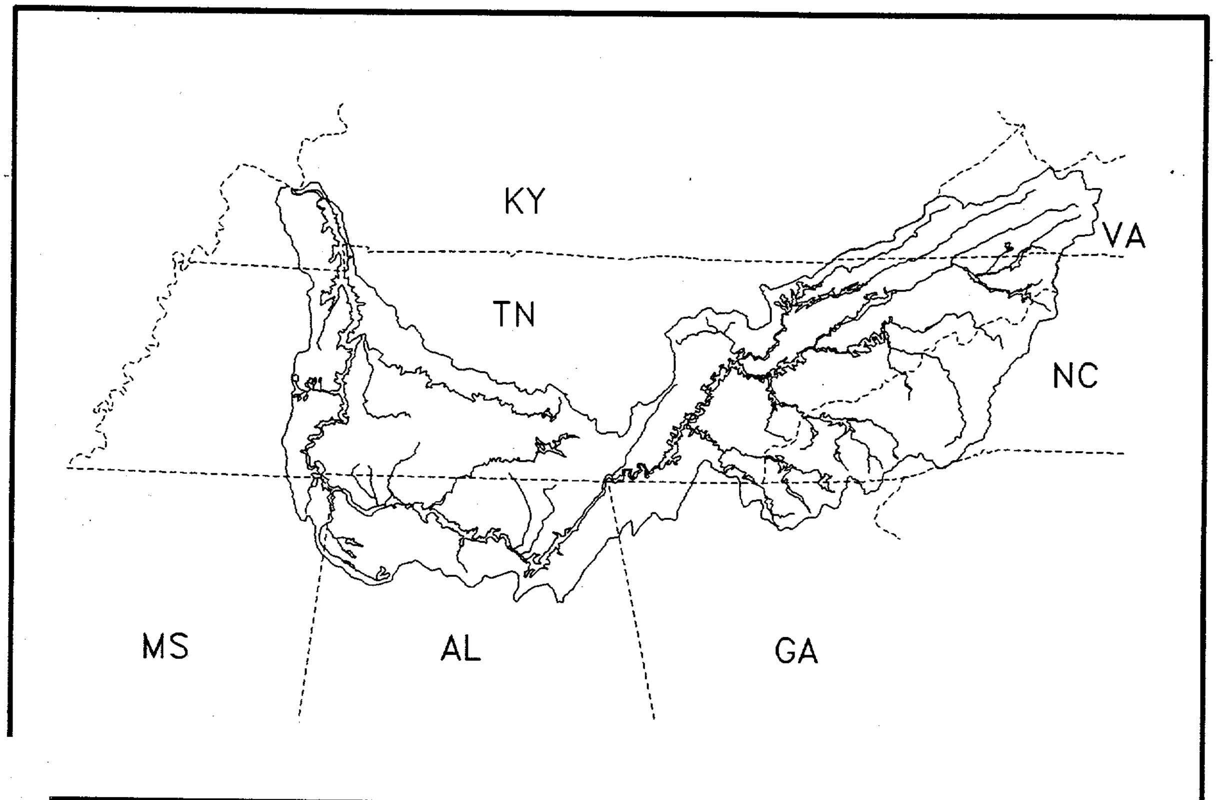
Tennessee
Valley
Authority

Water Resources Division
Chattanooga, Tennessee

TVA/WR/AB--91/12
OCTOBER 1991

RESERVOIR MONITORING - 1990

FISH TISSUE STUDIES IN THE TENNESSEE VALLEY IN 1989



WATER RESOURCES &
ECOLOGICAL MONITORING

WATER RESOURCES MANAGEMENT

TVA/WR/AB--91/12

TENNESSEE VALLEY AUTHORITY

Resource Development
River Basin Operations
Water Resources

RESERVOIR MONITORING - 1990

FISH TISSUE STUDIES IN THE TENNESSEE VALLEY IN 1989

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October 1991

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EXECUTIVE SUMMARY

TVA has been involved in fish tissue studies for a number of years. Because of the significant interest expressed by Valley states and the fishing public, TVA's involvement in these studies has been expanded progressively from year to year. TVA coordinates these efforts with state and federal agencies to avoid duplication of effort.

TVA analyzes tissues of Tennessee Valley fish as part of both intensive and screening evaluations. Intensive studies are conducted on reservoirs where contamination problems are known or suspected, and they include analysis of individual fillets from important fish species from several areas in the reservoir. Primary objectives of intensive studies are to define the species affected and the geographical boundaries of contamination. These studies continue over a period of years to document when the contaminant ceases to be a problem. This information is used by state public health officials to determine if fish consumption advisories are necessary to protect human health. Screening studies, on the other hand, are based on analysis of composited, rather than individual fillets, and are intended to identify possible problem areas with a need for an intensive investigation. Screening studies were initiated in 1987 and are intended to be sampled on a rotational basis, where each reservoir is revisited every three years as long as concentrations remain low.

The approach most commonly used in these studies is to examine a reservoir as part of the Valley-wide Fish Tissue Screening Study, which uses channel catfish as an indicator species. Channel catfish was selected as the indicator species because it is highly sought by both commercial and sport fishermen, because individuals usually have relatively high concentrations of most contaminants compared to other species, and because an historical data base exists for that species.

If problems are identified, an intensive study is usually undertaken the next year that would include analysis of individual channel catfish at a greater number of locations than sampled in the screening study. Also, other important species would be examined, including one or more of the following: largemouth bass, striped bass, buffalo, crappie, carp, white bass, and possibly others.

Immediately after collection, fish are placed on wet ice and a systematic examination made on the external and internal conditions of each fish. Other information taken for each fish includes total length, total weight, sex, fillet weights, and liver weight. Each fillet is wrapped in aluminum foil and bagged separately to maintain individual identity, regardless of whether for a screening or an intensive study. All samples are stored frozen until analyzed in the chemistry laboratory.

Fish collected for screening studies are usually analyzed for metals, PCBs, and pesticides on EPA's Priority Pollutant List. Fish for intensive studies are analyzed only for the contaminant of concern, which has been identified by screening studies, or is known as an historic problem. Lipid content is determined on all samples.

Screening Studies

Results of screening studies in 1989 did not reveal any new areas in need of intensive studies. Two areas (Parksville Reservoir on the Ocoee River and John Sevier Detention Pool on the Holston River) had been identified in previous years of screening to be in need of more detailed examination. Because of other priorities, this was not possible in 1989, so both waterbodies were reexamined at the screening level. The 1989 efforts supported results from previous years. In Parksville Reservoir, relatively high concentrations of PCBs (1.0 µg/g) and selenium (1.0 µg/g) are the contaminants of concern; on John Sevier Detention Pool, concern exists for one or more of the following: PCBs, chlordane, mercury, and cadmium.

An ancillary objective of the 1989 screening studies was to determine if increased turbulence and runoff due to heavy rainfall and flood conditions caused a measurable increase in contaminant concentration. Screening studies had been conducted on most mainstream reservoirs in 1988. Autumn 1988 continued a prolonged drought in the Tennessee Valley, starting in summer 1984. The drought came to an abrupt end in 1989, with significant rainfall and flooding in winter, spring and summer. To capitalize on this opportunity, the mainstream reservoirs were resampled in autumn 1989. Increased contaminant concentrations were documented at several sample areas, especially those in the upper end of the reservoirs (i.e., downstream of the next dam, where turbulence would be expected to be greatest). The most common contaminant to increase was PCBs, although none of the increases were great enough to show need for an intensive study. DDT concentrations increased substantially on Wheeler Reservoir, which was known to have an historic DDT problem. Because of these observed increases in 1989 and continued heavy rainfall in early 1990, sample site selection for autumn 1990 was aimed at further evaluating potential increases.

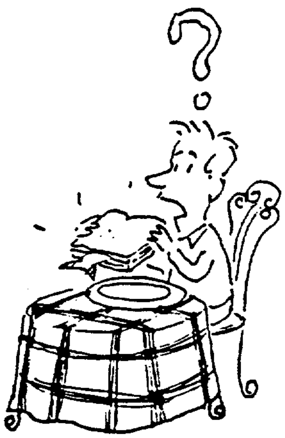
Intensive Studies

Five TVA reservoirs were examined intensively in 1989: Wilson, Nickajack, Watts Bar, Fort Loudoun, and Tellico reservoirs. On all lakes the contaminant of concern was PCBs, and chlordane was of concern in some. Fish consumption advisories (limit quantity eaten or avoid any consumption) are in effect for all these reservoirs, except Wilson. A copy of the most recent public notice published in January 1991, providing appropriate advice from the Tennessee Department of Health and Environment, is provided in appendix C. Advice provided in this public notice was based in large part on results of these studies. Most advisories were continued from 1988 with only a few changes.

Wilson Reservoir (in Alabama) was examined intensively because of an historic PCB problem, which was first discovered in 1984 and decreased steadily through 1987 to basically non-detectable levels. In 1985, the Northwest Alabama Regional Health Department notified local markets to discontinue selling catfish from Wilson Reservoir; this notice was discontinued in early 1987, as a result of decreased concentrations. A

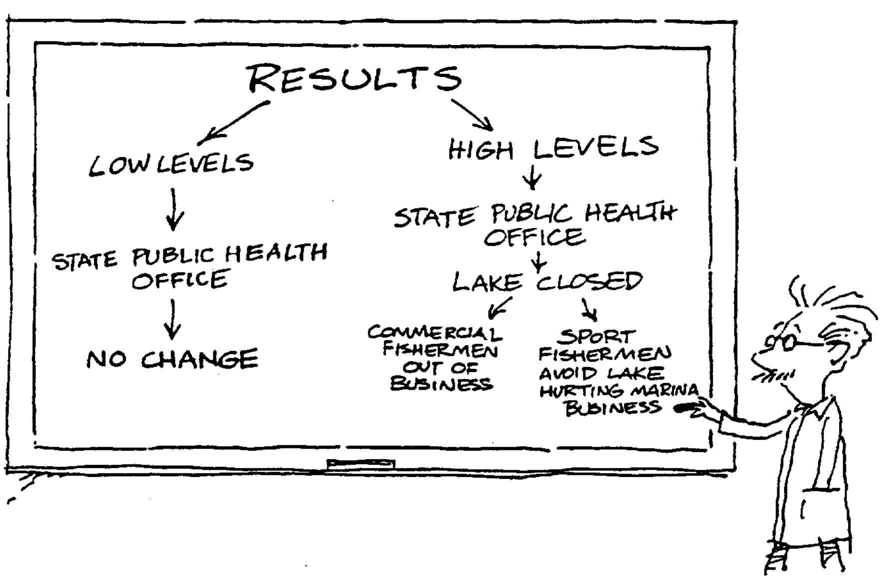
PCB source from TVA's Power Service Center into a small embayment (Fleet Hollow), at the downstream end of Wilson Reservoir, was probably responsible for the problem within that embayment, but not for the problem throughout the reservoir. Likewise, remediation efforts by TVA during early to the mid-1980's would be expected to be responsible for correcting the localized problem, but not the reservoir-wide problem. The cause of the reservoir-wide problem was never fully known; likewise the reason for the reservoir-wide recovery was not known. The most plausible explanation for the observed decreases throughout the reservoir was that the fish examined in 1984 were collected about four months following a 100-year flood event. As stated previously, the period following 1984 was extremely dry through 1988, with little runoff and low flows in the Tennessee River. Return of heavy rainfall, particularly in early summer 1989 (generally similar to that in 1984), provided an opportunity to determine if high PCB concentrations occurred again. The 1989 results showed an increase at all sample sites with the greatest increases in Fleet Hollow. However, the increases were not sufficiently high to warrant advice to the public. Because of the heavy rainfall in early 1990, the intensive study was conducted again in autumn 1990 to determine if concentrations increased further.

VALLEY-WIDE FISH TISSUE STUDY



You can't tell a fish by it's cover--is it safe to eat?

Routine, cooperative monitoring by State, Federal, and other interested agencies is necessary to ensure protection of public health.



Results are provided to all involved parties and are used by State officials to advise the public appropriately.

(coordinated by Tennesee Valley Authority)

FISH TISSUE STUDIES
IN THE TENNESSEE VALLEY IN 1989

1.0 INTRODUCTION

The Tennessee Valley Authority (TVA) has been involved in fish tissue studies for a number of years. Because of the significant interest expressed by Valley states and the fishing public, TVA's involvement in these studies has expanded progressively from year to year.

TVA analyzes tissues of Tennessee Valley fish as part of both intensive and screening evaluations. Intensive studies are conducted on reservoirs where contamination problems are known or suspected and include analysis of individual fillets from important fish species from several areas in the reservoir. Primary objectives of intensive studies are to define the species affected and the geographical boundaries of contamination. These studies continue over a period of years to document when the contaminant ceases to be a problem. This information is used by state public health officials to determine if fish consumption advisories are necessary to protect human health. Screening studies, on the other hand, are based on analysis of composited rather than individual fillets and are intended to identify possible problem areas with a need for an intensive investigation.

This report provides results from both intensive studies and screening studies conducted in 1989. In the past, intensive studies were reported individually, resulting in several such reports each year, and screening studies were combined in a single report each year. This change to a consolidated annual fish tissue report was made to increase efficiency, to gain a Valley-wide perspective, and to avoid confusion created by the increased number of reports each year. A list of fish tissue reports prepared for previous years is provided in appendix A along with instructions for ordering copies of reports.

Chapter 2 of this report summarizes the philosophical approach and generic procedures used by TVA in fish tissue studies. Chapter 3 provides results and discussion for all 1989 screening studies, and chapter 4 provides similar information for each intensive study. Chapters 3 and 4 also identify specific methodologies (e.g., species, locations, etc.) as appropriate. The final chapter identifies problem areas for particular contaminants, provides a Valley-wide perspective by comparing contaminant concentrations among reservoirs, and presents risk assessment calculations where appropriate data exist.

2.0 RATIONALE AND GENERAL PROCEDURES

2.1 Sample Collection and Handling

2.1.1 Strategy

All fish tissue studies are closely coordinated among TVA and various state agencies to ensure all needs are met and to avoid duplication of effort. Planning meetings are usually held in the summer followed by collection efforts in autumn. In many cases efforts are combined so that one organization collects the fish and another analyzes them. Coordinated efforts such as these allow for most efficient use of available funds. When more than one analytical laboratory is involved, samples are split between the labs to allow proper comparisons.

Several important decisions must be made in studies such as these. Should analyses be conducted on fish composites or individual fish? Should whole fish or fillets be analyzed? Should fillets have the skin on or off? Should the bellyflap (which is rich in lipids and lipophilic contaminants) be left on the fillet or removed? These are all valid options and all have been used in previous studies (McCracken 1983). Selection of specific protocols is dependent upon the objective of the study.

Should analyses be conducted on fish composites or individual fish?--TVA's approach differs between screening studies and intensive studies because the objectives of those studies differ. Screening studies are intended to identify reservoirs with potential problems, whereas intensive studies are intended to define the extent of the problem identified by the screening studies. Therefore, screening studies are based on composited samples analyzed for a broad array of contaminants, and intensive studies are based on analysis of individual samples for only those analytes identified to be a potential problem. Analysis of individual samples provides a measure of variation in the population thus allowing statistical testing among locations and over time.

Should whole fish or fillets be analyzed?--The primary objective of most TVA fish tissue studies is oriented toward human health. In that case, it makes little sense to examine whole fish. Therefore, in most cases, TVA fish tissue studies are based on analysis of fillets. Typically, analysis of whole fish is preferable when fish are used as "environmental monitors" to determine the condition of the environment or to identify previously unknown contaminants (FWGPM 1974 and McCracken 1983).

Should fillets have skin on or off? Should the bellyflap be left on the fillet?--The decision point for both these questions is whether one wishes to produce a "worst-case," or a less conservative, scenario. Fillets with skin and bellyflap left on usually have higher concentrations of most contaminants (worst-case), especially organochlorine contaminants, than skin-off, bellyflap-removed (best-case) fillets. A study by Cornell University has shown up to a 50 percent reduction in concentration of PCBs and mirex when comparing "best-case" and "worst-case" prepared fillets (Gall and Voiland 1990). Based on the need for a conservative approach in protection of public health, TVA studies are designed to produce a worst-case estimate of contamination so as to best protect the fish consumer.

Therefore, all TVA analyses are conducted on fillets with bellyflap left on for all species and skin left on for all species except catfish (catfish skin is rarely, if ever, eaten with the fillet).

2.1.2 Species Examined

The approach most commonly used in these studies is to examine a reservoir as part of the Valley-wide Fish Tissue Screening Study (described in detail in Section 3.1), which uses channel catfish as an indicator species. Channel catfish was selected as the indicator species because it is highly sought by both commercial and sport fisherman, because individuals usually have relatively high concentrations of most contaminants compared to other species, and because an historical data base exists for that species.

If problems are identified, an intensive study is usually undertaken the next year that would include analysis of individual channel catfish at a greater number of locations than sampled in the screening study. Also, other important species would be examined at the screening level. Depending upon their importance in the reservoir and the availability of funds, these species would include one or more of the following: largemouth bass, striped bass, buffalo, crappie, carp, white bass, and possibly others. If problems are identified in any of these species, they would be examined intensively (i.e., fillets analyzed individually) during the subsequent year.

2.1.3 Field Handling

Fish are usually collected with gill nets, or with boat-mounted electro-fishing gear. Slat baskets are occasionally used for catfish, if other collection techniques are not successful. In some cases, fish (usually catfish or buffalo) are obtained from commercial fishermen, but only if a TVA (or state) employee accompanies the fishermen and witnesses that the fish were harvested from the desired collection area. To the extent possible, collection of these fish is coordinated with all other on-going collection efforts to minimize costs.

Immediately after collection, fish are placed on wet ice and as soon as possible (not to exceed 24 hours) taken to one of TVA's biological laboratories for examination and processing. Examination involves systematic observations on the external and internal conditions of each fish. Other information taken for each fish includes total length, total weight, sex, fillet weights, and liver weight. Each fillet is wrapped in aluminum foil and bagged separately to maintain individual identity, regardless of whether for a screening or an intensive study. All samples are stored frozen until analyzed in the chemistry laboratory.

2.2 Analytical Laboratory

2.2.1 Analytes

Fish collected for screening studies are usually analyzed for metals, PCBs, and pesticides on EPA's Priority Pollutant List. Fish for intensive studies are analyzed only for the contaminant of concern, which has been identified by screening studies or is known as an historic problem. The most common contaminant of concern in the

Tennessee Valley is PCBs, with chlordane a distant second. Several TVA reservoirs have fish consumption advisories due to PCB-contaminated fish. These will be further described in chapter 4.

The lipid content of a sample (determined gravimetrically and expressed as a percentage) has been found to be an invaluable quality assurance tool, as well as being essential in conducting spatial or temporal statistical analyses. For these reasons, lipid content is determined on all samples.

Preparation of fillets for individual analysis is accomplished by homogenizing the entire fillet. This is necessary because contaminants are not evenly distributed throughout the fillet, and homogenization of only a portion would bias the results. An aliquot is then removed from the homogenate for analysis.

A composite sample is prepared by taking an equal aliquot from each of five independently homogenized fillets. Preparation of composite samples in this manner is necessary to avoid biasing of results due to compositing fillets of different sizes. The alternative way to avoid a size bias is to collect fish of a consistent size. This would allow homogenizing all five fillets at the same time, thereby reducing time required for that step. However, TVA's experience has shown that this alternative is not desirable because it increases collection costs, limits applicability of results to only the size of fish tested, and prevents samples from maintaining their identity, if the need arises later for individual analysis.

2.2.2 Quality Assurance

TVA's standard Quality Assurance (QA) program requires running one replicate, one spike, one blank, and one surrogate out of every ten samples. TVA also routinely splits samples with other analytical laboratories if that agency is participating in fish tissue studies on TVA waters. In 1989 a rather extensive split-sample QA effort was made on several reservoirs in east Tennessee. Laboratories from TVA, Tennessee Department of Health and Environment, EPA Region IV, and the Oak Ridge National Laboratory were included. Details of this effort are provided in appendix B.

2.3 Data Analyses

2.3.1 Screening Studies

Statistical analyses are not conducted on results from screening studies because replicate samples are not collected. Results from these studies are compared to preselected, tiered concentrations. If measured concentrations are low relative to the tiered concentrations, then no follow-up studies are warranted. If measured concentrations are high, follow-up studies would be conducted. More thorough explanation of this tiered approach is provided in section 3.1.

2.3.2 Intensive Studies

Statistical techniques used to examine results from intensive studies range from descriptive statistics to analysis of covariance. The more sophisticated procedures are used when one variable (such as PCB concentration) is found to be dependent on another (such as lipid content or fish weight). Detailed explanation of this approach is provided in chapter 4.

3.0 SCREENING STUDIES

This chapter presents and discusses results from TVA's routine, long-term monitoring studies which are Valley-wide in coverage. Also presented in this chapter are results of a multi-year screening effort conducted on Chickamauga Reservoir for TVA's Power Generating Group. This latter effort was conducted as part of the aquatic monitoring program for Sequoyah and Watts Bar Nuclear Plants.

3.1 Routine, Long-Term Monitoring Studies

TVA has two fish-tissue screening programs: One examines fish annually at inflow points of eight of the major tributaries to the Tennessee River reservoir system; the other looks at fish from within the reservoirs on a rotating basis, with the goal of sampling each reservoir at least once every three years. To differentiate between the studies, areas sampled at inflow points are called Fish Tissue-Inflow (FT-I) sites; areas included in the reservoir efforts are called Fish Tissue-Reservoir (FT-R) sites. The two studies have different objectives and slightly different protocols.

FT-I is intended to identify year-to-year trends in contaminants entering the reservoir system from major watersheds. This program, which started in 1986, uses catfish, rough fish, and game fish as indicators, FT-R, initiated in 1987, screens toxic levels in fish throughout the Tennessee Valley, in coordination with other organizations involved in such studies. Communication with state, federal, and industry-based biologists avoids duplication of effort; further, the FT-R study depends on these biologists to supply some of the fish for its analyses. TVA collects fish from the remaining FT-R sites, analyzes all fish, and furnishes results to the cooperating groups.

Results from FT-R are intended to lead to one of three alternatives. If all values for toxics in fish flesh from a reservoir are low (termed tier 1), that reservoir will be resampled in about three years; if some values are high (termed tier 3), it will be recommended for an intensive study with detailed plans and funding sources developed by all involved organizations. If levels of toxics are between those extremes (termed tier 2), that reservoir will be sampled again at the screening level the next year to better determine whether a problem exists. Values termed low and high were selected a priori from a combination of sources including Food and Drug Administration (FDA) tolerances and action levels (FDA 1987), Preliminary Guidance Values (Travis, et al. 1986), and subjective evaluations based on experience with such studies in the Tennessee Valley. Specific tier levels for each contaminant included in this study are provided in table 3.1-1.

This report presents the results from screening studies in 1989. Results of similar investigations in the three previous years were reported earlier (TVA 1988, 1989b, and 1990). In addition to further sampling needs indicated from results of 1988 studies, selection of 1989 FT-R collection sites was governed by a unique opportunity to evaluate effects of flood versus drought conditions on certain levels in fish. Fish were collected from all mainstream Tennessee River reservoirs in autumn 1988 in various studies. At that time, the Tennessee Valley had been in drought conditions for the previous four years, which had resulted in reduced runoff and low river flows. Heavy rainfall in spring and summer 1989 resulted in periodic flooding and substantially increased flows. Therefore, FT-R efforts for 1989 were directed at remaining mainstream reservoirs not being sampled as part of other studies, as well as returning to those FT-R sites where fish had exceeded the tier 1 level in 1988. Collection sites for all 1989 fish screening samples are listed in table 3.1-2 and shown on figure 3.1-1.

3.1.1 Methods

Study Species

Fish collected for analysis at FT-I monitoring stations include five specimens each of game fish, catfish, and rough fish. The order of preference for species within each category are listed below. If five individuals of the most preferred species within a category could not be collected, individuals from the next preferred species were substituted to achieve the full complement of five.

Game	Catfish	Rough
Largemouth bass	Channel	Carp
Crappies	Blue	Freshwater drum
Spotted bass	Flathead	Buffalos
Smallmouth bass	Bullhead	Redhorses
Bluegill		
Other sunfishes		

Because FT-R is such a broad screening effort, a single indicator species, channel catfish, is used to allow the greatest coverage of Valley reservoirs at the lowest possible cost. Channel catfish was selected because it is highly sought by both commercial and sport fisherman, and because catfish typically show higher levels of most toxics compared to other species. Every effort is made to collect five channel catfish at each site, but blue catfish are utilized as a last resort supplement, if sampling time runs out.

Sample Processing

Immediately following their collection in the field, all fish are placed and kept on ice until processing at the biological lab. Prior to processing, each fish is sexed, measured, weighed, and external and internal (organs) conditions noted. All fish are filleted with care taken to retain all flesh, including ribs and bellyflap. Skin is left on game and rough fish (scales are removed), but the skin is removed from catfish. One fillet from each of the five fish from each location is randomly selected (coin toss) to form the composite for metal analyses; the other fillet from each fish provides the composite for analyses of organic constituents. Each group of five fillets is rinsed in cold water, weighed, wrapped in aluminum foil, and placed in separate, labeled, plastic bags. Samples are frozen immediately following processing, and stored frozen until laboratory analysis.

For the FT-R study, livers are also removed from each catfish, weighed and composited with other livers from that site, and stored in clearly identifiable plastic bags for laboratory analysis.

Laboratory Analyses

Laboratory analyses for both FT-R and FT-I studies are performed on composited fillets (five fish per composite), where each fillet is individually homogenized and an equal aliquot withdrawn from each fillet to prevent size bias. Analyses on composited fillets include lipid content and priority pollutant metals, pesticides and PCBs. For those organics where the Environmental Protection Agency (EPA) priority pollutant list includes more than one isomer or metabolite (e.g., alpha, beta, and gamma BHC or endrin and endrin aldehyde), these are analyzed separately in the laboratory, but reported here as a total value. Livers are analyzed only for metals. All data are stored on EPA's STORET system.

3.1.2 Results and Discussion

Collections and Observations on Fish

Specific data for each of the 239 fish in the 1989 collections are provided in table 3.1-3. The LABID number provides the means for connecting the levels of metals and organics found in laboratory analyses (tables 3.1-4, 5, & 6) with the physical data for specific fish samples.

Only 6 of the 245 individual fish samples planned for collection at 25 Valley-wide and eight inflow sites in 1989 were missed. Only four of the five desired catfish were collected at FBRM 42 on Douglas Reservoir, at SFHRM 19 on Boone Reservoir, and at ERM 135 on Tims Ford Reservoir; at the Powell River fixed-station site (mile 65) just two catfish were taken. Therefore, the lab sample for those stations was composited from 1 to 3 fewer fillets than at the other 29 stations.

In addition to the above planned samples, two special fish collections were made in 1989. In addition to the regular channel catfish samples, striped bass (hybrids) and blue catfish were collected on Boone Reservoir, at the request of the Tennessee Wildlife Resources Agency; their analyses are included in this section. Fish of several species were also collected and analyzed from three stations on Chickamauga Reservoir because of suspected metal and organics problems; results from that semi-intensive study are discussed in section 3.2.

Externally, most fish collected in this study appeared to be healthy. Of the total 239 fish, 15 had some kind of abnormality, including two carp with deformed head and/or spine; two largemouth bass with lower mandible lesions; one bass with severe fin erosion; and one catfish with a broken, healed caudal fin and hump on its back. More eye problems were noted than in previous years; five fish had exothalmic eyes (pop-eye), two were blind in one eye, one catfish had an eye completely gone, and one bass had a growth on one eye. The relatively low occurrence of these conditions indicates rather healthy fish populations overall. However, since seven of the nine eye anomalies were noted at the FT-I site on the French Broad River (mile 71), this may be indicative of more stressful conditions there. The other two eye problems were also observed at inflow sites in the upper, eastern part of the Valley. As in 1988, some fish again showed external abnormalities (skin lesions, fin erosion, eye problems) at HRM 110.

Although the great majority of fish collected in 1989 appeared to have healthy internal organs, the number observed with some type of noteworthy problem was considerably higher than in 1988, probably due to more attention being paid to those observations in 1989. Fifteen catfish and nine bass had discolored and/or enlarged livers, and four catfish had nodules, grubs, or parasites on their livers. With one exception (two fish at Nolichucky), all of the catfish with abnormal kidneys, livers and spleens came from the lower part of the Tennessee Valley, i.e., Wheeler Reservoir downstream, whereas bass with such conditions were only found in the upper Valley. Catfish from Parksville Lake (ORM 12) were skinny and had parasites on all organs. No information positive or negative was reported on length/weight relationships, except as noted for the skinny catfish from Parksville Lake.

The following individuals were observed to have substantial fat in the visera; blue catfish - one fish from Emory River and three of four fish from Boone Lake; striped bass hybrids from Boone also contained much fat; channel catfish - nearly all those collected in the lower lake and tailwater of Kentucky Reservoir; drum and bass from the Powell River; carp, bass and catfish from French Broad and Nolichucky rivers. High internal fat content is another indicator of fish health and is especially important as fish prepare for winter.

Tissue Analyses

Metals--Results of laboratory analyses for metals on the 49 composited fillet samples are presented in table 3.1-4. Antimony, cadmium, silver and thallium were not detected in any samples. Beryllium was detected in Chickamauga Reservoir samples and this will be discussed in 3.2 of this report. Although copper was not detected in any of the 1988 tissue samples (possibly due to use of a relatively high detection limit) it was found in some amounts above the laboratory 0.2 detection limit at most sites in 1989. Because copper is an essential life element for fish, concentrations of it would have to be substantially above 2.0 μg/g to be considered a problem. Only one sample in 1989 was at that level, fillets of largemouth bass collected at Elk River mile 21 had 5.6 μg/g of copper. Copper concentrations of this magnitude had not been observed in any previous years, and were not observed in either of the other two fish samples from this FT-I site in 1989. Results from 1990 collections will be scrutinized closely for high copper values. Nickel, which is usually not documented in fish tissue in the Tennessee Valley, was found at one site (PRM 65) at a concentration slightly above the detection limit of 1.0 μg/g, but not enough to warrant further study.

Lead, selenium, mercury and zinc were detected in nearly all fillet composites. Selenium and zinc are essential elements for life and usually found in fish tissue samples. Lead is a common environmental pollutant due to its many industrial uses; however, the highest level found (0.55 μg/g) was well below that requiring further evaluation (2.0 μg/g). Zinc is not usually a problem, even at high levels up to 75 μg/g, although selenium and lead may be a concern at sufficiently high concentrations, i.e., above 2-3 μg/g.

Mercury was found at or near the tier 2 level of 0.5 μg/g only in largemouth bass at Holston River mile 110 in 1989. Similar levels had been found in 1988. Mercury in 1989 Hiwassee River samples at mile 12 had decreased from that observed in 1988. Both of those sites are part of FT-I and are automatically resampled annually.

Comparison of metal concentrations in fish collected in 1989 to the selected tier levels in table 3.1-1 shows that few samples exceeded the tier 2 required rescreening level, and none exceeded the established tier 3 levels. The high concentration of copper (5.6 μg/g) in bass at the Elk River inflow site is noteworthy and will be re-examined in 1990 because this is an FT-I site.

As in the previous two years, selenium concentrations of near 1.0 μg/g (the tier 2 level) continued to be found in fish from

Parksville Reservoir (ORM 12), indicating a need for further studies there. The higher selenium results, along with continued high PCB concentrations (discussed later) and a history of water quality problems in that reservoir, support the need for a detailed examination of Parksville Reservoir.

Catfish livers were again collected from all 25 FT-R sites for analyses of metals, because this organ typically contains higher metal concentration than muscle tissue (table 3.1-5). Presence of metals in livers had some similarities to that in fillets-antimony, nickel, silver, and thallium were not detected in any liver samples; arsenic, beryllium and cadmium were detected in only a few samples at levels close to the detection limit. Low levels of chromium and lead were widespread in samples throughout the reservoir system, but not approaching tier 2 levels. Mercury was detected near the tier 2 level in Tims Ford Reservoir (ERM 21) but only at lower levels elsewhere. Zinc was present in all samples, but again at usually less than half the tier 2 level.

Copper and selenium had the highest metal concentrations in livers. Copper concentrations were high in Pickwick Reservoir TRM 235 (4.4 µg/g); Parksville Reservoir (8.6) and Boone Reservoir 34.0 µg/g, which is in stark contrast to 1988, when no copper was detected in catfish livers at those sites. Selenium levels were also high in livers in Parksville and Boone Reservoirs. Maximum concentrations of copper (34.0 µg/g), selenium (3.1 µg/g), and zinc (29.0 µg/g) were much higher than in fillets, arsenic was higher in only one liver sample (Boone). Lead and mercury were higher in fillets than in livers, which was a change from 1988, when the reverse was true.

A comparison of metal concentrations in livers and fillets from mainstream verses tributary reservoirs showed generally higher levels of most metals in fish from the tributary lakes. The data base to determine "normal" concentration of metals in livers for use as indicators of environmental contamination, is still being developed.

