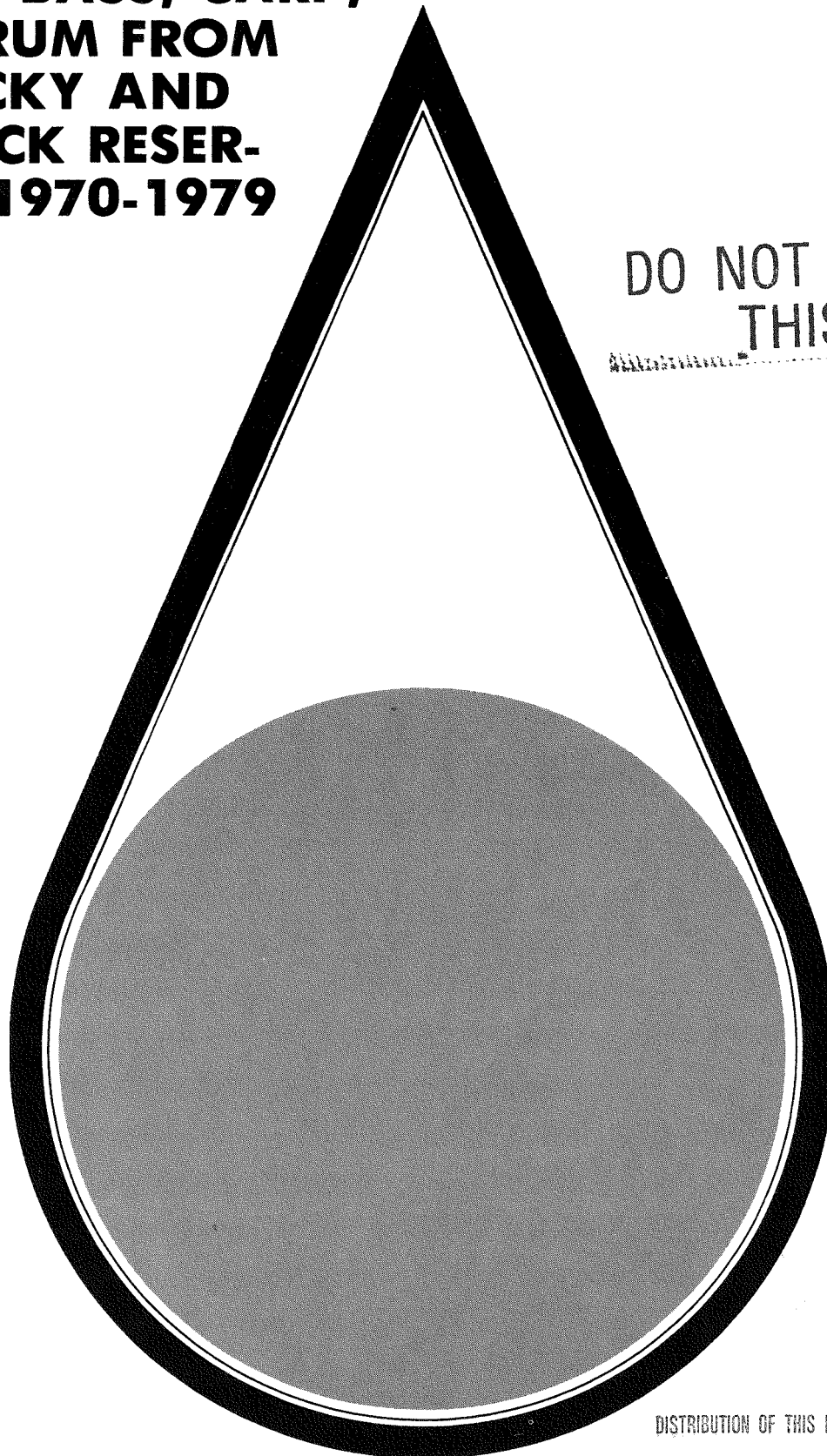


TECHNICAL REPORT SERIES  
**TRENDS IN THE MERCURY  
CONCENTRATION IN LARGE-  
MOUTH BASS, CARP,  
AND DRUM FROM  
KENTUCKY AND  
PICKWICK RESER-  
VOIRS 1970-1979**

