Reservoir			Pool 8		
	Sediment	Fish	Turtles	Sediment	Fish	Turtles
Al	2899	17.7	30	2653	37	7.9
As	0.98	<0.044*	0.083	3.97	<0.064	<0.053
Ba	151	0.153	0.50	154	0.50	0.32
Be	0.72	<0.004	<0.005	0.93	<0.006	<0.005
B	22.7	0.27	1.62	27.6	0.129	0.72
Cd	<0.034	0.046	0.144	<0.041	<0.023	0.029
Co	8.4	<0.131	0.177	14.3	<0.193	<0.158
Cr	21.6	0.112	0.180	28.8	0.45	0.135
Cu	3.04	0.22	4.0	2.91	0.34	0.79
Fe	12240	37	1410	20075	49	611
Pb	12.9	0.43	<0.316	31.4	<0.386	<0.316
Mg	213	256	123	179	318	150
Mn	528	1.92	3.3	1432	4.5	2.23
Hg	0.015	0.057	0.39	0.056	0.033	0.40
Mo	<0.96	<0.438	0.74	<1.174	<0.644	<0.526
Ni	14.8	<0.066	0.124	18.4	<0.097	<0.079
Se	<0.144	0.29	0.92	0.473	0.164	1.09
Sr	10.9	0.27	0.52	11.1	4.6	<0.158
V	35.8	0.060	0.74	48.4	0.125	0.094
Zn	43.2	7.8	13.0	50.6	14.8	14.0

*Detection limits calculated from dry weight values provided by the laboratory.

Table 20R. Organochlorine Constituents Found in Composite Whole-body Fish Samples From NWRs in Tennessee.

	alpha Chlordane	gamma Chlordane	DDD	p,p' DDE	DDT	Dieldrin	HCB	trans Nonachlor	cis Nonachlor	PCBs	Toxaphene
Reelfoot NWR (1989)											
Carp (2)*				x		x					x
Channel catfish (2)				x		x					
White crappie (1)				x		x					
Gar** (2)	x		x	x		x		x			x
Yellow bass (2)				x		x					
Lake Isom NWR (1988)											
Spotted gar (2)			x	x							
Smallmouth buffalo (2)			x	x							
Chickasaw NWR (1988)											
Wardlows Pocket											
Gar*** (1)	x	x	x	x			x	x	x	x	
Bigmouth buffalo (1)				x						x	
Chisolm Lake											
Spotted gar (1)				x						x	
Smallmouth buffalo (1)				x						x	
Lower Hatchie NWR											
Champion Lake (1988)											
Spotted gar (1)			x	x				x		x	
Bowfin (2)				x							
Sunk Lake (1990)											
Gar** (2)	x		x	x		x		x			
Gizzard shad (2)				x							
Quillback (1)				x							

Table 20R, continued.

	alpha Chlordane	gamma Chlordane	DDD	p,p' DDE	DDT	Dieldrin	HCB	trans Nonachlor	cis Nonachlor	PCBs	Toxaphene
Hatchie NWR (1988)											
Powell Lake											
Spotted gar (1)			x	x	x						
Spotted sucker (1)			x	x	x	x					
Bowfin (1)			x	x	x	x					
Kelso Lake											
Spotted gar (1)			x	x							
Bowfin (1)			x	x	x						
Cross Creeks NWR (1988)											
Channel catfish (3)											
Pool 2				x						x	
Lower Pool 4				x						x	
Upper Pool 4				x						x	
Blue catfish (2)											
Elk Reservoir				x						x	
Pool 8										x	
Turtles (Pseudemys)											
Pool 2				x						x	
Lower Pool 4											
Upper Pool 4											
Turtles (Chelydra)											
Elk Reservoir											
Pool 8											

* Number of composite samples. ** Species not determined. *** Composite sample of spotted and shortnose gar.

Table 21R. Organochlorine Concentrations (ppm, wet weight) in Composite Whole-body Fish Samples From NWRs in Tennessee.

	alpha Chlordane	gamma Chlordane	(p,p') DDD	(p,p') DDE	(p,p') DDT	Dieldrin	HCB	trans Nonachlor	cis Nonachlor	PCBs	Toxaphene
Reelfoot NWR (1989)											
Carp	<0.01	<0.01	<0.01	0.1	<0.01	0.03	<0.01	<0.01	<0.01	<0.05	0.21
Carp	<0.01	<0.01	<0.01	0.06	<0.01	0.03	<0.01	<0.01	<0.01	<0.05	0.05
Channel catfish	<0.01	<0.01	<0.01	0.02	<0.01	0.03	<0.01	<0.01	<0.01	<0.05	<0.05
Channel catfish	<0.01	<0.01	<0.01	0.03	<0.01	0.03	<0.01	<0.01	<0.01	<0.05	<0.05
White crappie	<0.01	<0.01	<0.01	0.02	<0.01	0.03	<0.01	<0.01	<0.01	<0.05	<0.05
Gar*	0.02	<0.01	<0.01	0.26	<0.01	0.03	<0.01	<0.01	<0.01	<0.05	<0.05
Gar*	<0.01	<0.01	0.06	1.3	<0.01	<0.01	<0.01	0.03	<0.01	<0.05	0.3
Yellow bass	<0.01	<0.01	<0.01	0.03	<0.01	0.03	<0.01	<0.01	<0.01	<0.05	<0.05
Yellow bass	<0.01	<0.01	<0.01	0.06	<0.01	0.03	<0.01	<0.01	<0.01	<0.05	<0.05
Lake Isom NWR (1988)											
Spotted gar	<0.01	<0.01	0.02	0.12	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Spotted gar	<0.01	<0.01	0.02	0.23	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Smallmouth buffalo	<0.01	<0.01	0.02	0.08	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Smallmouth buffalo	<0.01	<0.01	0.02	0.08	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Chickasaw NWR (1988)											
Wardlows Pocket											
Gar**	0.03	0.01	0.03	0.18	<0.01	<0.01	0.01	0.01	0.02	0.71	<0.05
Bigmouth buffalo	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	<0.01	<0.01	0.42	<0.05
Chisolm Lake											
Spotted gar	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	<0.01	<0.01	0.24	<0.05
Smallmouth buffalo	<0.01	<0.01	<0.01	0.11	<0.01	<0.01	<0.01	<0.01	<0.01	0.45	<0.05

Table 21R, continued.

	alpha Chlordane	gamma Chlordane	(p,p') DDD	DDE	DDT	Dieldrin	HCB	trans Nonachlor	cis Nonachlor	PCBs	Toxaphene
Lower Hatchie NWR											
Champion Lake (1988)											
Spotted gar	<0.01	<0.01	0.04	0.19	<0.01	<0.01	<0.01	0.01	<0.01	0.51	<0.05
Bowfin	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Sunk Lake (1990)											
Gar*	0.01	<0.01	0.03	0.14	<0.01	<0.01	<0.01	0.01	<0.01	<0.05	<0.05
Gar	0.02	<0.01	0.04	0.18	<0.01	0.01	<0.01	0.01	<0.01	<0.05	<0.05
Gizzard shad	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Gizzard Shad	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Quillback	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Hatchie NWR (1988)											
Powell Lake											
Spotted gar	<0.01	<0.01	0.03	0.2	0.04	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Spotted sucker	<0.01	<0.01	0.05	0.15	0.01	0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Bowfin	<0.01	<0.01	0.01	0.05	0.01	0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Kelso Lake											
Spotted gar	<0.01	<0.01	0.02	0.14	<0.05	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Bowfin	<0.01	<0.01	0.01	0.07	0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Cross Creeks NWR (1988)											
Channel catfish											
Pool 2	<0.01	<0.01	<0.01	0.12	<0.01	<0.01	<0.01	<0.01	<0.01	0.39	<0.05
Lower Pool 4	<0.01	<0.01	<0.01	0.15	<0.01	<0.01	<0.01	<0.01	<0.01	0.82	<0.05
Upper Pool 4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05

Table 21R, continued.

	alpha Chlordane	gamma Chlordane	(p,p') DDD	DDE	DDT	Dieldrin	HCB	trans Nonachlor	cis Nonachlor	PCBs	Toxaphene
Cross Creeks NWR (1988)											
Blue catfish											
Elk Reservoir	<0.01	<0.01	<0.01	0.1	<0.01	<0.01	<0.01	<0.01	<0.01	0.17	<0.05
Pool 8	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Turtles (*Pseudemys*)											
Pool 2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Lower Pool 4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Upper Pool 4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Turtles (*Chelydra*)											
Elk Reservoir	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05
Pool 8	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05

* Species not determined.
** Composite sample of spotted and shortnose gar specimens.