Organics--Table 3.1-6 provides results from pesticides and PCB analyses. Pesticides not detected in any samples included aldrin, toxaphene, BHC, and heptachlor; endosulfan and dieldrin each were found only in one sample, at slightly above the detection limit (0.02 µg/g). Endrin was found at low concentrations (0.02-0.06 µ/g) at eight widely-scattered stations throughout the Valley, including tributary reservoirs where it was not detected previously. Thus, the distribution of endrin is not related just to agriculture activities in the drainages of mainstream reservoirs, as was suggested in the 1988 report.

As in previous years' samples, chlordane and DDTr were the most commonly encountered pesticides in fish tissues. Chlordane was detected in 28 of 49 samples, exceeding the tier 1 level of 0.1 µg/g in three reservoirs (Pickwick, Tims Ford, and Boone). The highest concentration (0.29 µg/g) was found in striped bass in Boone, but it was also found at a high level (0.18 µg/g) there in blue catfish. A precautionary advisory from THDC against eating carp and catfish from Boone Reservoir remains in effect.

DDT was detected in 46 of the 49 samples, most frequently and at higher levels in the mainstream reservoirs, but only one sample exceeded the tier 2 level of 2.0 µg/g. A level of 4.38 µg/g was found in catfish from TRM 300 in Wheeler Reservoir, which, although quite high, is still below the FDA required action level of 5.0 µg/g. The presence of

DDT in the aquatic environment in north Alabama, has been known for many years, so the current high level in Wheeler Reservoir fish is not a surprise, especially given the floods and high runoff of 1989.

PCBs were found in 39 of 49 samples, up from 1988 occurrences, but concentrations were still mostly below the tier 2 levels of 1.0 µg/g. Samples from only two reservoirs (Wheeler and Parksville) exceeded that level; neither of those was above the tier 3 level of 1.5 µg/g, but close enough perhaps to suggest continued sampling would be prudent. Continued high levels of several metals and pesticides in Parksville Lake supports the need for a more detailed evaluation of toxic materials there.

The highest and second-highest concentration of both metal and organic contaminants by location and species are summarized in table 3.1-7 for quick identification of "worst-case" conditions. For example, two areas stand out in the table as possible toxic "high-spots" that investigators may wish to examine more closely: SFHRM 19 (Boone Reservoir) and FBRM 71. The site in Boone Reservoir (elaborated on earlier) had the highest levels in 1989 samples of chlordane and endrin (hybrid striped bass) and the second-highest levels of arsenic and dieldrin (striped bass) and chlordane (blue catfish). The second site (FBRM 71) had the highest levels of arsenic (bass), dieldrin (bass), and endosulfan (carp) and the second-highest levels of mercury (bass).

3.1.3 Recommendations

Results from 1989 continue to provide evidence of the need for more thorough evaluations of toxic problems in Parksville Reservoir on the Ocoee River and the John Sevier Detention Pool (HRM 110) on the Holston River. Although studies on the Holston River have been recommended several times in reports on results for previous years (TVA 1988, 1989, 1990), such a study has yet to be conducted. The Holston River drains several highly industrialized and urbanized areas, and high concentrations of several toxics, especially metals, have been recognized for many years (TVA 1988). It would appear that fish from the entire stretch of the river above the John Sevier Detention Pool contain many similar high toxic concentrations, but they appear most evident in the pool area, which most likely serves as a catch basin for toxic materials being carried down the river. Parksville Reservoir has always been slightly acidic because of its drainage from the mine areas of Copper Basin. The presence of higher than normal concentrations of PCBs and selenium there also merit further evaluation.

DDT levels at TRM 300 on Wheeler Reservoir and levels of chlordane in Boone Reservoir are high enough to require intensive studies of those contaminants. The present advisory against eating fish from Boone Reservoir needs to be expanded to include striped bass. Three FT-I sites showed high-enough contaminant levels for rescreening, but fish are collected for tissue analyses at those stations on a regular annual basis. Eight FT-R sites that showed a need for resampling of various contaminants are listed in table 3.1-8.

Planning for 1990 FT-R fish collections had to be completed before the preparation of this report. Selection of collection sites continued to be governed by a further opportunity to evaluate effects of flood versus drought conditions on contaminant levels in fish. Rainfall was above normal again in 1990. Therefore, FT-R sampling efforts in 1990 were again directed at examining mainstream reservoirs not being sampled in other studies, as well as returning to those sites where the levels of metals and organic in fish tissue exceeded the tier 1 level in 1989. FT-R collection sites for autumn 1990 are identified in table 3.1-9.

Table 3.1-1. Contaminant Concentrations[a] Used as the Guidelines for Planning the Level of Continued Fish Tissue Studies in Tennessee Valley Waters

Parameter	Laboratory Detection Limit (µg/g)	Tier 1 Return to Rotation System (µg/g)	Tier 2 Resample at Screening Level Following Year (µg/g)	Tier 3 Recommend Intensive Study (µg/g)
Antimony	2.0	< 5.0	≥ 5.0	b
Arsenic	0.03	< 0.5	≥ 0.5	≥0.7
Beryllium	0.02	< 0.1	≥ 0.1	≥0.3
Cadmium	0.001	< 0.5	≥ 0.5	≥1.0
Chromium	0.02	< 0.7	≥ 0.7[c]	≥1.5[c]
Copper	0.2	< 3.0	≥ 3.0	b
Lead	0.2	< 1.5	≥ 1.5	≥2.0
Mercury	0.1	< 0.5	≥ 0.5	≥0.7
Nickel	1.0	< 2.0	≥ 2.0[c]	≥4.0[c]
Selenium	0.02	< 1.0	≥ 1.0	≥3.0
Silver	0.2	<12.0	≥12.0	b
Thallium	1.0	< 1.0	≥ 1.0	≥3.0
Zinc	0.1	<75.0	≥75.0	b
Aldrin	0.01	< 0.1	≥ 0.1	≥ 0.2
Benzene Hexachloride	0.01	< 0.1	≥ 0.1	≥ 0.2
Chlordane	0.01	< 0.1	≥ 0.1	≥ 0.2
DDT	0.01	< 2.0	≥ 2.0	≥ 4.0
Dieldrin	0.01	< 0.1	≥ 0.1	≥ 0.2
Endosulfan	0.01	< 3.0	≥ 3.0	≥ 5.0
Endrin	0.01	< 0.1	≥ 0.1	≥ 0.2
Heptachlor	0.01	< 0.1	≥ 0.1	≥ 0.2
Toxaphene	0.5	< 2.0	≥ 2.0	≥ 3.0
PCBs	0.1	< 1.0	≥ 1.0	≥ 1.5

a. These levels will be used as a general guide. Specific recommendations will be made on a case-by-case basis.

b. Selection of a level for this metal, which would result in a recommendation to conduct intensive studies, cannot be made at this time.

c. Chromium and nickel frequently occur as a result of laboratory contamination from the blending process. A suspected source would have to exist before further examination would be recommended on the basis of metal concentrations found in laboratory analyses.

Table 3.1-2. Collection Sites, Fish Tissue Screening Studies, Autumn 1989

Site[a]	Valley-wide Screening Studies[b] (Reservoir Sites)	Ambient Monitoring Studies[c] (Inflow Sites)
Lower Tennessee River		
TRM 7	X	
TRM 22	X	
Kentucky Reservoir		
TRM 30	X	
TRM 61	X	
TRM 98	X	
TRM 136	X	
TRM 172	X	
TRM 192	X	
Duck River Mile 12		X
Pickwick Reservoir		
TRM 210	X	
TRM 235	X	
TRM 255	X	
Wheeler Reservoir		
TRM 275	X	
TRM 300	X	
TRM 339	X	
Elk River Mile 21		X
Tims Ford Reservoir		
ERM 135	X	
ERM 150	X	
Guntersville Reservoir		
TRM 351	X	
TRM 382	X	
TRM 394	X	
Hiwassee River Mile 12		X
Parksville Reservoir		
ORM 14	X	
Emory River Mile 7		X
Powell River Mile 65		X

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Table 3.1-2 (Continued)

Site[a]	Valley-wide Screening Studies[b] (Reservoir Sites)	Ambient Monitoring Studies[c] (Inflow Sites)
Douglas Reservoir		
FBRM 35	X	
FBRM 42	X	
FBRM 58	X	
FBRM 71		X
Nolichucky River Mile 5		X
Holston River Mile 110		X
Boone Reservoir		
SFHRM 19	X	

a. TRM = Tennessee River Mile; ERM = Elk River Mile; ORM = Ocoee River Mile; FBRM = French Broad River Mile; SFHRM = South Fork Holston River Mile.

b. CHC = Channel Catfish; LMB = Largemouth Bass; Catfish = Composite of more than one catfish species; BLC = Blue Catfish; Str/Hyb = Striped Bass X White Bass Hybrid.

c. The ambient monitoring study uses composited fillets from catfish, rough fish, and game fish collected annually from major inflow sites.

Table 3.1.3. Specific Physical Information on Individual Fish Collected for Tissue Analysis from Inflow and Reservoir Locations, 1989 (inflow stations one indicated by (*)

COLLECTION SITE	DATE	SPECIES [a]	SEX	LABID [b]	LENGTH (mm)	WEIGHT (g)
Tennessee River						
Tennessee River mile 7.0	891107	CHC	FMAL	240	360	494
Tennessee River mile 7.0	891107	CHC	MALE	240	384	592
Tennessee River mile 7.0	891107	CHC	MALE	240	376	500
Tennessee River mile 7.0	891107	CHC	MALE	240	382	558
Tennessee River mile 7.0	891107	CHC	MALE	240	369	434
Tennessee River mile 22.0	891107	CHC	FMAL	241	531	1562
Tennessee River mile 22.0	891107	CHC	FMAL	241	460	946
Tennessee River mile 22.0	891107	CHC	MALE	241	500	1134
Tennessee River mile 22.0	891107	CHC	MALE	241	465	970
Tennessee River mile 22.0	891107	CHC	MALE	241	422	730
Kentucky Reservoir						
Tennessee River mile 30.0	891010	CHC	FMAL	242	535	1362
Tennessee River mile 30.0	891010	CHC	FMAL	242	470	780
Tennessee River mile 30.0	891010	CHC	FMAL	242	474	880
Tennessee River mile 30.0	891010	CHC	MALE	242	592	2210
Tennessee River mile 30.0	891010	CHC	MALE	242	478	916
Tennessee River mile 61.0	891026	CHC	FMAL	243	574	2358
Tennessee River mile 61.0	891026	CHC	MALE	243	470	966
Tennessee River mile 61.0	891026	CHC	MALE	243	487	1144
Tennessee River mile 61.0	891026	CHC	MALE	243	483	1128
Tennessee River mile 61.0	891026	CHC	MALE	243	427	744
Tennessee River mile 97.7	891109	CHC	FMAL	244	520	1725
Tennessee River mile 97.7	891109	CHC	FMAL	244	495	1142
Tennessee River mile 97.7	891109	CHC	MALE	244	660	3170
Tennessee River mile 97.7	891109	CHC	MALE	244	341	374
Tennessee River mile 97.7	891109	CHC	MALE	244	378	518
Tennessee River mile 136.0	891031	CHC	FMAL	245	397	614
Tennessee River mile 136.0	891031	CHC	FMAL	245	445	864
Tennessee River mile 136.0	891031	CHC	FMAL	245	390	642
Tennessee River mile 136.0	891031	CHC	MALE	245	378	598
Tennessee River mile 136.0	891031	CHC	MALE	245	380	528
Tennessee River mile 172.0	891127	CHC	FMAL	246	670	3840
Tennessee River mile 172.0	891127	CHC	MALE	246	710	4410
Tennessee River mile 172.0	891127	CHC	MALE	246	763	7071
Tennessee River mile 172.0	891127	CHC	MALE	246	594	2064
Tennessee River mile 172.0	891127	CHC	MALE	246	522	1620
Tennessee River mile 191.6	891128	CHC	FMAL	247	512	1888
Tennessee River mile 191.6	891128	CHC	FMAL	247	492	1494
Tennessee River mile 191.6	891128	CHC	MALE	247	590	2248
Tennessee River mile 191.6	891128	CHC	MALE	247	603	2216
Tennessee River mile 191.6	891128	CHC	MALE	247	512	1656

Table 3.1-3 (Continued)

COLLECTION SITE	DATE	SPECIES[a]	SEX	LABID[b]	LENGTH (mm)	WEIGHT (g)
Kentucky Reservoir (Continued)						
Duck River mouth*	890626	C	FMAL	11975	540	1956
Duck River mouth	890626	C	MALE	11975	560	2368
Duck River mouth	890628	DRM	FMAL	11975	270	184
Duck River mouth	890628	DRM	FMAL	11975	275	272
Duck River mouth	890628	DRM	MALE	11975	255	188
Duck River mouth	890626	LMB	FMAL	11976	295	278
Duck River mouth	890626	LMB	MALE	11976	510	2024
Duck River mouth	890626	LMB	MALE	11976	370	666
Duck River mouth	890626	WHS	MALE	11976	320	482
Duck River mouth	890626	WHS	MALE	11976	342	530
Duck River mouth	890628	CHC	FMAL	11977	355	488
Duck River mouth	890628	CHC	FMAL	11977	310	332
Duck River mouth	890628	CHC	FMAL	11977	350	316
Duck River mouth	890628	CHC	FMAL	11977	415	704
Duck River mouth	890628	CHC	FMAL	11977	470	1112
Pickwick Reservoir						
Tennessee River mile 210.0	891026	CHC	MALE	248	345	324
Tennessee River mile 210.0	891026	CHC	MALE	248	385	608
Tennessee River mile 210.0	891026	CHC	MALE	248	385	544
Tennessee River mile 210.0	891026	CHC	MALE	248	302	286
Tennessee River mile 210.0	891026	CHC	MALE	248	380	564
Tennessee River mile 235.0	891026	CHC	FMAL	249	445	812
Tennessee River mile 235.0	891026	CHC	FMAL	249	401	580
Tennessee River mile 235.0	891026	CHC	MALE	249	415	690
Tennessee River mile 235.0	891026	CHC	MALE	249	302	264
Tennessee River mile 235.0	891026	CHC	MALE	249	380	530
Tennessee River mile 255.0	891024	CHC	FMAL	254	456	954
Tennessee River mile 255.0	891024	CHC	FMAL	254	403	834
Tennessee River mile 255.0	891024	CHC	MALE	254	503	1982
Tennessee River mile 255.0	891024	CHC	MALE	254	448	1048
Tennessee River mile 255.0	891024	CHC	UNK	254	485	1088
Wheeler Reservoir						
Tennessee River mile 275.0	891031	CHC	FMAL	255	315	216
Tennessee River mile 275.0	891031	CHC	FMAL	255	315	266
Tennessee River mile 275.0	891031	CHC	FMAL	255	315	230
Tennessee River mile 275.0	891031	CHC	MALE	255	397	572
Tennessee River mile 275.0	891031	CHC	MALE	255	313	218
Tennessee River mile 300.0	891102	CHC	FMAL	256	465	1236
Tennessee River mile 300.0	891102	CHC	FMAL	256	425	912
Tennessee River mile 300.0	891102	CHC	FMAL	256	232	162
Tennessee River mile 300.0	891102	CHC	MALE	256	386	634
Tennessee River mile 300.0	891102	CHC	MALE	256	381	586

Table 3.1-3 (Continued)

COLLECTION SITE	DATE	SPECIES[a]	SEX	LABID[b]	LENGTH (mm)	WEIGHT (g)
Wheeler Reservoir (Continued)						
Tennessee River mile 339.0	891107	CHC	FMAL	257	505	1488
Tennessee River mile 339.0	891114	CHC	FMAL	257	320	260
Tennessee River mile 339.0	891114	CHC	FMAL	257	375	464
Tennessee River mile 339.0	891114	CHC	FMAL	257	400	500
Tennessee River mile 339.0	891107	CHC	MALE	257	620	2508
Elk River						
Elk River mile 21.0*	890607	LMB	FMAL	11972	355	614
Elk River mile 21.0	890607	LMB	MALE	11972	346	678
Elk River mile 21.0	890607	LMB	MALE	11972	390	968
Elk River mile 21.0	890607	LMB	MALE	11972	320	448
Elk River mile 21.0	890607	LMB	MALE	11972	295	302
Elk River mile 21.0	890607	C	FMAL	11973	575	2560
Elk River mile 21.0	890607	C	FMAL	11973	620	2930
Elk River mile 21.0	890607	C	FMAL	11973	585	2302
Elk River mile 21.0	890607	C	FMAL	11973	420	1014
Elk River mile 21.0	890607	C	MALE	11973	552	2108
Elk River mile 21.0	890612	CHC	FMAL	11974	355	486
Elk River mile 21.0	890612	CHC	FMAL	11974	395	640
Elk River mile 21.0	890612	CHC	FMAL	11974	398	608
Elk River mile 21.0	890612	CHC	MALE	11974	366	454
Elk River mile 21.0	890612	CHC	MALE	11974	475	1232
Tims Ford Reservoir						
Elk River mile 135.0	890927	CHC	FMAL	880	287	166
Elk River mile 135.0	890927	CHC	FMAL	880	526	1751
Elk River mile 135.0	890927	CHC	MALE	880	434	692
Elk River mile 135.0	890927	CHC	MALE	880	534	1420
Elk River mile 150.0	891215	CHC	FMAL	881	412	642
Elk River mile 150.0	891215	CHC	FMAL	881	403	642
Elk River mile 150.0	891215	CHC	MALE	881	455	786
Elk River mile 150.0	891215	CHC	MALE	881	475	364
Elk River mile 150.0	891215	CHC	MALE	881	412	494
Guntersville Reservoir						
Tennessee River mile 351.0	891107	CHC	FMAL	258	400	744
Tennessee River mile 351.0	891107	CHC	FMAL	258	471	906
Tennessee River mile 351.0	891107	CHC	FMAL	258	360	384
Tennessee River mile 351.0	891107	CHC	MALE	258	354	358
Tennessee River mile 351.0	891107	CHC	MALE	258	353	336
Tennessee River mile 382.0	891117	CHC	FMAL	259	355	384
Tennessee River mile 382.0	891117	CHC	FMAL	259	370	568
Tennessee River mile 382.0	891117	CHC	FMAL	259	295	218

Table 3.1-3 (Continued)

COLLECTION SITE	DATE	SPECIES[a]	SEX	LABID[b]	LENGTH (mm)	WEIGHT (g)
Guntersville Reservoir (Continued)						
Tennessee River mile 382.0	891117	CHC	FMAL	259	308	210
Tennessee River mile 382.0	891117	CHC	MALE	259	325	320
Tennessee River mile 394.0	891117	CHC	FMAL	260	370	364
Tennessee River mile 394.0	891117	CHC	FMAL	260	340	338
Tennessee River mile 394.0	891117	CHC	FMAL	260	355	360
Tennessee River mile 394.0	891117	CHC	FMAL	260	340	328
Tennessee River mile 394.0	891117	CHC	FMAL	260	375	416
Chickamauga Reservoir						
Hiwassee River mile 12.0*	890706	C	FMAL	11978	367	746
Hiwassee River mile 12.0	890706	C	FMAL	11978	670	5104
Hiwassee River mile 12.0	890706	C	FMAL	11978	630	3816
Hiwassee River mile 12.0	890706	DRM	FMAL	11978	237	164
Hiwassee River mile 12.0	890706	DRM	MALE	11978	290	258
Hiwassee River mile 12.0	890706	LMB	FMAL	11979	293	346
Hiwassee River mile 12.0	890706	LMB	MALE	11979	258	216
Hiwassee River mile 12.0	890706	LMB	MALE	11979	268	256
Hiwassee River mile 12.0	890706	LMB	MALE	11979	341	558
Hiwassee River mile 12.0	890706	SPB	FMAL	11979	290	328
Hiwassee River mile 12.0	890706	BLC	FMAL	11980	305	172
Hiwassee River mile 12.0	890706	BLC	FMAL	11980	390	414
Hiwassee River mile 12.0	890706	CHC	FMAL	11980	330	254
Hiwassee River mile 12.0	890706	CHC	FMAL	11980	325	208
Hiwassee River mile 12.0	890706	CHC	MALE	11980	325	248
Parksville Reservoir						
Ocoee River mile 14.0	891114	CHC	FMAL	882	431	677
Ocoee River mile 14.0	891114	CHC	FMAL	882	671	3083
Ocoee River mile 14.0	891114	CHC	MALE	882	540	1177
Ocoee River mile 14.0	891114	CHC	MALE	882	491	848
Ocoee River mile 14.0	891114	CHC	MALE	882	422	666
Emory River						
Emory River mile 8*	890724	C	FMAL	11955	576	2373
Emory River mile 8	890724	C	FMAL	11955	542	2143
Emory River mile 8	890724	C	MALE	11955	495	1693
Emory River mile 8	890724	C	MALE	11955	563	2288
Emory River mile 8	890724	C	MALE	11955	572	2409
Emory River mile 8	890724	BLC	MALE	11956	623	2477
Emory River mile 8	890724	CHC	FMAL	11956	400	456
Emory River mile 8	890724	CHC	FMAL	11956	417	552
Emory River mile 8	890724	CHC	MALE	11956	427	667
Emory River mile 8	890724	CHC	MALE	11956	355	410

Table 3.1-3 (Continued)

COLLECTION SITE	DATE	SPECIES[a]	SEX	LABID[b]	LENGTH (mm)	WEIGHT (g)
Emory River (Continued)						
Emory River mile 8	890724	LMB	FMAL	11954	375	883
Emory River mile 8	890724	LMB	FMAL	11954	343	596
Emory River mile 8	890724	LMB	FMAL	11954	311	354
Emory River mile 8	890724	LMB	MALE	11954	328	448
Emory River mile 8	890724	LMB	MALE	11954	312	361
Powell River						
Powell River mile 65.3	890605	CHC	FMAL	11957	387	551
Powell River mile 65.3	890605	YEB	UNK	11957	264	283
Powell River mile 65.3	890605	DRM	FMAL	11958	600	3280
Powell River mile 65.3	890605	DRM	FMAL	11958	526	2322
Powell River mile 65.3	890605	DRM	FMAL	11958	352	577
Powell River mile 65.3	890605	DRM	MALE	11958	345	483
Powell River mile 65.3	890605	DRM	MALE	11958	351	494
Powell River mile 65.3	890605	SMB	FMAL	11959	225	161
Powell River mile 65.3	890605	SMB	FMAL	11959	265	249
Powell River mile 65.3	890605	SMB	MALE	11959	271	247
Powell River mile 65.3	890605	SMB	MALE	11959	246	211
Powell River mile 65.3	890605	SMB	MALE	11959	252	207
Douglas Reservoir						
French Broad River mile 35.0	891213	CHC	FMAL	883	369	495
French Broad River mile 35.0	891213	CHC	FMAL	883	347	371
French Broad River mile 35.0	891213	CHC	FMAL	883	368	389
French Broad River mile 35.0	891201	CHC	FMAL	883	385	466
French Broad River mile 35.0	891213	CHC	MALE	883	368	384
French Broad River mile 42.0	891201	CHC	FMAL	884	354	423
French Broad River mile 42.0	891201	CHC	FMAL	884	330	323
French Broad River mile 42.0	891201	CHC	FMAL	884	318	234
French Broad River mile 42.0	891213	CHC	MALE	884	372	511
French Broad River mile 58.0	891201	CHC	FMAL	885	402	567
French Broad River mile 58.0	891201	CHC	MALE	885	584	2574
French Broad River mile 58.0	891201	CHC	MALE	885	490	1243
French Broad River mile 58.0	891201	CHC	MALE	885	465	1083
French Broad River mile 58.0	891201	CHC	MALE	885	530	1483
French Broad River						
French Broad River mile 71.4*	890920	CHC	FMAL	11960	457	928
French Broad River mile 71.4	890920	CHC	FMAL	11960	294	185
French Broad River mile 71.4	890920	CHC	MALE	11960	410	552
French Broad River mile 71.4	890920	CHC	MALE	11960	403	617
French Broad River mile 71.4	890920	CHC	MALE	11960	358	381
French Broad River mile 71.4	890920	LMB	FMAL	11961	411	1228

Table 3.1-3 (Continued)

COLLECTION SITE	DATE	SPECIES[a]	SEX	LABID[b]	LENGTH (mm)	WEIGHT (g)
French Broad River (Continued)						
French Broad River mile 71.4	890920	LMB	FMAL	11961	360	831
French Broad River mile 71.4	890920	LMB	FMAL	11961	363	863
French Broad River mile 71.4	890920	LMB	FMAL	11961	313	491
French Broad River mile 71.4	890920	LMB	MALE	11961	476	1971
French Broad River mile 71.4	890920	C	FMAL	11962	537	1973
French Broad River mile 71.4	890920	C	MALE	11962	528	2108
French Broad River mile 71.4	890920	C	MALE	11962	435	1484
French Broad River mile 71.4	890920	C	MALE	11962	434	1640
French Broad River mile 71.4	890920	C	MALE	11962	397	895
Nolichucky River						
Nolichucky River mile 5.3*	890920	CHC	FMAL	11969	362	352
Nolichucky River mile 5.3	890920	CHC	MALE	11969	568	2004
Nolichucky River mile 5.3	890920	CHC	MALE	11969	356	353
Nolichucky River mile 5.3	890921	CHC	MALE	11969	454	741
Nolichucky River mile 5.3	890921	CHC	MALE	11969	419	634
Nolichucky River mile 5.3	890921	C	MALE	11970	528	1900
Nolichucky River mile 5.3	890921	C	MALE	11970	503	1754
Nolichucky River mile 5.3	890921	C	MALE	11970	497	1871
Nolichucky River mile 5.3	890921	C	MALE	11970	486	1529
Nolichucky River mile 5.3*	890921	C	MALE	11970	473	1336
Nolichucky River mile 5.3	890920	LMB	FMAL	11971	328	583
Nolichucky River mile 5.3	890920	LMB	FMAL	11971	306	430
Nolichucky River mile 5.3	890920	LMB	FMAL	11971	287	348
Nolichucky River mile 5.3	890921	LMB	FMAL	11971	326	510
Nolichucky River mile 5.3	890921	LMB	MALE	11971	286	375
Holston River						
Holston River mile 110*	890615	C	FMAL	11951	684	5063
Holston River mile 110	890615	C	FMAL	11951	630	3869
Holston River mile 110	890615	C	FMAL	11951	642	3830
Holston River mile 110	890615	C	MALE	11951	548	2110
Holston River mile 110	890615	C	FMAL	11951	530	2049
Holston River mile 110	890615	CHC	FMAL	11953	455	943
Holston River mile 110	890615	CHC	FMAL	11953	520	1344
Holston River mile 110	890615	CHC	FMAL	11953	313	285
Holston River mile 110	890615	CHC	FMAL	11953	287	200
Holston River mile 110	890615	CHC	MALE	11952	304	222
Holston River mile 110	890615	LMB	FMAL	11952	294	370
Holston River mile 110	890615	LMB	MALE	11952	357	603
Holston River mile 110	890615	LMB	MALE	11952	374	732
Holston River mile 110	890615	LMB	MALE	11952	406	873
Holston River mile 110	890615	LMB	MALE	11952	297	371

Table 3.1-3 (Continued)

COLLECTION SITE	DATE	SPECIES[a]	SEX	LABID[b]	LENGTH (mm)	WEIGHT (g)
Boone Reservoir						
S. Fk. Holston River mile 19.0	891211	BLC	FMAL	886	634	2440
S. Fk. Holston River mile 19.0	891211	BLC	FMAL	886	668	3504
S. Fk. Holston River mile 19.0	891211	BLC	MALE	886	639	2661
S. Fk. Holston River mile 19.0	891211	BLC	MALE	886	757	5720
S. Fk. Holston River mile 19.0	891211	HYS	FMAL	887	699	4680
S. Fk. Holston River mile 19.0	891211	HYS	MALE	887	625	2888
S. Fk. Holston River mile 19.0	891211	HYS	MALE	887	634	2364
S. Fk. Holston River mile 19.0	891211	HYS	MALE	887	534	2323
S. Fk. Holston River mile 19.0	891211	HYS	MALE	887	577	3404

a. Species abbreviations: CHC = channel catfish; BLC = blue catfish; LMB = largemouth bass; SMB = smallmouth bass; SPB = spotted bass; C = carp; DRM = drum; HYS = Hybrid striped bass; WHS = white crappie; YEB = yellow bullhead.

b. The LABID (laboratory identification) number is the mechanism used to relate physical information in Table 3.1-3 to information on tissue levels of metals in Table 3.1-4 and 3.1-6 and organics in Table 3.1-5. Fish with the same LABID number in this table were composited for laboratory analysis.