March 1983  
Division of Air and Water Resources  
Office of Natural Resources  
Tennessee Valley Authority

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Office of Natural Resources  
Division of Air and Water Resources

TRENDS IN THE MERCURY CONCENTRATION IN LARGEMOUTH BASS, CARP, AND DRUM  
FROM KENTUCKY AND PICKWICK RESERVOIRS  
1970-1979

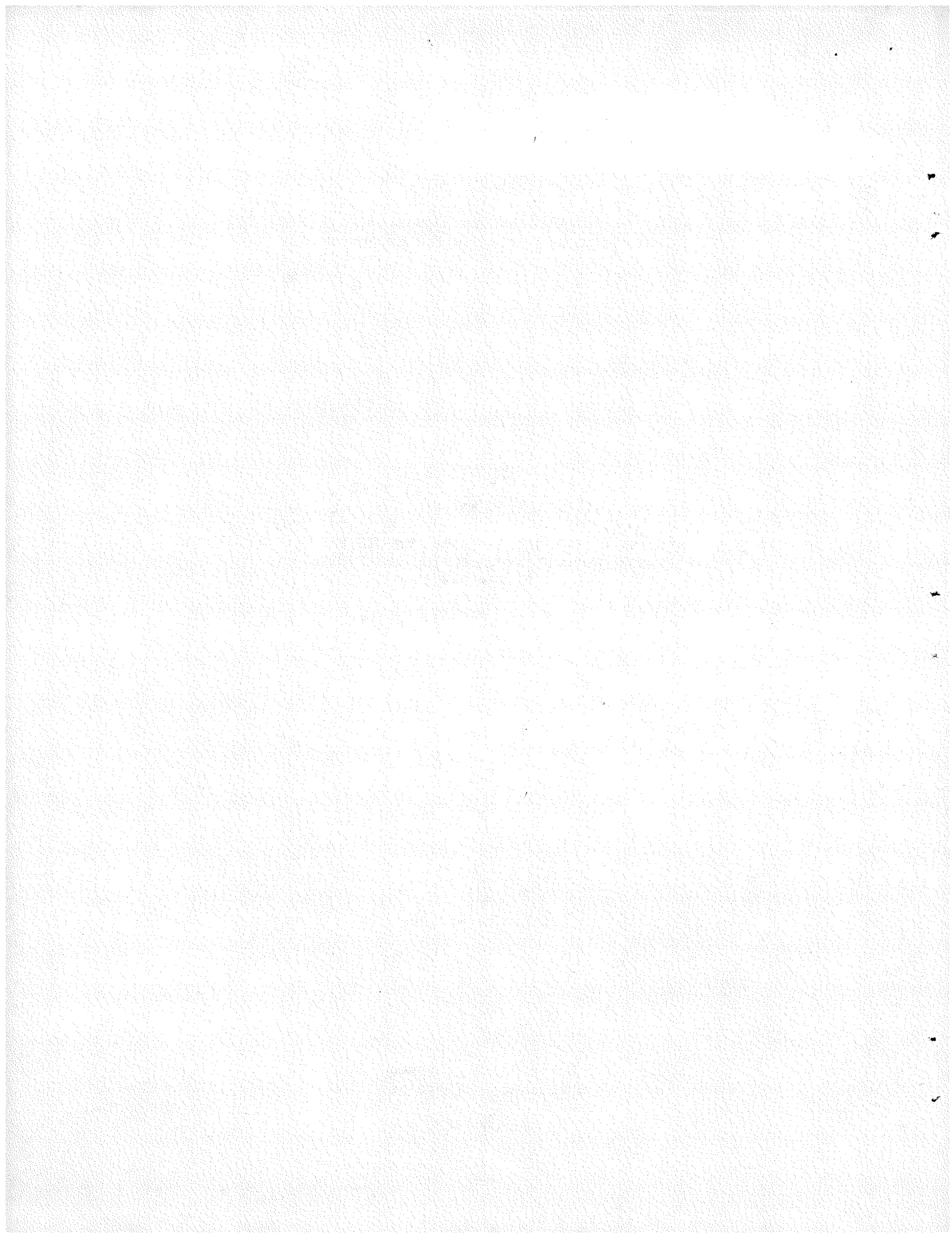
Prepared by

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Chattanooga, Tennessee

March 1983

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TRENDS IN THE MERCURY CONCENTRATION IN LARGEMOUTH BASS, CARP, AND DRUM  
FROM KENTUCKY AND PICKWICK RESERVOIRS  
1970-1979

Introduction

In 1967 a joint meeting of several government organizations adopted a guideline of 1.0  $\mu\text{g/g}$  as the safe concentration for mercury in edible fish flesh. The Federal Government formally adopted the 1.0  $\mu\text{g/g}$  guideline in 1968, and in 1970 the United States Food and Drug Administration (FDA) reduced the guideline concentration to 0.5  $\mu\text{g/g}$ . In June 1978 the FDA changed the guideline back to 1.0  $\mu\text{g/g}$ .<sup>1</sup> In response to the 1970 adoption of the 0.5 guideline, and the discovery of mercury contaminated fish in the Great Lakes, the Tennessee Valley Authority (TVA) initiated an extensive investigation to determine mercury levels in fish within the Tennessee River drainage basin. The results of this investigation revealed two areas where significant numbers of fish were found to contain total mercury concentrations exceeding the FDA's former 0.5  $\mu\text{g/g}$  guideline. Both areas were located downstream from industrial plants that produced chlorine using the mercury cathode cell process.

One area was an 80-mile stretch of the North Fork Holston River in southwest Virginia. An abandoned chlor-alkali plant at Saltville, Virginia, has been shown to be the source of mercury contamination, and its impact on aquatic life, water, and sediment has been thoroughly documented.<sup>2,3,4,5,6,7</sup>

The second area in the Tennessee River drainage basin where fish were found to contain mercury concentrations exceeding 0.5  $\mu\text{g/g}$  was a 220-mile reach of the Tennessee River that included the two impoundments, Pickwick and Kentucky Reservoirs. The Tennessee River originates at Knoxville, Tennessee, where the Holston and French Broad Rivers join, and flows 600 miles (965 km) through the States of Tennessee, Alabama, Mississippi, and Kentucky before confluence with the Ohio River at Paducah, Kentucky. The river is impounded by nine dams. Pickwick and Kentucky Dams are sequentially the last two downstream and are respectively located at Tennessee River miles (TRM) 206.7 and 22.4 (see figure 1).