Table 22R. Metals Detected in Fish and Turtle Samples From NWRs in Tennessee.

Reelfoot NWR (1989)	Al	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mg	Mn	**Hg**	Ni	Se	Sr	Sn	V	Zn
Carp (2)*	x		x				x	x		x	x	x		x	x			x
Channel catfish (2)	x		x				x	x		x	x	x		x	x			x
White crappie (1)			x				x	x		x	x	x		x	x			x
Gar** (2)			x				x	x		x	x	x		x	x	x		x
Yellow bass (2)			x				x	x		x	x	x		x	x			x
Lake Isom NWR (1988)																		
Spotted gar (2)	x			x	x	x	x	x			x	x	x	x				x
Smallmouth buffalo (2)	x	x		x	x	x	x	x			x	x	x	x				x
Chickasaw NWR (1988)																		
Wardlows Pocket																		
Gar*** (1)	x					x	x	x			x	x	x	x				x
Bigmouth buffalo (1)	x	x			x	x	x	x			x	x	x	x				x
Chisolm Lake																		
Spotted gar (1)	x	x		x	x	x	x	x	x		x	x	x	x				x
Smallmouth buffalo (1)	x	x			x	x	x	x			x	x	x	x				x
Lower Hatchie NWR																		
Champion Lake (1988)																		
Spotted gar (1)	x		x	x		x	x	x			x	x	x	x				x
Bowfin (1)	x	x		x		x	x	x			x	x	x	x				x
Sunk Lake (1990)																		
Gar** (2)	x	x				x	x	x		x	x	x	x	x	x			x
Gizzard shad (2)	x	x				x	x	x		x	x	x		x	x		x	x
Quillback (1)	x	x				x	x	x		x	x	x		x	x			x

Table 22R. Continued.

Hatchie NWR (1988)	Al	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mg	Mn	**Hg**	Ni	Se	Sr	Sn	V	Zn
Powell Lake																		
Spotted gar (1)	x						x	x			x	x	x	x				x
Spotted sucker (1)	x					x	x	x	x		x	x	x	x				x
Bowfin (1)		x				x	x	x			x	x	x	x				x
Kelso Lake																		
Spotted gar (1)	x					x	x	x	x		x	x	x	x				x
Bowfin (1)	x	x				x	x	x			x	x	x	x				x
Cross Creeks NWR (1988)																		
Channel catfish (3)																		
Pool 2				x				x										
Lower Pool 4																		
Upper Pool 4																		
Blue catfish (2)																		
Elk Reservoir				x				x										
Pool 8																		
Turtles (*Pseudemys*)																		
Pool 2																		
Lower Pool 4																		
Upper Pool 4																		
Turtles (*Chelydra*)																		
Elk Reservoir																		
Pool 8																		

* Number of composite samples. ** Species not determined. *** Composite sample of spotted and shortnose gar specimens.

Table 23R. Metal concentrations (ppm, wet weight) in composite whole-body fish samples from NWRs in Tennessee.

Reelfoot NWR (1989)	Al	As	B	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mg	Mn	Hg	Ni	Se	Sr	Sn	V	Zn
Carp	16	<0.09		1.8				0.96	81		276	13.9	0.082		0.44	5.2	<14		69
Carp		<0.111		3.12				<0.74	50		337	8.4	0.051		0.341	12.8	<13		86
Channel catfish	9.3	<0.08		2.74				0.8	51		289	42	0.016		0.31	5.6	<14		15.8
Channel catfish	6.6	<0.08		<0.57				0.721	46		271	7	0.013		0.219	3.7	<14		17.1
White crappie	<5	<0.07		1.48				0.492	16.5		362	4.5	0.027		0.203	15.5	<15		17.7
Gar*	<8	<0.117		1.77				<0.8	47		2750	14.9	0.103		0.231	26.4	19.2		26.2
Gar*	<7	<0.105		2.11				0.89	32.5		2741	4.7	0.166		0.269	25.7	13.6		20.6
Yellow bass	<5	<0.07		2.27				2.26	24.4		417	13.4	0.014		0.366	13.5	<15		25.4
Yellow bass	<5	<0.08		2.38				3.35	38.8		406	16.3	0.01		0.393	12.5	<15		25.8
Lake Isom NWR (1988)																			
Spotted gar	6					0.02	2.6	0.6	42			40	0.04	1.3	0.23				18.1
Spotted gar	24.6				0.01		6.9	0.4	76			37	0.5	3.2	0.2				21.4
Smallmouth buffalo	13.9					0.01	0.17	1.39	91			16.1	0.11	0.1	0.23				19.3
Smallmouth buffalo	58	0.1			0.01		0.1	0.91	112			29.9	0.08	0.1	0.22				18.6
Chickasaw NWR (1988)																			
Wardlows Pocket																			
Gar**	8						7	0.6	62			14	0.1	3.2	0.4				22.4
Bigmouth buffalo	28.9	0.2				0.02	0.23	0.98	46			8.8	0.028	0.1	0.4				18.6
Chisolm Lake																			
Spotted gar	7	1.9			0.01	0.02	3	0.7	42	1181		30	0.203	1.5	0.29				23.8
Smallmouth buffalo	64	0.1				0.02	0.4	0.69	88			31	0.09	0.3	0.4				15.9

Table 23R, continued.

Lower Hatchie NWR	Al	As	B	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mg	Mn	Hg	Ni	Se	Sr	Sn	V	Zn
Champion Lake (1988)																			
Spotted gar	10						1.9	0.5	44			57	0.219	1.3	0.29				19
Bowfin	9	0.1					0.09	0.68	60			8.5	0.7	0.21	0.4				12.4
Lower Hatchie NWR																			
Sunk Lake (1990)																			
Gar*	12	0.1		4			5	0.9	64		2573	26.4	0.25	2.5	0.29	27.3			21.5
Gar*	9			3.3			2.8	0.7	54		1992	20.5	0.27	1	0.29	22.2			19.3
Gizzard shad	62	0.1		3.3				0.7	147		304	29	0.05		0.4	5.1		0.2	14.1
Gizzard shad	76	0.2		2.9				0.7	120		304	34	0.07		0.3	5.9		0.2	14.6
Quillback	46	0.2		3			1	0.6	88		345	9.3	0.028		0.4	9.9			12.7
Hatchie NWR (1988)																			
Powell Lake																			
Spotted gar	10					0.02	5.3	0.8	57	0.3		156	0.5	2.5	0.29				20.2
Spotted sucker	7					0.01		0.87	53			22.5	0.222	0.1	0.4				17.3
Bowfin	15.2	0.19				0.01	0.18	1.14	70			13.3	0.4	0.14	0.3				11.3
Kelso Lake																			
Spotted gar	13	ND				0.02	3	0.5	49	0.3		117	0.4	1.7	0.27				18.4
Bowfin	36	0.17				0.02	0.3	0.82	80			10.4	0.4	0.3	0.3				12.5

Table 23R, continued.

Cross Creeks NWR (1988)	Al	As	B	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mg	Mn	Hg	Ni	Se	Sr	Sn	V	Zn
Channel catfish																			
Pool 2	333		0.6	2.9		0.056	0.45	0.38	247	0.49	318	35	0.078	0.67	0.34	2.9		0.62	16.2
Lower Pool 2	98	ND	0.33	1.08			0.24	0.212	128	0.41	307	15.5	0.074	0.26	0.35	1.46		0.25	13.8
Upper Pool 4	125	0.059	0.6	1.03		0.168	0.3	0.37	125	0.56	288	17	0.057	0.254	0.4	0.91		0.29	17
Blue catfish																			
Elk Reservoir	17.7		0.27	0.153		0.046	0.112	0.22	37	0.43	256	1.92	0.057		0.29	0.27		0.06	7.8
Pool 8	37		0.129	0.5			0.45	0.34	49		318	4.5	0.033		0.164	4.6		0.125	14.8
Turtles (*Pseudemys*)																			
Pool 2																			
Lower Pool 4																			
Upper Pool 4																			
Turtles (*Chelydra*)																			
Elk Reservoir																			
Pool 8																			

* Species not determined. ** Composite sample of spotted and shortnose gar specimens.

Table 24R. Metals Detected in Sediment Samples From Six NWRs in West Tennessee.