Table 3.1-4. Concentrations (µg/g) of Metals in Composited Fish Flesh Samples from Inflow and Reservoir Locations,[a] 1989

Collection Site	Species[b]	LABID[c]	Antimony	Arsenic	Beryllium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Thallium	Zinc
Tennessee River															
TRM 7	CHC	240	<2.00	0.07	<0.02	<0.10	0.29	0.40	<0.02	<0.10	<1.00	0.06	<0.10	<1.00	7.20
TRM 22	CHC	241	<2.00	<0.02	<0.02	<0.10	0.17	<0.20	0.04	0.12	<1.00	0.08	<0.10	<1.00	4.80
Kentucky Reservoir															
TRM 30	CHC	242	<2.00	<0.02	<0.02	<0.10	0.12	0.20	0.17	<0.10	<1.00	0.06	<0.10	<1.00	7.00
TRM 61	CHC	243	<2.00	0.05	<0.02	<0.10	0.14	0.40	<0.02	<0.10	<1.00	0.05	<0.10	<1.00	7.00
TRM 98	CHC	244	<2.00	0.06	<0.02	<0.10	0.11	0.40	0.57	<0.10	<1.00	0.06	<0.10	<1.00	5.80
TRM 136	CHC	245	<2.00	0.06	<0.02	<0.10	0.09	0.60	0.10	<0.10	<1.00	0.12	<0.10	<1.00	7.60
TRM 172	CHC	246	<2.00	<0.02	<0.02	<0.10	0.13	0.40	0.05	0.12	<1.00	0.11	<0.10	<1.00	6.40
TRM 192	CHC	247	<2.00	0.08	<0.02	<0.10	0.11	0.20	0.55	<0.10	<1.00	0.12	<0.10	<1.00	5.40
Duck River	C/DRM	11,975	<2.00	<0.02	<0.02	<0.10	0.06	1.60	<0.02	0.21	<1.00	0.41	<0.10	<1.00	8.60
DRM 12	LMB/WHS	11,976	<2.00	0.05	<0.02	<0.10	0.09	1.60	0.09	0.21	<1.00	0.21	<0.10	<1.00	8.00
DRM 12	CHC	11,977	<2.00	<0.02	<0.02	<0.10	0.05	1.20	<0.02	<0.10	<1.00	0.18	<0.10	<1.00	7.00
Pickwick Reservoir															
TRM 210	CHC	248	<2.00	0.04	<0.02	<0.10	0.59	0.60	0.16	<0.10	<1.00	0.11	<0.10	<1.00	6.40
TRM 235	CHC	249	<2.00	<0.02	<0.02	<0.10	0.17	1.20	0.04	<0.10	<1.00	0.15	<0.10	<1.00	8.20
TRM 255	CHC	254	<2.00	<0.02	<0.02	<0.10	0.09	0.20	0.03	<0.10	<1.00	0.15	<0.10	<1.00	6.60
Wheeler Reservoir															
TRM 275	CHC	255	<2.00	<0.02	<0.02	<0.10	0.15	0.40	<0.02	<0.10	<1.00	0.15	<0.10	<1.00	5.80
TRM 300	CHC	256	<2.00	0.05	<0.02	<0.10	0.08	0.20	0.09	<0.10	<1.00	0.20	<0.10	<1.00	6.40
TRM 339	CHC	257	<2.00	0.07	<0.02	<0.10	0.10	0.80	0.34	<0.10	<1.00	0.23	<0.10	<1.00	7.60
Elk River															
ERM 21	LMB	11,972	<2.00	0.04	<0.02	<0.10	0.12	5.60	<0.02	0.19	<1.00	0.17	<0.10	<1.00	17.00
ERM 21	C	11,973	<2.00	<0.02	<0.02	<0.10	0.04	1.20	<0.02	<0.10	<1.00	0.26	<0.10	<1.00	13.00
ERM 21	CHC	11,974	<2.00	<0.02	<0.02	<0.10	0.07	1.20	0.07	0.14	<1.00	0.06	<0.10	<1.00	5.80

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Table 3.1-4 (Continued)

Collection Site	Species[b]	LABID[c]	Antimony	Arsenic	Beryllium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Thallium	Zinc
Tims Ford Reservoir															
ERM 135	CHC	880	<2.00	<0.02	<0.02	<0.10	0.04	0.40	<0.02	<0.10	<1.00	0.12	<0.10	<1.00	7.60
ERM 150	CHC	881	<2.00	<0.02	<0.02	<0.10	0.08	<0.20	0.04	0.16	<1.00	0.15	<0.10	<1.00	7.40
Guntersville Reservoir															
TRM 351	CHC	258	<2.00	0.10	<0.02	<0.10	0.13	0.40	<0.02	<0.10	<1.00	0.12	<0.10	<1.00	7.00
TRM 382	CHC	259	<2.00	0.03	<0.02	<0.10	0.08	0.40	0.06	<0.10	<1.00	0.22	<0.10	<1.00	6.20
TRM 394	CHC	260	<2.00	<0.02	<0.02	<0.10	0.05	0.20	<0.02	<0.10	<1.00	0.28	<0.10	<1.00	6.60
Chickamauga Reservoir															
HIRM 12	C/DRM	11,978	<2.00	0.03	<0.02	<0.10	0.11	1.60	0.12	0.22	<1.00	0.62	<0.10	<1.00	17.00
HIRM 12	SPB/LMB	11,979	<2.00	<0.02	<0.02	<0.10	0.06	1.20	<0.03	0.35	<1.00	0.35	<0.10	<1.00	8.60
HIRM 12	CHC	11,980	<2.00	<0.02	<0.02	<0.10	0.06	1.20	0.13	<0.10	<1.00	0.19	<0.10	<1.00	6.60
Parksville Reservoir															
ORM 14	CHC	882	<2.00	<0.02	<0.02	<0.10	0.03	0.40	0.06	<0.10	<1.00	0.78	<0.10	<1.00	7.00
Emory River															
ERM 7	LMB	11,954	<2.00	<0.02	<0.02	<0.00	0.07	0.40	<0.02	0.24	<1.00	0.42	<0.10	<1.00	8.20
ERM 7	C	11,955	<2.00	<0.02	<0.02	0.00	0.09	1.00	<0.02	0.30	<1.00	0.44	<0.10	<1.00	13.00
ERM 7	BLC/CHC	11,956	<2.00	<0.02	<0.02	0.00	0.05	0.20	<0.02	0.30	<1.00	0.22	<0.10	<1.00	7.60
Powell River															
PRM 65	CHC/YEB	11,957	<2.00	<0.02	<0.02	<0.10	0.06	0.40	<0.02	0.11	<1.00	0.35	<0.10	<1.00	6.60
PRM 65	DRM	11,958	<2.00	0.03	<0.02	<0.10	0.04	<0.20	<0.02	0.26	2.00	0.77	<0.10	<1.00	7.00
PRM 65	SMB	11,959	<2.00	0.04	<0.02	<0.10	0.07	0.60	<0.02	0.25	<1.00	0.48	<0.10	<1.00	8.80
Douglas Reservoir															
FBRM 35	CHC	883	<2.00	<0.02	<0.02	<0.10	0.03	0.40	0.10	0.12	<1.00	0.14	<0.10	<1.00	7.40
FBRM 42	CHC	884	<2.00	0.03	<0.02	<0.10	0.08	0.60	0.04	0.12	<1.00	0.10	<0.10	<1.00	5.80
FBRM 58	CHC	885	<2.00	<0.02	<0.02	<0.10	0.04	0.20	0.03	0.26	<1.00	0.10	<0.10	<1.00	6.40

Table 3.1-4 (Continued)

Collection Site	Species[b]	LABID[c]	Antimony	Arsenic	Beryllium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Thallium	Zinc
French Broad River															
FBRM 71	CHC	11,960	<2.00	<0.02	<0.02	<0.10	0.18	1.20	0.06	0.28	<1.00	0.06	<0.10	<1.00	6.60
FBRM 71	LMB	11,961	<2.00	0.18	<0.02	<0.10	0.06	0.40	0.09	0.36	<1.00	0.20	<0.10	<1.00	6.60
FBRM 71	C	11,962	<2.00	<0.02	<0.02	<0.10	0.19	1.00	0.06	0.22	<1.00	0.22	<0.10	<1.00	12.00
Nolichucky River															
NRM 5	CHC	11,969	<2.00	<0.02	<0.02	0.00	0.15	0.40	0.43	0.17	<1.00	0.13	<0.10	<1.00	8.20
NRM 5	C	11,970	<2.00	<0.02	<0.02	0.00	0.09	0.80	0.12	0.12	<1.00	0.22	<0.10	<1.00	15.00
NRM 5	LMB	11,971	<2.00	0.04	<0.02	0.00	0.05	1.40	0.02	0.22	<1.00	0.09	<0.10	<1.00	5.40
Holston River															
HRM 110	C	11,951	<2.00	<0.02	<0.02	<0.00	0.07	0.40	<0.02	0.30	<1.00	0.29	<0.10	<1.00	18.00
HRM 110	LMB	11,952	<2.00	<0.02	<0.02	<0.00	0.08	0.40	<0.02	0.50	<1.00	0.32	<0.10	<1.00	12.00
HRM 110	CHC	11,953	<2.00	<0.02	<0.02	<0.00	0.18	1.40	0.06	0.25	<1.00	0.23	<0.10	<1.00	8.00
Boone Reservoir															
SFHRM 19	BLC	886	<2.00	<0.02	<0.02	<0.10	0.04	0.20	0.05	0.16	<1.00	0.12	<0.10	<1.00	7.00
SFHRM 19	HYS	887	<2.00	0.15	<0.02	<0.10	0.05	0.60	<0.02	0.10	<1.00	0.37	<0.10	<1.00	5.00

a. Station abbreviations as listed in table 3.1-2, footnote a; and DRM = Duck River Mile; HIRM = Hiwassee River Mile; EMRM = Emory River Mile; PRM = Powell River Mile; NRM = Nolichucky River Mile; and HRM = Holston River Mile.

b. Species abbreviations: CHC = channel catfish; BLC = blue catfish; LMB = largemouth bass; SMB = smallmouth bass; SPB = spotted bass; C = carp; DRM = drum; HYS = hybrid stripped bass; C/DRM = carp and drum; LMB/WHS = largemouth bass and white crappie; BLC/CHC = blue catfish and channel catfish; SPB/LMB = spotted bass and largemouth bass; CHC/YEB = channel catfish and yellow bullhead.

c. See table 3.1-3, footnote b.

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Table 3.1-5. Concentrations (µg/g) of Metals in Composited Catfish Livers from Reservoir Sites,[a] 1989

Location	Species[b]	LABID[c]	Antimony	Arsenic	Beryllium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Thallium	Zinc
Tennessee River															
TRM 7	CHC	269	<2.00	<0.02	<0.02	<0.10	0.09	2.60	0.05	<0.10	<1.00	1.00	<0.10	<1.00	24.00
TRM 22	CHC	270	<2.00	<0.02	<0.02	<0.10	0.06	2.00	0.08	0.11	<1.00	1.00	<0.10	<1.00	26.00
Kentucky Reservoir															
TRM 30	CHC	271	<2.00	<0.02	<0.02	<0.10	0.09	1.80	0.08	0.13	<1.00	0.46	<0.10	<1.00	21.00
TRM 61	CHC	272	<2.00	<0.02	<0.02	0.20	<0.02	2.20	0.06	<0.10	<1.00	1.00	<0.10	<1.00	26.00
TRM 98	CHC	273	<2.00	<0.02	<0.02	0.10	<0.02	1.80	0.09	-	<1.00	0.98	<0.10	<1.00	24.00
TRM 136	CHC	274	<2.00	<0.02	<0.02	<0.10	0.07	1.40	0.05	<0.10	<1.00	0.48	<0.10	<1.00	17.00
TRM 172	CHC	275	<2.00	<0.02	<0.02	<0.10	<0.02	1.60	0.04	0.14	<1.00	0.90	<0.10	<1.00	21.00
TRM 192	CHC	276	<2.00	<0.02	<0.02	<0.10	<0.02	2.20	0.04	<0.10	<1.00	1.30	<0.10	<1.00	25.00
Pickwick Reservoir															
TRM 210	CHC	277	<2.00	<0.02	<0.02	0.20	0.06	2.40	0.04	0.10	<1.00	1.10	<0.10	<1.00	26.00
TRM 235	CHC	278	<2.00	<0.02	<0.02	0.10	0.29	4.40	0.05	0.28	<1.00	1.80	<0.10	<1.00	29.00
TRM 255	CHC	281	<2.00	<0.02	<0.02	<0.10	0.05	1.20	0.07	0.18	<1.00	0.78	<0.10	<1.00	21.00
Wheeler Reservoir															
TRM 275	CHC	282	<2.00	<0.02	<0.02	<0.10	<0.02	2.40	0.04	0.16	<1.00	0.92	<0.10	<1.00	26.00
TRM 300	CHC	283	<2.00	<0.02	<0.02	<0.10	0.06	2.20	0.06	0.10	<1.00	1.10	<0.10	<1.00	22.00
TRM 339	CHC	284	<2.00	<0.02	<0.02	0.20	<0.02	2.20	0.05	0.12	<1.00	0.74	<0.10	<1.00	25.00
Tims Ford Reservoir															
ERM 135	CHC	868	<2.00	<0.02	<0.02	<0.10	<0.02	1.60	0.04	0.43	<1.00	1.20	<0.10	<1.00	21.00
ERM 150	CHC	869	<2.00	<0.02	<0.02	<0.10	0.04	3.00	0.07	0.35	<1.00	0.61	<0.10	<1.00	27.00
Guntersville Reservoir															
TRM 351	CHC	285	<2.00	<0.02	<0.02	<0.10	<0.02	1.60	0.06	<0.10	<1.00	0.73	<0.10	<1.00	23.00
TRM 382	CHC	286	<2.00	<0.02	<0.02	<0.10	0.04	2.60	0.05	<0.10	<1.00	1.10	<0.10	<1.00	23.00
TRM 394	CHC	287	<2.00	<0.02	<0.02	<0.10	<0.02	2.60	0.04	0.00	<1.00	1.60	<0.10	<1.00	30.00

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Table 3.1-5 (Continued)

Location	Species[b]	LABID[c]	Antimony	Arsenic	Beryllium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Thallium	Zinc
Parksville Reservoir															
OCRM 14	CHC	870	<2.00	<0.02	<0.02	0.20	<0.02	8.60	0.29	<0.10	<1.00	3.10	<0.10	<1.00	27.00
Douglas Reservoir															
FBRM 35	CHC	871	<2.00	<0.02	<0.02	<0.10	0.21	1.20	<0.02	0.10	<1.00	0.54	<0.10	<1.00	18.00
FBRM 42	CHC	872	<2.00	<0.02	<0.02	<0.10	<0.02	1.20	0.04	<0.10	<1.00	0.78	<0.10	<1.00	15.00
FBRM 58	CHC	873	<2.00	<0.02	0.18	<0.10	0.07	1.40	<0.02	0.25	<1.00	0.64	<0.10	<1.00	17.00
Boone Reservoir															
SFHRM 19	BLC	874	<2.00	<0.02	0.10	<0.10	0.18	3.00	<0.02	0.20	<1.00	1.20	<0.10	<1.00	24.00
SFHRM 19	HYS[d]	875	<2.00	0.35	0.08	0.40	0.14	34.00	<0.02	<0.10	<1.00	3.00	<0.10	<1.00	29.00

a. Station abbreviations are listed in table 3.1-2, footnote a.

b. Species abbreviations: CHC = channel catfish; BLC = blue catfish; HYS = hybrid striped bass

c. See table 3.1-3, footnote b.

d. Striped bass livers were collected and analyzed at the special request of Tennessee Wildlife Resource Agency.

Table 3.1-6. Concentrations (μg/g) of Pesticides and PCBs in Composited Fish Flesh Samples from Inflow and Reservoir Locations,[a] 1989

Collection site	Species[b]	LABID[c]	Lipid (%)	Aldrin	Dieldrin	Toxophene	Benzene Hexachlo	Chlordane	DDTr	Endo-sulfan	Endrin	Hepta-chlor	PCBs
Tennessee River													
TRM 7	CHC	240	12.00	<0.01	<0.01	<0.50	<0.01	0.02	0.50	<0.01	0.02	<0.01	0.40
TRM 22	CHC	241	7.50	<0.01	<0.01	<0.50	<0.01	0.04	0.43	<0.01	0.01	<0.01	0.30
Kentucky Reservoir													
TRM 30	CHC	242	5.60	<0.01	<0.01	<0.50	<0.01	0.02	0.55	<0.01	0.01	<0.01	0.30
TRM 61	CHC	243	11.00	<0.01	<0.01	<0.50	<0.01	0.02	0.73	<0.01	0.01	<0.01	0.20
TRM 98	CHC	244	9.30	<0.01	<0.01	<0.50	<0.01	0.02	0.60	<0.01	0.01	<0.01	0.20
TRM 136	CHC	245	8.30	<0.01	<0.01	<0.50	<0.01	0.02	0.63	<0.01	0.01	<0.01	0.20
TRM 172	CHC	246	12.00	<0.01	<0.01	<0.50	<0.01	0.05	1.22	<0.01	<0.01	<0.01	0.60
TRM 192	CHC	247	15.00	<0.01	<0.01	<0.50	<0.01	0.07	0.91	<0.01	0.02	<0.01	0.80
DRM	C/DRM	11,975	2.10	<0.01	<0.01	<0.50	<0.01	<0.01	0.08	<0.01	<0.01	<0.01	0.10
DRM	LMB/WHS	11,976	1.00	<0.01	<0.01	<0.50	<0.01	<0.01	0.12	<0.01	<0.01	<0.01	0.30
DRM	CHC	11,977	5.00	<0.01	<0.01	<0.50	<0.01	<0.01	0.36	<0.01	<0.01	<0.01	0.30
Pickwick Reservoir													
TRM 210	CHC	248	6.50	<0.01	<0.01	<0.50	<0.01	0.03	0.93	<0.01	0.01	<0.01	0.20
TRM 235	CHC	249	6.70	<0.01	<0.01	<0.50	<0.01	0.04	1.74	<0.01	<0.01	<0.01	0.50
TRM 255	CHC	254	7.40	<0.01	<0.01	<0.50	<0.01	0.11	1.27	<0.01	<0.01	<0.01	0.60
Wheeler Reservoir													
TRM 275	CHC	255	7.10	<0.01	<0.01	<0.50	<0.01	<0.01	1.38	<0.01	<0.01	<0.01	0.20
TRM 300	CHC	256	14.00	<0.01	<0.01	<0.50	<0.01	<0.01	4.38	<0.01	<0.01	<0.01	1.00
TRM 339	CHC	257	12.00	<0.01	<0.01	<0.50	<0.01	0.08	1.61	<0.01	0.02	<0.01	1.30
Elk River													
ERM 21	LMB	11,972	1.90	<0.01	<0.01	<0.50	<0.01	<0.01	0.24	<0.01	<0.01	<0.01	<0.10
ERM 21	C	11,973	4.40	<0.01	<0.01	<0.50	<0.01	<0.01	0.09	<0.01	<0.01	<0.01	<0.10
ERM 21	CHC	11,974	5.60	<0.01	<0.01	<0.50	<0.01	0.01	0.64	<0.01	<0.01	<0.01	0.10

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Table 3.1-6 (Continued)

Collection site	Species[a]	LABID[b]	Lipid (%)	Aldrin	Dieldrin	Toxophene	Benzene Hexachlo	Chlordane	DDTr	Endo-sulfan	Endrin	Hepta-chlor	PCBs
Tims Ford Reservoir													
ERM 135	CHC	880	4.60	<0.01	<0.01	<0.50	<0.01	0.13	0.22	<0.01	0.04	<0.01	0.30
ERM 150	CHC	881	3.40	<0.01	<0.01	<0.50	<0.01	0.03	0.08	<0.01	0.02	<0.01	<0.10
Guntersville Reservoir													
TRM 351	CHC	258	9.20	<0.01	<0.01	<0.50	<0.01	0.03	0.52	<0.01	0.01	<0.01	0.70
TRM 382	CHC	259	9.10	<0.01	<0.01	<0.50	<0.01	0.03	0.16	<0.01	0.02	<0.01	0.60
TRM 394	CHC	260	7.50	<0.01	<0.01	<0.50	<0.01	0.02	0.42	<0.01	0.02	<0.01	0.50
Chickamauga Reservoir													
HRM 12	CDRM	11,978	6.20	<0.01	<0.01	<0.50	<0.01	0.01	0.15	<0.01	<0.01	<0.01	0.10
HRM 12	SPB/LMB	11,979	1.00	<0.01	<0.01	<0.50	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.10
HRM 12	CHC	11,980	5.20	<0.01	<0.01	<0.50	<0.01	0.02	0.11	<0.01	<0.01	<0.01	0.30
Parksville Reservoir													
ORM 14	CHC	882	3.70	<0.01	<0.01	<0.50	<0.01	<0.01	0.12	<0.01	<0.01	<0.01	1.30
Watts Bar Reservoir													
ERM 8	LMB	11,954	1.20	<0.01	<0.01	<0.50	<0.01	<0.01	0.13	<0.01	0.01	<0.01	0.20
ERM 8	C	11,955	4.90	<0.01	<0.01	<0.50	<0.01	0.01	0.10	<0.01	0.01	<0.01	0.40
ERM 8	BLC/CHC	11,956	3.60	<0.01	<0.01	<0.50	<0.01	0.07	0.05	<0.01	0.02	<0.01	0.80
Powell River													
PRM 65	CHC/YEB	11,957	4.60	<0.01	<0.01	<0.50	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
PRM 65	DRM	11,958	3.10	<0.01	<0.01	<0.50	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.10
PRM 65	SMB	11,959	1.60	<0.01	<0.01	<0.50	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10

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Table 3.1-6 (Continued)

Collection site	Species[a]	LABID[b]	Lipid (%)	Aldrin	Dieldrin	Toxophene	Benzene Hexachlo	Chlordane	DDTr	Endo-sulfan	Endrin	Hepta-chlor	PCBs
Douglas Reservoir													
FBRM 35	CHC	883	7.00	<0.01	<0.01	<0.50	<0.01	0.01	0.07	<0.01	0.03	<0.01	<0.10
FBRM 42	CHC	884	8.70	<0.01	<0.01	<0.50	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	0.10
FBRM 58	CHC	885	7.00	<0.01	<0.01	<0.50	<0.01	0.07	0.65	<0.01	0.03	<0.01	0.30
French Broad River													
FBRM 71	CHC	11,960	4.00	<0.01	<0.01	<0.50	<0.01	0.03	0.08	<0.01	<0.01	<0.01	0.20
FBRM 71	LMB	11,961	2.10	<0.01	<0.01	<0.50	<0.01	0.02	0.10	<0.01	0.01	<0.01	<0.10
FBRM 71	C	11,962	6.30	<0.01	<0.01	<0.50	<0.01	<0.01	0.16	0.02	<0.01	<0.01	0.30
Nolichucky River													
NRM 5	CHC	11,969	3.40	<0.01	<0.01	<0.50	<0.01	0.03	0.07	<0.01	<0.01	<0.01	0.20
NRM 5	C	11,970	8.10	<0.01	<0.01	<0.50	<0.01	0.03	0.13	<0.01	<0.01	<0.01	0.40
NRM 5	LMB	11,971	1.80	<0.01	<0.01	<0.50	<0.01	<0.01	0.07	<0.01	<0.01	<0.01	<0.10
Holston River													
HRM 110	C	11,951	4.20	<0.01	<0.01	<0.50	<0.01	0.02	0.07	<0.01	0.01	<0.01	0.40
HRM 110	LMB	11,952	0.50	<0.01	<0.01	<0.50	<0.01	<0.01	0.10	<0.01	<0.01	<0.01	0.10
HRM 110	CHC	11,953	6.00	<0.01	<0.01	<0.50	<0.01	0.03	0.10	<0.01	0.01	<0.01	0.30
Boone Reservoir													
SFHRM 19	BLC	886	8.40	<0.01	0.02	<0.50	<0.01	0.18	0.12	<0.01	0.06	<0.01	0.50
SFHRM 19	HYS	887	13.00	<0.01	<0.01	<0.50	<0.01	0.29	0.04	<0.01	0.06	<0.01	0.80

a. Station abbreviations are listed in table 3.1-2, footnote a, and table 3.1-4, footnote a.

b. Species abbreviations as listed in table 3.1-4.

c. See table 3.1-3, footnote b.

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Table 3.1-7 Highest and Second-Highest Concentrations (μg/g) of Each Contaminant in Fillets (by Collection Site) Found in Fish Tissue Screening Studies in 1989

Parameter	Detection Limit	Highest Concentration Found			Second-Highest Concentration Found		
		Level	Location[a]	Sample	Level	Location[a]	Sample
Metals							
Antimony	2.0	ND	-	-	-	-	-
Arsenic	0.02	0.18	FBRM 71	game	0.15	SFHRM 19	game
Beryllium[b]	0.02	0.40	TRM 483	rough	0.10	TRM 483	rough
Cadmium	0.02	0.29	TRM 7	cat	0.20	HiRM 5	cat
Chromium	0.02	0.59	TRM 210	cat	0.32	TRM 483	rough
Copper	2.0	5.6	ERM 21	game	1.6	DRM 18	game/rough
Lead	0.02	0.59	TRM 98	cat	0.55	TRM 200	cat
Mercury	0.02	0.50	HRM 110	game	0.36	FBRM 71	game
Nickel	1.0	2.0	PRM 65	rough	ND	-	-
Selenium	0.02	0.78	ORM 12	cat	0.77	PRM 65	rough
Silver	0.1	ND	-	-	-	-	-
Thallium	1.0	ND	-	-	-	-	-
Zinc	0.1	18.0	HRM 110	rough	17.0	ERM 21 HiRM 12	game rough
Organics							
Aldrin	0.01	ND	-	-	-	-	-
BHC	0.01	ND	-	-	-	-	-
Chlordane	0.01	0.29	SFHRM 19	game	0.18	SFHRM 19	cat
DDTr	0.01	4.38	TRM 300	cat	1.61	TRM 339	cat
Dieldrin	0.01	0.05	FBRM 71	game	0.02	SFHRM 19	cat
Endosulfan	0.01	0.02	FBRM 71	rough	ND	-	-
Endrin	0.01	0.06	SFHRM 19	cat/game	0.04	ERM 135	cat
Heptachlor	0.01	ND	-	-	-	-	-
Toxaphene	0.5	ND	-	-	-	-	-
PCBs	0.1	1.3	TRM 339 ORM 12	cat cat	1.0	TRM 300	cat

a. Location abbreviations:
DRM--Duck River Mile
ERM--Elk River Mile
FBRM--French Broad River Mile
HiRM--Hiwassee River Mile
HRM--Holston River Mile
ORM--Ocoee River Mile
PRM--Powell River Mile
SFHRM--South Fork Holston River Mile
TRM--Tennessee River Mile

b. Results presented in section 3.2 of this report.

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Table 3.1-8. Contaminant Results (μg/g net weight) from Reservoir and Inflow Sites in 1989 that Indicate a Need for Continued Sampling and Evaluations

Location[a]	Species[b]	Tier 2 Contaminants which need to be resampled at screening level		Tier 3 Contaminants which need to be evaluated in intensive study	
Kentucky Reservoir TRM 192	CHC	Chlordane	0.07[c]		
		PCBs	0.8[c]		
Pickwick Reservoir TRM 255	CHC	Chlordane	0.11		
Wheeler Reservoir TRM 300	CHC	PCBs	1.0	DDT	4.4
TRM 339	CHC	Chlordane	0.08[c]		
		DDTr	1.6		
		PCBs	1.3		
Guntersville Reservoir TRM 350	CHC	PCBs	0.7[c]		
Elk River Mile 21	LMB	Copper	5.6		
Tims Ford Reservoir ERM 135	CHC	Chlordane	0.13		
Parksville Reservoir ORM 12	CHC	PCBs	1.3		
Emory River Mile 7	Catfish	PCBs	0.8[c]		
	LMB	Endrin	0.1		
Holston River Mile 110	CHC	Endrin	0.1		
	LMB	Mercury	0.5		
Boone Res. SFHRM 19	BLC	Chlordane	0.18		
	Str/Hyb	PCBs	0.8[c]	Chlordane	0.29

a. Site abbreviations are listed in tables 3.1-2 and 3.1-4.

b. CHC = Channel Catfish; LMB = Largemouth Bass; Catfish = Composite of more than one catfish species; BLC = Blue Catfish; Str/Hyb = Striped Bass X White Bass hybrid.

c. These concentrations are near but do not exceed tier 2 levels.

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Table 3.1-9 Recommended Reservoir Collection Sites For Valley-Wide Fish Tissue Screening Studies For Autumn 1990

Site[a]	
Lower Tennessee River	Guntersville Reservoir
TRM 7	TRM 351
TRM 22	TRM 382
	TRM 394
Kentucky Reservoir	Nickajack Reservoir
TRM 30	TRM 425
TRM 61	TRM 457
Big Sandy Creek Mile 5	
TRM 98	Chickamauga Reservoir
TRM 136	TRM 483
TRM 172	TRM 495
TRM 192	TRM 526
Pickwick Reservoir	Parksville Reservoir
TRM 210	ORM 14
TRM 235	
TRM 255	
Wilson Reservoir	Watts Bar Reservoir
TRM 260	TRM 532
TRM 270	TRM 562
	TRM 598
	CRM 20
Wheeler Reservoir	Fort Loudoun Reservoir
TRM 275	TRM 604
TRM 300	TRM 628
TRM 339	TRM 651
	Tellico Reservoir
	LTRM 1
	LTRM 11

a. Fish from several mainstem reservoirs (Wilson, Nickajack, Chickamauga, Watts Bar, Fort Loudoun) will also be sampled in autumn 1990 as parts of other studies. LTRM = Little Tennessee River Mile; CRM = Clinch River Mile.

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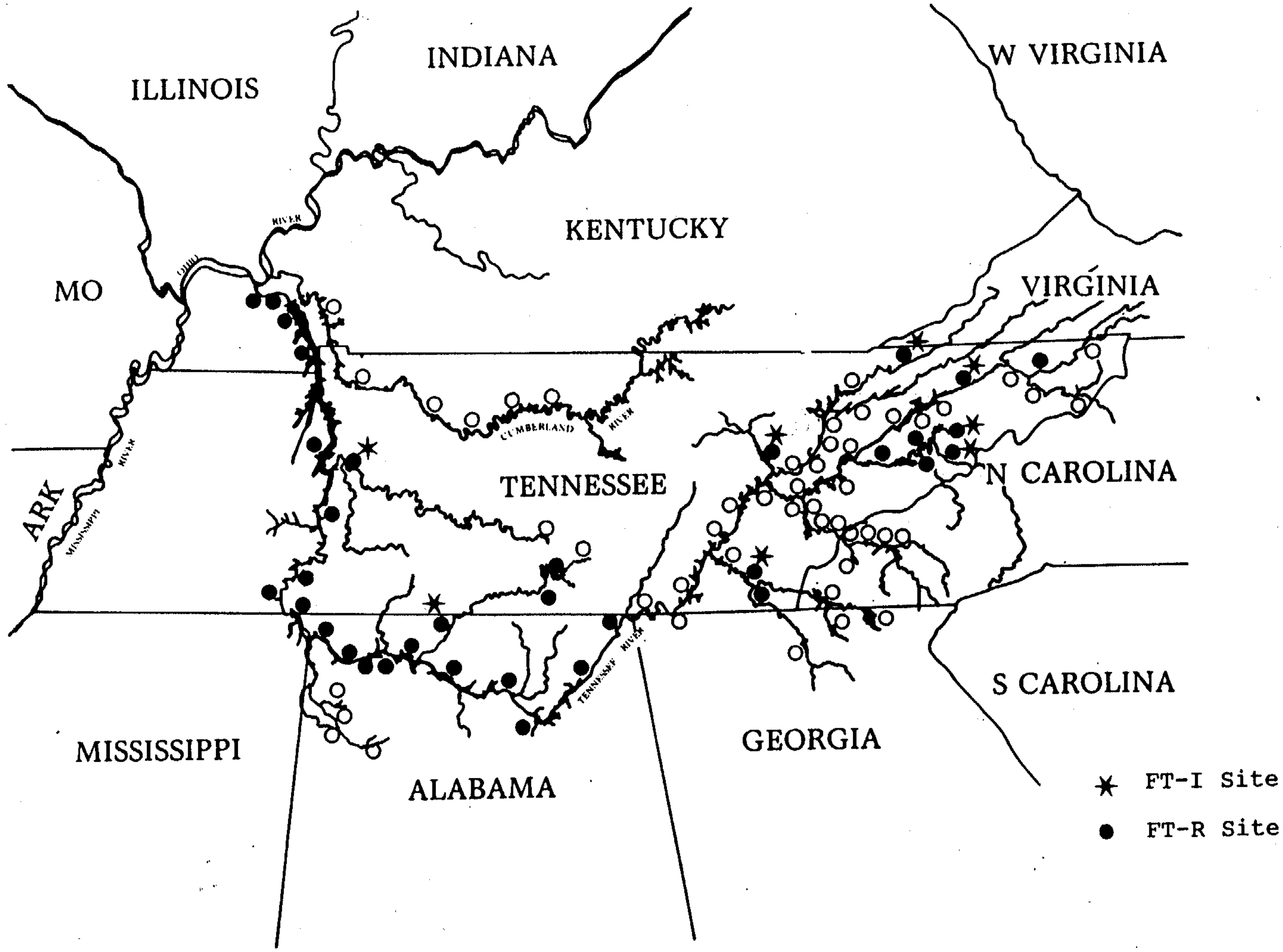

Figure 3.1-1 Filled circles identify sites where fish were collected as part of TVA screening studies in 1989.

3.2 Special Screening Study - Chickamauga Reservoir

TVA has conducted aquatic monitoring programs on Chickamauga Reservoir for a number of years to evaluate effects of locating and operating two nuclear power plants (Sequoyah and Watts Bar) on a single reservoir. In 1987 these programs were critically reviewed, upgraded, and a unified program established where separate programs had existed for each facility.

One component established in the new program was examination of selected toxics in fish tissue. The objective of this study was to determine if toxics accumulate in fish in Chickamauga Reservoir to the extent that either the fish are potentially affected or the public is threatened through consumption of fish.

The fish tissue component was initiated in the autumn of 1987. Catfish, primarily small blue catfish, were collected from ongoing studies and analyzed for metals on the Environmental Protection Agency's list of priority pollutants and PCBs. Analyses on those fish found either non-detectable or low concentrations of all analytes.

The report summarizing the 1987 results recommended that catfish be collected for tissue analysis from Chickamauga Reservoir for at least one more year to identify year-to-year variability (Dycus 1988). It also recommended that a greater effort be made to collect more channel catfish and to exclude individuals less than 454 g (1 lb) for analysis in an attempt to alleviate the concern for biases potentially introduced by analyzing small fish.

Catfish for the second year of study were collected in the autumn of 1988. Those results, based on relatively large channel catfish, showed higher PCB concentrations than observed in 1987 (Dycus 1990a). None of the samples had concentrations which exceeded the FDA tolerance of 2.0 µg/g. However, concentrations in samples from one location were near the more conservative value of 1.0 µg/g sometimes used by state health departments to protect local consumer groups such as sport fishermen, who FDA acknowledges may not be protected by their 2.0 µg/g (44 Fed. Reg. 127:38330-38340). Higher PCB concentrations observed in 1988 than 1987 could have been due to analyzing larger channel catfish in 1988 compared to the smaller blue catfish the previous year. To further examine the year-to-year variability documented between 1987 and 1988 and the relatively high PCB concentrations found at one site, it was recommended that the study be repeated in autumn 1989.

Another need for a study in 1989 was to determine if discharge of water contaminated with low levels of PCBs from Sequoyah Nuclear Plant (SQN) was sufficient to be manifested in downstream biota (channel catfish, a known bioaccumulator of PCBs). TVA was granted special permission from the Tennessee Division of Water Pollution Control to discharge this water to the diffuser pond and subsequently to Chickamauga Reservoir while draining a treatment pond, which had become contaminated with Aroclor 1242 during a transformer fire in 1982. The goal of this effort was to drain the treatment pond then excavate bottom materials for proper disposal.

This report documents results from the 1989 collections, which, together with other TVA fish tissue analyses, will be provided to state officials for their use in advising the public on consumption of fish from TVA waters.

3.2.1 Methods

Channel catfish was selected as the indicator species because monitoring programs conducted by the State of Tennessee and TVA have shown them to be good accumulators of many organic and metal pollutants. Both fillets and livers were analyzed.

Study design in 1989 was the same as in previous years. Fifteen channel catfish were to be collected from each of three sections of Chickamauga Reservoir--(1) near the Sequoyah Nuclear Plant at Tennessee River mile (TRM) 483, (2) near the Watts Bar Nuclear Plant at TRM 526, and (3) within the Hiwassee River at Hiwassee River mile (HiRM) 5.0.

Field sampling procedures and processing of fish in the biological laboratory were the same as described in section 3.1.1 except as follows: One fillet from each of the 15 catfish from a reservoir section was to be randomly selected, and then these fillets were to be divided into three groups to provide three, five-fish composites for each section. All fillets were immediately frozen and later taken to the laboratory for analyses. Livers from all 15 catfish from a location were to be composited, weighed, wrapped in aluminum foil, placed in a labeled plastic bag, frozen, and later sent to the analytical laboratory for analyses. This would provide a total of nine flesh samples and three liver samples for analyses.