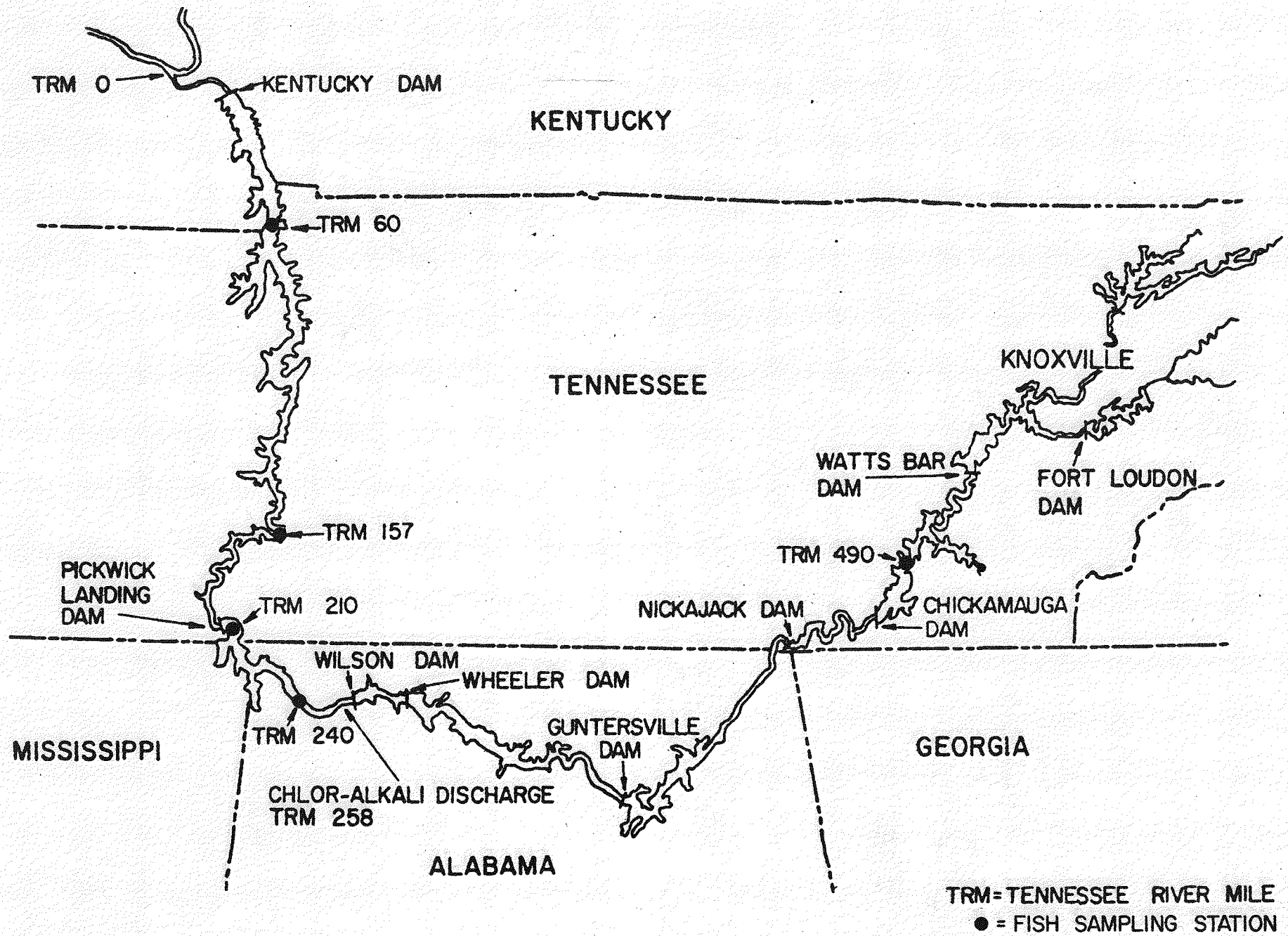


FIGURE 1. Fish sampling stations in Kentucky, Pickwick, and Chickamauga Reservoirs.

The source of the mercury input to Pickwick and Kentucky Reservoirs is the wastewater discharge from a chlor-alkali plant which enters Pickwick Reservoir at TRM 258.2, 1.4 miles below Wilson Dam. This plant belongs to the Diamond Shamrock Chemical Company in Muscle Shoals, Alabama, but was constructed in 1951 by the Leonard Monsanto Company for the United States Government. The plant was operational for only 60 days after its completion and did not reopen again until 1955, when it was purchased by Diamond Shamrock. The normal capacity of the plant is 360 tons of chlorine per day, 350 tons of caustic soda per day, and 85 tons of potassium hydroxide per day. According to a 1970 report,<sup>8</sup> however, the plant has only operated at its maximum production capacity since 1965.