	Sb	Al	As	B	Ba	Be	Cd	Co	Cr	Cu	Fe	Pb	Mg	Mn	Hg	Ni	Se	Ag	Sr	Tl	V	Zn
Reelfoot NWR (1988)*																						
Donaldson Ditch	NA	ND	x	ND	x	x	ND	x	x	x	x	x	x	x	x	x	x	NA	x	NA	x	x
Samburg	NA	ND	x	ND	x	x	ND	x	x	x	x	x	x	x	x	x	x	NA	x	NA	x	x
Horse Island Ditch	NA	ND	x	ND	x	x	ND	x	x	x	x	x	x	x	x	x	x	NA	x	NA	x	x
Buck Basin	NA	ND	x	ND	x	x	ND	x	x	x	x	x	x	x	x	x	x	NA	x	NA	x	x
Upper Blue Basin	NA	ND	x	ND	x	x	ND	x	x	x	x	x	x	x	x	x	x	NA	x	NA	x	x
Lower Hatchie NWR																						
Sunk Lake (1990)	NA	x	x	x	x	x	x	NA	x	x	x	x	x	x	x	x	x	x	x	ND	x	x
Cross Creeks NWR (1988)																						
Pool 2	ND	x	x	x	x	x	x	x	x	x	x	x	x	x	ND	x	x	ND	x	NA	x	x
Lower Pool 4	ND	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	ND	x	NA	x	x
Upper Pool 4	ND	x	x	x	x	x	ND	x	x	x	x	x	x	x	x	x	x	ND	x	NA	x	x
Elk Reservoir	ND	x	x	x	x	x	ND	x	x	x	x	x	x	x	x	x	x	ND	x	NA	x	x
Pool 8	ND	x	x	x	x	x	ND	x	x	x	x	x	x	x	x	x	ND	ND	x	NA	x	x

* based on results reported by Broshears (1991) for upper layer core samples.
NA-Not analyzed. ND-Not detected.

Table 25R. Metal Concentrations (ppm, dry weight), unless noted otherwise) in Sediment Samples From Six NWRS in West Tennessee.

	Sb	Al	As	B	Ba	Be	Cd	Co	Cr	Cu	Fe	Pb	Mg	Mn	Hg	Ni	Se	Ag	Sr	Tl	V	Zn
		(%)									(%)		(%)	(%)								
Reelfoot NWR (1988)*																						
Donaldson Ditch	NA	6.90	5.80	NA	740	2.00	ND	14.0	64.0	23.00	NA	14.0	0.83	0.06	0.060	30.0	0.700	NA	160	NA	110	83
Samburg	NA	6.40	8.40	NA	660	2.00	ND	14.0	62.0	25.00	NA	19.0	0.93	1.10	0.140	34.0	0.400	NA	120	NA	95	97
Horse Island Ditch	NA	7.80	11.00	NA	620	2.00	ND	18.0	80.0	32.00	NA	29.0	0.92	1.40	0.120	41.0	1.000	NA	99	NA	130	120
Buck Basin	NA	9.00	18.00	NA	660	2.00	ND	19.0	91.0	44.00	NA	28.0	1.00	1.90	0.160	53.0	1.000	NA	80	NA	150	160
Upper Blue Basin	NA	7.00	12.00	NA	580	2.00	ND	14.0	73.0	27.00	NA	21.0	0.86	1.60	0.120	35.0	1.200	NA	110	NA	120	110
Average**		7.42	11.04		652	2.00		15.8	74.0	30.20		22.2	0.91	1.21	0.120	38.6	0.860		114		121	114
Lower Hatchie NWR																						
Sunk Lake (1990)																						
Sediment 1	NA	5.82	14.90	13	348	2.20	0.900	NA	44.0	35.80	5.66	56.0	6.80	1.45	0.099	47.0	1.100	3	51.5	ND	81.2	160
Sediment 2	NA	5.67	13.00	15	354	2.10	0.900	NA	32.0	34.30	5.54	53.0	6.00	1.57	0.100	42.0	0.850	3	52.3	ND	73.6	153
Sediment 3	NA	4.61	18.00	10	335	2.00	2.000	NA	46.0	36.00	4.77	61.0	6.34	1.78	0.160	50.0	1.300	10	52.3	ND	78.0	182
Sediment 4	NA	2.63	8.40	6	247	1.30	0.600	NA	21.0	18.00	2.48	28.0	4.83	1.04	0.033	26.0	0.400	6	39.3	ND	47.0	81.2
Average**		4.68	13.58	11	321	1.90	1.100		35.8	31.03	4.61	49.5	5.99	1.46	0.098	41.3	0.913	6	48.8		70.0	144.

Table 25R, Continued.

Cross Creeks NWR																						
Pool 2	ND	7.30	2.69	41.8	281	1.01	0.869	13.2	37.3	5.81	1.98	26.2	0.84	0.09	<0.02	22.6	0.473	ND	21.4	NA	62	69.0
Lower Pool 4	ND	7.57	3.86	40.8	283	1.67	0.853	15.8	42.0	6.32	2.26	36.1	0.74	1.44	0.076	27.5	0.495	ND	23.7	NA	68	77.2
Upper Pool 4	ND	8.46	3.05	32	236	1.16	ND	11.4	32.6	5.91	1.74	24.3	0.86	0.76	0.054	20.9	0.361	ND	21.3	NA	50	65.1
Elk Reservoir	ND	2.90	0.98	22.7	151	0.72	ND	8.4	21.6	3.04	1.22	12.9	0.21	0.05	0.015	14.8	<0.144	ND	10.9	NA	36	43.2
Pool 8	ND	2.65	3.97	27.6	154	0.93	ND	14.3	28.8	2.91	2.01	31.4	0.18	1.43	0.056	18.4	0.473	ND	11.1	NA	48	50.6
Average**		5.78	2.91	33	221	1.10	0.861	12.6	32.5	4.80	1.84	26.2	0.57	0.75	0.044	20.8	0.360		17.7		52.8	61.0

* based on results reported by Broshears (1991) for upper layer core samples.
NA-Not analyzed. ND-Not detected.

DISCUSSION

Schultz *et al.* (1985) collected black crappie, bluegill, gizzard shad, and sediment samples at Reelfoot NWR in 1983. Low levels of α-BHC, p,p'-DDE, and p,p'-DDD were detected in their whole-body fish samples. While only one bluegill sample contained DDD (0.10 ppm, wet weight), nine of their 12 composite fish samples (75%) contained DDE at concentrations ranging from 0.007 ppm to 0.018 ppm (wet weight), with the highest concentration found in bluegill. Four of the 15 sediment samples (27%) collected by Schultz *et al.* (1985) also contained DDE at concentrations ranging from 0.9 ppm to 11 ppm, wet weight.

Organochlorine contaminants were detected in our Reelfoot NWR fish samples at somewhat higher concentrations than those of Schultz *et al.* (1985). Four additional organochlorines (α-chlordane, dieldrin, trans-nonachlor, and toxaphene) were found in our fish samples, however, no species were common to both studies. Conversely, Schultz *et al.* (1985) found DDD and DDE in sediment while we detected no organochlorine contaminants. Although DDE was found in both investigations, DDT and PCBs were not detected in the 1983 or 1989 samples.

Schultz *et al.* (1985) found four metals (Cu, Fe, Hg and Zn) in all 12 fish samples collected in 1983. They reported two additional metals (Pb and V) in gizzard shad. Most metal concentrations were higher in our 1989 samples, however, no direct comparison between the same species is possible. Except for the 1989 gar samples, which were higher, Hg concentrations were similar in the 1983 and the 1989 fish samples.

Comparisons of sediment metal concentrations in the 1983 and the 1989 samples is difficult. Results reported by Schultz *et al.* (1985) are in wet weight and do not include percent moisture values. The 1989 results reported by Broshears (1991) are dry weight values and also do not include moisture data. Considering that dry weight values may be greater than wet weight values by a factor of 3 or more, most of the metals results appear to be similar. The Hg values for 1983 samples (Schultz *et al.* 1985) may be slightly higher than those for 1989 (Broshears 1991).

The major contaminant of concern for the bald eagle egg from Reelfoot NWR was DDE (3.8 ppm, wet weight). Although considered high, Aroclor 1260 and toxaphene were not thought to be detrimental to the embryo (Wiemeyer 1988). Seven of the 18 contaminants (39%) detected in the bald eagle egg were also found in fish samples from Reelfoot or Lake Isom NWRs. Notably, PCBs, cis-nonachlor, and DDT were not found by Schultz *et al.* (1985) in fish or sediment samples. These three contaminants were also not detected in any of our fish or sediment samples from Reelfoot and Lake Isom NWRs. Arsenic was detected in only one of our 13 fish samples collected at Lake Isom or Reelfoot NWRs in 1988 and 1989, and was not found in the 12 samples collected in 1983 by Schultz *et al.* (1985).

The DDE concentration in the bald eagle egg collected in 1987 varied from 345 to 21 times higher than the average concentration in the 1983 fish samples (Schultz *et al.* 1985) or our set of fish samples from Lake Isom and Reelfoot NWRs, respectively, collected in 1988 and 1989. The Hg concentration in the bald eagle egg was 6.8 to 2.5 times higher than the average concentration in the 1983 fish samples or our samples from Lake Isom and Reelfoot NWRs, respectively.