Laboratory analytical techniques and detection limits are summarized in section 3.1.1. Statistical techniques were not used on these data (explanation provided below).

3.2.2 Results and Discussion

Physical Characteristics of Fish

Fish for this study were collected during one of two time periods--either the end of September 1989 or January 1990. This split occurred because of uncertainties related to commitment of funding for the project. Collection efforts were not as successful as in previous years. Fifteen channel catfish were collected from TRM 526 and 14 channel catfish plus one blue catfish from TRM 483. However, repeated efforts at the Hiwassee River site yielded only four catfish. Hence, because of differing sample size, statistical techniques were not used in comparing results from three sites.

Because there was special concern in the area downstream from SQN due to the approved discharge of PCBs, ten gizzard shad (to be potentially analyzed as two, five-fish composites) had been retained while collecting catfish at TRM 483. In absence of the full complement of samples from HRM 5, it was decided to use the laboratory effort allocated for those samples on the two gizzard shad samples. This would allow a more complete evaluation of a PCB problem (if one existed) by examining these important forage fish.

Smaller catfish were collected from TRM 526 than the other two sites. Average weights of the catfish composited at TRM 526 were 983, 674, and 624 g compared to 1005, 834, and 1113 g at TRM 483 and 1096 g at HiRM 5 (table 3.2-1). Gross observation on external and internal conditions indicated all fish were generally healthy with no noteworthy anomalies. Lipid content (a measure of the fat level expressed as a percentage) is another indicator of "health" of a fish population and is also important in studies where fat soluble compounds like PCBs are evaluated. Lipid content in channel catfish is usually 4 to 8 percent although some individuals may have less than 1 percent or greater than 15 percent. Lipid levels in these composited fillets ranged from 5 to 9 percent (table 3.2.1), which indicated fairly healthy fish from all locations.

Metals

Similar to the 1987 and 1988 results, all metals were low or present at what could be considered background levels. As expected, liver samples contained higher levels of certain metals (especially copper, selenium, and zinc) than fillet samples. For this reason, livers were included as environmental indicators in this study.

Four metals (antimony, nickel, silver, and thallium) were not detected in any of the samples (catfish fillet composites or liver composites or gizzard shad composites, tables 3.2.1 and 3.2.2). Arsenic was detected in only one sample, a fillet composite with a concentration at the detection limit of 0.02 µg/g. This observation differs substantially from 1988 results when arsenic was found in all samples (Dycus 1990a).

Only selenium and zinc were found in all samples (tables 3.2.1 and 3.2.2). Both are essential elements and their presence is expected. It is also expected that livers would have higher concentrations of these metals than fillets (Moore and Ramamoorthy 1984).

The remaining metals (beryllium, cadmium, chromium, lead and mercury) occurred sporadically in various types of samples (tables 3.2.1 and 3.2.2). Although some nominal trends were evident in the distribution of a few of these metals, the only noteworthy trend was for beryllium. Beryllium has rarely been documented in fish tissue samples from the Tennessee Valley. The Valley-wide fish tissue study has not found beryllium from any reservoir sites since it started in 1987 (Dycus 1989 and 1990b). This metal was not found in any of the 1988 samples from Chickamauga Reservoir (Dycus 1990a) but was found in a few samples (one from each location) in 1987 (Dycus 1988).

The 1989 samples from Chickamauga Reservoir had detectable concentrations of beryllium only at TRM 483 (tables 3.2.1 and 3.2.2). Beryllium occurred in two of the three fillet composites (0.06 and 0.10 µg/g, table 3.2-1) and in both gizzard shad composites (0.04 and 0.08 µg/g, table 3.2-2). The presence of beryllium at this site yet absent at all other reservoir sites sampled in 1989 is noteworthy. However, concentrations in these samples were only slightly above the detection limit of 0.02 µg/g, making these results inappropriate for drawing firm conclusions. Because beryllium is carcinogenic, its presence could have human health implications. To resolve this issue it is recommended that all samples from TRM 483 collected in 1989 be reanalyzed along with new samples collected there in autumn 1990.

PCBs

Results from the 1987 study showed PCBs to be present at low levels (range 0.2 to 0.4 µg/g) in all fillet samples and not detectable in any liver samples (Dycus 1988). Results for 1988 showed PCBs were present in all samples (including liver composites) and at higher concentrations than in 1987 (Dycus 1990a). Concentrations in fillets ranged from 0.5 to 1.1 µg/g and in livers from 0.1 to 0.2 µg/g in 1988 samples. Concentrations in 1988 tended to be higher at TRM 526 (mean 0.8 µg/g) than at either of the other two locations (0.6 µg/g at each location).

In 1989 PCB concentrations in catfish were similar to those observed in 1988 in both concentration and geographical distribution (table 3.2-3). Concentrations were higher at TRM 526 (range 0.9 to 1.2 µg/g, mean 1.1 µg/g) than at TRM 483 (range 0.5 to 0.8 µg/g, mean 0.6 µg/g) or HiRM 5 (0.7 µg/g in the one sample). Concentrations in whole gizzard shad composites were slightly lower than in catfish fillet composites (0.4 and 0.5 µg/g in the two composites, table 3.2-2).

The similarity of PCB concentrations at TRM 483 in 1989 and 1988 indicates that PCB-contaminated water discharged from the SQN treatment pond to Chickamauga Reservoir was not sufficient to be manifested in channel catfish downstream of the discharge. Additionally, Aroclors 1254 and 1260 were the only PCBs present in these samples, whereas the Aroclor in the treatment pond was 1242.

Occurrence of higher PCB concentrations in channel catfish from upper Chickamauga Reservoir (TRM 526) in 1988 and 1989 may be a reflection of the contamination problem in Watts Bar Reservoir. Fish from Watts Bar Reservoir have been under investigation for PCB contamination for several years. Ten channel catfish from lower Watts Bar Reservoir (TRM 532) collected in autumn 1989 had an average PCB concentration of 0.8 µg/g with a range of 0.3 to 1.5 µg/g (see section 4.3).

Pesticides

Most pesticides (aldrin, dieldrin, endosulfan, lindane, and toxaphene) were not detected in any samples (tables 3.2-2 and 3.2-3). Heptachlor was detected in only one sample, a gizzard shad composite with

0.04 µg/g (table 3.2-2). Endrin was detected in several samples but at concentrations only slightly above the detection limit of 0.01 µg/g. As would be expected, the commonly encountered isomers of DDT were present in all samples but at relatively low concentrations, maximum 0.8 µg/g.

Chlordane, another commonly encountered pesticide, was found in all samples (table 3.2-2 and 3.2-3). Concentrations tended to be lower at TRM 483 (0.04, 0.08, and 0.10 µg/g) than at the other sites (0.10, 0.11, and 0.15 µg/g at TRM 526 and 0.13 µg/g at HRM 5). The FDA action level for chlordane is 0.3 µg/g. Because FDA acknowledges that their tolerance and action levels do not protect sport and subsistence fisherman, fish with concentrations that approach even half the FDA action level must be viewed conservatively. TVA's Valley-wide fish tissue study uses 0.10 µg/g as its tier 2 level (table 3.1-1) to indicate need for further evaluation.

3.2.3 Project Status/Recommendations

Based on observed concentrations of PCBs and chlordane in the 1989 samples, as well as the presence of beryllium only downstream from SQN, this study was repeated in autumn 1990. The same study design was followed except that the sample site at HiRM 5 was replaced with a site at TRM 495 (just downstream from the Hiwassee River) because of difficulties in collecting channel catfish from the Hiwassee River. Laboratory analyses were expected to be completed in summer 1991 and will be provided in a subsequent report.

Table 3.2-1. Physical Information and Concentrations (µg/g) of Metals in Catfish Samples Collected from Chickamauga Reservoir for Tissue Analysis in September 1989–January 1990

Location	Collection Date	Length (mm)	Weight (g)	Sex	Lipids %	Sb	As	Be	Cd	Cu	Cr	Pb	Hg	Ni	Se	Ag	Tl	Zn
TRM 483	09-26-89	441	646	M														
	09-26-89	476	1070	F														
	09-26-89	363	358	M														
	09-26-89	578	2001	F														
	09-27-89	479	951	F														
	Fillet Composite				8.0	<2.0	<0.02	<0.02	<0.1	<0.2	<0.02	<0.02	<0.1	<1.0	0.15	<0.1	<1.0	5.4
	09-27-89	387	448	F														
	09-27-89	462	775	F														
	09-28-89	510	1228	M														
	09-28-89	453	780	M														
	09-28-89	462	941	F														
	Fillet Composite				9.0	<2.0	<0.02	0.10	<0.1	<0.2	0.03	<0.02	<0.1	<1.0	0.11	<0.1	<1.0	8.4
	09-28-89	474	938	M														
	09-28-89	565	1628	M														
	09-28-89	462	828	F														
	10-31-89	475	1029	F														
	10-31-86	519	1133	F														
	Fillet Composite				9.0	<2.0	<0.02	0.06	<0.1	<0.2	0.02	0.06	<0.1	<1.0	0.31	<0.1	<1.0	6.2
	Liver Composite					<2.0	<0.02	<0.02	<0.1	2.4	0.11	0.08	<0.1	<1.0	1.4	<0.1	<1.0	24
TRM 526	01-17-90	505	1334	M														
	01-17-90	435	804	F														
	01-17-90	460	938	F														
	01-17-90	446	879	M														
	01-17-90	451	958	M														
	Fillet Composite				5.0	<2.0	0.02	<0.02	<0.1	0.4	0.02	0.02	0.25	<1.0	0.12	<0.1	<1.0	6.2
	01-17-90	398	645	F														
	01-17-90	417	689	M														
	01-17-90	406	692	M														
	01-17-90	431	692	F														
	01-17-90	427	654	F														
	Fillet Composite				7.0	<2.0	<0.02	<0.02	<0.1	0.2	0.08	0.04	0.12	<1.0	0.12	<0.1	<1.0	5.4

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Table 3.2-1 (Continued)

Location	Collection Date	Length (mm)	Weight (g)	Sex	Lipids %	Sb	As	Be	Cd	Cu	Cr	Pb	Hg	Ni	Se	Ag	Tl	Zn
	01-17-90	393	615	F														
	01-17-90	407	716	F														
	01-17-90	392	615	F														
	01-17-90	399	608	F														
	01-17-90	398	566	F														
	Fillet Composite				8.0	<2.0	<0.02	<0.02	<0.1	0.2	0.11	0.04	<0.1	<1.0	0.12	<0.1	<1.0	6.2
	Liver Composite					<2.0	<0.02	<0.02	<0.1	2.6	0.07	0.88	<0.1	<1.0	0.68	<0.1	<1.0	19
HIRM 5.0	11-01-89	489	970	F														
	11-01-89	520	1149	F														
	01-24-90	552	1804	F														
	01-24-90	371	461	M														
	Fillet Composite				8.0	<2.0	<0.02	<0.02	0.2	0.4	0.08	0.03	<0.1	<1.0	0.11	<0.1	<1.0	7.2
	Liver Composite					<2.0	<0.02	<0.02	0.3	2.4	0.08	0.10	<0.1	<1.0	0.38	<0.1	<1.0	23

Table 3.2-2 Concentrations (µg/g) of Metals and Organics in Composited Whole Gizzard Shad (Five per Composite) Collected from Chickamauga Reservoir at TRM 483 in September 1989

Analyte	Gizzard Shad Composite-1	Gizzard Shad Composite 2
Antimony	<2.0	<2.0
Arsenic	<0.02	<0.02
Beryllium	0.08	0.04
Cadmium	<0.1	0.1
Copper	0.16	0.32
Chromium	0.6	1.0
Lead	0.34	0.31
Mercury	<0.1	<0.1
Nickel	<1.0	<1.0
Selenium	0.30	0.13
Silver	<0.1	<0.1
Thallium	<1.0	<1.0
Zinc	11.0	13.0
Lipids (%)	7.0	6.0
Aldrin	<0.01	<0.01
Dieldrin	<0.01	<0.01
Toxaphene	<0.5	<0.5
BHC	<0.01	<0.01
Chlordane	0.06	0.01
DDTr	0.05	0.02
Endosulfan	<0.01	<0.01
Endrin	0.01	<0.01
Heptachlor	0.04	<0.01
PCB	0.5	0.4

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Table 3.2-3 Concentrations (μg/g) of Pesticides and PCBs in Catfish Collected from Chickamauga Reservoir for Tissue Analysis in September 1989–January 1990

Location	Sample	Percent Lipids	Aldrin	Dieldrin	Toxophene	BHC	Chlordane	DDTr	Endosulfan	Endrin	Heptochlor	PCB
TRM 483	Fillet Composite 1	8.0	<0.01	<0.01	<0.5	<0.01	0.10	0.05	<0.01	0.02	<0.01	0.8
	Fillet Composite 2	9.0	<0.01	<0.01	<0.5	<0.01	0.04	0.03	<0.01	<0.01	<0.01	0.5
	Fillet Composite 3	9.0	<0.01	<0.01	<0.5	<0.02	0.08	0.04	<0.01	0.01	<0.01	0.6
TRM 526	Fillet Composite 1	5.0	<0.01	<0.01	<0.5	<0.01	0.11	0.08	<0.01	0.02	<0.01	1.1
	Fillet Composite 2	7.0	<0.01	<0.01	<0.5	<0.01	0.15	0.06	<0.01	0.02	<0.01	1.2
	Fillet Composite 3	8.0	<0.01	<0.01	<0.5	<0.01	0.10	0.04	<0.01	0.01	<0.01	0.9
HiRM 5	Fillet Composite 1	8.0	<0.01	<0.01	<0.5	<0.01	0.13	0.04	<0.01	0.01	<0.01	0.7

4.0 INTENSIVE RESERVOIR STUDIES

Intensive studies in TVA reservoirs as described in this report are undertaken in areas with known or suspected problems. Two primary objectives of these intensive studies are to define the geographical boundaries of fish contamination and to determine the temporal trend in contaminant concentrations in fish from reservoirs where the extent of contamination has been defined.

Most of the reservoirs that are the subject of this report have been under investigation for several years because of contamination with PCBs. They include Watts Bar, Tellico, and Fort Loudoun, all reservoirs in the upper part of the Tennessee Valley, and Chickamauga, Nickajack and Wilson Reservoirs in the middle and lower sections of the Tennessee River. As a result of the contamination, the Tennessee Department of Health and Environment (TDHE) issued several public notices in recent years advising against consumption of certain fishes from those lakes in Tennessee. High PCB levels were found in catfish from Wilson Reservoir, Alabama, in 1984, and from June 1985 until fall 1987, during which time PCB levels decreased significantly, area retail markets were not permitted to sell catfish from that lake. In addition to TVA and TDHE, representatives from the Tennessee Wildlife Resources Agency (TWRA) and the Oak Ridge National Laboratory (ORNL) participated in the design and conduct of these investigations.

The purpose of this report is to describe the results of PCB (and chlordane) analyses of fish from these reservoirs in autumn 1989 and to compare with results from previous years. Preliminary results were shared with all study team members as soon as they were received from the analytical laboratory rather than waiting on this formal report. Therefore decisions on updating existing health advisories and selection of study areas for autumn 1990 were made months before this document was prepared. Results are presented in the order of the lowermost reservoir first (Wilson) and proceeding upstream.

4.1 Wilson Reservoir

TVA conducted a four-year study (1984-87) on Wilson Reservoir to examine polychlorinated byphenyl (PCB) levels in catfish. Substantial PCB concentrations were found in catfish tissue in the initial study year (1984) prompting the Northwest Alabama Regional Health Department (NARHD) to issue official notice to retail fish markets in June 1985 to discontinue selling catfish from Wilson Reservoir.

Catfish collected in subsequent years showed large year-to-year reductions in PCB concentrations, particularly between 1984 and 1985. Analysis of catfish collected in 1986 and 1987 continued to show decreased levels. Beginning in late 1987, area retail markets were allowed to resume selling catfish from Wilson Reservoir.

Available information was not sufficient to determine the cause of the observed reductions in PCB levels. The source of PCBs in catfish collected in 1984 outside of Fleet Hollow, an area with known PCB-contaminated sediments, was never identified. Extreme hydrologic conditions in the Tennessee River appeared to offer the most plausible explanation. The 1984 catfish were collected five months after record high flows in the river due to a 100-year flood, while substantially reduced flows prevailed in subsequent years due to a severe, extended drought. Because PCBs have low water solubility, they typically occur in sediments, and any event substantially influencing sediments, e.g. turbulence induced by high lows, would be expected to also influence PCB levels.

Because of the low PCB levels observed in 1987, it was decided to discontinue annual sampling of catfish in Wilson Reservoir; further sampling at previous levels would not be required unless a major flood (>200,000 cfs) occurred during May or June. If such a flood had not occurred in three years, catfish would be collected from the same locations sampled in earlier studies, but only those from Fleet Hollow and TRM 260 would be analyzed initially.

In 1989, heavy rainfall periods occurred in January, March, and late June with Wilson Dam releases of >200,000 cfs in all periods. Consequently, it was decided to again collect catfish for PCB analysis in the fall of 1989, for comparison with results from samples in 1984-87.

4.1.1 Methods

Field Sampling and Processing

In 1989, catfish (mostly channel, but some blue catfish) were collected from the same four locations as in previous years. These stations were; Fleet Hollow, an area known to have PCBs in its sediments; TRM 260 in the mouth of Stinson Hollow, and TRM 270 (near mouth of Town Creek), areas with historical PCB and DDT data; and lower Shoal Creek, a heavily fished area for both sport and commercial fishing (figure 4.1-1).

Nine catfish were collected with gill nets from each station; length, weight and sex were recorded on field forms, along with observations of fish condition. Immediately after collection fish were taken to the TVA biological laboratory in Muscle Shoals for processing. Skin was removed and fish filleted; rib cage and belly flap were left in tact on each fillet, which was weighed, labeled, wrapped in aluminum foil and placed in a plastic bag. One fillet from each fish was randomly selected for laboratory analysis and the other fillet retained for possible future use. Fillets were frozen immediately for processing, and those selected for analyses were sent to the TVA analytical lab in Chattanooga.

Laboratory Processing

Each fish tissue sample was partially thawed and then diced with a knife. Diced tissue was then thoroughly ground using a mechanical grinder. After grinding, appropriate amounts of tissue were dispersed into glass jars and frozen pending analysis. PCBs were extracted with petroleum ether from individual, homogenized fillets using a cell disruptor. The extract was then cleaned with concentrated sulfuric acid and analyzed for Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260 using a precalibrated gas chromatograph equipped with an electron capture detector and a electronic integrator. Lipid content of individual fillets was determined gravimetrically. Specifics of the quality assurance program were provided in the 1986 study (Dycus and Lowery 1987) and will not be repeated here.

Data Analyses

A broad array of statistical techniques was used to further examine these results. As an indicator of "health" of fish population, analysis of covariance was used to compare length/weight relationships of channel and blue catfish from Wilson Reservoir to length/weight relationships for these species in other TVA reservoirs. A two-way analysis of variance (ANOVA) was used to test if lipid content and/or fish size (length and weight) differed among sample locations or between years. Lipid content and fish size have been found in other studies to have an important influence on PCB levels. Simple and partial correlations were used to examine association between PCB levels and other variables such as lipid content and fish weight.

Differences in PCB levels among locations and years were examined using either ANOVA and Duncan's Multiple Range Test or analysis of covariance. Because PCBs are lipophilic compounds, these data were examined closely to determine if analysis of covariance was needed to eliminate differences due to variations in lipid content. The first step was to test the null hypothesis that PCB levels do not depend upon lipid content for one or more stations. This involved regressing PCB concentration against lipid content simultaneously for each station. If the slopes for all stations were not different from zero (failure to reject the null hypothesis), then no adjustment for lipid content was necessary and ANOVA was the appropriate test. If the slope for any station was significantly different from zero (rejection of null hypothesis), then covariance analysis was needed. Prior to proceeding to covariance analysis, data were tested for homogeneity of slopes (parallel lines). If this null hypothesis was accepted, data were analyzed using covariance analysis by comparing the distance between the parallel regression lines of adjusted means. A similar procedure was used to compare length/weight relationships described above.

Prior to statistical analyses, concentrations of PCBs were transformed to approximate a normal distribution using a $\log_{10}(x + 1)$ transformation ($x + 1$ was used because some values were between zero and one). Lipid content was transformed using arc sine. An α of 0.05 was chosen as the level of significance. Samples with less than detectable levels (0.1 µg/g) were included at the detection limit in developing averages.

4.1.2 Results and Discussion

Physical Characteristics

As in previous collections, field and laboratory observations of catfish collected in 1989 revealed no obvious, abnormal external or internal conditions. All fish appeared to be normal and healthy.

Five of the nine catfish from TRM 260 were blue catfish; the remainder of the 1989 collection were channel catfish. Mean lengths and weights of channel and blue catfish in 1989 varied by stations from previous years (table 4.1-1). Specific information for each fish is in table 4.1-2. Those collected in Fleet Hollow and TRM 270 were considerably smaller, those from TRM 260 were much larger than in all previous years; Shoal Creek fish were slightly larger, but similar in size to those collected at that station in 1986 and 1987. Lengths and weights of 1989 fish at TRM 260 were significantly greater than at other locations that year. Analysis of covariance of length/weight relationships showed that blue and channel catfish collected from Wilson Reservoir in 1989 were not significantly different from those species in other TVA mainstream reservoirs (table 4.1-3). However, the 1989 fish were not as heavy per unit length as those collected in 1984.

A two-way ANOVA, to determine if there were differences in lipid content or fish size among locations and years, showed significantly greater lipid content in 1989 than in other years (table 4.1-4). Tests for both length and weight had significant interaction among years and locations. This was due to the inconsistent average size of fish from TRM 260 relative to the other locations over time. The smallest average-size fish were collected at TRM 260 in 1984, whereas the largest average-size fish came from that location in 1989.

PCB Concentration

With one exception, PCB levels in catfish from all locations in 1989 were low, relative to the FDA tolerance of 2.0 µg/g (table 4.1-5). One individual channel catfish from Fleet Hollow had a level of 2.2 µg/g; two other individuals had PCB levels of 1.6 and 1.2 µg/g, but the mean concentration for Fleet Hollow was 0.9 µg/g. Mean concentrations for the other three locations were 0.6, 0.4 and 0.4 µg/g for TRM 260, TRM 270 and Shoal Creek, respectively.

Statistical comparison of 1989 PCB levels among locations was based on ANOVA because the preliminary test for analysis of covariance showed correction for lipid content was unnecessary. A two-way ANOVA was run for locations and species to be sure that combining results for channel and blue catfish did not introduce a bias in results--test results were not significant for species, locations or interactions at the 0.05 level.

The 1989 results showed increased PCB levels at all four stations over recent years, the first reversal in the downward trend since 1984. Concentrations in 1989 were higher than in 1986 and 1987, but were still lower than in 1985 and much lower than in 1984, when PCB levels in most catfish exceeded the FDA tolerance of 2.0 µg/g at all stations (table 4.1-5). Although PCB levels in 1989 were higher for the first time in several years, only one of 36 specimens had a level above 2.0 µg/g (2.2). The overall average for 1989 was 0.6 µg/g, compared with 2.6, 1.0, 0.5 and 0.2 in 1984, 1985, 1986, and 1987, respectively. In 1989, all the 36 catfish collected had levels above the detection limit of 0.1 µg/g, a substantial contrast to 1987, when 20 of the 36 fish analyzed had less than detectable levels.

Statistical comparison of PCB levels observed in 1989 to levels in previous years was based on a two-way analysis of covariance (year and location main effects) because of a significant relationship between PCB level and lipid content for the entire data set. Mean PCB concentrations adjusted to a common lipid content for each location over time showed a significant interaction between location and year. The interaction occurred because the pattern of PCB levels among locations differed from year to year (tables 4.1-6 and 4.1-7). Highest adjusted mean PCB concentrations were at TRM 260 in 1984 and 1987, and at Fleet Hollow in 1985, 1986, and 1989. Adjusted mean PCB concentrations were highest in 1984 at all locations, with decreases at all stations in subsequent years until 1989, when levels again increased throughout the reservoir.

Correlation analyses were run on 1989 data because it had proved useful in evaluating data from previous years, particularly the PCB: lipid and PCB; distance correlations. The PCB: lipid correlation, which was significant in all previous years except 1987, when most fish had PCB levels below the detection limit, was not significant in 1989. However, the PCB: distance correlations in 1989 were significant for the first time since 1985 (table 4.1-8).

At Fleet Hollow, the site of historic PCB contamination, corrective actions taken by TVA in the early 1980s to reduce or eliminate PCB contaminated soils from entering this small embayment (21 surface acres) seem to have been successful, as evidenced by the reduced PCB levels there in catfish. However, similar reductions in PCB levels observed at the other three locations upstream of Fleet Hollow was not considered to be the result of the corrective actions in Fleet Hollow. As noted earlier, the most plausible theory for those reductions was thought to be related to the extreme hydrologic conditions (severe drought) that occurred in 1985-88.

This theory that increased PCBs were influenced by hydrologic conditions could only be tested following additional flood conditions; therefore, it was decided to suspend further sampling until a year when a major flood occurred in May or June. That condition happened in 1989 (figure 4.1-2), hence the resumption of sampling in Wilson Reservoir the following autumn at the same level and stations as in previous years. PCB concentrations in 1989 increased at all stations over the levels in the previous drought years, suggesting that floods and high flows in early summer may be expected to result in some increased PCB levels in reservoirs with historic PCB contamination. Nevertheless, the mean PCB levels in catfish collected in 1989 were still substantially below those observed in 1984.

4.1.3 Recommendations

Since there was a slight increase in PCB levels at all stations in 1989, and substantial rainfall with heavy releases from TVA mainstream reservoirs occurred again in early 1990 the decision was made to resample all Wilson stations in the fall of 1990 to further examine the relationship of high flows and PCB levels.

Table 4.1-1. Minimum, Maximum, and Mean Lengths and Weights of Channel and Blue Catfish Collected from Four Stations on Wilson Reservoir 1984, 1985, 1986, 1987, and 1989

		Length (mm)			Weight (g)		
Location	Year	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Fleet Hollow	1984	324	470	370	315	1060	554
	1985	281	460	419	144	882	484
	1986	259	619	426	274	2315	768
	1987	320	480	401	262	956	557
	1989	310	460	376	252	982	499
TRM 260	1984	234	421	331	125	870	388
	1985	238	550	420	98	1810	664
	1986	335	474	411	316	934	582
	1987	416	490	455	594	1036	853
	1989	455	530	499	894	1520	1163
TRM 270	1984	268	567	374	120	2270	649
	1985	312	474	430	228	1200	656
	1986	330	518	413	294	1370	738
	1987	385	435	410	414	842	610
	1989	307	482	377	226	1080	541
Shoal Creek	1984	321	432	349	300	900	415
	1985	330	451	378	291	940	536
	1986	400	452	429	522	888	688
	1987	330	530	407	268	1340	611
	1989	320	490	422	220	1132	677

Table 4.1-2. Detailed information on physical characteristics, lipid content, and PCB concentration (µg/g wet weight) for each fish collected from Wilson Reservoir, 1989

LOCATION[a]		DATE	SPECIES[b]	SEX	LENGTH (mm)	WEIGHT (g)	LIPIDS (%)	TOTAL PCBS
TRM	270.0	891019	CHC	FM	437	792	13.0	0.4
TRM	270.0	891019	CHC	FM	315	512	6.8	0.4
TRM	270.0	891019	CHC	MA	308	300	8.6	0.3
TRM	270.0	891019	CHC	FM	416	634	15.0	0.7
TRM	270.0	891019	CHC	FM	482	1080	6.6	0.4
TRM	270.0	891019	CHC	FM	368	500	14.0	0.5
TRM	270.0	891019	CHC	MA	410	508	0.8	0.7
TRM	270.0	891019	CHC	FM	351	324	4.2	0.2
TRM	270.0	891019	CHC	MA	307	226	6.3	0.2
TRM	260.0	891013	CHC	FM	455	956	7.8	0.5
TRM	260.0	891013	CHC	MA	550	1520	1.9	0.6
TRM	260.0	891013	CHC	FM	490	1260	4.9	0.3
TRM	260.0	891017	CHC	FM	520	1346	9.6	0.5
TRM	260.0	891017	BLC	FM	505	1232	7.1	0.7
TRM	260.0	891017	BLC	FM	465	894	11.0	0.5
TRM	260.0	891017	BLC	FM	530	1306	6.1	1.1
TRM	260.0	891017	BLC	MA	495	1014	5.6	0.6
TRM	260.0	891017	BLC	FM	480	944	8.2	0.3
FH	0.9	891012	CHC	FM	460	824	6.4	1.2
FH	0.9	891012	CHC	FM	315	288	6.8	0.5
FH	0.9	891012	CHC	FM	385	478	3.8	0.4
FH	0.9	891012	CHC	MA	360	376	5.8	0.3
FH	0.9	891012	CHC	FM	310	252	6.4	0.9
FH	0.9	891012	CHC	FM	335	294	5.3	0.4
FH	0.9	891012	CHC	FM	355	382	6.0	0.5
FH	0.9	891012	CHC	FM	460	982	11.0	1.6
FH	0.9	891012	CHC	FM	410	616	3.8	2.2
SCM	1.2	891017	CHC	MA	450	644	0.7	0.3
SCM	1.2	891017	CHC	FM	490	936	2.4	0.3
SCM	1.2	891017	CHC	MA	450	850	8.2	0.3
SCM	1.2	891017	CHC	FM	320	220	3.4	0.2
SCM	1.2	891017	CHC	FM	490	1132	9.8	0.9
SCM	1.2	891018	CHC	FM	483	1008	3.8	0.4
SCM	1.2	891018	CHC	MA	388	492	8.1	0.3
SCM	1.2	891018	CHC	FM	378	490	4.1	0.3
SCM	1.2	891018	CHC	MA	352	236	3.8	0.2

a. TRM = Tennessee River Mile; FH = Fleet Hollow; SCM = Shoal Creek Mile
b. CHC = Channel Catfish; BLC = Blue Catfish

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Table 4.1-3. Covariance Analyses on Length/Weight Relationships for Blue and Channel Catfish from Wilson Reservoir Compared to the Respective Data Bases in the TVA Life History Data File

	Mean Rank Low to High*					
Blue Catfish	1989	1987	1986	1985	Life History	1984
Channel Catfish	1985	1987	1989	1986	Life History	1984

*Means at locations underscored by same line were not significantly different at $\alpha = 0.05$. Means not so underscored were significantly different.

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Table 4.1-4. Two-Way Analysis of Variance (Location and Year Main Effects) and Duncan's Multiple Range Test on Lipid Content, and Total Length, and Total Weight in Catfish from Wilson Reservoir, 1984, 1985, 1986, 1987, and 1989

		P>F	Duncan's Multiple Range Test[a] Mean Rank Low to High				
Lipid content	Location	0.0315					
	Year	0.0002	1986	1985	1984	1987	1989
	Interaction	0.0870					
Total length	Location	0.3461					
	Year	0.0001	1984	1985	1989	1986	1987
	Interaction	0.0051					
Total weight	Location	0.3670					
	Year	0.0001	1985	1984	1987	1986	1989
	Interaction	0.0118					

a. Years underscored by same line were not significantly different at $\alpha = 0.05$. Years not so underscored were significantly different.

Table 4.1-5. Summary of Total[a] PCB Concentrations (µg/g wet weight) in Individual Catfish Fillets from Wilson Reservoir, Collected October 1984, December 1985, October 1986, October 1987, and October 1989

Year	Back Half of Fleet Hollow	Front Half of Fleet Hollow	TRM[b] 260	Lower Shoal Creek	TRM 270	Totals
1984						
Range	0.8–10	0.5–7.7	1.6–7.9	0.8–4.3	0.3–5.0	0.3–10
Mean	2.8	1.9	4.2	2.4	1.9	2.6
Number ≥ 2.0 µg/g	4	1	8	5	4	22
Number of Fish	9	9	9	9	9	45
1985						
Range	0.56–5.3		0.24–3.7	<0.1–0.56	0.22–1.5	<0.1–5.3
Mean	1.76		1.17	0.39[c]	0.74	1.01
Number ≥ 2.0 µg/g	2		2	0	0	4
Number of Fish	9		9	9	9	36
1986						
Range	<0.1–1.9		<0.1–1.5	<0.1–0.60	0.1–0.90	<0.1–1.9
Mean	0.72		0.46	0.22	0.42	0.46
Number ≥ 2.0 µg/g	0		0	0	0	0
Number of Fish	9		9	9	9	36
1987						
Range	<0.1–0.5		<0.1–0.3	<0.1–1.1	<0.1–0.3	<0.1–1.1
Mean	0.17		0.13	0.24	0.22	0.19
Number ≥ 2.0 µg/g	0		0	0	0	0
Number of Fish	9		9	9	9	36
1989						
Range	0.3–2.2		0.3–1.1	0.2–0.9	0.2–0.7	0.2–2.2
Mean	0.88		0.56	0.37	0.43	0.56
Number ≥ 2.0 µg/g	1		0	0	0	1
Number of Fish	9		9	9	9	9

a. Sum of individual aroclors which occurred in concentrations greater than or equal to the detection limit of 0.1 µg/g.

b. TRM = Tennessee River Mile.
Fish were not collected from this location in 1985 and 1986 because of its close proximity to the other location in Fleet Hollow.

c. Total PCB concentrations less than detection limit of 0.1 µg/g were averaged as 0.1 µg/g.