The Diamond Shamrock's plant wastewater is discharged to Pond Creek which flows approximately one and one-half miles before entering the Tennessee River (i.e., near the headwaters of Pickwick Reservoir) at TRM 258.2. In April of 1970, the Diamond Shamrock Company began retrofitting their plant to control the discharge of mercury; the resulting reduction in mercury losses from the plant was substantial. For example, prior to April 1970 it was not uncommon for the plant's wastewater discharge to contain as much as 22 kg per day of mercury. In July of 1970, after implementation of abatement measures, however, an analysis of the plant's wastewater indicated the mercury discharge to be 1.03 kg per day (23.3 µg/L, with an average flow of 19.0 cfs). By December 1970, the plant's wastewater discharge contained less than 0.08 kg of mercury per day. More recently, the annual average daily losses, calculated from the State of Alabama's discharge monitoring reports, have been as follows:

1976 - 0.55 kg/day  
1977 - 0.59 kg/day  
1978 - 0.54 kg/day  
1979 - 0.52 kg/day

The initial findings of TVA's study resulted in the States of Tennessee and Alabama closing Pickwick Reservoir to commercial fishing. Kentucky Reservoir was not closed at the time because only a marginal number of fish were found that exceeded 0.5 ppm. Subsequently, TVA, EPA,

and the State of Tennessee began a joint monitoring program to follow trends in the fish mercury concentrations and to provide timely knowledge if and when concentrations declined below the FDA guideline. The monitoring investigation continued from 1970 through 1979.

Since the 1960s the scientific literature has contained a large number of papers addressing mercury concentrations in various fish species. Westermark,<sup>9</sup> Johnels and Westermark,<sup>10</sup> Berglund and Wretling,<sup>11</sup> and Westoo,<sup>12</sup> among others, reported on mercury levels in fish from Swedish lakes and streams. Reports by Fimreite, et al.,<sup>13</sup> Wobeser, et al.,<sup>14</sup> and Pligh,<sup>15</sup> are examples of documentation of investigations on mercury content in Canadian fish, while mercury studies on fish in United States streams and lakes have been reported by authors such as Benson, et al.,<sup>16</sup> Huckabee,<sup>17</sup> Cumbie,<sup>18</sup> and Aronson, et al.<sup>19</sup>

With few exceptions, such as the work by Bishop and Neary,<sup>20</sup> field investigations involving the measurement of mercury in fish have been performed under discrete temporal limitations. Usually studies were designed to determine mercury concentrations in fish at a given time and location. Very little information is available on temporal trends, especially in fish-mercury concentrations downstream from improving industrial discharges.

The purpose of this report is to identify the long-term trends associated with the study's data and evaluate the effect of the reduced mercury loading on the mercury content in fish downstream from the Diamond Shamrock's plant discharge. Additionally, data analysis will be presented to show the interlaboratory variability of total mercury analysis on fish tissue.

#### Methodology

Fish were collected for total mercury analysis from Kentucky, Pickwick, and Chickamauga Reservoirs. Figure 1 shows the relative locations of these reservoirs, the fish sampling sites, and the chlor-alkali plant's discharge. Fish were collected from TRM 60 and 157 in Kentucky Reservoir, from TRM 210 and 240 in Pickwick Reservoir, and from TRM 490 in Chickamauga Reservoir. The sampling site in Chickamauga Reservoir

(TRM 490) is upstream from the chlor-alkali plant discharge and was initially selected to monitor fish mercury concentrations downstream from another industrial operation. After it was determined that mercury contamination did not exist at this location, however, sampling continued in order to supplement an established background data base for use in comparisons with the data collected from Pickwick and Kentucky Reservoirs.