Schultz *et al.* (1986) collected largemouth bass and freshwater drum samples at Cross Creeks NWR in 1985. A total of six composite samples (three per species) was collected. Of the nine organochlorine contaminants analyzed, endrin was not detected in any samples. Three chemicals (p,p'-DDT, dieldrin and oxychlordane) were each detected at low concentrations in one largemouth bass sample.

Schultz *et al.* (1986) found PCBs and trans-nonachlor in all samples at concentrations ranging from 0.08 to 0.50 ppm and 0.01 to 0.08 ppm (wet weight), respectively. Freshwater drum and largemouth bass had average PCB concentrations of 0.12 and 0.27 ppm, respectively. Trans-nonachlor values averaged 0.02 and 0.04 ppm in each of these species, respectively.

Toxaphene and DDE were also prevalent in the 1985 samples. Toxaphene was found in four samples (2 per species) at average concentrations of 0.23 ppm (drum) and 0.21 ppm (largemouth bass). Five of the six samples contained DDE at values ranging from 0.03 ppm (drum) to 0.11 ppm (bass). Average concentrations was slightly higher in largemouth bass (0.07 ppm).

Of the nine metals analyzed by Schultz *et al.* (1986), three (As, Cd and Pb) were not detected. Mercury (Hg) ranged from 0.08 to 0.18 ppm (wet weight), and averaged 0.14 ppm in drum and 0.10 ppm in bass. Copper (Cu) was reported at 4.3 ppm in one largemouth bass sample, but was otherwise below 0.85 ppm (Schultz *et al.* 1986).

Only two organochlorine contaminants (DDE and PCBs) were detected in our 1988 samples from Cross Creeks NWR. As compared to Schultz *et al.* (1986), average DDE (0.12 ppm) and PCB (0.48 ppm) values were slightly higher in our fish samples, however, the average Hg concentration (0.060 ppm) was lower. Although all Cu values in the 1988 fish samples were below 0.40 ppm, Cu concentrations in our turtle samples approached the 4.3 ppm value reported by Schultz *et al.* (1986).

Winger *et al.* (1988) reported results for 588 composite whole-body fish samples, representing 36 species, collected from 20 NWRs in the Southeast during 1980-1986. Samples from Cross Creeks, Tennessee, and Wheeler NWRs were collected as part of their survey. Total DDT-related residues ranged from about 150 ppm (mean, wet-weight) at Wheeler NWR to 0.01 ppm at Reelfoot NWR. Of the three NWRs samples in Tennessee, mean DDT-related residues were highest (0.31 ppm) at Tennessee NWR. Apparently the results reported by Winger *et al.* (1988) include those for the gar samples that were collected, whereas, earlier reports by Schultz *et al.* (1985, 1986) do not.

Our DDT-related results for fish samples from Reelfoot NWR were somewhat higher than those of Winger *et al.* (1988), as were our channel catfish values at Cross Creeks NWR. Although Winger *et al.* (1988) did not detect dieldrin or toxaphene at Reelfoot NWR, dieldrin was consistently detected in our samples. Toxaphene was found in three of our nine fish samples.

While no PCBs were detected at Reelfoot NWR by either Winger *et al.* (1988) or the present study, both surveys found PCBs at Cross Creeks NWR. On average, our PCBs results were about 1.5-2 times greater than those reported by Winger *et al.* (1988) for refuges in Tennessee.

Average Hg values reported by Winger *et al.* (1988) varied from 1.41 ppm (wet weight) at Overflow NWR to 0.08 ppm at Reelfoot NWR. Their mean Hg residues were similar at Cross Creeks and Tennessee NWRs (0.12 and 0.16 ppm, respectively). In the present study, average Hg values at Lower Hatchie NWR (Champion Lake) and Hatchie NWR easily exceeded mean values reported by Winger *et al.* (1988) for NWRs in Tennessee.

None of the organochlorine results observed in our study exceeded the maximum values reported by Schmitt *et al.* (1985, 1990), and most concentrations were below the geometric means calculated for the National Contaminant Biomonitoring Program (NCBP). The most notable exception was DDE (1.3 ppm) in one gar sample from Reelfoot NWR, which was about five times greater than the geometric mean for NCBP samples collected in 1984 (Schmitt *et al.* 1990).

At Upper Pool 4 (Cross Creeks NWR) and Wardlow's Pocket (Chickasaw NWR), PCBs in gar (0.82 and 0.71 ppm, respectively) exceeded NCBP means reported for 1980-81 (0.33 ppm) and 1984 (0.39 ppm) samples. Also, one NCBP site (Cumberland River at Clarksville) had a significant increase ($p \leq 0.05$, n=98) between the 1976-77 sampling period and 1984 (Schmitt *et al.* 1990). No significant decreases for organochlorine residues were noted for this NCBP site.

Our results for six metals (As, Cd, Cu, Pb, Se, Zn) typically did not exceed maximum values for NCBP samples reported by May and McKinney (1981), Lowe *et al.* (1985) or Schmitt and Brumbaugh (1990). Although most of the Hg results observed for our samples were considered low, six of 34 samples (18%) fell between maximum values for 1984 NCBP samples (0.37 ppm) and the 1980-81 NCBP samples (0.77 ppm) reported by Schmitt and Brumbaugh (1990). Gar or bowfin comprised these six samples from Lake Isom, Chickasaw and Hatchie NWRs.

At all three refuges sampled, average sediment concentrations for seven metals (Al, Be, Mg, Mn, Ni, V and Zn) were 2-3 times greater than the geometric means reported by Shacklette and Boerngen (1984) for soils in the eastern United States (Table 1D). An additional four metals (As, Ba, Pb and Se) were in this category at two of the three refuges samples. Chromium and Sr substantially exceeded the soil values of Shacklette and Boerngen (1984) only at Reelfoot NWR, while Fe did so only at Lower Hatchie NWR.

Based on the Illinois stream sediment classification reported by Kelly and Hite (1984), Cr and Mn were considered elevated ($\geq$23 ppm and $\geq$0.18%, respectively) at all three refuges sampled.

Arsenic ($\geq$11 ppm) and Zn ($\geq$100 ppm) were elevated at both Reelfoot and Lower Hatchie NWRs, while Cd and Pb ($\geq$1.0 and $\geq$38 ppm, respectively) were elevated only at Lower Hatchie.

Canadian sediment quality guidelines published by Persaud *et al.* (1989) indicated that average Mn concentrations at all three refuges exceeded the limit of tolerance or severe effects levels (0.111%). Also, Fe was greater than the limit of tolerance (4%) at Lower Hatchie NWR. Lowest effect levels (LELs) published by Persaud *et al.* (1989) and Jaagumaji (1992) were exceeded for Cr (26 ppm) and Ni (16 ppm) at all three NWRs. Arsenic and Cu LELs were exceeded at Reelfoot and Lower Hatchie NWRs, while Pb and Zn did so only at Lower Hatchie. Average Hg concentrations did not exceed the Canadian tolerance values, although values at Reelfoot and Lower Hatchie NWRs approached the LEL (0.12 ppm) reported by Persaud *et al.* (1989).

Table 1D. Comparison of Average Sediment Metal Concentrations (ppm, dry weight) at Three NWRs With Soil Values (Geometric Means) Reported by Shacklette and Boerngen (1984).

		NWRs		
Metals	Eastern United States	Reelfoot*	Lower Hatchie	Cross Creeks
Al (%)**	3.30	7.420	4.680	5.780
As	4.80	11.04	13.58	2.91
B	31	NA	11.00	32.98
Ba	290.00	652.00	321.00	221.00
Be	0.55	2.00	1.90	1.10
Cr	33.00	74.00	35.80	32.50
Cu	13.00	30.20	31.03	4.80
Fe (%)	1.40	NA	4.61	1.84
Hg	0.081	0.120	0.098	0.040
Mg (%)	0.21	0.91	5.99	0.57
Mn (%)	0.0260	1.21	1.46	0.75
Mo	0.32	ND	ND	ND
Ni	11.00	38.60	41.30	20.80
Pb	14.00	22.20	49.50	26.20
Se	0.30	0.860	0.913	0.360
Sr	53.00	114.00	48.90	17.70
V	43.00	121.00	70.00	52.80
Zn	40.00	114.00	144.10	61.00

* Based on Broshears (1991)-upper cores.