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Table 4.1-6. Results (P>F) of Analyses of Covariance on PCB Concentrations in Catfish from Wilson Reservoir from the same locations in 1984, 1985, 1986, 1987, and 1989

	Shoal Creek					TRM 260					TRM 270				
	1984 (1)	1985 (2)	1986 (3)	1987 (4)	1989 (5)	1984 (6)	1985 (7)	1986 (8)	1987 (9)	1989 (10)	1984 (11)	1985 (12)	1986 (13)	1987 (14)	1989 (15)
1	.	0.0001	0.0001	0.0001	0.0001	0.0125	0.0007	0.0001	0.0001	0.0001	0.0715	0.0001	0.0001	0.0001	0.0001
2	0.0001	.	0.4726	0.2544	0.8260	0.0001	0.0079	0.9278	0.2986	0.8797	0.0001	0.1359	0.8302	0.0843	0.3815
3	0.0001	0.4726	.	0.6733	0.6186	0.0001	0.0008	0.4185	0.7451	0.3949	0.0001	0.0280	0.3509	0.3088	0.8566
4	0.0001	0.2544	0.6733	.	0.3562	0.0001	0.0002	0.2192	0.9220	0.1984	0.0001	0.0091	0.1772	0.5328	0.8192
5	0.0001	0.8260	0.6186	0.3562	.	0.0001	0.0041	0.7563	0.4133	0.7114	0.0001	0.0877	0.6646	0.1274	0.5030
6	0.0125	0.0001	0.0001	0.0001	0.0001	.	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
7	0.0007	0.0079	0.0008	0.0002	0.0041	0.0001	.	0.0102	0.0003	0.0136	0.1014	0.2348	0.0143	0.0001	0.0007
8	0.0001	0.9278	0.4185	0.2192	0.7563	0.0001	0.0102	.	0.2583	0.9506	0.0001	0.1611	0.9014	0.0705	0.3376
9	0.0001	0.2986	0.7451	0.9220	0.4133	0.0001	0.0003	0.2583	.	0.2475	0.0001	0.0122	0.2097	0.4852	0.8993
10	0.0001	0.8797	0.3949	0.1984	0.7114	0.0001	0.0136	0.9506	0.2475	.	0.0001	0.1873	0.9524	0.0553	0.2908
11	0.0715	0.0001	0.0001	0.0001	0.0001	0.0001	0.1014	0.0001	0.0001	0.0001	.	0.0051	0.0001	0.0001	0.0001
12	0.0001	0.1359	0.0280	0.0091	0.0877	0.0001	0.2348	0.1611	0.0122	0.1873	0.0051	.	0.2011	0.0017	0.0216
13	0.0001	0.8302	0.3509	0.1772	0.6646	0.0001	0.0143	0.9014	0.2097	0.9524	0.0001	0.2011	.	0.0548	0.2834
14	0.0001	0.0843	0.3088	0.5328	0.1274	0.0001	0.0001	0.0705	0.4852	0.0553	0.0001	0.0017	0.0548	.	0.3880
15	0.0001	0.3815	0.8566	0.8192	0.5030	0.0001	0.0007	0.3376	0.8993	0.2908	0.0001	0.0216	0.2834	0.3880	.
16	0.8233	0.0001	0.0001	0.0001	0.0001	0.0065	0.0014	0.0001	0.0001	0.0001	0.1127	0.0001	0.0001	0.0001	0.0001
17	0.0359	0.0001	0.0001	0.0001	0.0001	0.0001	0.1784	0.0001	0.0001	0.0002	0.7655	0.0119	0.0002	0.0001	0.0001
18	0.0001	0.2658	0.0683	0.0253	0.1835	0.0001	0.1173	0.3065	0.0326	0.3450	0.0016	0.7027	0.3687	0.0053	0.0529
19	0.0001	0.2334	0.6356	0.9602	0.3311	0.0001	0.0001	0.2000	0.8819	0.1863	0.0001	0.0078	0.1603	0.5707	0.7850
20	0.0001	0.1590	0.0360	0.0112	0.1030	0.0001	0.2114	0.1877	0.0167	0.2059	0.0041	0.9422	0.2329	0.0017	0.0223

Table 4.1-6. (cont.)

Fleet Hollow

	1984 (16)	1985 (17)	1986 (18)	1987 (19)	1989 (20)
1	0.8233	0.0359	0.0001	0.0001	0.0001
2	0.0001	0.0001	0.2658	0.2334	0.1590
3	0.0001	0.0001	0.0683	0.6356	0.0360
4	0.0001	0.0001	0.0253	0.9602	0.0112
5	0.0001	0.0001	0.1835	0.3311	0.1030
6	0.0065	0.0001	0.0001	0.0001	0.0001
7	0.0014	0.1784	0.1173	0.0001	0.2114
8	0.0001	0.0001	0.3065	0.2000	0.1877
9	0.0001	0.0001	0.0326	0.8819	0.0167
10	0.0001	0.0002	0.3450	0.1863	0.2059
11	0.1127	0.7655	0.0016	0.0001	0.0041
12	0.0001	0.0119	0.7027	0.0078	0.9422
13	0.0001	0.0002	0.3687	0.1603	0.2329
14	0.0001	0.0001	0.0053	0.5707	0.0017
15	0.0001	0.0001	0.0529	0.7850	0.0223
16	.	0.0601	0.0001	0.0001	0.0001
17	0.0601	.	0.0039	0.0001	0.0100
18	0.0001	0.0039	.	0.0220	0.7595
19	0.0001	0.0001	0.0220	.	0.0102
20	0.0001	0.0100	0.7595	0.0102	.

Table 4.1-7. Selected Results of Analysis of Covariance (table 4.1-6) for Each Sample Location Over Time Showing Mean PCB Levels Adjusted to a Common Lipid Content

Location	Adjusted* Mean PCB level				
	1984	1985	1986	1987	1989
Fleet Hollow	2.22	1.47	0.65	0.20	0.72
TRM 260	3.68	1.05	0.43	0.22	0.44
Shoal Creek	2.32	0.41	0.28	0.20	0.37
TRM 270	1.58	0.73	0.45	0.10	0.24

*Adjusted to a common lipid content; adjusted means underscored by the same line were not significantly different at $\alpha = 0.05$; means not so underscored were significantly different.

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Table 4.1-8 Results of Correlation Analysis on Catfish Data from Wilson Reservoir Collected 1984, December 1985, October 1986, October 1987, and October 1989

	1984		1985		1986		1987		1989	
	Correlation Coefficient	P>F	Correlation Coefficient	P>F	Correlation Coefficient	P>F	Correlation Coefficient	P>F	Correlation Coefficient	P>F
Simple Correlation										
PCB: Weight	0.300	0.0454	0.000	0.9980	0.375	0.0265	0.227	0.1830	0.329	0.0498
PCB: Lipid	0.518	0.0003	0.356	0.0330	0.500	0.0019	0.323	0.0546	0.162	0.3456
PCB: Distance	-0.155	0.3104	-0.400	0.0157	-0.186	0.2776	0.221	0.1950	-0.404	0.0145
Weight: Lipids	0.576	0.0001	0.572	0.0003	0.182	0.2960	0.055	0.7483	0.153	0.3728
Weight: Distance	-0.033	0.8291	0.231	0.1759	0.091	0.6047	-0.093	0.5878	-0.224	0.1889
Lipids: Distance	0.001	0.9484	0.038	0.8273	0.090	0.6008	0.582	0.0002	0.140	0.4156
Partial Correlation										
PCB: Weight	0.018	0.9655	-0.135	0.3684	0.310	0.0387	0.218	0.1887	0.207	0.1852
PCB: Lipid	0.427	0.0023	0.355	0.0230	0.402	0.0086	0.207	0.2117	0.177	0.2547
PCB: Distance	-0.160	0.2302	-0.326	0.0354	-0.186	0.2046	0.074	0.6514	0.365	0.0227

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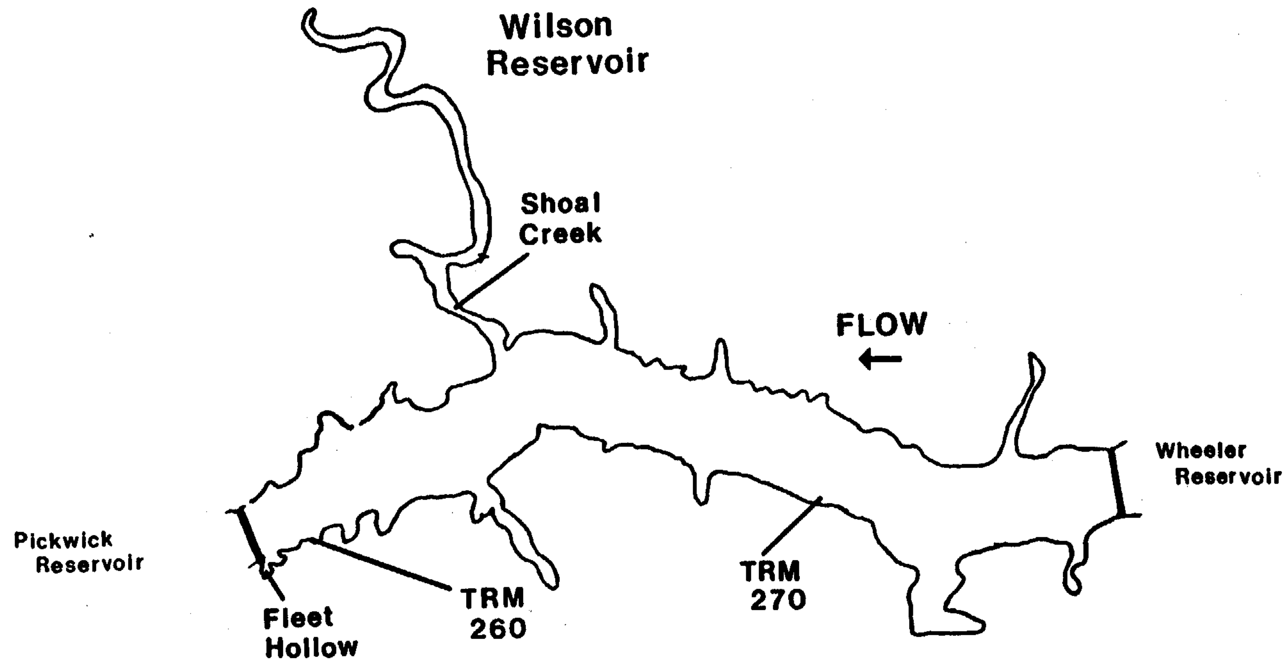


Figure 4.1-1 Collection Locations for Catfish used in PCB Study on Wilson Reservoir, Autumn 1989.

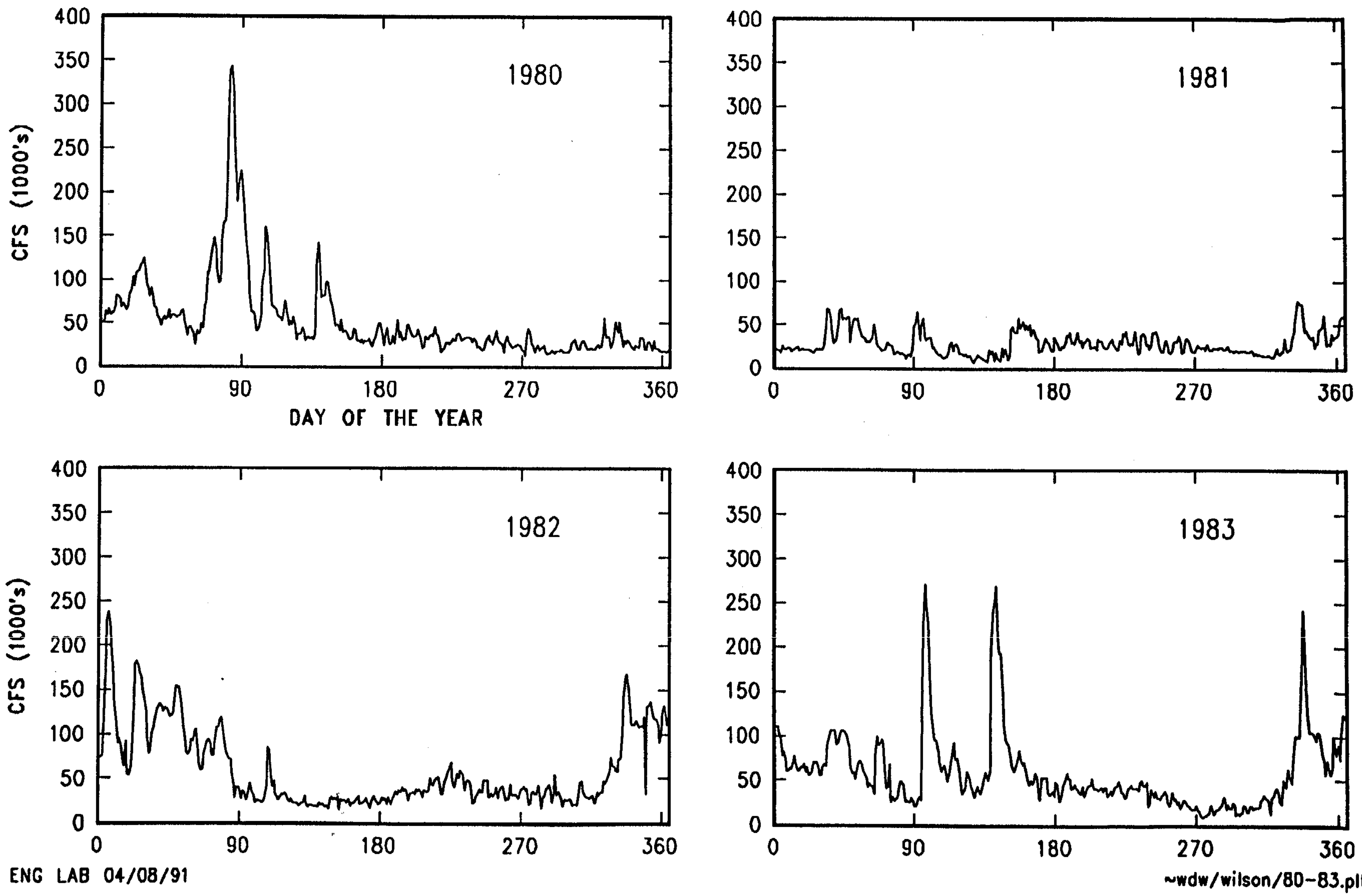


Figure 4.1-2 Daily Average Discharges from Wilson Dam (1980-1989)

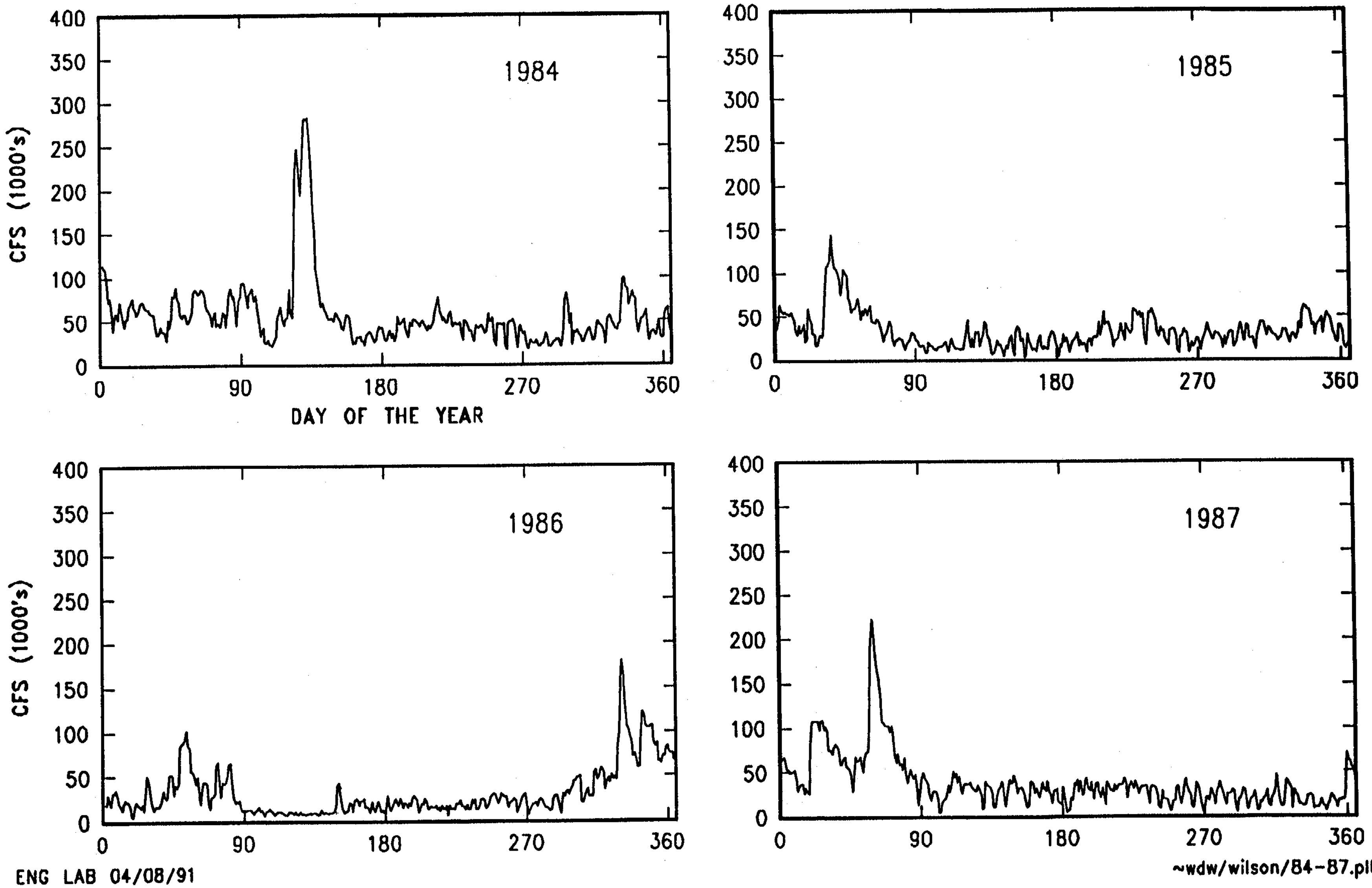
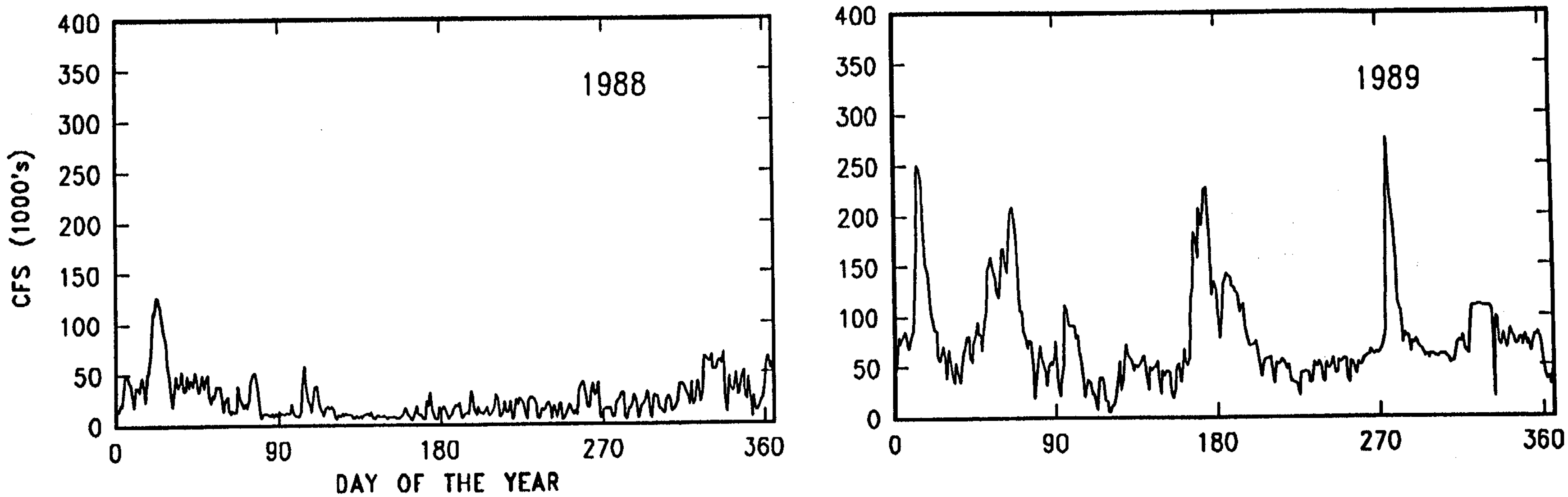


Figure 4.1-2 (Continued)



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~wdw/wilson/88-89.plt

Figure 4.1-2 (Continued)

4.2 Nickajack Reservoir

Results of the Valley-wide Fish Tissue Screening Study in 1987 found sufficiently high concentrations of both PCBs and chlordane in catfish (the indicator species) from Nickajack Reservoir to warrant further investigation. Concentrations of these chlorinated organics exceeded the predetermined "tier 3" levels (table 3.1-1) established to trigger a more in-depth study to better define apparent problems. The five-catfish fillet composite sample from the lower reservoir location (Tennessee River mile 425) contained 1.9 µg/g PCBs and 0.21 µg/g chlordane, while the composite sample from the upper area (TRM 457) contained 1.3 µg/g PCBs and 0.25 µg/g chlordane (Dycus 1989a).

A follow-up study was planned for autumn 1988, but fish were actually collected in January and February, 1989. Ten channel catfish were analyzed individually from two locations, TRM 425 and 435; in addition, tissue was examined from three catfish from TRM 457. Composites of largemouth bass and crappie were analyzed by species from the first two sites; two smallmouth buffalo samples were analyzed from TRM 435. No detectable concentrations of chlordane and only relatively low PCB concentrations were found in the species other than catfish. Concentration of both organics in channel catfish were slightly lower than observed in the 1987 screening study but were still sufficiently high to be of concern. Therefore, another follow-up study was designed for autumn 1989 to further refine geographical distribution of PCB and chlordane contamination in catfish in Nickajack Reservoir and to investigate concentrations in other important sport species.

4.2.1 Methods

Ten channel catfish were to be collected from the three locations sampled previously (TRMs 425, 435, and 457), and an additional location (TRM 470) in the tailwaters of Chickamauga Dam. One fillet from each of the 36 channel catfish was sent to the TVA biological laboratory in Chattanooga for analysis of lipids, chlordane and PCBs; the remaining fillets from each of the catfish were retained for future use. In addition to the catfish, a total of ten striped bass and ten sauger were to be retained from any of the four locations where catfish were collected and their fillets furnished to the analytical laboratory. This was deemed acceptable given the strong surviving probability of those species.

All procedures involved in field sampling and processing, laboratory and data analyses were similar to those described for Wilson Reservoir (section 4.1) earlier in this report, or for chlordane in the previous report on fish from Nickajack Reservoir in 1989 (Dycus 1990c), and will not be repeated here.

4.2.2 Results and Discussion

Channel Catfish

Physical Characteristics--The full complement of ten channel catfish was collected in autumn 1989 at TRMs 457, 425, and 435; only six were collected from TRM 470 (table 4.2-1).

Gross physical examination of the 36 catfish showed 23 were "normal," three had internal parasites, two had abnormal liver spots, and the remaining eight had various observable abnormalities, such as enlarged gall bladder, low fat, healing ulcerations, small testes, and/or bloody spots in spleen or eggs. None of these observations indicated an unusual condition for a wild population.

In the previous two collections, the catfish from Nickajack were rather large. Average weights ranged from 1,150 to 1,401g in 1987 and 1,620 to 2,175g in January-February 1989 (Dycus 1989a, 1990c). The absence of small catfish (only one below 1,200g and none below 945g) was noteworthy, prompting a need to examine that situation in future collection efforts. The autumn 1989 collection, however, contained many small catfish at each station (table 4.2-1). Most of the larger fish were collected from TRM 425 and 435, but those collections also contained several small catfish (below 900g). The smallest fish came from TRM 457, where, except for one fish weighing 1,001g, the range was only 315 to 655g (average 560g).

Average lipid levels at each station in autumn 1989 were not as high as those observed in previous collections, but were still relatively high (above 10 percent) throughout the reservoir (table 4.2-1). Fish weight and percent lipids did not exhibit a consistent relationship; some of the smaller fish had the highest percent lipid content, e.g., 856g (20 percent); 347g (13 percent); 611g (17 percent). Conversely, some large fish had a low percentage of lipids, e.g., 1,268g (3 percent); 1,667g (4.8 percent); 1,532g (3.8 percent). Thus, although it can be generally expected that large fish will have relatively high lipid levels, there will obviously be exceptions, as exhibited in these samples.

A one-way analysis of variance and Duncan's Multiple Range Test were used to test location differences for fish size and lipid content (table 4.2-2). Lipid content did not differ among locations. Fish weight was significantly lower at TRM 457 than at the other three stations.

A one-way analysis of covariance was used to compare weight-per-unit length of channel catfish from Nickajack Reservoir to those in the TVA life history data file for mainstream Tennessee River reservoirs. Test results showed channel catfish collected in autumn 1989 from Nickajack were significantly heavier than those in this data file (table 4.2-3).

PCB Concentrations--The screening study in 1987 had found PCB concentrations of 1.9 and 1.3 µg/g in the composite samples from TRMs 425 and 457, respectively (Dycus 1989a). Analyses of individual catfish for a follow-up, intensive study (fish collected in January-February 1989) found lower concentrations at TRM 425 (average 0.9 µg/g and range 0.4 to 1.9 µg/g) than in the screening study, but similar concentrations at TRM 457 (average 1.3 µg/g and range 0.9 to 1.7 µg/g, Dycus 1990c). Concentrations at TRM 435 (not sampled in screening study) averaged 1.2 µg/g and ranged from 0.6 to 1.9 µg/g. Differences in concentrations between the two studies were not tested statistically because there were no replicate samples in the screening study.

Average PCB concentrations in the latest intensive study (autumn 1989) were lower at both TRM 435 and 457 (0.7 µg/g each) than in the previous 1989 collection, but higher (1.3 µg/g) at TRM 425 (Table 4.2-1). One male catfish from TRM 425 had a level of 2.0 µg/g and three others at this station had concentrations between 1.5 and 2.0 µg/g. One immature fish at TRM 457 also had a PCB level of 2.0 µg/g, although all the other individuals from there were below 1.0 µg/g. At the station in Chickamauga tailwaters, TRM 470, PCBs in the six-fish sample averaged
0.8 µg/g and ranged from 0.5 to 1.0.

PCB concentrations are often related to both fish size and lipid content. Preliminary regression tests did not detect a significant relationship between PCB concentration and lipid content or fish weight at any of the locations, so adjustment was unnecessary (table 4.2-4). A one-way analysis of variance indicated there were significant location differences in PCBs (table 4.2-5); Duncan's Multiple Range Test showed significantly higher PCB concentration at station TRM 425 than at all other stations. None of the other three station samples were significantly different from each other.

Absence of a significant relationship between PCB concentration and lipid content and/or fish weight is noteworthy. Such a result was also found for the previous Nickajack intensive study. These results differ from those for other trend studies on Fort Loudoun and Wilson Reservoirs, which have shown the importance of evaluating these relationships among locations and over time (Dycus and Lowery 1988, Dycus 1989b). The reasons for the lack of these relationships for catfish from Nickajack Reservoir is not clear at this point. Further study may shed light on this observation.

Multi-year comparisons were made with similar results, i.e, PCBs were not related with lipids or weight, so adjustments were unnecessary. A two-way ANOVA failed to identify significant differences among stations (TRM 425, 435, 457) or years; however the interaction between them was significant. The greatest difference in PCBs between years was at TRM 457, where the mean PCB concentration for catfish was much higher in early 1989 than in autumn 1989 sample.

The trend in January-February 1989 was a general increase in PCB concentrations from down to upstream; however, in autumn 1989, the reverse was generally true with higher concentrations at the two upper stations.

Chlordane--Chlordane concentrations in the composite catfish sample from the 1987 screening study were 0.21 µg/g at TRM 425 and 0.25 at TRM 457, both exceeding the tier 3 level of 0.20 µg/g. Concentrations observed in the more intensive January-February 1989 study averaged 0.22, 0.11 and 0.16 µg/g at TRM 425, 435, and 457 respectively. The larger sample of 36 fish from the autumn 1989 collection averaged <0.1 µg/g at all four locations; only at TRM 425 were any of the individual fish above 0.1, and none reached 0.2 µg/g (table 4.4-1).

A preliminary test indicated a significant relationships between chlordane concentration and catfish weight, but not between chlordane and lipid content, the reverse of what occurred in the previous intensive study (table 4.2-4). Occurrence of this significant relationship in the preliminary test indicates that the slope of the line regressing chlordane concentration against fish weight for at least one location was significantly different from zero, showing a need to adjust chlordane concentrations to a common weight. Covariance analysis adjusted for catfish weight indicated chlordane concentrations were different among the sites (table 4.2-4). Adjusted chlordane concentrations were significantly lower at TRM 435 than at 470 and 425, but not significantly different from TRM 457. Concentrations at the three stations other than TRM 435 were not significantly different from each other (table 4.2-5).

Multi-year statistical comparisons (covariance analysis) showed chlordane concentrations were significantly related to lipid content but not to fish weight, although the former relationship was not consistent, i.e, lines not parallel. The difference in time of year when the two collections were made may be a factor in this indicated dependency. The mid-winter collection of January and February 1989 on the average was composed of larger (heavier fish) with higher lipid content, whereas the autumn 1989 samples consisted of more smaller fish with fewer lipids.

The greatest significant difference in the multi-year comparisons of chlordane was at TRM 457, where the change in mean weight was greatest. However, chlordane concentrations decreased at all stations from the first to the second collection in 1989.

Other Species

Four striped bass were collected, two each at TRMs 425 and 470; a total of three sauger were collected at TRM 430 (2) and 470 (1). None of these game fish showed any unusual external or internal abnormalities. The limited size of this data set precludes any strong statements with respect to the condition and health of striped bass and sauger in Nickajack Reservoir.

Collection date, weight, length, and sex for individuals of these species are provided in table 4.2-6. Also included are lipid content, chlordane and PCB concentrations from analyses of those fish.

One female striped bass from TRM 425 had a chlordane concentration of 0.12 µg/g and lipid content of 11 percent. The other three striped bass and all three sauger had less than detectable levels of chlordane and low lipid content. PCBs were detected in five of the seven sport fish but concentrations were all below 1.0 µg/g (range 0.2-0.7 µg/g).

Results from these screening samples would appear to indicate little need to examine more closely PCB or chlordane concentrations in sauger; the same is true for PCBs in striped bass. Because one of the four striped bass had a chlordane concentration of <1.0 µg/g, examination of a larger sample is probably justified. Since only small samples of both sport fishes were available for tissue analyses in 1989, it would seem appropriate to reserve judgment on the limited

PCB/chlordane results obtained here until larger samples of sauger and striped bass fillets are available from Nickajack Reservoir.

4.2.3 Recommendations

Based on 1989 results, the State of Tennessee (TWRA) issued a precautionary advisory for catfish because of PCBs in Nickajack Reservoir (appendix C). This advisory suggests that children, pregnant women and nursing mothers avoid eating catfish from Nickajack and that all other persons limit their consumption of the catfish to 1.2 pounds per month. Because of this advisory, Nickajack went to the trend study stage, meaning ten catfish from each of two locations (TRM 425 and 457) were collected in autumn 1990, for individual analysis of both PCBs and chlordane.