From 1970 through 1972, fish collections were performed bi-monthly. After 1972, fish collections coincided with the seasons as closely as practicable. Fish collection generally was limited to three species, largemouth bass (Micropterus salmoides), drum (Apodinotus grunniens), and carp (Cyprinus carpio). These species were selected because of their value in sport and commercial fishing as well as to evaluate long-term trends in fish of different trophic levels. After the specimens were collected (by electrofishing), each was classified to species and sex, and the weight and length recorded. The fish were then filleted and the fillets placed in plastic bags and immediately frozen until laboratory analysis could be performed. After collection, 50 percent of the fish collected were retained by TVA for total mercury analysis and the remainder were retained by the Tennessee Division of Water Quality Control for total mercury analysis.

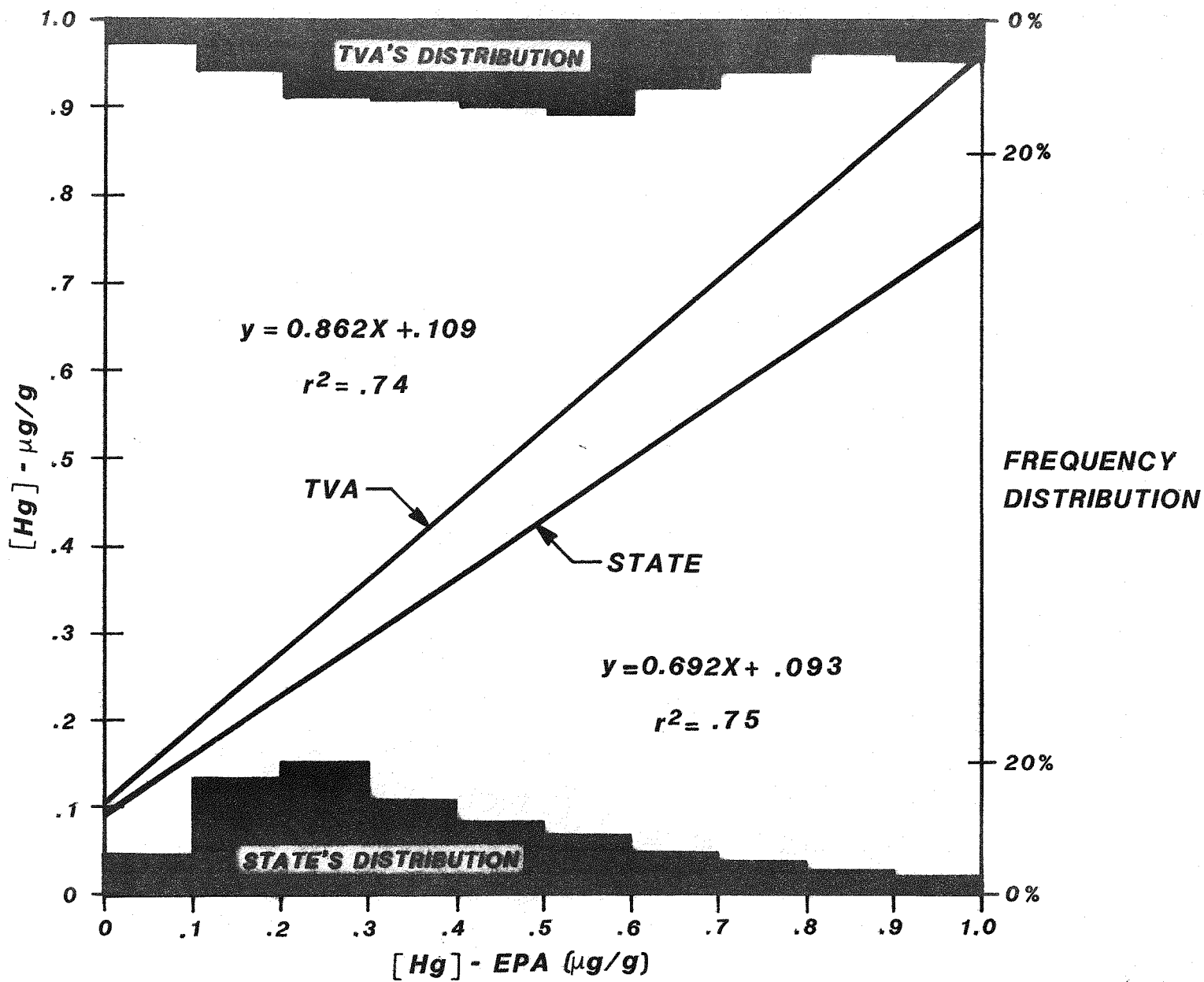
In preparation for analysis each fillet was finely diced. Three aliquots of the diced fillets were then analyzed for total mercury. The mean of these three measurements was the value used as the concentration of total mercury in each fish sample. The TVA laboratory and the Tennessee State laboratory also provided aliquots from 10 percent of all fish samples (after dicing) to EPA for total mercury analysis to provide interlaboratory quality control. All three laboratories used the cold-vapor mercury analysis technique developed by Hatch and Ott,<sup>21</sup> and refined for the analysis of fish tissue by Uthe, et al.<sup>22</sup>