** Values for Al, Fe and Mg are expressed as percent.

CONCLUSIONS AND RECOMMENDATIONS

The absence of organochlorine pesticides in our sediment samples is disconcerting given their persistence and the prevalence of row-crop agriculture in the refuge watersheds. It is of particular concern at Reelfoot NWR because of the DDE results reported by Schultz *et al.* (1985). Suspended sediment loading to Reelfoot Lake of almost 3,000 tons per year at base flow, and up to 134,000 tons for stormflow loading, have been measured for South Reelfoot Creek (Lewis *et al.* 1992). North Reelfoot Creek also contributes substantial suspended sediment loading to Reelfoot Lake. This tremendous loading, variance in sampling locations, and potential differences in analytical techniques may account for some of the variation observed between the 1983 and the 1988 sediment samples.

Dredging to remove accumulated sediment is most likely to occur at or near Reelfoot NWR. Caution is advised on the removal and disposal of such material without chemical characterization for organochlorine pesticides and heavy metals. Dredging could suspend or re-suspend sediment contaminants in the water column. Also, the deeper sediment layers uncovered (>3 feet) could contain much higher contaminant concentrations.

PCBs were detected in fish at refuge locations periodically flooded by the Mississippi River or the Cumberland River. Concentrations were generally higher than those previously reported for NWRs in Tennessee, but were below maximum or mean values reported for samples collected nationally (Schmitt *et al.* 1990).

The PCB residues in our fish samples were well below residues linked to mortality by a variety of investigators. As noted by Niimi (1996), dietary and aqueous exposure studies on several species indicate lethal body burdens of over 100 mg/kg for PCBs in young fish and more than 250 mg/kg for older fish (Hattula and Karlog 1972; Mayer *et al.* 1977; and Mauck *et al.* 1978). Other studies have reported reduced growth in trout with PCB concentrations more than 100 mg/kg, and in trout fed more than 300 mg of PCBs per kg body weight for 90-365 days (Leatherland and Sonstegard 1978; Mayer *et al.* 1977; and Cleland *et al.* 1988). Inhibited spawning and reduced hatching in fish with tissue concentrations >30 mg/kg, and mortality in fry with >125 mg/kg PCBs have been reported (Freeman and Idler 1975; Mauck *et al.* 1978). Spawning and hatching success were not affected in minnows with more PCBs >350 mg/kg (Nebeker *et al.* 1974; DeFoe *et al.* 1978).

Some people may infer from Eisler (1986) and USEPA (1980) that whole-body residues of 0.4 mg Aroclor 1242/kg (wet weight) in rainbow trout were associated with low egg survival (25%) and numerous (70%) fry deformities. The original paper, however, clearly stated that the batch of eggs from hatchery-reared fish contained 2.7 μg/g of Aroclor 1242. Cumulative mortality (75%) and deformities (60-70%) at 30 days posthatch were related to Aroclor 1242 in the eggs, not the adults. Eggs obtained from the same hatchery in 1971 contained 0.39 ppm PCBs (0.33

μg/g of Aroclor 1254 and 0.06 μg/g of Aroclor 1232). The 1971 batch of eggs and 10-28% mortality after 30 days and no unusual incidence of terata (Hogan and Brauhn 1975).

Of the numerous studies reviewed by Niimi (1996), whole-body residues linked to various sublethal responses in a variety of fish were usually well above 1 mg/kg. This was particularly true for adult fish species likely to naturally occur on refuges in west Tennessee or major river systems such as the Mississippi, Cumberland, Tennessee or Ohio Rivers. Any subsequent evaluation should include analysis of specific fish tissues which may more accurately reflect contaminant impacts.

PCBs in the bald eagle egg from Reelfoot NWR could indicate residues accumulated from feeding on the Mississippi River, or other locations, since no PCBs were found in fish from Reelfoot or Lake Isom NWR. Turtles were not analyzed at Reelfoot and could represent a potential exposure pathway for bald eagles.

Total PCBs in the bald eagle egg (5.4 ppm) from Reelfoot NWR were in the lower concentration ranges reported by Anthony (1993) for the Columbia River and by Kubiak and Best (1991) for the Great Lakes (1985-1990). Based on bald eagle productivity curves developed by Kubiak and Best (1991), total PCBs of 5-10 ppm in eggs were associated with one young produced per active nesting pair of adults. Typical productivity observed at bald eagle nests in Tennessee and Kentucky is 1-2 young produced per year (Bob Hatcher, TWRA, personal communication). Nest success is also affected by the age (experience) of the nesting pair.

DDE was the most prevalent organochlorine contaminant detected. Concentrations were typically higher in gar or bottom feeders with high lipid values. Neither DDE nor PCBs were notably higher in turtles collected from Cross Creeks NWR as compared to fish. Although all of our fish samples were whole-body, all DDE concentrations were well below the FDA Tolerance Level of 5.0 ppm, which applies to fillet portions and total DDT concentrations.

The DDE residue in the bald eagle egg from Reelfoot NWR (3.8 ppm) was in the concentration range (2-9 ppm) associated with 12-15% eggshell thinning in ospreys (Wiemeyer *et al.* 1988). It was, however, well below the egg residue (10 ppm) associated with 10% eggshell thinning in bald eagle eggs from the Columbia River basin (Anthony *et al.* 1993). Wiemeyer *et al.* (1993) reported DDE concentrations between 2.2 and 3.5 ppm in bald eagle eggs from nests which produced an average of one young per year, while 3.5-6.2 ppm were found in eggs from nests which averaged 0.5 young per year over a 5-year period. Thus, the DDE residue in the bald eagle egg from Reelfoot NWR is cause for some concern, particularly when the PCB and Hg residues are considered.

Mercury residues in our whole-body fish samples were well below tissue concentrations associated with mortality in one year old walleye (Scherer *et al.* 1975), and three generations of brook trout (McKim *et al.* 1976). Most of the Hg residues we detected were also below those found by Heath and Bidwell (1993) in rock bass from a reference site on the South River

(Virginia). Mean muscle and liver Hg concentrations (1.4 and 2.9 ppm, respectively) reported for rockbass from the contaminated reach of the river were not associated with adverse physiological or biochemical effects (Heath and Bidwell 1993). Mercury in the bowfin from Lower Hatchie NWR (0.7 ppm) approached the lower concentrations associated with diminished predator avoidance behavior in mosquitofish (Kania and O'Hara 1974).

It is important to note that early life stages of fish are more sensitive to Hg than adults. Water concentrations of 100 mg/l (inorganic Hg) resulted in 100% mortality to rainbow trout early life stages within 8 days (Birge *et al.* 1979). Mean residues in the exposed fish were 0.068 ppm at four days and 0.097 ppm at 7.5 days, as compared to mean pre-exposure residues of 0.019 ppm (Birge *et al.* 1979).

The Hg concentration (0.28 ppm) in the bald eagle egg from Reelfoot NWR is well below the concentration (8 ppm) linked to decreased reproductive success of golden eagles in Scotland by Newton and Gallbraith (1991). It is also below the geometric mean in unhatched bald eagle eggs (0.4 ppm) reported by Wiemeyer *et al.* (1984).

Based on the whole-body fish sample results, values for fillet samples would not be expected to exceed any applicable action levels established by the Food and Drug Administration (FDA 1984). Concentrations of DDE, PCBs and Hg were sufficient at several locations to warrant concern for fish-eating birds, particularly when cumulative exposures and effects are considered. This concern is somewhat ameliorated because many of the fish collected were too large for consumption by most piscivorous birds, except raptors.

Overall there does not appear to be any immediate need for mitigation or clean-up of environmental contamination at any of the six NWRs sampled in this study. It is recommended, however, that any future sampling give consideration to including turtles and forage fish to provide a more complete evaluation of contaminant exposure pathways.

The recently completed "Exposure to Chemical Contaminants at National Wildlife Refuges in the Lower Mississippi River Ecosystem" by Cooperative Research Units at North Carolina State University and Tennessee Technological University should serve to provide additional information on four NWRs (Reelfoot, Lake Isom, Chickasaw and Lower Hatchie) discussed here.

Refuge managers can best enhance overall environmental quality on NWRs by:

1) improving farming practices to reduce soil erosion and the associated transport of environmental contaminants to aquatic systems;

2) implementing an integrated pest management program that couples the proper use of appropriate pesticides with other techniques;

3) installing and protecting vegetative buffer strips along stream channels in the watershed; and

4) working actively with private landowners in the refuge watershed to improve land use practices.

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APPENDICES

Appendix A

Elution Profiled For Florisil, Silica Gel and Silicic Acid Column Separations

Florisil Column (used for tissue samples)

Fraction I (6% ethyl ether containing 2% ethanol, and 94% petroleum ether): HCB, alpha-BHC, beta-BHC, gamma-BHC, delta-BHC, oxychlordane, heptachlor epoxide, gamma-chlordane, trans-nonachlor, toxaphene, PCBs, o,p'-DDE, alpha-chlordane, p,p'-DDE, p,p'-DDT, cis-nonachlor, o,p'-DDT, p,p'-DDD, mirex, dicofol, endosulfan I (split with F-II).