Table 4.2-1. Physical Characteristics and Concentrations (µg/g wet weight) of Chlordane and PCBs in Channel Catfish from Nickajack Reservoir, Collected October and November 1989

Mile[a]	Collection Date	Species	Sex	Length	Weight	Percent Lipid	Cl	PCB
425	11/01/89	CHC[b]	male	412	721	6.1	0.11	0.9
425	11/01/89	CHC	male	445	856	20.0	0.14	2.0
425	11/01/89	CHC	female	502	1268	3.0	0.09	1.6
425	11/01/89	CHC	immature	339	347	13.0	0.06	1.2
425	11/01/89	CHC	female	331	346	8.9	0.02	0.6
425	11/02/89	CHC	male	565	1798	14.0	0.05	0.9
425	11/02/89	CHC	male	529	1613	9.4	0.14	1.6
425	11/02/89	CHC	female	429	692	11.0	0.04	1.0
425	11/02/89	CHC	male	548	1667	4.8	0.17	1.8
425	11/02/89	CHC	male	482	1170	13.0	0.07	1.2
$\bar{x}$					1048	10.3	0.09	1.3
435	10/18/89	CHC	male	439	815	8.5	0.06	0.6
435	10/18/89	CHC	female	498	1450	12.0	0.09	1.2
435	10/18/89	CHC	female	392	638	12.0	0.06	0.9
435	10/18/89	CHC	female	498	1264	8.1	0.01	0.6
435	10/19/89	CHC	female	450	1060	11.0	0.06	0.7
435	10/19/89	CHC	male	420	700	3.4	0.02	0.7
435	10/19/89	CHC	female	494	1439	15.0	0.07	0.9
435	10/19/89	CHC	female	443	919	10.0	0.03	0.6
435	10/19/89	CHC	male	645	3204	13.0	0.02	0.4
435	10/24/89	CHC	male	457	914	9.4	0.04	0.6
$\bar{x}$					1240	10.2	0.05	0.7
457	12/11/89	CHC	female	436	638	3.2	0.02	0.6
457	12/11/89	CHC	immature	344	315	8.4	0.03	0.8
457	12/11/89	CHC	female	408	557	10.0	0.03	0.6
457	12/11/89	CHC	female	332	308	9.5	0.05	0.8
457	12/11/89	CHC	female	374	458	11.0	0.10	0.7
457	12/11/89	CHC	female	406	655	17.0	0.05	0.9
457	12/11/89	CHC	immature	348	327	8.5	0.02	2.0
457	12/11/89	CHC	female	415	611	17.0	0.06	0.9
457	12/11/89	CHC	female	470	1001	16.0	0.09	0.7
457	12/11/89	CHC	male	438	727	8.0	0.06	0.9
$\bar{x}$					560	10.9	0.05	0.7
470	11/16/89	CHC	female	375	454	11.0	0.07	0.8
470	11/16/89	CHC	female	542	1532	3.8	0.09	1.0
470	11/16/89	CHC	female	361	409	9.2	0.06	0.5
470	11/16/89	CHC	male	474	1280	8.4	0.06	0.6
470	11/16/89	CHC	female	442	781	12.0	0.09	0.7
470	11/16/89	CHC	female	583	2591	21.0	0.11	0.9
$\bar{x}$					1175	10.9	0.08	0.8

a. Tennessee River Mile
b. CHC = Channel Catfish

Table 4.2-2. Results of One-Way Analysis of Variance and Duncan's Multiple Range Test on Lipid Content, Length, and Weight of Channel Catfish Among Locations in Nickajack Reservoir, Fall 1989

		Duncan's Multiple Range Test[a]			
Parameter	P>F	Location with Lowest Mean			Location with Highest Mean
Lipid content	0.9841				
Length	0.0918				
Weight	0.0237	TRM 457	TRM 425	TRM 470	TRM 435

a. Locations underscored by same line were not significantly different at $\alpha = 0.05$; lines not so underscored were significantly different.

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Table 4.2-3. Results of Analysis of Covariance Comparing Length/Weight Relationship of Channel Catfish from Nickajack Reservoir to Channel Catfish Contained in the TVA Life History Data File for Mainstem Reservoirs on the Tennessee River

Preliminary Test Used to Determine Need to Adjust Weight to Common Length	Decision	Test of Parallel Lines	Results of Analyses of Covariance
Sign; P>F = 0.0001	Use analysis of covariance	Lines parallel; use of covariance appropriate	Nickajack > Life History (P>F = 0.0001)

Table 4.2-4. Results of Statistical Tests Used To Compare Location Differences in PCB and Chlordane Concentrations in Channel Catfish from Nickajack Reservoir, 1989

Analyte	Parameter	Preliminary Test (Is there a significant relationship between analyte and parameter)	Decision based on preliminary test	If ANOVA (P>F)	If analysis of covariance (test of parallel lines	Analysis of covariance results
PCB	Lipid content	No (P>F = 0.9783)	Use ANOVA	0.0040	N/A	N/A
	Weight	No (P>F = 0.6340)	Use ANOVA	0.0040	N/A	N/A
Chlordane:	Lipid content	No (P>F = 0.3885)	Use ANOVA	0.0256	N/A	N/A
	Weight	Yes (P>F = 0.0374)	Lipid adjustment not needed, but must use covariance analysis to adjust for weight	N/A	P>F = 0.3769	P>F = 0.0150 sites differ

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Table 4.2-5. Results of One-Way Analysis of Variance and Duncan's Multiple Range Test on PCBs and Chlordane Concentrations Among Locations in Nickajack Reservoir, Fall 1989

Parameter	P>F	Duncan's Multiple Range Test[a]			
		Location with Lowest Mean			Location with Highest Mean
PCB	0.0040	TRM 435	TRM 470	TRM 457	TRM 425
Chlordane	0.0256	TRM 435	TRM 457	TRM 470	TRM 425

a. Locations underscored by same line were not siginficantly different at α = 0.05; lines not so underscored were significantly different.

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Table 4.2-6. Physical Characteristics and Concentrations (μg/g Wet Weight) of Chlordane and PCB in Striped Bass and Sauger from Nickajack Reservoir, collected October, November 1989

Mile	Species[a]	Collection Date	Sex	Length (mm)	Weight (g)	% Lipid	Cl (μg/g)	PCBs (μg/g)
TRM 425	STB	10-31-89	F	588	2,592	11.0	0.12	0.7
	STB	11-2-89	F	395	767	5.0	<0.01	0.5
TRM 435	S	10-11-89	F	476	1,016	2.0	<0.01	<0.1
	S	10-31-89	M	397	618	1.0	<0.01	<0.1
TRM 470	STB	11-17-89	F	342	482	5.0	<0.01	0.2
	STB	11-17-89	F	383	779	5.0	<0.01	0.3
	S	11-16-89	F	434	850	4.0	<0.01	0.3

a. STB = Striped bass; S = Sauger

4.3 Watts Bar Reservoir

After several years of extensive PCB examinations, Watts Bar Reservoir is now considered to be in the trend study stage, looking at PCB contamination over time. Previous collections (1985-88) identified substantial PCB contamination in catfish and striped bass (Dycus and Hickman, 1988; Dycus 1990d). The tailwaters area of Fort Loudoun Dam was first examined in 1985, and the study reach was expanded downstream each year thereafter. The first collection of fish from the entire length of Watts Bar Lake to look at the extent of contamination was in 1988; these included channel catfish collections from four locations between TRM 532 (near Watts Bar Dam) and TRM 598 (near Fort Loudoun Dam) and one location on the Clinch River (CRM 2) near its confluence with the Tennessee River. Individual striped bass and smallmouth buffalo and composites of largemouth bass, crappie and sauger were also collected in 1988 and analyzed to determine if there was a potential problem with those important game and commercial species.

Catfish from another location on the Clinch River (CRM 19), near Melton Hall Dam, collected and analyzed by Oak Ridge Natural Laboratory (ORNL) were provided in the TVA report (Dycus, 1990d) but not included in the statistical analyses. Chlordane analyses were also run on fish from several stations in the Clinch River for 1988; results were reported in appendix A of Dycus (1990d).

This document describes the results of PCB analyses of fish collected from Watts Bar Reservoir in the fall and winter of 1989-90 and compares them to results from previous year. Chlordane analyses are again reported as results from interlab split samples, but this time included in discussion and comparison with 1988 data. Results were shared among all members of the study team as soon as they were received from the analytical laboratories, rather than waiting for this formal report. Therefore, decisions on selection of study design for autumn 1990 were made considerably before completion of this report. Health advisories already in effect for Watts Bar Lake indicating catfish, striped bass and hybrid striped bass should not be consumed, and precautionary advisories for white bass, sauger, carp, smallmouth buffalo, and largemouth bass, were to remain unchanged.

4.3.1 Methods

Channel catfish were to be collected in fall 1989 at or near the same five Watts Bar Reservoir locations as in 1988. TVA was responsible for ten channel catfish at TRM 598 below Fort Loudoun Dam and ten channel catfish from TRM 570. ORNL was responsible for collecting ten catfish from CRM 1 and from TRM 531 and TRM 557, as well as eight catfish from each of two additional stations (CRM's 9 and 20) farther upstream on the Clinch River. A detailed split-sample analytical effort among the various involved interagency labs was undertaken because of the desire to combine data sets. Details of the analytical results and QA/QC procedures for the split samples described in appendix B. Comparative statistical analyses were done on all 62 channel catfish from the seven locations in 1989 for lipids and PCBs. Chlordane analyses were run on the split sample for TRM 570, on seven catfish for TRM 598 and for individual fish from TRM 557 and 532, but statistical comparisons were not done on chlordane.

In addition to the catfish samples, sauger and striped bass were to be collected and analyzed by the TVA laboratory for continued examination of potential problems with game species in the Watts Bar reservoir area. Ten sauger were to be collected from TRM 598 and CRM 1 and ten striped bass from TRM 532. Because insufficient samples by year and location were available statistical analyses were not run for game species. Except for the split samples mentioned above, all procedures involved in field sampling and processing, laboratory and data analyses were similar to those described for Wilson Reservoir earlier in section 4.1 of this report and will not be repeated here. Each fish was analyzed individually.

4.3.2 Results and Discussion

Channel Catfish

Physical Characteristics-Previous observations on channel catfish from throughout Watts Bar Reservoir had found no external anomalies, but internal parasites were noted in about 30 percent of the fish from the upper part of the lake in 1988-87. In 1988, a much higher occurrence (90 percent) of internal parasites was found in catfish from the forebay area (TRM 532) near the dam.

Observations on physical conditions of catfish in 1989 were only made in the TVA collections at TRMs 570 and 600. Observations on external conditions were similar to 1988, i.e, no external anomalies, but internal parasites were numerous at TRM 600; 90 percent of the catfish there had from >5 to <50 parasites mostly on the liver but also observed in the kidney and spleen. At TRM 570, only one of the ten fish had internal parasites.

Sizes (length and weight) and lipid content of catfish analyzed from 1989 are summarized in table 4.3-1 and detailed in table 4.3-2.

Neither fish weight nor lipid content differed significantly among sample locations in 1989 (table 4.3-3).

PCB Concentrations--PCB concentrations in catfish collected in 1989 and previous years are detailed in table 4.3-2 and summarized in table 4.3-4.

In 1988, the first year for PCB examinations throughout the entire length of Watts Bar Reservoir, concentrations averaged 1.4, 2.7, 2.1 and 2.4 µg/g at TRMs 532, 569, 573, and 598, respectively. Maximum concentrations at those same four stations were 4.3, 7.5, 7.4, and 4.4. Two other locations the Clinch River arm (CRM 2 & 19) averaged 2.2 & 0.6 µg/g with maxima of 4.2 and 2.4 µg/g (table 4.3-4). More important, at all of the stations except the one farthest up the Clinch River, from 40 to 60 percent of the sampled fish contained concentrations above the FDA tolerance level 2.0 µg/g. In 1989, the PCB levels were much improved (table 4.3-4). Mean concentrations were below 2.0 µg/g at all stations, and, except for station TRM 570 where 30 percent of the individual catfish showed levels above 2.0 µg/g, two stations had no fish and three stations had only one of ten fish above that level.

Statistical examination of the 1989 results indicated PCB levels were significantly different between TRM stations 598 & 557 with the former having higher levels. Analysis of covariance was used to adjust PCB levels for lipid content and weight, since preliminary tests for both were significant (table 4.3-5). However, the test for parallel lines in lipid content indicated non-parallel lines, due primarily to negative relationship of PCB concentration to lipid content at station CRM 9.3; therefore, the covariance test on lipid content was not appropriate. The test adjusting PCB concentrations for fish weight found significantly lower levels at TRMs 557 and 532 than at the other sample stations on the main Tennessee River; those levels were more similar to those on the lower Clinch River. Lower PCB concentrations in catfish from the downstream end of Watts Bar Reservoir were also noted in 1988 samples (Dycus 1990d).

Year-to-year differences (1988-89) were also tested statistically, since data were available for all locations for the first time. A two-way ANOVA showed no significant differences for lipid content or fish size by location. Fish weights did not differ significantly between 1988 and 1989, but lipid content was significantly greater in 1988 (table 4.3-6).

The preliminary test on PCB concentrations found adjustment was needed for both lipid content, and weights and the parallel line test showed use of covariance analysis was appropriate. The two-way analysis of covariance (with lipid adjustment) found PCBs were not significantly different among locations, but they were different between the two years with significantly lower PCB concentrations in 1989 than in 1988 (table 4.3-7). With adjustments for weight, PCB levels at TRM 532 were different from all other locations, which were not significantly different from one another, and the difference between years was also significant (table 4.3-7).

The station immediately below Fort Loudoun Dam (TRM 598/600) was selected for analysis of PCB over time, because data were available for 1985 through 1989. During that period mean PCB levels were 1.4, 2.7, 1.5, 2.4 and 1.8 µg/g, respectively. Maximum levels were 2.0, 4.3, 3.1 4.4, and 1.8, respectively. No definite pattern of increased or decreased concentrations was evident, i.e, mean and maximum concentration fluctuated through the years. Highest levels were found in 1986 and 1988. In 1988, 50 percent of the ten-fish samples had concentrations above 2.0 μg/g; in the latest sample (1989) two of seven fish exceeded that level (table 4.3-4).

Various statistical tests were run on the five-year data set for TRM 598. Preliminary tests showed significant relationship between PCB concentration and lipid content, but not to weight. Fish weights were not significantly different, but lipid contents were among years. Lipid content was much higher in 1985 than in all other years. PCB levels (adjusted for lipid content) showed significant differences by years (table 4.3-8). Concentrations were highest in 1986 and 1988, lowest in 1985 and 1987, and intermediate in 1989. Thus, no trend or pattern of increase or decrease has been observed for PCB concentrations in channel catfish at station 598 in Watts Bar in the last five years.

Chlordane--Chlordane analyses were run on ten channel catfish from TRM 570 and on seven from TRM 598/600. Total chlordane at TRM 570 ranged from <.01 to 0.32 μg/g and at TRM 600 from 0.02 to 0.49 μg/g. Mean concentrations were 0.16 and 0.19 μg/g, respectively. Only one fish at each location showed a concentration of $\geq$ 0.3 (the FDA action level for chlordane), although several others were between 0.2 and 0.3 μg/g (table 4.3-2). Additional details on chlordane data and statistical analyses are presented in the discussion on inter-laboratory split samples later in this report.

Other Species

Striped bass and hybrids--Ten striped bass and hybrids were collected at TRM 532 in January 1990. Most had numerous nematodes in the mesentery and intestines. Weights ranged from 666 to 2673 grams (table 4.3-2).

PCB concentrations in these fish ranged from 0.4-0.8 and averaged 0.5 µg/g. This represents a considerable decrease from fall 1988 when mean PCB concentration in striped bass/hybrids from the same location was 2.0 µg/g, with a range of 0.2 to 4.8 µg/g. In 1988, three striped bass had concentrations above 2.0 µg/g; in 1990, none of the ten striped bass had concentrations at that level.

Sauger--Sauger were collected at two locations in Watts Bar Reservoir in 1989/90; nine fish at TRM 598/600 in November 1989 and eight at CRM 2 in January 1990. Weights ranged from 554 to 1159g at TRM 600 and from 699 to 2201g at CRM 2. None of the former had notable internal or external abnormalities; two of the sauger at CRM 2 had tumors or parasites in the spleen.

PCB concentrations were relatively low in sauger from both locations--means of 0.4 and 0.3 µg/g at TRM 600 and CRM 2, respectively, with no individual fish ≥ 1.0 µg/g.

4.3.3 Recommendations

PCB concentrations in channel catfish from Watts Bar Reservoir were much improved over those sampled in 1988. Mean concentrations decreased at all stations, and the number of fish with levels of ≥ 2.0 µg/g was dramatically lower. Of 40 fish analyzed in 1988, from the four main reservoir stations, almost 50 percent (19) had levels ≥ 2.0; in 1989, out of 36 individual catfish only five (<14 percent) were ≥ 2.0 µg/g. However, catfish from the upper reservoir stations (TRM 570/598) still contained high PCB levels with several individual fish at each station ≥ 2.0 μg/g. Striped bass and sauger had much lower PCB levels in 1989/90 than in previous samples, but it is too soon to tell if either of these conditions represents a trend. Analysis of catfish samples at the one station (TRM 598) over a five-year period showed considerable year-to-year fluctuation in PCB levels, which may be the typical situation rainfall and runoff conditions vary annually.

Decisions on selection of study design for fall 1990 in Watts Bar Reservoir were made by the study team considerably before completion of this report. Although decreased PCB levels were noted in fish from all Watts Bar locations and there were considerably fewer fish with high levels above 2.0 μg/g, it was decided to continue the sampling and analysis of PCB levels in catfish at the same four locations in the main reservoir and those in the Clinch River to further determine if a trend in decreasing PCB levels was actually occurring, or if 1989 was just a year of downward fluctuation. Striped bass samples were also to be collected at the lowest and uppermost reservoir stations (TRM 532 and 598). Chlordane levels would also be analyzed on all fish samples. Health advisories and precautions against eating fish already in effect on Watts Bar Reservoir were to remain unchanged.

Table 4.3-1. Summary (Minimum, Maximum and Mean) for Lengths, Weights and Lipid Contents in Channel Catfish from Watts Bar Reservoir, 1989 and Previous Years

Location	Year	Number	Length (mm)			Weight (g)			Lipid Content (%)		
			Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
TRM 532	1988	10	398	706	531	494	4210	1763	0.7	16.0	4.6
	1989	10*	342	562	465	320	1695	1033	1.0	5.0	2.9
TRM 565	1987	6	310	561	470	239	1786	1103	1.4	3.8	2.5
565	1988	10	390	657	492	411	2765	1124	0.9	13.0	5.5
557	1989	9*	347	500	398	324	1015	544	0.8	4.3	2.1
TRM 573	1987	10	436	640	492	806	2814	1225	1.5	8.3	4.9
	1988	10	346	615	450	264	2425	929	0.2	7.6	3.7
TRM 570	1989	10	339	649	466	431	2742	1063	1.5	6.4	3.9
TRM 598	1987	10	360	523	457	336	1330	757	3.3	7.3	5.3
	1988	10	452	659	504	829	2957	1289	2.1	8.5	5.2
	1989	7	382	666	514	425	3229	1437	0.8	14.0	5.9
CRM 0.5/2.0	1988	8	435	605	510	745	2262	1278	0.1	11.0	5.3
	1989	10*	368	620	435	393	2380	794	1.0	5.8	3.3
CRM 9	1989	8*	400	523	440	521	1505	755	0.4	6.4	3.5
CRM 20/21	1988	10	370	790	513	406	1118	1774	1.0	11.5	3.8
	1989	8*	374	530	443	414	1321	736	0.3	7.0	3.3

*Collected by Oak Ridge National Laboratory

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Table 4.3-2. Detailed information on physical characteristics, lipid content, PCB concentration, and chlordane (μg/g wet weight) for each fish collected from Watts Bar Reservoir, 1989 and 1990[a]

LOCATION[b]		DATE	SPECIES[c]	SEX	LENGTH (mm)	WEIGHT (g)	LIPIDS (%)	TOTAL PCBS (μg/g)	CHLORDANE (μg/g)
CRM	0.5	.	CHC	.	478	915	.	1.2	.
CRM	0.5	.	CHC	.	620	2380	.	3.8	.
CRM	0.5	.	CHC	.	407	595	.	1.0	.
CRM	0.5	.	CHC	.	415	628	.	1.1	.
CRM	0.5	.	CHC	.	368	415	.	0.4	.
CRM	0.5	.	CHC	.	375	393	.	0.2	.
CRM	0.5	.	CHC	.	430	552	.	0.4	.
CRM	0.5	.	CHC	.	388	428	.	0.2	.
CRM	0.5	.	CHC	.	500	1234	.	0.5	.
CRM	0.5	.	CHC	.	371	401	.	1.2	.
CRM	9.3	.	CHC	.	40	548	.	0.6	.
CRM	9.3	.	CHC	.	43	569	.	0.0	.
CRM	9.3	.	CHC	.	44	665	.	0.4	.
CRM	9.3	.	CHC	.	41	521	.	1.2	.
CRM	9.3	.	CHC	.	46	811	.	0.4	.
CRM	9.3	.	CHC	.	52	1505	.	1.3	.
CRM	9.3	.	CHC	.	45	827	.	0.3	.
CRM	9.3	.	CHC	.	41	592	.	2.1	.
CRM	20.0	.	CHC	.	53	1273	.	0.5	.
CRM	20.0	.	CHC	.	37	414	.	1.3	.
CRM	20.0	.	CHC	.	48	504	.	0.7	.
CRM	20.0	.	CHC	.	39	448	.	0.9	.
CRM	20.0	.	CHC	.	40	479	.	0.5	.
CRM	20.0	.	CHC	.	41	486	.	0.7	.
CRM	20.0	.	CHC	.	47	962	.	2.0	.
CRM	20.0	.	CHC	.	50	1321	.	3.1	.
TRM	530.5	.	CHC	.	562	1483	.	0.7	.
TRM	530.5	.	CHC	.	466	986	.	1.2	.
TRM	530.5	.	CHC	.	398	527	.	0.3	.
TRM	530.5	.	CHC	.	456	795	.	0.8	.
TRM	530.5	.	CHC	.	342	320	.	0.2	.
TRM	530.5	.	CHC	.	433	702	.	1.5	.
TRM	530.5	.	CHC	.	491	1070	.	0.7	.
TRM	530.5	.	CHC	.	456	1125	.	1.1	.
TRM	530.5	.	CHC	.	532	1695	.	1.0	.
TRM	530.5	.	CHC	.	515	1634	.	0.4	.

Table 4.3-2 (continued)

LOCATION [b]	DATE	SPECIES [c]	SEX	LENGTH (mm)	WEIGHT (g)	LIPIDS (%)	TOTAL PCBS (µg/g)	CHLORDANE (µg/g)
TRM 557.0	.	CHC	.	347	377	.	0.2	.
TRM 557.0	.	CHC	.	365	372	.	0.0	.
TRM 557.0	.	CHC	.	375	324	.	0.5	.
TRM 557.0	.	CHC	.	500	1013	.	0.5	.
TRM 557.0	.	CHC	.	432	700	.	0.4	.
TRM 557.0	.	CHC	.	445	668	.	0.5	.
TRM 557.0	.	CHC	.	375	502	.	0.2	.
TRM 557.0	.	CHC	.	372	504	.	0.4	.
TRM 557.0	.	CHC	.	369	436	.	0.1	.
TRM 570.0	891011	CHC	FM	408	431	2.3	1.1	0.1
TRM 570.0	891011	CHC	FM	339	268	1.5	0.2	0.0
TRM 570.0	891012	CHC	FM	622	2742	6.4	2.3	0.3
TRM 570.0	891012	CHC	MA	649	2582	6.0	2.5	0.3
TRM 570.0	891013	CHC	MA	455	917	6.3	1.6	0.3
TRM 570.0	891013	CHC	FM	450	895	1.9	0.9	0.1
TRM 570.0	891013	CHC	FM	500	1100	5.2	2.3	0.3
TRM 570.0	891013	CHC	FM	414	626	2.8	1.2	0.1
TRM 570.0	891013	CHC	MA	388	433	2.5	0.4	0.0
TRM 570.0	891013	CHC	FM	439	633	3.8	0.8	0.1
TRM 598.0	891107	CHC	MA	608	1581	2.5	1.4	0.2
TRM 598.0	891107	CHC	MA	417	613	14.0	4.2	0.5
TRM 598.0	891107	CHC	MA	505	1241	6.5	0.8	0.1
TRM 598.0	891107	CHC	MA	666	3229	6.7	2.6	0.3
TRM 598.0	891107	CHC	MA	620	2508	4.3	1.8	0.2
TRM 598.0	891107	CHC	MA	382	425	5.0	1.4	0.1
TRM 598.0	891107	CHC	MA	402	466	0.8	0.4	0.0
TRM 600.0	891107	SAU	FE	478	1016	2.3	0.1	.
TRM 600.0	891107	SAU	FE	465	1061	2.2	0.1	.
TRM 600.0	891107	SAU	FE	482	1082	2.7	0.8	.
TRM 600.0	891107	SAU	MA	413	616	2.4	0.1	.
TRM 600.0	891107	SAU	FE	432	761	1.2	0.1	.
TRM 600.0	891107	SAU	FE	460	978	2.2	0.2	.
TRM 600.0	891107	SAU	FE	483	1159	2.4	0.1	.
TRM 600.0	891107	SAU	MA	400	554	1.2	0.2	.
TRM 600.0	891107	SAU	FE	556	1581	4.7	0.9	.
CRM 2.0	900122	SAU	FE	545	1967	4.6	0.5	.
CRM 2.0	900122	SAU	FE	405	729	2.2	0.2	.
CRM 2.0	900123	SAU	FE	488	1321	5.2	0.2	.
CRM 2.0	900123	SAU	FE	568	2201	4.6	0.5	.
CRM 2.0	900123	SAU	FE	463	1267	4.0	0.2	.
CRM 2.0	900123	SAU	FE	526	1785	4.8	0.4	.
CRM 2.0	900124	SAU	FE	476	1246	3.3	0.2	.
CRM 2.0	900124	SAU	MA	418	699	2.0	0.2	.

Table 4.3-2 (continued)

LOCATION[b]		DATE	SPECIES[c]	SEX	LENGTH (mm)	WEIGHT (g)	LIPIDS (%)	TOTAL PCBS (µg/g)	CHLORDANE (µg/g)
TRM	532.0	900131	STB	MA	384	805	9.6	0.4	.
TRM	532.0	900131	STB	MA	527	1968	13.0	0.8	.
TRM	532.0	900131	STB	FE	510	1642	10.0	0.5	.
TRM	532.0	900131	STB	FE	555	2166	14.0	0.7	.
TRM	532.0	900131	STB	MA	364	666	11.0	0.3	.
TRM	532.0	900131	STB	MA	585	2675	9.8	0.8	.
TRM	532.0	900131	STB	FE	590	2573	12.0	0.6	.
TRM	532.0	900131	STB	MA	377	764	12.0	0.4	.
TRM	532.0	900131	STB	FE	573	2422	17.0	0.7	.
TRM	532.0	900131	STB	FE	656	3512	9.4	0.5	.

a. Some detailed information on samples collected by ORNL (date, sex, % lipids, and chlordane concentrations) was not available for this report; chlordane was not analyzed in sauger from TRM 600 and CRM 2, nor in striped bass/hybrids from TRM 532.

b. TRM = Tennessee River Mile; CRM = Clinch River Mile

c. Species: CHC = Channel Catfish; SAU = Sauger; STB = Striped bass

Table 4.3-3. Results of One-Way Anova on Channel Catfish Weight and Lipid Content Among Sample Sites on Watts Bar Reservoir in 1989

	P>F
Lipid Content	0.1223
Weight	0.1681

Table 4.3-4. Summary of Total PCB Concentrations in Catfish Fillets from Watts Bar Reservoir in 1987, 1988, and 1989

Year	TRM 530-532	TRM 557-562	TRM 570-573	TRM 598-600	CRM 0.5-2.0	CRM 9.0-9.3	CRM 19-20.5
1987							
Range	NS	0.1-4.4	0.9-3.0	0.4-3.1			
Mean		1.4	2.1	1.5	NS	NS	NS
Number ≥2.0 µg/g		1	6	3			
Number of fish		6	10	10			
1988							
Range	0.1-4.3	1.3-7.5	0.1-7.4	0.8-4.4	0.1-4.6		0.2-2.4
Mean	1.4	2.7	2.1	2.4	2.2		0.6
Number ≥2.0 µg/g	4	6	4	5	4	NS	1
Number of fish	10	10	10	10	8		8
1989							
Range	0.2-1.5	0.1-0.5	0.2-2.5	0.4-4.2	0.2-3.8	0.3-2.1	0.9-3.1
Mean	0.8	0.3	1.3	1.8	1.0	0.8	1.2
Number ≥2.0 µg/g	0	0	3	2	1	1	1
Number of fish	10	9	10	7	10	8	8

NS = No Sample from that location.

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Table 4.3-5. Results of Statistical Tests Used to Compare PCB Concentrations in Channel Catfish Among Sample Locations on Watts Bar Reservoir, 1989

Parameter	Preliminary Test (Is there a significant relationship between PCB concentration and parameter?)	Decision based on preliminary test	If covariance used (test of parallel lines)	Covariance results (P>F)
Lipid content	Yes	Adjust PCB concentration for both lipid content and weight; use analysis of covariance	Lines not parallel	N/A
Fish Weight	Yes		Lines parallel	P>F = 0.0023 TRM 557, TRM 532, CRM 9.0, CRM 0.5, TRM 570, CRM 20, TRM 598

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Table 4.3-6. Two-Way Anova and Duncan's Multiple Range Test on Lipid Content and Total Weight of Channel Catfish from Watts Bar Reservoir, 1988 and 1989 (Location and Year Main Effects)

	P>F	Duncan's Multiple Range Test[a] Mean Rank Low to High
Lipid Content		
Location	0.2511	-
Year	0.0222	1989 1988
Interaction	0.1533	-
Total Weight		
Location	0.1304	-
Year	0.0664	-
Interaction	0.2751	-

a. Location or years underscored were not significantly different at $\alpha = 0.05$; years not so underscored were significantly different.

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Table 4.3-7. Decision Path Followed and Results of Two-Way Testing (Location and Year) by Analysis of Variance or Covariance for PCB Concentration in Channel Catfish from Watts Bar Reservoir, 1988 and 1989

Species	Parameter	Preliminary test results (Is there a significant relationship between PCB concentration and parameter?)	Decision based on preliminary test	If covariance used (test of parallel line)		Covariance results (P>F)
Channel catfish	Lipid content	Yes	Adjust PCB concentration for lipid content; use covariance	Lines parallel	Location	0.3626
					Year	0.0022*
					Interaction	0.1145
	Weight	Yes	Adjust PCB concentration for weight; use covariance	Lines parallel	Location	0.0121
					Year	0.0008*
					Interaction	0.0176

*PCB concentrations were significantly lower in 1989 than in 1988.

Table 4.3-8. Results of Statistical Tests Used to Compare PCB Concentrations in Channel Catfish at Station TRM 598/600 Over A 5-Year Period, 1985-89

Parameter	Preliminary Test (Is there a significant relationship between PCB concentration and parameter?)	Decision based on preliminary test	If covariance used (test of parallel lines)	Covariance results (P>F)
Lipid content	Yes	Adjust PCB concentration for lipid content use covariance	Lines parallel	P>F = 0.0002 1985 1987 1989 1988 1986
Fish Weight	No	No need to adjust	N/A	

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4.4 Fort Loudoun Reservoir

Contamination of catfish (mostly channel catfish) and largemouth bass with PCBs in Fort Loudoun Reservoir, especially the Little River embayment, has been known for several years. Several warnings and advisories (the latest 1991; appendix C) have been issued by the Tennessee Department of Health and Environment (TDHE) against consumption of catfish and largemouth bass from Fort Loudoun Lake, and the Tennessee Wildlife Resources Agency (TWRA) has banned commercial fishing for catfish there.

A series of samples of catfish was collected throughout Fort Loudoun Reservoir in 1981, and PCB concentrations above 2.0 µg/g were found at four of five stations. The worst conditions were at Little River, where 62 of 64 catfish had levels above 2.0 µg/g and the mean concentration was 6.6; the second-highest level (4.5 µg/g) was found at TRM 628. In 1985, sampling was expanded to seven stations; in catfish, PCB levels above 2.0 µg/g were found at five locations, with the highest level in Little River, where the mean concentration from ten fish was 4.4 µg/g, with seven of those registering above 2.0. A small number (one-three) of bass at five of the stations had PCB concentrations above 2.0 µg/g.

Beginning in 1987, catfish and bass samples for PCBs each year were confined to the Little River embayment, (the area considered to be the primary source of PCBs in Fort Loudoun Reservoir) and an area in the main body of the reservoir (TRM 628), a few miles downstream from the confluence of Little River with the Tennessee River. In 1987, PCB levels in catfish showed a considerable decrease from those in 1985, although the mean concentration at both locations was still slightly above

2.0 μg/g. These lower levels in 1987 were interpreted as a possible indication that PCB levels in Fort Loudoun Reservoir catfish might be decreasing over time. However, results in 1988 contradicted that when the mean concentration at Little River station rose to 3.5 μg/g, and eight of ten catfish there contained had levels above 2.0. Since 1987, only the Little River location had any largemouth bass with PCB concentrations above 2.0 μg/g. Samples were collected again in autumn of 1989 to examine the temporal trend in PCB concentrations in Fort Loudoun.