## Results

Sampling stations, species collected, year of sampling, and laboratories involved made data analysis cumbersome, while the relationships of fish length (age) and species to total mercury content added to the variation in the data. Because of the large number of variables, it was desirable to use an assortment of statistical tools to account for variability in the data in order to clearly identify any existing trends. Statistical techniques used in the data analysis to determine trends and evaluate interlaboratory quality control were performed using the computerized Statistical Analysis System (SAS).

### Data Comparisons

As previously mentioned, approximately 50 percent of the fish collected were analyzed for total mercury by TVA and 50 percent by the State of Tennessee, with each organization splitting 10 percent of their samples with EPA. Student's t-test was performed on the paired TVA and EPA split samples and on the paired State and EPA split samples after combining the data from all sampling stations by year and species for each agency. Results of these analyses (see Appendix A) indicate that during approximately 50 percent of the sampling years, EPA's data for total mercury concentrations were significantly different, at the 95 percent confidence level ( $\alpha = 0.05$ ), from both TVA's and the State's data. An additional t-test was run on the same paired TVA/EPA and State/EPA split samples but with all the data combined (i.e., no grouping by year, species, or station). The results of this analysis (Appendix A) indicated that no significant difference existed between TVA's and EPA's data, while the State's and EPA's data were significantly different at  $\alpha = 0.01$ . Although these latter t-tests produced results partially contrary to the former, a least-squares regression performed on the same two data sets provides further insight regarding their equitableness. Regression lines for both sets of data are shown in figure 2; both models account for approximately 74 percent of the variation in the data and are significant at  $\alpha = 0.01$ . As the regression lines in figure 2 indicate, within the range of the majority of the



**FIGURE 2 LINEAR REGRESSIONS OF FISH SAMPLES SPLIT BETWEEN TVA AND EPA, AND THE STATE OF TENNESSEE AND EPA, AND THE FREQUENCY (%) DISTRIBUTION OF TVA AND THE STATE'S DATA**

data (shown by the frequency distributions), TVA's predicted values were generally higher than EPA's, while the State's values were generally lower. When considering the error in the models as well as the variation in the analytical measurement of total mercury in fish ( $\pm 0.04 \mu\text{g/g}$ ), however, it can be concluded that there is good agreement in the total mercury concentrations measured in the fish samples split between TVA and EPA, and between the State of Tennessee and EPA.