Fraction II (15% ethyl ether containing 2% ethanol, and 85% petroleum ether): dieldrin, endrin, dacthal, endosulfan I (split with F-I), endosulfan II (split with F-III), endosulfan sulfate (split with F-III).

Fraction III (50% ethyl ether containing 2% ethanol, and 50% petroleum ether): endosulfan II (split with F-II), endosulfan sulfate (split with F-II), malathion.

Florisil Mini-Column (used for soils)

Fraction I (12 ml of hexane, followed by 12 ml of 1% methanol in hexane): HCB, gamma-BHC (25%), alpha-BHC (splits with F-II), trans-nonachlor, o,p'-DDE, p,p'-DDE, o,p'-DDD, p,p'-DDD (splits with F-II), o,p'-DDT, p,p'-DDT, cis-nonachlor, cis-chlordane, trans-chlordane, PCBs, mirex, photomirex and derivatives.

Fraction II (24 ml of 1% methanol in hexane): g-BHC (75%), b-BHC, a-BHC (splits with F-I), delta-BHC, oxychlordane, heptachlor epoxide, toxaphene, dicofol, dacthal, endosulfan I, endosulfan II, endosulfan sulfate, octachlorostyrene, kepone (with additional 12 ml 1% methanol in hexane).

Silicic Acid

SA Fraction I (20 ml petroleum ether): HCB, mirex

SA Fraction II (100 ml petroleum ether): PCBs, p,p'-DDE (splits with SA-III)

SA Fraction III (20 ml of 1% acetonitrile, 80% methylene chloride, 19% hexane): alpha-BHC, beta-BHC, gamma-BHC, delta-BHC, oxychlordane, heptachlor epoxide, gamma-chlordane, trans-chlordane, toxaphene, o,p'-DDE, alpha-chlordane, p,p'-DDE (splits with SA-II), cis-nonachlor, o,p'-DDT, p,p'-DDD, p,p'-DDT, dicofol.

Appendix B

Tissue Sample Preparation For Metal Analyses

Tissue Preparation

Samples are homogenized using a Kitchen Aid food processor. Portions are then freeze dried for determination of moisture content and subsequent acid digestions.

Digestion for Inductively Coupled Plasma Emission (ICP) measurement. About 0.25 to 0.5 grams of freeze-dried tissue are placed in a 120 ml teflon microwave vessel and five ml of Baker Instra-Analyzed HNO_3 are added to the vessel. The vessel is then capped according to the manufacturer's instructions and heated in a CEM microwave oven for 3 minutes at 120 watts, 3 minutes at 300 watts, and 15 minutes at 450 watts. The resulting residue is diluted to 50 ml with 5% HCl.

Digestion for Graphite Furnace Atomic Absorption (GFAA) measurement. Using a CEM microwave oven, 0.25 to 0.5 grams of freeze-dried tissue are heated in a capped 120 ml teflon vessel in the presence of 5 ml of Baker Instra-Analyzed HNO_3 for 3 minutes at 120 watts, 3 minutes at 300 watts, and 15 minutes at 450 watts. The residue was is then diluted to 50 ml with laboratory pure water.

Digestion for mercury measurement by Cold Vapor Atomic Absorption (CVAA).
About 0.25 to 0.5 grams of sample are refluxed for 2 hours in 10 ml HNO_3 (Baker Instr-Analyzed) and diluted to 50 ml with 1% HCl.

Metal Analyses

ICP measurements were made using a Leeman Labs Plasma Spec I sequential spectrometer. GFAA measurements were made using a Perkin-Elmer Zeeman 3030 AA spectrophotometer with an HGA-600 graphite furnace and an AS-60 autosampler. Mercury measurements were conducted using $SNCL_4$ (as the reducing agent) and an Instrumentation Laboratories Model 251 AA spectrophotometer.

Appendix C

Sediment Sample Preparation for Cholorinated Hydrocarbon Pesticides, Polychlorinated Biphenyls, and Chlorophenoxy Acid Herbicide Analyses

Sample Preparation

Twenty grams of soil are weighed into a pesticide residue quality (PRQ)* centrifuge bottle and 10 ml of PRQ H_2O are added to the dry samples. The pH is adjusted to ≤ 2 using PRQ 12N sulfuric acid (usually about 1 ml). Fifty ml of acetone are added and the sample is shaken well six times over a 90 minute period (about every 15 minutes). Fifty ml of a 1:1 petroleum ether/ethyl ether (PE:EtoEt) mixture are added and the shaking is repeated. The sample is then centrifuged and the liquid decanted into a 500 ml separatory funnel containing 200 ml of PRQ water. The soil is re-extracted by shaking one minute with 50 ml 1:1 PE:EtoEt (10 ml H_2O may need to be added and the pH re-adjusted to ≤ 2), centrifuging again, and decanting the liquid into a separatory funnel.

Using PRQ 6N KOH (5 ml), the contents of separatory funnel are adjusted to pH ≥ 12, shaken vigorously for two minutes, and then allowed to stand for 30 minutes with intermittent shaking. The H_2O layer is separated and re-extracted with 100 ml 1:1 PE:EtoEt. The two petroleum ether extracts are then combined, capped, and reserved for analysis (this contains the chlorohydrocarbon pesticides, aliphatic and polynuclear aromatic hydrocarbons).

The aqueous layer is adjusted to pH ≤ 2 using three ml of PRQ 12N sulfuric acid and extracted with 100 ml 1:1 PE:EtoEt. The H_2O layer is separated and re-extracted with 100 ml 1:1 PE:EtoEt. The two petroleum ether extracts are then combined, capped, and reserved for analysis (this contains the chlorophenoxy acid herbicides).

Both the acid and the basic extracts are concentrated with Kuderna-Danish evaporators and their volumes reduced to adequate size for column clean-up.

Column Cleanup

Neutral Fraction (N/P and chlorohydrocarbon pesticides, aliphatic and polynuclear aromatic hydrocarbons). The sample extract is adjusted to exact volume and an appropriate aliquot removed for column clean-up techniques specific to analyte. For pesticides, a mini-florisil column is used, and for hydrocarbons a 1% deactivated silica gel column is used (Appendix A and B).

Acid Fraction (Chlorophenoxy acid herbicides)

Derivitization. The sample volume is reduced to approximately 0.5 ml and ethylated using diazoethane (15 minutes). The sample is exchanged to hexane (N-EVAP) and the volume reduced to 0.2 ml.

Column Clean-Up. Two grams of 1% deactivated silica gel are placed in a 7 mm i.d. chromatography column (#22 Kontes). This is topped with one cm of Na_2SO_4 and the column pre-wetted with 10 ml of hexane. The sample is then divided into three fractions as follows:

Fraction A: The sample is added and the container rinsed with two 0.5 ml washes of 20 % benzene in hexane. The column is then eluted with nine ml of the same solution (this fraction contains PCP).

Fraction B: Ten ml of 40% benzene in hexane are added. This is followed by ten ml of 60% benzene in hexane (this fraction contains Dalapon, PNP, Silvex, Dinoseb and a portion of Dicamba).

Fraction C: Ten ml of 80% benzene in hexane are added and followed by ten ml of 100% benzene (this fraction contains Dichlorprop, 2,4-D, 2,4,5-T, 2,4-DB, Bentazon, Blazer, and the remaining Dicamba).

Reference for column clean-up for chlorophenoxy acid herbicides:

Shafik, T. A., H.C. Sullivan and H.R. Enos. 1973. Multi-residue procedure for halo and nitrophenols: measurement of exposure to biodegradable pesticides yielding these compounds as metabolites. J. Agr. Food Chemistry 21:295-298.

* PRQ glassware and other equipment is obtained by rinsing 3 times with acetone followed by 3 rinses with petroleum ether.

Appendix D

Organochlorine and Metals Results (ppm, dry weight)

Table D1. Chlorinated Hydrocarbon Insecticides Detected in 1989 Fish Samples from Reelfoot NWR (ppm, dry weight).