This document describes the results of PCB analysis of catfish and bass collected from Fort Loudoun Reservoir in the autumn of 1989 and compares them to results from previous years. The results were shared with cooperating state and federal agencies as soon as they were received from the analytical laboratory, and decisions on updating existing advisories and selection of study design for autumn 1990 were necessarily made months before this document was prepared. The Public Health Advisory issued in April 1989 against eating catfish and bass from Fort Loudoun Reservoir remained in effect through the 1990 sampling period.

4.4.1 Methods

Study design in 1989 included a special effort to evaluate the effect of different fillet techniques on PCB concentration. The protocol used to date had been to analyze complete fillets (i.e., ribs and bellyflap attached) with skin removed from catfish and skin left on scaled fish, such as largemouth bass, which had scales removed. No particular effort was taken to avoid puncturing internal organs during fillet removal. This protocol provides what could be considered a worst-case fillet concentration.

An alternative procedure was being considered for adoption by TVA because the procedure had been recommended by the Mid-American Fish Contaminants Group, of which TVA was a member. This alternative procedure differs from the TVA procedure, in that, care is taken not to puncture internal organs, and ribs with adjoining musculature are removed from the fillet. The procedure is flexible concerning the bellyflap which could be retained or discarded. For this test, the bellyflap was retained with the fillet for analysis.

The test was conducted on 20 channel catfish from Little River and 20 from TRM 628. Ten largemouth bass were also collected from TRM 628 and processed the same as in previous years. Following measuring, weighing, and making observations on external characteristics of a catfish, a coin was tossed to determine if the right or left fillet was to be removed using the alternative procedure. The other fillet was then removed using the old procedure. Each fillet was then wrapped in aluminum foil and placed in a separate, labeled plastic bag. Fillets were handled the same after that point.

A paired T-test was used to examine differences in PCB concentrations and lipid content between the two fillets from each fish. The level of significance chosen was 0.05.

Other procedures involved in field sampling and processing, laboratory and data analyses were similar to those described earlier in this report for Wilson Reservoir (section 4.1) and will not be repeated here. Each fillet was analyzed individually.

4.4.2 Results and Discussion

Channel Catfish

All the desired catfish at TRM 628 were collected in November 1989; three catfish from Little River were taken in October, and the remaining 17 in December 1989.

Physical Characteristics--In the early years (1981-85) of this Fort Loudoun study, catfish collected in the vicinity of Little River were in poorer condition and had more anomalies than those from other sections of the reservoir. In 1987 and 1988, most of the catfish collected in the reservoir had no observed parasites or external anomalies. In 1989, however, nine of 20 catfish from TRM 628 had parasites on the liver, two were skinny, one was blind, and one had a small spleen. In the Little River sample of 20 catfish, four were observed to be skinny, seven had swollen kidneys, and 13 had numerous internal parasites, mostly on the liver, but also on the kidneys, spleen and throughout the gut cavity on some. Fish conditions in 1989 appeared to be similar to the poorer conditions observed in 1981 and 1985 and a reversal of the improved conditions noted in 1987 and 1988.

Sizes (length and weight) of catfish analyzed from 1989 are summarized in table 4.4-1 and detailed in table 4.4-2. Neither catfish weight nor lipid content differed significantly between the two sample locations in 1989 (table 4.4-3). A two-way ANOVA indicated lipid content did not differ significantly among years or locations; but fish weight did with heavier fish collected in the last three years than in 1985 (table 4.4-4).

PCB Concentrations--PCB concentrations in catfish collected in 1989 and previous years are summarized in table 4.4-5; details for 1989 are given in table 4.2-2. Mean concentrations in 1989 were 2.1 and 4.2 µg/g at TRM 628 and Little River, respectively. These results are higher than in 1987 and 1988 at both stations. At Little River, the mean concentration was a continuation of the increase over the last three years, and the 1989 level there was nearly back to that found in 1985. Of the total 20 catfish from Little River, 16 had a PCB concentration of more than 2.0 µg/g, the FDA Tolerance level; at TRM 628, nine of 20 fish were above the 2.0 µg/g level.

Preliminary statistical tests showed no significant relationship between PCB concentration and lipid content, but there was a significant relationship between PCBs and fish weight. Tests were run on 1989 data alone for location differences (table 4.4-6) and on data for all years to examine year and location differences. Since adjustment for weight was necessary, analysis of covariance was appropriate to test differences between locations for 1989 data. The analysis of covariance indicated significant differences in PCB concentrations between locations, with significantly higher concentrations in catfish from Little River Embayment than in those from TRM 628, which has been true in all previous collections (table 4.4-6).

Because of the significant PCB/weight relationship, a two-way analyses of covariance, adjusted for weight, was the appropriate test for location and year differences (table 4.4-7). Test results showed PCBs were significantly lower in catfish from TRM 628 than in those from Little River, which again has been the case each year of this study. PCB levels were significantly different among years, with 1989 having the highest adjusted PCB concentration, followed by 1985 (table 4.4-8). Adjusted PCB concentrations was significantly higher in 1989 than in 1987 and 1988. Following the 1988-89 analyses, it is evident that PCB levels in catfish in Fort Loudoun Reservoir, at least in the Little River Embayment, are not decreasing over time, as was thought in 1987.

The special study to evaluate filleting techniques involved comparing lipid content and PCB concentration in fillets removed the conventional way to concentrations removed according to a protocol suggested by the Mid-American Fish Contaminants Group. Data derived from fillets removed by this alternative procedure were used only for this special test. Results from data analyses described above were based on the fillets removed the conventional way.

A comparison of lipid content and PCB concentration between each pair of fillets is provided in table 4.4-9. The lipid content was slightly, but consistently higher, in fillets removed the conventional way. Mean lipid content in fillets from Little River catfish was 3.6 percent for fillets removed using the old procedures and 3.4 percent for the alternative procedure. Similar results were found for the TRM 628 catfish with lipid content 4.6 percent for the old procedure and 4.2 percent for the new procedure. The paired T-test (combining all 40 pairs) showed the lipid content in fillets removed using the old procedure was significantly higher (P>F = 0.0099) than the lipid content in fillets removed using the alternative procedure.

PCB concentrations averaged the same (4.2 µg/g) in fillets from Little River catfish regardless of the filleting techniques. At TRM 628 PCB concentrations were slightly higher in fillets removed the old way (2.3 µg/g) than in fillets removed the alternative way (2.1 µg/g). The paired T-test run on all 40 pairs of fillets did not find a significant difference (P>F = 0.3018).

Based on these results, there appears to be little to be gained or lost by switching to the alternative fillet technique. The procedure used in previous TVA studies should provide comparable results to those from other agencies, if they decide to follow the protocol suggested by the Mid-American Group. Therefore, the "old" procedure will continue to be used in TVA fish tissue studies.

Largemouth Bass

Physical Characteristics--All ten largemouth bass from TRM 628 in 1989 were healthy with no lesions or other abnormalities reported. Average size of largemouth bass for TRM 628 in 1989 was smaller than those taken in 1988, but larger than those in the three previous years (table 4.4-10). The report for 1988 stated that an explicit effort was made that year to collect large fish from TRM 628 (Dycus 1990d). A length-weight covariance analysis for Fort Loudoun fish versus the life-history data showed that the weight of fish collected in 1989 were not significantly different from those in the data base or from those in other years in Fort Loudoun.

PCB Concentration--Average PCB concentrations in bass in 1989 from TRM 628 were 0.4 µg/g; the highest level was 0.8 µg/g (table 4.4-11). Since bass were collected at only one location, no tests for location differences were possible as in previous years. Preliminary tests were run to determine if significant relationships existed between PCB concentrations and lipid content and/or weight; these tests showed PCB levels were related to both variables, so an analysis of covariance was necessary to test differences among years at this location (table 4.4-7). Test results on PCB levels, adjusted for both lipid content and fish weight, showed a continued decline in PCBs from year to year since 1986 at TRM 628 (table 4.4-8). The latest data continued to confirm that the advisory against eating largemouth bass (greater than two pounds) outside of Little River Embayment may no longer be necessary, i.e., with respect to PCBs. However, the status of other contaminants in Fort Loudoun bass is unknown at this time. PCB levels in largemouth bass from Little River Embayment have remained fairly constant through the years since 1985, e.g., 1.8, 2.6, 2.5, 1.7 µg/g in 1985, 1986, 1987, and 1988, respectively.

4.4.3 Recommendations

Given the results to date, a slightly different direction was selected for studies in autumn 1990. There was a distinct lack of information on other contaminants in fish from Fort Loudoun Reservoir. Therefore, the emphasis for autumn 1990 was to broaden this data base. As a result, five channel catfish were collected from three reservoir locations--lower (TRM 604), middle (TRM 628), and upper (TRM 651). These fish were analyzed as composites (by location) for PCBs, pesticides, and metals as part of the Valley-wide fish tissue study.

In addition, ten channel catfish were collected from TRM 628 to continue the trend data base for that location. Because of the continued decline in PCB levels in bass at the main reservoir trend station since 1986, and higher priorities for available funds and personnel, no largemouth bass were to be collected in 1990.

Table 4.4-1. Minimum, Maximum, and Mean Lengths and Weights of Channel Catfish Collected from Fort Loudoun Reservoir 1981, 1985, 1987, 1988, and 1989

Location	Year	Length (mm)			Weight (g)		
		Minimum	Maximum	Mean	Minimum	Maximum	Mean
TRM 628	1981[a]	483	610	549	1587	2948	2313
	1985[a]	330	655	441	270	2720	834
	1987	410	645	507	580	2275	1385
	1988	391	577	466	538	1732	968
	1989	344	573	474	292	2169	1002
Little River	1981	330	584	424	255	1587	759
	1985	295	585	386	176	2230	533
	1987	375	562	454	426	2294	1072
	1988	420	606	987	948	2493	1637
	1989	384	583	487	469	2022	1035

a. Some individuals were blue catfish.

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Table 4.4-2. Detailed information on physical characteristics, lipid content, and PCB concentration (µg/g wet weight) for each fish collected from Fort Loudoun Reservoir, 1989

LOCATION[a]	DATE	SPECIES[b]	SEX[c]	LENGTH (mm)	WEIGHT (g)	LIPIDS (%)	TOTAL PCBS
LRM 3	891005	CHC	U	404	502	5.8	1.2
LRM 3	891005	CHC	FM	384	485	7.0	3.2
LRM 3	891005	CHC	FM	402	469	5.6	2.2
LRM 3	891214	CHC	MA	583	2022	1.0	3.1
LRM 3	891214	CHC	MA	440	757	5.2	1.2
LRM 3	891214	CHC	FM	447	842	6.6	8.3
LRM 3	891214	CHC	U	451	824	6.7	2.8
LRM 3	891214	CHC	FM	477	954	4.8	2.5
LRM 3	891214	CHC	MA	453	932	0.9	5.2
LRM 3	891214	CHC	U	537	1272	1.5	3.2
LRM 3	891214	CHC	MA	525	1199	3.1	5.8
LRM 3	891214	CHC	U	540	1405	1.8	6.1
LRM 3	891214	CHC	U	530	1618	5.6	3.4
LRM 3	891214	CHC	MA	557	1450	1.2	5.9
LRM 3	891214	CHC	U	558	1355	1.3	6.9
LRM 3	891214	CHC	U	535	1010	1.0	1.7
LRM 3	891214	CHC	U	501	1052	2.0	5.0
LRM 3	891214	CHC	U	472	908	4.4	7.9
LRM 3	891214	CHC	U	504	883	1.8	7.4
LRM 3	891214	CHC	MA	444	771	5.2	1.3
TRM 629	891127	CHC	U	508	1242	3.5	2.7
TRM 629	891127	CHC	U	518	1123	14.0	3.4
TRM 629	891127	CHC	U	433	641	4.3	1.1
TRM 629	891127	CHC	U	344	292	3.8	1.5
TRM 629	891127	CHC	FM	376	418	2.2	0.6
TRM 629	891128	CHC	MA	545	1495	0.8	2.9
TRM 629	891128	CHC	U	573	1419	3.8	3.2
TRM 629	891128	CHC	FM	535	1289	4.5	4.3
TRM 629	891128	CHC	MA	462	849	0.7	1.6
TRM 629	891128	CHC	U	450	749	5.5	3.4
TRM 629	891128	CHC	U	533	1476	1.9	1.9
TRM 629	891128	CHC	U	430	799	6.8	1.8
TRM 629	891128	CHC	FM	550	2169	11.0	2.2
TRM 629	891128	CHC	U	420	833	1.6	4.2
TRM 629	891128	CHC	U	425	598	2.8	2.2
TRM 629	891128	CHC	U	528	1107	2.6	1.9
TRM 629	891128	CHC	MA	560	1682	4.5	2.1
TRM 629	891128	CHC	MA	410	503	0.6	2.4
TRM 629	891128	CHC	MA	478	847	6.8	1.6
TRM 629	891128	CHC	MA	400	503	6.2	1.1

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Table 4.4-2 (continued)

LOCATION[a]	DATE	SPECIES[b]	SEX[c]	LENGTH (mm)	WEIGHT (g)	LIPIDS (%)	TOTAL PCBS
TRM 629	891127	LMB	MA	366	825	1.7	0.4
TRM 629	891127	LMB	FM	483	1743	2.0	0.5
TRM 629	891127	LMB	MA	388	917	4.6	0.8
TRM 629	891127	LMB	FM	444	1421	3.2	0.7
TRM 629	891127	LMB	FM	489	1870	2.5	0.6
TRM 629	891127	LMB	FM	344	661	0.9	0.1
TRM 629	891127	LMB	MA	397	976	2.7	0.4
TRM 629	891127	LMB	MA	314	446	1.7	0.2
TRM 629	891127	LMB	MA	326	441	0.8	0.3
TRM 629	891127	LMB	MA	324	428	1.6	0.3

a. LRM = Little River Mile; TRM = Tennessee River Mile
b. CHC = Channel Catfish; LMB = Largemouth Bass
c. U = Unknown Sex

Table 4.4-3. Results of One-Way ANOVA on Location Differences of Fish Weight and Lipid Content for Channel Catfish from Fort Loudoun Reservoir in 1989

Species	Parameter	P>F
Channel catfish	Weight	0.5831
	Lipid content	0.4921

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Table 4.4-4. Two-Way Analysis of Variance and Duncan's Multiple Range Test on Lipid Content, and Total Weight in Channel Catfish from Fort Loudon Reservoir 1985, 1987, 1988, and 1989 (Location and Year Main Effects)

		P>F	Duncan's Multiple Range Test[a] Mean Rank Low to High
Lipid content	Location	0.9541	
	Year	0.1164	
	Interaction	0.3427	
Total weight	Location	0.6643	
	Year	0.0018	1985 1989, 1987, 1988
	Interaction	0.0813	

a. Locations or years underscored by same line were not significantly different at $\alpha = 0.05$. Years not so underscored were significantly different.

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Table 4.4-5. Summary of Total[a] PCB Concentrations (μg/g Wet Weight) in Individual Catfish Fillets from Fort Loudoun Reservoir, Collected in Spring 1981 and Fall of 1985, 1987, 1988, and 1989

	TRM 604	TRM 617	TRM 628[b]	Little River	TRM 638	TRM 643	TRM 651
1981							
Range	1.5-5.8	c	2.3-7.2	<1.0-22	c	<1.0-1.6	<1.0-4.4
Mean[d]	3.5		4.5	6.6		1.4	2.1
Number ≥2.0 μg/g	4		5	62		0	1
Number of fish	5		5	64[e]		5	5
1985							
Range	<0.1-2.9	0.18-2.4	0.16-2.8	1.3-9.3	<0.1-4.9	<1.0-1.1	<0.1-1.0
Mean	1.7	1.2	1.4	4.4	1.3	0.75	0.62
Number ≥2.0 μg/g	3	3	2	7	2	0	0
Number of fish	10	10	10	10	10	10	10
1987							
Range	c	c	0.1-4.5	0.2-5.3	c	c	c
Mean			2.2	2.4			
Number ≥2.0 μg/g			2	5			
Number of fish			10	10			
1988							
Range	c	c	0.2-4.4	1.8-7.1	c	c	c
Mean			1.1	3.5			
Number ≥2.0 μg/g			1	8			
Number of fish			10	10			
1989							
Range			0.6-4.3	1.2-8.3			
Mean			2.1	4.2			
Number ≥ 2.0 μg/g			9	16			
Number of fish			20	20			

a. Sum of individual aroclors which occurred in concentrations greater than or equal to the detection limit of 1 μg/g in 1981 and 0.1 μg/g in 1985.

b. Additional catfish were collected in 1982 but not reported here.

c. Fish were not collected from this location.

d. Total PCB concentration less than detection limit (1 μg/g in 1981 and 0.1 μg/g in 1985) were averaged as the detection limit.

e. Four of these specimens were collected in spring 1981 at the same time as specimens from the other locations. The remaining 60 were collected in December 1981.

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Table 4.4-6. Results of Statistical Tests Used To Compare PCB Concentrations in Channel Catfish from the Two Sample Locations on Fort Loudoun Reservoir in 1989

Species	Parameter	Preliminary test results - (Is there a significant relationship between PCB concentration and parameter?)	Decision based on preliminary test	If ANOVA used (P>F)	If covariance used (test of parallel line)	Covariance results (P>F)
Channel catfish	Lipid content	No	Use ANOVA	0.0001	N/A	N/A
	Weight	Yes	Use covariance	N/A	Lines parallel; use of covariance appropriate	0.0036[a]

a. Mean PCB concentration (adjusted for weight) was significantly higher at Little River than at TRM 628.

Table 4.4-7. Decision Path Followed in Determining Appropriate Statistical Test of Significance (Analyses of Variance or Analysis of Covariance) To Examine Temporal (Among Years) and Spatial (Among Locations) Differences in PCB Concentrations in Channel Catfish and Largemouth Bass (Among Years Only) from Fort Loudoun Reservoir 1985, 1986, 1987, 1988 and 1989

Species	Parameter	Preliminary test[a]	Decision based on preliminary test
Channel catfish	Lipid content	Not significant	Lipid adjustment not needed; use ANOVA to adjust for weight
	Weight	Significant	Adjustment needed use covariance (see table 4.4.8)
Largemouth bass	Lipid content	Significant	Must adjust PCB concentrations for both lipid content and weight, achieved by use of analysis of covariance (see table 4.4-8)
	Weight	Significant	See above

a. Used to determine whether there is a significant relationship between PCB concentration and parameter (lipid and/or weight) for each test group (location and year).

b. Results of Duncan's Multiple Range Test showed PCB concentrations were significantly higher in catfish from Little River Embayment than those from TRM 628.

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Table 4.4-8. Results of Two-Way Analysis of Covariance (Location and Year Main Effects) on PCB Concentrations in Channel Catfish and Largemouth Bass (year only) from Fort Loudoun Reservoir 1985, 1986, 1987, 1988, and 1989

Species	Test of parallel lines[a]		Analysis of covariance test results	
	Lipid adjustment	Weight adjustment	Location	Year
Channel catfish	N/A	Lines parallel	P>F = 0.0001[b] TRM 628<LRM 3	P>F = 0.0003[b] 1987 1988 1985 1989
Largemouth bass	Lines parallel	Lines parallel		P>F = 0.0001[c] 1989 1988 1987 1985 1986

a. Used to determine whether parameter (lipid and/or weight) has the same influence on PCB concentration for each test group (location and year). If slopes of regression lines for each test group are significantly different, analysis of covariance should not be used.

b. Based on adjustments for fish weight; test for lipids not run.

c. Based on adjustments for fish weight and lipids (TRM 628 only).

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Table 4.4-9. PCB Concentration and Lipid Content in Fillets Removed Using the TVA Standard Method versus an Alternative Procedure; Test Species was Channel Catfish from Fort Loudoun Reservoir Autumn 1989

	Little River				TRM 628			
	PCB (μg/g)		Lipids (%)		PCB (μg/g)		Lipids (%)	
Fish Number	Original Method	Alternative Method	Original Method	Alternative Method	Original Method	Alternative Method	Original Method	Alternative Method
1	1.2	1.0	5.8	4.9	2.7	3.6	3.5	4.0
2	3.2	3.4	7.0	7.3	3.4	3.1	14.0	13.0
3	2.2	2.0	5.6	5.1	1.1	0.6	4.3	2.5
4	3.1	4.1	1.0	1.2	1.5	1.4	3.8	3.4
5	1.2	1.4	5.2	5.7	0.6	0.7	2.2	2.2
6	8.3	8.9	6.6	6.6	2.9	3.2	1.0	1.1
7	2.8	3.0	6.7	6.5	2.2	2.2	3.8	3.4
8	2.5	2.3	4.8	4.4	4.3	4.5	4.5	6.2
9	5.2	6.1	0.9	0.8	1.6	1.2	0.7	0.6
10	3.2	2.9	1.5	1.4	3.4	3.2	5.5	5.4
11	5.8	4.7	3.1	2.3	1.9	1.5	1.9	1.6
12	6.1	6.7	1.8	1.8	1.8	1.5	8.8	5.7
13	3.4	3.4	5.6	5.1	2.2	2.2	11.0	11.0
14	5.9	4.5	1.2	0.8	4.2	2.6	1.6	1.2
15	6.1	7.4	1.3	1.3	2.2	2.2	2.8	2.6
16	1.7	1.7	1.0	0.8	1.9	1.7	4.6	2.6
17	5.0	4.4	2.0	1.5	2.1	2.1	4.5	4.5
18	7.1	7.5	4.4	3.9	2.4	2.7	0.6	0.7
19	7.4	7.6	1.8	1.8	1.6	1.4	6.8	6.4
20	1.3	1.0	5.2	4.0	1.1	1.0	6.2	5.4
$\bar{X}$	4.2	4.2	3.6	3.4	2.3	2.1	4.6	4.2

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Table 4.4-10. Minimum, Maximum, and Mean Lengths and Weights of Largemouth Bass Collected from Fort Loudoun Reservoir 1985, 1986, 1987, 1988, and 1989

		Length (mm)			Weight (g)		
Location	Year	Minimum	Maximum	Mean	Minimum	Maximum	Mean
TRM 628	1985	282	466	331	334	1900	652
	1986	275	451	365	290	1400	793
	1987	280	491	323	296	2156	591
	1988	361	480	403	832	2054	1207
	1989	314	489	387	428	1870	972
Little River	1985	236	494	342	168	2042	687
	1986	364	534	443	770	2920	1528
	1987	316	489	414	514	2080	1284
	1988	311	535	394	391	2941	1118
	1989	NS[a]	NS	NS	NS	NS	NS

a. NS = Not sampled.

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Table 4.4-11. Summary of Total[a] PCB Concentrations (µg/g Wet Weight) in Individual Largemouth from Fort Loudoun Reservoir, Bass Collected in 1981 and Fall of 1985, 1986, 1987, 1988, and 1989

	TRM 604	TRM 617	TRM 628[b]	Little River	TRM 638	TRM 643	TRM 651[b]
1981							
Range	1.0–1.1	c	<1.0	<1.0–2.0	c	c	<1.0–1.4
Mean[d]	1.0		1.0	1.4			1.1
Number ≥2.0 µg/g	0		0	2			0
Number of fish	5		2	8			5
1985							
Range	<0.1–0.84	0.11–4.0	0.23–3.2	0.59–4.5	<0.1–1.4	0.41–3.6	<1.0–2.3
Mean	0.36	1.4	1.0	1.8	0.47	1.6	0.6
Number ≥2.0 µg/g	0	3	1	3	0	3	1
Number of fish	10	10	10	10	10	10	10
1986							
Range	f	<0.1–2.2	<0.1–2.7	<0.1–7.1	e	<0.1–1.7	f
Mean		0.5	1.0	2.6		0.4	
Number ≥2.0 µg/g		1	2	5		0	
Number of fish		10	10	10		10	
1987							
Range	c	c	<0.1–1.3	<0.1–6.1	c	c	c
Mean			0.3	2.5			
Number ≥2.0 µg/g			0	5			
Number of fish			10	10			
1988							
Range	c	c	<0.1–1.0	0.2–4.8	c	c	c
Mean			0.5	1.7			
Number ≥2.0 µg/g			0	3			
Number of fish			10	10			
1989							
Range	c	c	0.1–0.8	c	c	c	c
Mean			0.4				
Number ≥2.0 µg/g			0				
Number of fish			10				

a. Sum of individual aroclors which occurred in concentrations greater than or equal to the detection limit of 1 µg/g in 1981 and 0.1 µg/g in 1985 and 1986.
b. Some individuals were spotted bass.
c. Fish were not collected from this location.
d. Total PCB concentration less than detection limit (1 µg/g in 1981 and 0.1 µg/g in 1985) were averaged as the detection limit.
e. Fish were collected from this location in 1986 but not analyzed.
f. No largemouth bass could be collected from this location in 1986.

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4.5 Tellico Reservoir

Tellico Reservoir is currently in the trend study stage. A PCB problem (in catfish only) was first documented in 1985 (Dycus & Hickman 1986), when seven of 12 composite samples contained levels near or above 2.0 µg/g. The problem was better defined in autumn 1986 (with some collections in winter 1987, Dycus and Hickman 1988), when ten catfish from each of five locations were analyzed individually. Contamination was still evident, but concentrations were lower than those observed in 1985. Only five of the 50 catfish were above 2.0 µg/g.

Studies were continued in autumn 1987 and 1988 (actual collection dates in January-February 1989) to determine year-to-year trends in PCB concentrations from lower and mid-reservoir areas at Little Tennessee River miles (LTRM) 1 and 11, respectively. Average PCB concentrations were higher in 1988/89 than in 1987; five of 20 fish had levels above 2.0 µg/g vs. three of 20 in 1987. The present study continued the PCB trend analyses on catfish in autumn 1989.

4.5.1 Methods

Ten channel catfish were collected from the same two locations (LTRM 1 and 11) as in the previous years. All procedures involved in field sampling and processing, laboratory and data analyses were similar to those described for Wilson Reservoir samples earlier in this report (section 4.1) and will not be repeated here. Each fish was analyzed individually.

4.5.2 Results and Discussion

Physical Characteristics--A high incidence of internal parasites (larval tapeworms) had been observed in channel catfish from Tellico

Reservoir during previous years, 1985-88. Infestation rate in 1988 was 90 percent at LTRM 1 and 100 percent at LTRM 11. The same level of incidence was not observed in 1989. Only one catfish from LTRM 11 was reported to have numerous parasites; two other fish had a few. None of the ten catfish from LTRM 1 were reported to have parasites.

Other abnormalities noted in fish from LTRM 1 included yellow fillets, frayed gills, mildly eroded fins and nodules on the liver; four fish had swollen kidneys; all of the above conditions were found on fish that were dead when collected in the slat baskets. Two fish were noted to be skinny. At LTRM 11, one fish was reported as skinny; most had nodules on the liver.

Sizes (length and weight) of catfish collected in 1989 are summarized in table 4.5-1 and detailed in table 4.5-2. A few large fish were collected at each site, but the mean weight was less than in 1988. No statistically significant difference was detected in lipid content or fish weight between the two locations (table 4.5-3). When analyzed with data from previous years in a two-way analysis of variance (location and year as main effects), both lipid content and fish weight showed significant differences among years (table 4.5-4). The significant weight difference was the same as previously reported, even with the addition of 1989 weight data; much larger fish were collected in 1986 than in the last three years. Lipid content was significantly higher in 1989 catfish than in 1988, although it was not significantly different from 1986 and 1987.

<u>PCB Concentrations</u>--Average PCB concentrations in 1989 were 1.6 and 0.9 µg/g at LTRMs 1 and 11, respectively (table 4.5-5); this compared

to 1.6 and 1.2 in 1988 and 0.9 and 1.0 µg/g in 1987. Of the two catfish at LTRM 1 with levels above 2.0 µg/g in 1989, one small female had a PCB level of 4.1 µg/g.

Preliminary statistical tests for 1989 alone and for 1989 in combination with previous years, showed no significant relationship between PCB levels and lipid and/or fish weight, so there was no need to adjust for either. Therefore, ANOVA, rather than analysis of covariance, was the appropriate procedure for analyzing PCB levels. Neither the one-way ANOVA for location (table 4.5-6) nor the two-way ANOVA for locations and years (table 4.5-7) showed significant differences in PCB concentrations. Evidently, PCB levels in catfish from Tellico Reservoir are not decreasing, as was possibly indicated after the 1987 tests, but are merely fluctuating over time with no distinct trend.

4.5.3 Recommendations

Following examination of the 1989 results, which indicated PCB levels had remained about the same for the past four years, it was decided to discontinue annual sampling at the same effort. It is anticipated that sampling at the trend-study effort (ten channel catfish from LTRMs 1 and 11) will be repeated in autumn 1991. In the interim (autumn 1990) samples were collected as part of the Valley-wide Fish Tissue Screening Study. This involved collection of five channel catfish from each of the same two locations and analyzing them as a five-fish composite for PCBs, pesticides, and metals. This broad spectrum analysis had not been conducted on Tellico Reservoir catfish since the initial year of study in 1985.

Table 4.5-1. Minimum, Maximum, and Mean Lengths and Weights of Catfish[a] Collected from Tellico Reservoir 1985, 1986, 1987, 1988, and 1989

		Length (mm)			Weight (g)		
Location	Year	Minimum	Maximum	Mean	Minimum	Maximum	Mean
LTRM 1.0	1985	NS[b]	NS	NS	NS	NS	NS
	1986	365	656	495	444	3750	1600
	1987	376	666	467	451	2902	1110
	1988	396	611	468	452	2481	1092
	1989	367	643	461	459	2593	1024
LTRM 10-11.5	1985	334	808	435	328	6200	1008
	1986	359	710	534	330	3650	1877
	1987	340	490	395	331	1075	551
	1988	390	627	509	570	2610	1332
	1989	388	592	494	350	3104	1271

a. All individuals were channel catfish except four of the ten at LTRM 1.0 in 1986 were blue catfish. Data for both species were combined for this location.

b. NS = Not sampled.

Table 4.5-2. Detailed information on physical characteristics, lipid content, and PCB concentration (µg/g wet weight) for each fish collected from Tellico Reservoir, 1989

LOCATION[a]	DATE	SPECIES[b]	SEX	LENGTH (mm)	WEIGHT (g)	LIPIDS (%)	TOTAL PCBS
LTRM 1	891121	CHC	FM	438	798	6.3	0.3
LTRM 1	891121	CHC	MA	403	512	5.3	1.3
LTRM 1	891121	CHC	MA	451	673	2.1	1.6
LTRM 1	891121	CHC	FM	367	459	13.0	4.1
LTRM 1	891121	CHC	MA	447	823	6.9	1.2
LTRM 1	891121	CHC	FM	373	459	3.8	0.7
LTRM 1	891121	CHC	MA	412	574	11.0	2.6
LTRM 1	891121	CHC	MA	643	2115	2.0	1.3
LTRM 1	891121	CHC	MA	585	2593	4.4	1.6
LTRM 1	891121	CHC	MA	493	1234	1.6	1.1
LTRM 11	891127	CHC	MA	436	641	5.2	0.2
LTRM 11	891127	CHC	MA	472	1086	8.6	0.6
LTRM 11	891127	CHC	FM	388	350	1.3	0.4
LTRM 11	891127	CHC	FM	476	804	9.4	1.2
LTRM 11	891127	CHC	FM	423	745	11.0	2.5
LTRM 11	891203	CHC	MA	568	3104	10.0	1.6
LTRM 11	891203	CHC	FM	492	1130	5.6	0.3
LTRM 11	891203	CHC	MA	592	1773	2.9	0.8
LTRM 11	891203	CHC	MA	592	2020	8.8	1.4
LTRM 11	891203	CHC	MA	505	1063	8.4	0.1

a. LTRM = Little Tennessee River Mile
b. CHC = Channel Catfish

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Table 4.5-3. Results of One-Way ANOVA on Location Difference of Fish Weight and Lipid Content for Channel Catfish from Tellico Reservoir in 1989

Parameter	P>F
Total weight	0.4086
Lipid content	0.3399

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Table 4.5-4. Two-Way Analysis of Variance and Duncan's Multiple Range Test on Lipid Content and Total Weight in Catfish from Tellico Reservoir 1986, 1987, 1988, and 1989 (Location and Year Main Effects)

		P>F	Duncan's Multiple Range Test[a] Mean Rank Low to High
Lipid content	Location	0.6423	
	Year	0.0345	1988 1986 1987 1989
	Interaction	0.0794	
Total weight	Location	0.7799	
	Year	0.0080	1987 1989 1988 1986
	Interaction	0.3003	

a. Locations or years underscored by same line were not significantly different at $\alpha = 0.05$. Years not so underscored were significantly different.

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Table 4.5-5. Summary of Total[a] PCB Concentrations in Catfish Fillets (Composites in 1985 and Individuals Thereafter) Collected from Tellico Reservoir in Autumn 1985, 1986, 1987, Winter 1988, and Autumn 1989.

	LTRM[b] 1.0	LTRM 10-11.5	LTRM 16-18	LTRM 23-24	TelIRM[b] 3-6
1985					
Range	c	1.0-3.2	1.2-2.6	1.4-1.9	0.67-1.8
Mean[e]		2.3	2.0	1.7	1.3
Number ≥2.0 µg/g		2	2	0	0
Number of fish		3-C[d]	3-C	3-C	3-C
1986					
Range	0.2-3.4	0.4-4.2	<0.1-1.2	<0.1-2.6	<0.1-1.8
Mean	1.4	1.6	0.34	0.83	0.47
Number ≥2.0 µg/g	2	2	0	1	0
Number of fish	10-1[f]	10-1	10-1	10-1	10-1
1987					
Range	<0.1-2.9	<0.2-2.2	c	c	c
Mean	0.9	1.0			
Number ≥2.0 µg/g	2	1			
Number of fish	10-1	10			
1988					
Range	0.3-4.2	072-2.2	c	c	c
Mean	1.6	1.2			
Number ≥2.0 µg/g	3	2			
Number of fish	10	10			
1989					
Range	0.3-4.1	0.1-2.5	c	c	c
Mean	1.6	0.9			
Number ≥2.0 µg/g	2	1			
Number of fish	10	10			

a. Sum of individual aroclors which occurred in concentrations greater than or equal to the detection limit of 1 µg/g.
b. LTRM = Little Tennessee River mile; TelRM = Tellico River mile.
c. Fish were not collected from this location.
d. Three composites of five fish each were analyzed from each location.
e. Total PCB concentration less than detection limit were averaged as the detection limit.
f. Ten catfish were analyzed individually from each location; all were channel catfish except four blue catfish at LTRM 1.0.

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Table 4.5-6. Results of Statistical Tests Used To Compare PCB Concentrations in Channel Catfish from the Two Sample Locations on Tellico Reservoir in 1989

Parameter	Preliminary test results (Is there a significant relationship between PCB concentration and parameter?)	Decision based on preliminary test	PCB Concentration If ANOVA used (P>F)
Lipid content	No	Adjustment not needed; use ANOVA	0.0917
Fish weight	No	Adjustment not needed; use ANOVA	

Table 4.5-7. Decision Path Followed and Results of Two-Way Testing (Location and Year) by Analysis of Variance for PCB Concentrations in Channel Catfish from Tellico Reservoir in 1986, 1987, and 1988, and 1989

Parameter	Preliminary test results (Is there a significant relationship between PCB concentration and parameter?)	Decision based on preliminary test	If ANOVA Used	(P>F)
Lipid content	No	No need to adjust PCB concentration for lipid content, Use ANOVA	Location Year Location/Year	0.5685 0.1510 0.3263
Weight	No	No need to adjust PCB concentration for weight, Use ANOVA	Location Year Location/Year	0.5685 0.5685 0.3263

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APPENDIX A

CHRONOLOGICAL LISTING OF TVA REPORTS RELATING TO TOXICS IN FISH

NOTE: Copies of reports are available from:

Water Resources Library
Tennessee Valley Authority
Haney Building 2C
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Chattanooga, TN 37402-2801
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CHRONOLOGICAL LISTING OF TVA REPORTS RELATING TO TOXICS IN FISH

MONITORING OF MERCURY CONCENTRATIONS IN FISHES COLLECTED FROM PICKWICK AND KENTUCKY RESERVOIRS MAY 1970 - FEBRUARY 1971 - April 1971

CONTROL AND CONFIDENCE INTERVAL CHARTS FOR MONITORING MERCURY CONTAMINATION OF FISH - A. L. Jensen - June 1971

SUMMARY OF OCOEE RIVER WATER QUALITY, SEDIMENT, AND BIOLOGICAL DATA COLLECTED THROUGH SEPTEMBER 1975 - Ralph Brown and Dennis Meinert I-WQ-76-1 - May 1976

EVALUATION OF THE MERCURY MONITORING PROGRAM FROM THE NORTH FORK HOLSTON RIVER - Thomas W. Toole and Richard Ruane - E-WQ-76-2 - September 1976

TRENDS IN THE MERCURY CONTENT OF FISH FROM KENTUCKY, PICKWICK, AND CHICKAMAUGA RESERVOIRS 1970-1977 - Jack Milligan - I-WQ-78-15 - December 1978

ANALYSIS OF MERCURY DATA COLLECTED FROM THE NORTH FORK OF THE HOLSTON RIVER - Jack Milligan and Richard Ruane - TVA/EP-78/12 - December 1978

ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION HUNTSVILLE SPRING BRANCH, INDIAN CREEK, AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA-TASK 1-DDT LEVELS IN IMPORTANT FISH SPECIES THROUGHOUT WILSON, WHEELER, AND GUNTERSVILLE RESERVOIRS-Final Data Report - August 1980

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ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION HUNTSVILLE SPRING BRANCH, INDIAN CREEK, AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA-TASK 5-AQUATIC BIOTRANSPORT (EXCLUDING VERTEBRATES)-Final Data Report - August 1980

ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION HUNTSVILLE SPRING BRANCH, INDIAN CREEK, AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA-TASK 6-Vol. 1-HYDROLOGIC AND SEDIMENT DATA-Final Data Report - August 1980

ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION HUNTSVILLE SPRING BRANCH, INDIAN CREEK AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA-TASK 6-Vol II-HYDROLOGICAL AND SEDIMENTOLOGICAL CALCULATIONS-DATA ANALYSIS-Final Data Report - August 1980

ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION HUNTSVILLE SPRING BRANCH, INDIAN CREEK AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA-TASK 6-Vol III-HYDROLOGICAL AND SEDIMENTOLOGICAL CALCULATIONS-INPUT DATA-Final Data Report - August 1980

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POLYCHLORINATED BIPHENYL (PCB) CONCENTRATIONS IN CATFISH FROM FLEET HOLLOW, WILSON RESERVOIR - Donald Dycus, Peter Hackney, and William Barr - TVA/ONR/WRF-83/11 - May 1983

SUMMARY OF EXISTING WATER, SEDIMENT, FISH, AND SOIL DATA IN THE VICINITY OF THE OAK RIDGE RESERVATION - August 1983

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NORTH ALABAMA WATER QUALITY ASSESSMENT: VOLUME VII-CONTAMINANTS IN BIOTA - Donald Dycus - TVA/ONRED/AWR-86/33 - April 1986

PCB CONCENTRATIONS IN WILSON RESERVOIR CATFISH-1985 - Donald Dycus and Donny Lowery - TVA/ONRED/AWR-86/57 - September 1986

CONCENTRATIONS OF PCBs, DDTr, AND SELECTED METALS IN BIOTA FROM GUNTERSVILLE RESERVOIR - Donald Dycus and Donny Lowery - TVA/ONRED/AWR-87/18 - October 1986

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RESULTS OF PCB AND CHLORDANE ANALYSES ON FISH COLLECTED FROM NICKAJACK RESERVOIR IN JANUARY AND FEBRUARY 1989 - Donald Dycus - TVA/WR/AB--90/9 - July 1990

PCB STUDIES ON FISH FROM WATTS BAR, FORT LOUDOUN, TELLICO, AND MELTON HILL RESERVOIRS - 1988 - Donald Dycus - TVA/WR/AB--90/11 - September 1990

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APPENDIX B

RESULTS OF INTERLABORATORY QUALITY ASSURANCE EFFORT FOR KNOXVILLE AREA PCB STUDY (AUTUMN 1989 FISH COLLECTION)

Appendix B

RESULTS OF INTERLABORATORY QUALITY ASSURANCE EFFORT FOR KNOXVILLE AREA PCB STUDY (AUTUMN 1989 FISH COLLECTION).

The interagency study team for fish tissue studies on east Tennessee reservoirs includes the Tennessee Valley Authority (TVA), the Tennessee Department of Health and Environment (TDHE), the Tennessee Wildlife Resources Agency (TWRA), and the Oak Ridge National Laboratory (ORNL). These agencies coordinate activities to maximize available manpower and financial resources.

In establishing the study needs for fish collections in autumn 1989, the team recognized that laboratories in TVA (TVA-ECHE), TDHE (TN-EL), and ORNL would all be involved in analytical efforts. This necessitated splitting a subset of samples among the laboratories to evaluate differences potentially introduced by the multiple laboratory analysis scheme. In addition, EPA's Region IV facility in Athens, Georgia EPA-IV) was asked and agreed to participate as a referee laboratory.

The scheme for the QA program for 1989 was as follows:

1. TVA would supply ten homogenized fish aliquots collected at TRM 570 to ORNL, and TN-EL and EPA-IV laboratories. TVA would also include two Na_2SO_4 pooled samples to each laboratory.
2. ORNL would supply eight split homogenized fish aliquots to TVA and TN-EL laboratories from selected stations on the Clinch River.
3. TN-EL would supply two carp composites and one rainbow trout composite from Chilhowee Reservoir to TVA. ORNL will analyze only the rainbow trout composite.
4. All laboratories will have samples homogenized and submitted to the other participating laboratories by the end of February 1990.

Also the following were important steps each laboratory should take with respect to the QA study.

1. Each should take special precautions to ensure homogenity on the fish to be split with other laboratories.
2. All quality control data (blanks, spikes, duplicates, etc.) would be reported with the analytical results.

3. As a control measure, TVA-ECHE would include two Na_2SO_4-pooled aliquots in addition to the split samples that they submit to ORNL and TN-EL.

4. All laboratories would retain all standards and extracts for all QA samples.

A summary of each laboratory's analytical protocol for PCB and chlordane is provided in table B-1.

Results

Analytical results for percent lipids, TPCB and chlordane analyses for 1989 fish are provided in tables B-2 through B-9. Tables B-2, B-3 and B-4 detail percent (%) lipids, PCB, and chlordane values for channel catfish from TRM 570. These fish tissue samples were homogenized, matrixed with Na2SO4 salt, and distributed by TVA-ECHE. An overview of these data provides the following conclusions:

A. Percent (%) lipids values generated by ORNL, TVA ECHE, and the referee laboratory compared favorably (means 3.7 to 3.9); TN-EL values were lower (mean 3.0).

B. TPCB values generated by ORNL, TVA-ECHE, and the referee laboratory compared favorably (mean 1.1-1.6 µg/g); TN-EL values were higher (mean 2.1).

C. Total chlordane values generated by TN-EL, TVA-ECHE, and EPA-IV compared favorably (0.12 to 0.15 µg/g); values generated by ORNL were much less (0.04).

Tables B-5, B-6, and B-7 detail percent (%) lipids, PCB, and chlordane values obtained by the three participating laboratories for eight catfish from various stations on Watts Bar Reservoir (2), Clinch River (7), and Powell River (1). These fish tissue samples were homogenized and distributed by the ORNL. Tissue samples were "wet;" treatment with NaSO4 salt was not utilized immediately after the homogenization step. Review of the data provides the following conclusions:

A. Percent (%) Lipids values generated by ORNL and TN-EL compared favorably. TVA-ECHE values were higher.

B. TPCB values generated by the three participants compared very favorably.

C. Total Chlordane values generated by TN-EL and TVA-ECHE compared favorably. ORNL values were substantially less.

Tables B-8 and B-9 detail percent (%) lipids and PCB values for five-fish composites from Chilhowee Reservoir obtained by TN-EL and TVA-ECHE. These fish tissue samples were homogenized and distributed by TN-EL. Tissue samples were "wet." Review of the data provides the following conclusions:

A. Percent (%) lipids values for the two laboratories differed less than one percent on the average.

B. TPCB values compared favorably.

Statistical procedures used to test results among the four laboratories were the same as those described in section 4.1 for Wilson Reservoir. Data from TRM 570 were chosen for testing. PCB and chlordane concentrations were each regressed against lipid content to determine if a significant relationship existed for either. The preliminary test showed that both PCB concentrations and chlordane concentrations were significantly related to lipid content. Therefore, adjustment of both PCB and chlordane results to a constant lipid content was necessary before comparing laboratory results. A test of parallel lines indicated that the slopes of the regression lines for PCB versus lipid content and chlordane versus lipid content were parallel for all four laboratories. Hence, use of use analysis of covariance was appropriate.

Test results on adjusted PCB concentrations showed that the State of Tennessee laboratory results were significantly different from all the other laboratories; ORNL and EPA results were significantly different from one another, but TVA was not different from either ORNL or EPA (table B-10).

Test results on adjusted chlordane concentrations showed no significant difference among three laboratories (table B-10); ORNL data was not included in the statistical examination.

Recommendations

Absence of a significant difference in PCB concentrations between the TVA laboratory and the ORNL laboratory showed that the results provided from these two laboratories for all locations (ORNL - five locations and TVA - two locations) could be correctly compared to one another.

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TABLE NO. B-1

Analytlical Protocol for PCB and Chlordane in Fish from Watts Bar Reservoir, 1989

Significant Steps	LABORATORY TVA-ECHE	ORNL	TN-EL
1. Homogenization	Grinder & Na_2SO_4 Desiccation	Grinder	Dry Ice Blending
2. Extraction	Sonicator-Hexane	Sonicator-Methylene Chloride	Sonicator-Methylene Chloride
3. Concentration	None	yes to 10 ml	yes to 10 ml
4. Clean-up	H_2SO_4	Florisil	GPC
5. Analysis	GC/EC, Capillary Confirmation on Chlordane	GC/EC, packed for PCB; GC/EC, cap. for chlordane	GC/EC Megabore
6. Calculation	Chlordane 9 Congeners PCB - 1260 4 peaks PCB - 1254 3 peaks	Chlordane 2 Congeners	Chlordane-8 congeners PCB-selected peaks

TABLE NO. B-2

Results of Interlaboratory QC Effort for Percent (%) Lipids in Catfish Fillets from TRM 570, Watts Bar Reservoir, Autumn 1989

		PERCENT (%) LIPIDS			
TVA-ECHE ID	FISH/LAB ID	ORNL	TN-EL	TVA-ECHE	EPA-IV
90/01440	Catfish-1	2.17	1.44	2.3	2.1
90/01441	Catfish-2	1.51	1.44	1.5	1.4
90/01442	Catfish-3	6.93	4.59	6.4	6.0
90/01443	Catfish-4	5.74	4.34	6.0	5.5
90/01444	Catfish-5	6.23	3.36	6.3	5.9
90/01445	Catfish-6	2.03	2.17	1.9	1.9
90/01446	Catfish-7	5.22	4.59	5.2	5.3
90/01447	Catfish-8	2.94	2.42	2.8	2.6
90/01448	Catfish-9	2.59	2.17	2.5	2.4
90/01449	Catfish-10	4.02	3.36	3.8(3.6)	3.5
90/01455	Na2SO4-Pooled	2.06	1.64	3.4	2.9
90/01456	Na2SO4-Pooled	2.08	2.40	3.5	4.8
90/01457	Na2SO4-Blank	<0.001	NR	<0.1	CNT

NR = NOT REPORTED
CNT = CONTAMINATED WITH NA2SO4 "FINES"

	PERCENT (%) LIPIDS			
SUMMARY:	ORNL	TN-EL	TVA-ECHE	EPA-IV
Mean Value of ten catfish samples	3.94	2.99	3.87	3.66
Mean Value of two NA2SO4-POOLED controls	2.07	2.02	3.45	3.85

TABLE NO. B-3

Results of Interlaboratory QC Effort for Total PCB in Catfish Fillets from TRM 570 - Watts Bar Dam Reservoir, Autumn 1989

		TOTAL PCB (µg/g)			
TVA-ECHE ID	FISH/LAB ID	ORNL	TN-EL	TVA-ECHE	EPA-IV
90/01440	Catfish-1	0.84	1.80	1.1	1.4
90/01441	Catfish-2	0.18	0.66	0.2	0.29
90/01442	Catfish-3	2.00	2.81	2.3	2.6
90/01443	Catfish-4	2.24	3.00	2.5	2.6
90/01444	Catfish-5	1.33	1.71	1.6	1.9
90/01445	Catfish-6	0.77	3.61	0.9	1.1
90/01446	Catfish-7	1.89	3.14	2.3	2.8
90/01447	Catfish-8	0.94	2.02	1.2	1.6
90/01448	Catfish-9	0.35	0.76	0.4	0.47
90/01449	Catfish-10	0.74	1.65	0.8(0.7)	1.1
90/01455	Na2SO4-Pooled	0.83	0.87	0.8	0.73
90/01456	Na2SO4-Pooled	0.89	1.16	0.8	0.78
90/01457	Na2SO4 Blank	<0.01	ND	<0.1	<0.11

ND = NOT DETECTED

	TOTAL PCB (µg/g)			
SUMMARY:	ORNL	TN-EL	TVA-ECHE	EPA-IV
Mean Value of ten catfish samples	1.13	2.12	1.33	1.59
Mean Value of two NA2SO4-POOLED controls	0.86	1.02	0.80	0.76

TABLE NO. B-4

Results of Interlaboratory QC Effort for Chlordane

TRM 570 - Channel Catfish

TVA-ECHE ID	FISH/LAB ID	TOTAL CHLORDANE * (µg/g) ORNL	TN-EL	TVA-ECHE	EPA-IV
90/01440	Catfish-1	<0.02	0.13	0.13	0.13
90/01441	Catfish-2	<0.02	<0.02	<0.02	<0.02
90/01442	Catfish-3	0.07	0.19	0.27	0.22
90/01443	Catfish-4	0.06	0.24	0.30	0.26
90/01444	Catfish-5	0.04	0.14	0.25	0.17
90/01445	Catfish-6	0.04	0.15	0.11	0.10
90/01446	Catfish-7	0.10	0.17	0.25	0.22
90/01447	Catfish-8	0.04	0.12	0.12	0.12
90/01448	Catfish-9	<0.02	0.05	<0.02	<0.02
90/01449	Catfish-10	0.02	0.03	0.08	0.10
90/01455	Na2SO4-Pooled	0.06	0.03	0.08	0.07
90/01456	Na2SO4-Pooled	0.06	0.03	0.08	0.08
90/01457	Na2SO4 Blank	<0.02	ND	<0.02	<0.02

* Chlordane congeners were added and rounded according to the convention detailed in Section 7.4.2 of Referee Method for the Mid-American Fish Contaminants Group. Only congeners that are present at >0.02 µg/g are added to provide a "total" chlordane value.

ND - NOT DETECTED

SUMMARY	TOTAL CHLORDANE * (µg/g) ORNL	TN-EL	TVA-ECHE	EPA-IV
Mean Value of ten catfish samples	0.037	0.122	0.151	0.132
Mean Value of two NA2SO4-POOLED controls	0.060	0.030	0.080	0.075

TABLE NO. B-5

Results of Interlaboratory QC Effort for Percent (%) Lipids in Channel Catfish from Clinch/Powell/Tennessee River Locations, Autumn 1989

			PERCENT (%) LIPIDS		
TVA-ECHE ID	ORNL ID	LOCATION	ORNL	TN-EL	TVA-ECHE
90/02474	9736	PRM 30	1.67	1.96	2.0
90/02475	9787	CRM 51.0	11.6	9.75	13.
90/02476	9763	TRM 557	4.29	4.11	5.0
90/02477	9800	TRM 530.5	1.16	1.29	1.7
90/02478	5014	CRM 9.3	4.86	5.17	6.0
90/02479	5015	CRM 9.3	1.71	1.87	2.0
90/02480	5020	CRM 20	7.68	7.27	9.0
90/02481	7736	CRM 20	3.81	3.95	5.4

	PERCENT (%) LIPIDS		
SUMMARY	ORNL	TN-EL	TVA-ECHE
Mean Value of eight catfish samples	4.60	4.42	5.51

TABLE NO. B-6
Results of Interlaboratory QC Effort for Total PCB
Clinch/Powell/Tennessee Rivers, Autumn 1989

TVA-ECHE ID	ORNL ID	LOCATION	PERCENT PCB (µg/g) ORNL	TN-EL	TVA-ECHE
90/02474	9736	PRM 30	0.07	0.06	<0.1
90/02475	9787	CRM 51.0	1.84	1.91	1.7
90/02476	9763	TRM 557	0.61	0.64	0.6
90/02477	9800	TRM 530.5	0.61	0.76	1.1
90/02478	5014	CRM 9.3	0.87	1.01	1.0
90/02479	5015	CRM 9.3	0.79	0.83	0.9
90/02480	5020	CRM 20	3.43	3.49	3.3
90/02481	7736	CRM 20	0.57	0.53	0.7

SUMMARY	PERCENT PCB (µg/g) ORNL	TN-EL	TVA-ECHE
Mean Value of eight catfish samples	1.10	1.15	1.16

TABLE No. B-7
Results of Interlaboratory QC Effort for Chlordane
Clinch/Powell/Tennessee Rivers

TVA-ECHE ID	ORNL ID	LOCATION	TOTAL CHLORDANE * μg/g)		
			ORNL	TN-EL	TVA-ECHE
90/02474	9736	PRM 30	<0.02	<0.02	<0.02
90/02475	9787	CRM 51.0	0.15	0.42	0.35
90/02476	9763	TRM 557	0.02	0.07	0.07
90/02477	9800	TRM 530.5	<0.02	0.10	0.14
90/02478	5014	CRM 9.3	0.03	0.13	0.14
90/02479	5015	CRM 9.3	<0.02	0.07	0.04
90/02480	5020	CRM 20	0.18	0.54	0.45
90/02481	7736	CRM 20	<0.02	0.06	0.04

*Chlordane congeners were added and rounded according to the convention detailed in Section 7.4.2 of Referee Method for the Mid-American Fish Contaminants Group. Only congeners that are present at >0.02 μg/g are added to provide a "total" chlordane value.

SUMMARY	TOTAL CHLORDANE * μg/g)		
	ORNL	TN-EL	TVA-ECHE
Mean Value of eight catfish samples	0.048	0.174	0.154

TABLE NO. B-8

Results of Interlaboratory QC Effort for Percent (%) Lipids in Fish Tissue from Chilhowee Reservoir, Autumn 1989

Five-Fish Composites

TVA-ECHE ID	TN-EL ID	TYPE FISH	PERCENT (%) LIPIDS TN-EL	PERCENT (%) LIPIDS TVA-ECHE
90/02853	89-11-0057	ROCK BASS	1.4	0.7
90/02854	89-11-0058	RAINBOW TROUT	5.3	6.6
90/02855	89-11-0059	RAINBOW TROUT	2.9	2.9
90/02856	89-11-0060	WALLEYE	2.1	1.6
90/02857	89-11-0061	WHITE BASS	4.5	6.7
90/02858	89-11-0062	CARP	7.3	9.8
90/02589	89-11-0063	CARP*	8.2	11.0
90/02860	89-11-0064	LMB	1.6	1.4

*FOUR-FISH COMPOSITE

SUMMARY	PERCENT (%) LIPIDS TN-EL	PERCENT (%) LIPIDS TVA-ECHE
Mean Value of eight Fish Tissue Samples	4.16	5.09

TABLE NO. B-9

Results of Interlaboratory QC Effort for Total PCB in Fish Tissue from Chilhowee Reservoir, Autumn 1989

TVA-ECHE ID	TN-EL ID	TYPE FISH	TOTAL PCB (µg/g) TN-EL	TOTAL PCB (µg/g) TVA-ECHE
90/02853	89-11-0057	ROCK BASS	<0.04	<0.1
90/02854	89-11-0058	RAINBOW TROUT	<0.09	<0.1
90/02855	89-11-0059	RAINBOW TROUT	<0.04	<0.1
90/02856	89-11-0060	WALLEYE	<0.08	<0.1
90/02857	89-11-0061	WHITE BASS	<0.08	<0.1
90/02858	89-11-0062	CARP	<0.392	<0.5
90/02859	89-11-0063	CARP*	<0.386	<0.5
90/02860	89-11-0064	LMB	<0.09	<0.1

*FOUR-FISH COMPOSITE

SUMMARY	TOTAL PCB (µg/g) TN-EL	TOTAL PCB (µg/g) TVA-ECHE
Mean Value of eight composited fish tissue samples	0.0972	0.125

Table B-10. Results of Statistical Tests Used To Compare 1990 Laboratory Differences in PCB and Chlordane Concentrations in Channel Catfish from TRM 570, Watts Bar Reservoir, 1989

Analyte	Parameter	Preliminary test results[a] (Is there a significant relationship between PCB concentration and parameter?)	Decision based on preliminary test	If covariance used (test of parallel line)	Covariance results (P>F)
PCB	Lipid content	Significant (P>F = 0.0001)	Use Covariance to adjust for lipids	parallel	P>F = 0.0001 ORNL TVA EPA TN
Chlordane	Fish weight	Significant (P>F = 0.0001)	Use Covariance to adjust for lipids	parallel	P>F = 0.8381 TVA EPA TN

a. Used to determine whether there is a significant relationship between analyte and parameter for each test group.

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APPENDIX C

PUBLIC ADVISORY FROM THE
TENNESSEE DEPARTMENT OF HEALTH AND ENVIRONMENT
REGARDING PCB CONTAMINATION IN FISH
FROM SEVERAL TENNESSEE WATERBODIES

Appendix C

STATE OF TENNESSEE
DEPARTMENT OF HEALTH AND ENVIRONMENT
CORDELL HULL BUILDING
NASHVILLE, TENNESSEE 37247

FOR IMMEDIATE RELEASE

FOR FURTHER INFORMATION:
Linda Tidwell: (615) 741-3111
Paul Davis: (615) 741-2275

DEPARTMENT OF HEALTH AND ENVIRONMENT
REVISES FISHING ADVISORIES

NASHVILLE, January 15, 1991: The Department of Health and Environment, Division of Water Pollution Control, announced today revised fishing advisories for Boone Reservoir, Chilhowee Reservoir, Nickajack Reservoir, Nonconnah Creek and Watts Bar Reservoir. All other advisories remain unchanged.

According to Water Pollution Control Director Paul Davis, the Department issues fishing advisories when testing indicates that levels of toxic materials in fish tissue have exceeded those thought to be protective of human health. "Since eating contaminated fish is an avoidable risk, the Department issues advisories so the public can make informed choices concerning their health," said Davis.

Davis said that two of the changes reflect improved water quality. Additional monitoring has shown that the precautionary advisory to limit consumption of crappie taken from Boone Reservoir is no longer necessary. However, the precautionary advisory for carp and catfish remains in effect because of the presence of PCBs and chlordane. Additionally, lead is no longer considered to be a pollutant of concern in fish from Boone Reservoir.

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Fish sampling since 1987 has indicated that PCB levels in Chilhowee Reservoir have declined to the point that the advisory is no longer necessary. Therefore, the advisory to avoid consumption of carp and to limit consumption of rainbow trout taken from Chilhowee Reservoir is now removed.

Nickajack Reservoir, near Chattanooga, has been added to the list of Tennessee reservoirs with fish consumption advisories. "The Department is issuing a precautionary advisory for catfish because of PCBs in Nickajack," Davis said. "This advisory suggests that children, pregnant women and nursing mothers avoid eating catfish from Nickajack Reservoir and that all other persons limit their consumption of these catfish to 1.2 pounds per month. Data do not indicate that other fish species are contaminated," Davis added. The advisory includes the entire reservoir from Chickamauga Dam to Nickajack Dam and includes the portion of the Tennessee River adjacent to Chattanooga.

The posting of the Mississippi River and McKellar Lake near Memphis is being expanded to include the lower 1.8 miles of Nonconnah Creek. Both McKellar Lake and the lower portion of Nonconnah Creek are essentially backwater areas of the Mississippi River, and fish move freely between all three bodies of water. Since both the Mississippi and McKellar Lake are impacted by chlordane in fish flesh, it is considered prudent to extend this posting to the lower reaches of Nonconnah Creek. Fish taken from Nonconnah Creek should be considered unsafe for consumption.

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Additional sampling for PCBs in Watts Bar Reservoir has shown that PCB levels are fairly consistent in certain fish species throughout the reservoir. Therefore, the previous advisory to avoid consumption of catfish, striped bass and hybrid striped bass-white bass in the upper portion of the reservoir is being expanded to include the entire Tennessee River portion of the reservoir. The precautionary advisory for white bass, sauger, carp, smallmouth buffalo and largemouth bass remains in effect. The precautionary advisory to limit consumption of catfish taken in the Clinch River arm of the reservoir has also been expanded to include sauger.

There are two levels of fish consumption advisories. The mildest form is a precautionary advisory which recommends that children, pregnant women and nursing mothers should not eat the fish species named. All other persons should limit consumption of the named species to no more than 1.2 pounds per month. Unnamed species are considered safe for consumption. The second level of advisory is a no consumption advisory which is issued when all persons are advised to avoid eating the type of fish impacted.

Fish tissue sampling for toxic materials is carried out in conjunction with other agencies such as the Tennessee Valley Authority, the Tennessee Wildlife Resources Agency, the Environmental Protection Agency and the Oak Ridge National Laboratory.

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A list of current fishing advisories in Tennessee will be included in the Tennessee Wildlife Resources Agency fishing regulations for 1991. Also, the Department of Health and Environment has prepared a brochure entitled, "Tennessee Fishing Advisories." This brochure gives current locations of fishing advisories and provides some information on the pollutants involved. For more information or to obtain a copy of the brochure, contact the Division of Water Pollution Control, TERRA Building, 150 Ninth Avenue, North, Nashville, TN 37247-3420, telephone (615) 741-6623.

NOTE TO EDITORS: Attached for your information are a current listing of statewide fishing advisories and a fact sheet.

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FACT SHEET

There are two principal reasons for posting streams in Tennessee. A stream may be posted against contact with waters because of bacterial contamination. Also, a stream may be posted when average levels of toxic materials in the edible portion of fish pose an increased health risk, such as cancer, to the general public due to the consumption of contaminated fish. In issuing fish consumption advisories, the Department relies upon published guidance on the various contaminants from the U.S. Food and Drug Administration and the U.S. Environmental Protection Agency.

There are generally two levels of fish consumption advisories. The mildest form is a "limit consumption advisory" which is a precautionary advisory. This advisory may be issued when contaminants are detected at levels of concern but are lower than FDA action levels. Because scientific studies have shown that developing fetuses and children may be more susceptible to the harmful effects of toxic materials than are adults, a precautionary advisory warns that children, pregnant women, and nursing mothers should not eat the type fish that is contaminated. All others are advised to limit their consumption to 1.2 pounds per month. An exception to this is dioxin which has an intermediate precautionary advisory level in which people are warned to limit consumption to approximately one-half pound per month.

The second level of advisory is a "no consumption" warning. At this level, all persons are advised to avoid eating the type fish impacted.

In areas where bacterial contamination has caused a water contact advisory to be issued, the public is advised to avoid fishing as well as other water contact activities.

To help inform the public, the Department issues a press release whenever a stream or lake is posted and when advisories are issued. With the exception of some precautionary advisories, the Department also places warning signs at significant public access points on posted waters.

A1051008/COM

CURRENT FISH TISSUE ADVISORIES (JANUARY, 1991)

STREAM	COUNTY	PORTION	POLLUTANT	TYPE ADVISORY
Loosahatchie River	Shelby	Mile 0.0-20.9	Chlordane	Fish should not be consumed.
Wolf River	Shelby	Mile 0.0-18.9	Chlordane	Fish should not be consumed.
Mississippi River	Shelby	MS line to mile 745	Chlordane	Fish should not be consumed. Commercial fishing ban.
McKellar Lake and Nonconnah Creek	Shelby	mile 0.0 to Horn Lake Road bridge (mile 1.8)	Chlordane	Fish should not be consumed.
Boone Reservoir	Sullivan, Washington	Entirety	PCBs, chlordane	Precautionary advisory for carp and catfish.*
North Fork Holston River	Sullivan, Hawkins	Mile 0.0-6.2 TN/VA line	Mercury	Fish should not be consumed.
Woods Reservoir	Franklin	Entirety	PCBs	Catfish should not be consumed.
East Fork of Poplar Creek	Anderson, Roane	Mile 0.0 - 15.0	Mercury, metals, org. chemicals	Fish should not be consumed. Avoid contact with water.
Fort Loudoun Reservoir	Loudon, Knox, Blount	Entirety (48 miles)	PCBs	Commercial fishing for catfish prohibited. Catfish, largemouth bass over two pounds, and largemouth bass from the Little River embayment should not be consumed.
Tellico Lake	Loudon	Entirety (32.5 miles)	PCBs	Catfish should not be consumed.
Pigeon River	Cocke	N. Carolina line to Douglas Res.	Dioxin	Fish should not be consumed.
Watts Bar Reservoir	Roane, Meigs, Rhea	Tennessee River portion	PCBs	Catfish, striped bass, and hybrid striped bass-white bass should not be consumed. Precautionary advisory* for white bass, sauger, carp, smallmouth buffalo and largemouth bass.
	Roane	Clinch River arm	PCBs	Precautionary advisory for catfish and sauger*.
Melton Hill Reservoir	Knox, Anderson	Entirety	PCBs	Catfish should not be consumed.
Nickajack Reservoir	Hamilton, Marion	Entirety	PCBs	Precautionary advisory for catfish*.

This list subject to revision.

* Precautionary Advisory - Children, pregnant women, and nursing mothers should not consume the fish species named. All other persons should limit consumption of the named species to 1.2 pounds per month.