Samples	Toxaphene	p,p'-DDE	p,p'-DDD	alpha-Chlordane	trans-Nonachlor	Dieldrin
RFL-1 (Commom carp)	0.70	0.33	<0.03	<0.03	<0.03	0.10
RFL-2 (Common carp)	0.147	0.176	<0.03	<0.03	<0.03	<0.03
RFL-3 (Channel catfish)	<0.10	0.073	<0.03	<0.03	<0.03	0.10
RFL-4 (Channel catfish)	<0.10	0.113	<0.03	<0.03	<0.03	0.10
RFL-5 (Crappie*)	<0.10	0.085	<0.03	<0.03	<0.03	0.10
RFL-7 (Gar**)	<0.03	0.703	<0.03	<0.03	<0.03	0.10
RFL-8 (Gar**)	0.937	4.06	0.187	0.065	0.094	<0.03
RFL-9 (Yellow bass)	<0.10	0.128	<0.03	<0.03	<0.03	0.10
RFL-10 (Yellow bass)	<0.10	0.20	<0.03	<0.03	<0.03	0.10

* Sample consisted of two white crappie specimens and one black crappie specimen.
** Specimens not identified to species, but were most likely spotted, shortnose or longnose species.

Table D2. Metals Detected (ppm, dry weight) in 1989 Fish Samples from Reelfoot NWR.

Sample No.	RFL-1	RFL-2	RFL-3	RFL-4	RFL-5	RFL-7	RFL-8	RFL-9	RFL-10
Species	Carp	Carp	Catfish	Catfish	Crappie	Gar	Gar	Bass	Bass
Al	52.6	<20	33.1	23.4	<20.0	<20.0	<20.0	<20.0	<20.0
Ba	5.91	8.42	9.76	<2.0	6.17	4.56	6.09	9.32	9.08
Cu	3.16	<2.0	2.84	2.54	2.05	<2.00	2.56	9.25	12.8
Fe	267	135	182	165	68.8	122	93.7	100	148
Mg	910	1020	1030	954	1510	7070	7900	1710	1550
Mn	45.72	22.7	150	24.7	18.7	38.4	13.6	55.1	62.3
Sr	17.1	34.6	19.8	13.0	64.5	67.9	74.1	55.6	47.6
Sn	<20	<20	<20	<20	<20	31.5	20.9	<20.0	<20.0
Zn	228	234	56.4	60.2	73.7	67.5	59.5	104	98.6
As	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Hg*	0.275	0.137	0.058	0.045	0.111	0.266	0.478	0.0557	0.0382
Se	1.46	0.922	1.10	0.772	0.846	0.594	0.776	1.50	1.5
% Moisture	69.6	63.0	71.9	71.6	76.0	61.1	65.3	73.8	73.8

* Done by cold vapor atomic absorption.

Table D3. Organochlorines Detected (ppm,dry weight) in 1988 Fish Samples from Lake Isom NWR.

Species	Spotted Gar (1)	Spotted Gar (2)	Smallmouth Buffalo (1)	Smallmouth Buffalo (2)
Sample No.	LISG-1	LISG-2	LIBU-1	LIBU-2
p,p'-DDE	0.34	0.72	0.26	0.25
p,p'-DDD	0.06	0.06	0.06	0.06
AverageWeight (g)	431	744	1293	1349
% Moisture	65.0	68.2	69.4	67.6
% Lipids	3.30	1.04	10.1	12.2
Average Length (cm)	50.0	62.0	43.2	43.8
No. in Composite	3	4	5	5

Table D4. Metals Detected (ppm,dry weight) in 1988 Fish Samples from Lake Isom NWR.

Species	Spotted Gar (1)	Spotted Gar (2)	Smallmouth Buffalo (1)	Smallmouth Buffalo (2)
Sample No.	LISG-1	LISG-2	LIBU-1	LIBU-2
Al	21	75.3	44.0	167
Be	<0.01	0.02	<0.01	0.02
Cd	0.08	0.1	0.03	<0.03
Cr	8.4	21.0	0.55	0.2
Cu	1.8	1.4	4.40	2.64
Fe (ICP Analyses)	136	231	286	325
Mn	131	112	50.8	86.7
Ni	4.1	9.8	0.3	0.4
Zn	58.6	65.3	61.0	53.9
As	<0.2	<0.2	<0.1	0.4
Hg (AA Analyses)	1.2	1.5	0.36	0.24
Se	0.76	0.5	0.73	0.64
% Moisture	69.1	67.3	68.3	65.5

Table D5. Organochlorines Detected (ppm, dry weight) in 1988 Fish Samples from Chickasaw NWR.

Location	Wardlow's Pocket		Chisolm Lake	
Species	Spotted and Shortnose Gar[a]	Bigmouth Buffalo	Spotted Gar	Smallmouth Buffalo
Sample Id.	CHWP-SG	CHWP-BBU	CHCL-SG	CHCL-SBU
HCB	0.03	<0.04	<0.03	<0.04
Γ-Chlordane	0.03	<0.04	<0.03	<0.04
α-Chlordane	0.08	<0.04	<0.03	<0.04
t-Nonachlor	0.03	<0.04	<0.03	0.04
cis-Nonachlor	0.06	<0.04	<0.03	<0.04
PCBs (total)	1.99	1.45	0.75	1.60
p,p'-DDE	0.50	0.21	0.19	0.39
p,p'-DDD	0.08	<0.04	<0.03	<0.04
Average Weight (g)	620	1293	267	743
% Moisture	64.4	71.0	68.0	71.8
% Lipids	8.65	7.91	0.341	6.57
Average Length (cm)	53.5	43.5	47.6	36.6
No. in Composite	4	5	5	5

[a] Spotted and shortnose gar specimens combined.

Table D6. Metals Detected (ppm, dry weight) in 1988 Fish Samples from Chickasaw NWR.

Location	Wardlow's Pocket		Chisolm Lake	
Species	Spotted and Shortnose Gar[a]	Bigmouth Buffalo	Spotted Gar	Smallmouth Buffalo
Sample Id.	CHWP-SG	CHWP-BBU	CHCL-SG	CHCL-SBU
ICP Analyses				
Al	21	95.8	24	239
Be	<0.01	<0.01	0.02	<0.01
Cd	<0.03	0.07	0.08	0.06
Cr	18.1	0.77	11	1.7
Cu	1.7	3.24	2.4	2.57
Fe	162	154	144	328
Mn	36.5	29.0	104	116
Ni	8.3	0.4	5.1	1.1
Pb	<0.5	<0.4	4060	<0.5
Zn	58.3	61.7	81.9	59.2
AA Analyses				
As	<0.2	0.5	6.4	0.3
Hg (CVAA)*	0.25	0.094	0.697	0.34
Se	1.1	1.3	0.99	1.4
% Moisture	61.5	69.8	70.9	73.2

[a]Spotted and Shortnose gar specimens combined.
*Cold vapor atomic absorption.

Table D7. Organochlorine Contaminants Detected (ppm, dry weight) in 1988 Fish Samples from Lower Hatchie NWR.

	Champion Lake	
Species	Spotted Gar	Bowfin
Sample Id.	LHCL-SG	LHCL-BF
t-Nonachlor	0.03	<0.03
PCB's (total)	1.48	<0.05
p,p'-DDE	0.55	0.20
p,p'-DDD	0.12	<0.03
Average Weight (g)	536	933
% Moisture	65.6	74.8
% Lipids	4.80	1.98
Average Length (cm)	51.4	47.8
No. in Composite	5	5

Table D8. Organochlorine Contaminants Detected (ppm, dry weight) in 1990 Fish Samples from Sunk Lake at Lower Hatchie NWR.

Sample Number Species	SLFSH-1 Gar	SLFSH-2 Gar	SLFSH-3 Gizzard Shad	SLFSH-4 Gizzard Shad	SLFSH-5 Quillback
α-Chlordane	0.03	0.06	<0.03	<0.03	<0.03
t-Nonachlor	0.03	0.03	<0.03	<0.03	<0.03
Dieldrin	<0.03	0.03	<0.03	<0.03	<0.03
PCB's (total)	0.90	2.81	<0.03	<0.03	<0.03
p,p'-DDE	0.38	0.56	0.15	0.16	0.12
p,p'-DDD	0.08	0.12	<0.03	<0.03	0.06
Average Weight (g)	605	661	212	66	454
% Moisture	63.5	68.0	79.5	81.0	67.0
% Lipids	8.82	7.98	1.60	1.06	13.9
Average Length (cm)	57.6	60.0	31.1	24.6	30.5
No. in Composite	3	3	2	3	1

Table D9. Metals Detected (ppm, dry weight) in 1988 Fish Samples from Lower Hatchie NWR

	Champion Lake	
Species	Spotted Gar	Bowfin
Sample Id.	LHCL-SG	LHCL-BF
ICP Analyses		
Al	29	36
Cr	5.9	0.36
Cu	1.6	2.72
Fe	133	242
Mn	175	33.9
Ni	4.1	0.85
Zn	58.0	49.6
AA Analyses		
As	<0.2	0.5
Hg	0.668	2.7
Se	0.88	1.4
% Moisture	67.2	75.0

Table D10. Metals Detected (ppm, dry weight) in 1990 Fish Samples from Sunk Lake at Lower Hatchie NWR.

Sample Number Species	SLFSH-1 Gar	SLFSH-2 Gar	SLFSH-3 Gizzard Shad	SLFSH-4 Gizzard Shad	SLFSH-5 Quillback
ICP Analyses					
Al	31	26	300	396	140
Ba	10.8	9.6	15.8	15.1	9.2
Cr	13	8.1	2	2	3
Cu	2.3	2.1	3.6	3.9	1.9
Fe	172	158	705	627	266
Mg	6880	5790	1460	1590	1040
Mn	70.7	59.6	141	178	27.9
Ni	6.6	4	<2	2	<2
Sr	73.0	64.7	24.7	30.7	29.8
V	<0.3	<0.3	1.1	1.1	<0.3
Zn	57.5	56.1	67.8	76.2	38.3
AA Analyses					
As	0.2	<0.4	0.3	1.1	0.61
Hg (CV)	0.68	0.78	0.23	0.36	0.083
Se	0.77	0.84	2.0	1.4	1.2
Weight (g)	170.6	168.6	93.76	46.90	30.77
% Moisture	62.6	65.6	79.2	80.9	66.8

Table D11. Metals Detected (ppm, dry weight) in 1990 Sediment Samples from Sunk Lake at Lower Hatchie NWR.

Sample #	SLSED-1	SLSED-2	SLSED-3	SLSED-4
ICP Analyses				
Ag	3	3	10	6
Al	58200	56700	46100	26300
B	13	15	10	6
Ba	348	354	335	247
Be	2.2	2.1	2.0	1.3
Cd	0.9	0.9	2	0.6
Cr	44	32	43	21
Cu	35.8	34.3	36	18
Fe	56600	55400	47700	24800
Mg	6800	6660	6340	4830
Mn	1450	1570	1780	1040
Ni	47	42	50	26
Pb	56	53	61	28
Sr	51.5	52.3	52.3	39.3
V	81.2	73.6	78	47
Zn	160	153	182	81.2
AA Analyses				
As	14.9	13	18	8.4
Hg (CV)	0.099	0.10	0.16	0.033
Se	1.1	0.85	1.3	0.4
Weight (g)	39.30	59.92	39.51	70.67
% Moisture	66.9	86.8	96.6	34.3
% Total Volatile Solids	16.2	16.2	19.2	6.1
% Total Organic Carbon	4.3	4.1	5.9	0.8

Table D12. Organochlorine Contaminants Detected (ppm, dry weight) in 1988 Fish Samples from Hatchie NWR.

Location	Powell Lake #1			Kelso Lake	
Species	Spotted Sucker	Spotted Gar	Bowfin	Spotted Gar	Bowfin
Sample Id.	HPL-SSU	HPL-SG	HPL-BF	HKL-SG	HKL-BF
Dieldrin	0.03	<0.01	0.04	<0.01	<0.01
p,p'-DDE	0.50	0.63	0.20	0.43	0.28
p,p'-DDD	0.16	0.09	0.04	0.06	0.04
p,p'-DDT	0.13	0.03	0.04	<0.01	0.04
Average Weight (g)	740	442	803	536	933
% Moisture	69.8	68.2	75.4	67.2	74.8
% Lipids	9.58	2.71	2.48	1.75	2.58
Average Length (cm)	38.9	51.8	45.2	51.4	47.8
No. In Composite	5	5	3	5	5

Table D13. Metals Detected (ppm, dry weight) in 1988 Fish Samples from Hatchie NWR.

Location	Powell Lake #1			Kelso Lake	
Species	Spotted Sucker	Spotted Gar	Bowfin	Spotted Gar	Bowfin
Sample Id.	HPL-SSU	HPL-SG	HPL-BF	HKL-SG	HKL-BF
ICP Analyses					
Al	24	31	64.6	44	148
Cd	0.04	0.07	0.06	0.07	0.09
Cr	<0.1	16.9	0.75	11	1.2
Cu	2.82	2.4	4.84	1.7	3.34
Fe	172	181	299	160	328
Mn	73.1	495	56.3	385	42.3
Ni	0.2	7.9	0.60	5.6	1.4
Pb	<0.5	0.9	<0.5	0.9	<0.5
Zn	56.2	64.0	47.8	60.7	51.2
AA Analyses					
As	0.1	<0.2	0.82	<0.2	0.69
Hg	0.721	1.6	1.9	1.2	1.7
Se	1.2	0.93	1.4	0.88	1.1
% Moisture	69.2	68.4	76.4	69.6	75.5

Table D14. Metals Detected in Sediment, Fish and Turtle Samples from Pools 2 and 4 on Cross Creeks NWR (ppm, dry weight).

	Pool 2			Lower Pool 4			Upper Pool 4		
	Sediment	Fish	Turtle	Sediment	Fish	Turtle	Sediment	Fish	Turtle
Al	7300	1520	89.5	7570	456	97.8	8460	478	62.7
As	2.69	<0.20	<0.20	3.86	<0.20	<0.20	3.05	0.227	0.371
Ba	281	13.1	1.74	283	5.02	0.879	236	3.94	2.45
Be	1.01	<0.020	<0.020	1.67	<0.020	<0.020	1.16	<0.020	<0.020
B	41.8	2.75	9.60	40.8	1.51	10.50	32.0	2.30	4.98
Cd	0.869	0.258	0.724	0.853	<0.070	0.726	<0.700	0.640	0.225
Co	13.2	<0.600	<0.600	15.8	<0.600	<0.600	11.4	<0.600	<0.600
Cr	37.3	2.05	0.647	42.0	1.11	0.588	32.6	1.14	0.447
Cu	5.81	1.73	10.4	6.32	0.981	8.21	5.91	1.41	3.63
Fe	19,800	1130	7640	22,600	592	8470	17,400	478	4500
Pb	26.2	2.25	<1.20	36.1	1.90	<1.20	24.3	2.12	<1.20
Mg	836	1450	521	735	1420	465	864	1100	436
Mn	870	160	9.83	1440	71.8	6.95	758	64.8	25.8
Hg	<0.02	0.354	12.9	0.076	0.345	3.15	0.054	0.219	0.269
Mo	<16.0	<2.00	2.97	<16.0	<2.00	2.41	<16.0	<2.00	<2.00
Ni	22.6	3.06	0.794	27.5	1.20	0.788	20.9	0.969	0.742

Table D14, Continued.

	Pool 2			Lower Pool 4			Upper Pool 4		
	Sediment	Fish	Turtle	Sediment	Fish	Turtle	Sediment	Fish	Turtle
Se	0.473	1.56	13.2	0.495	1.64	4.87	0.361	1.51	1.93
Sr	21.4	14.4	1.23	23.7	13.3	0.846	21.3	6.77	3.47
V	62.2	0.387	2.78	68.1	2.81	2.32	49.5	1.15	1.55
Zn	69.0	46.1	45.0	77.2	74.1	46.6	65.1	63.7	33.7

Table D15. Metals Detected in Sediment, Fish and Turtle Samples from Elk Reservoir and Pool 8 on Cross Creeks NWR (ppm, dry weight).

	Elk Reservoir			Pool 8		
	Sediment	Fish	Turtles	Sediment	Fish	Turtles
Al	6040	80.9	114	4520	114	29.5
As	2.05	<0.20	0.317	6.76	<0.20	<0.020
Ba	315	0.697	1.90	263	1.57	1.18
Be	1.49	<0.020	<0.20	1.58	<0.020	<0.020
B	47.3	1.22	6.15	47.0	0.401	2.68
Cd	<0.700	0.211	0.547	<0.700	<0.070	0.109
Co	17.6	<0.600	0.672	24.3	0.600	<0.600
Cr	45.1	0.514	0.684	49.1	1.40	0.507
Cu	6.34	1.03	15.1	4.96	1.06	2.96
Fe	25,500	171	5360	34,200	152	2290
Pb	26.8	1.96	<1.20	53.5	<1.20	<1.20
Mg	443	1170	469	305	989	564
Mn	1100	8.77	12.7	2440	14.1	8.35
Hg	0.031	0.260	1.47	0.095	0.103	1.52
Mo	<16.0	<2.00	2.80	<16.0	<2.00	<2.00
Ni	30.8	<0.300	0.471	31.4	>0.300	<0.300
Se	<0.30	1.32	3.49	0.806	0.508	4.10
Sr	22.7	1.23	1.98	18.9	14.4	<0.600
V	74.7	0.275	2.82	82.5	0.387	0.352
Zn	90.0	35.6	49.5	86.2	46.1	52.5