As further evidence of the equitability of the data sets, the magnitude of the bias in the TVA/EPA and State/EPA split sample data was determined by calculating the mean relative and absolute errors for both sets of data. The percent relative error can be defined as the difference between two measurements on the same sample (a split sample) divided by the mean of their measurements expressed as a percent, and is calculated by:

$$\% \text{ Relative error} = \frac{\text{measurement 1} - \text{measurement 2}}{(\{\text{measurement 1} + \text{measurement 2}\}/2)} \times 100$$

The mean relative and absolute errors are simply the mean of all the individual relative and absolute error calculations for each pair of data, and indicate respectively the bias and magnitude of the difference (on the average) of the split sample measurements. The sign on the mean relative error indicates which laboratory measured higher mercury values. In table 1, the mean relative errors for the TVA/EPA split samples are presented for the individual years 1970-1979 as well as all years combined. The mean value for all years combined (+0.7) indicates that, on the average, TVA's mercury values were higher than EPA's. The mean absolute error, however, indicates that the magnitude of the difference was only  $\pm 9.2$  percent (calculated as one-half of 18.4 percent) of the average of the absolute errors. Values less than 10 percent are considered to indicate excellent comparable data.

The mean relative error data of the Tennessee/EPA split samples are shown in table 2. The mean relative error for all years combined (-13.9) indicates that on the average the State's values were lower than

Table 1

COMPARISON OF MERCURY CONCENTRATIONS IN FISH SAMPLES  
SPLIT BETWEEN TVA AND EPA

Year	N	Average relative error(%)	Average absolute error(%)
1970	9	-13.9	21.3
1971	71	-9.1	15.5
1972	72	-3.0	16.6
1973	26	15.4	18.4
1974	26	22.9	25.4
1975	16	3.5	28.0
1976	8	-1.0	5.4
1977	4	54.4	54.7
1978	9	-8.0	14.0
1979	14	-1.3	16.7
1970-1979	255	0.7	18.4

$$\text{Average relative error} = [\Sigma \left[ \frac{(TVA-EPA)}{((TVA+EPA)/2)} \right] \times 100] / N$$

$$\text{Average absolute error} = [\Sigma \left[ \frac{|TVA-EPA|}{((TVA+EPA)/2)} \right] \times 100] / N$$

TVA = Concentration of mercury in split samples analyzed by  
the Tennessee Valley Authority

EPA = Concentration of mercury in split samples analyzed by  
the Environmental Protection Agency

Table 2

COMPARISON OF MERCURY CONCENTRATIONS IN FISH SAMPLES  
SPLIT BETWEEN EPA AND THE STATE OF TENNESSEE

Year	N	Average relative error(%)	Average absolute error(%)
1970	0	-	-
1971	53	-11.0	22.4
1972	50	-9.9	17.9
1973	20	-25.2	27.3
1974	20	-8.5	24.3
1975	14	-23.2	25.0
1976	6	-30.8	32.4
1977	2	17.4	17.4
1978	6	-41.9	41.9
1979	12	-5.6	17.9
1970-1979	183	-13.9	22.7

$$\text{Average relative error} = [\Sigma [ \frac{(SPC-EPA)}{(\{SPC+EPA\}/2)} ] \times 100] / N$$

$$\text{Average absolute error} = [\Sigma [ \frac{|SPC-EPA|}{(\{SPC+EPA\}/2)} ] \times 100] / N$$

EPA = Concentration of mercury in split samples analyzed by  
the Environmental Protection Agency

SPC = Concentration of mercury in split samples analyzed by  
the State of Tennessee

EPA's. The average absolute error shows that the magnitude of the difference was  $\pm 11.4$  percent (calculated as one-half of 22.7) of the average of the absolute errors.

The relative error data tends to support the results obtained from the least-squares regression analysis. Simply put, TVA's split sample data was, on the average, higher than EPA's, while the State's was, on the average, lower than EPA's. The mean difference between the data sets, however, was within approximately 10 percent, indicating good analytical agreement between the split sample data.

As a further evaluation of the quality of the data, students' t-tests were performed comparing the TVA and State data for each year and each sampling station with the data for all three species combined (see Appendix A). This was done in order to establish the relative variability in the field sampling and, more importantly, to determine whether trends in one data set could be generalized to the other. Of the 31 t-tests run, 17 indicated no significant difference between TVA's and the State's data ( $\alpha = 0.05$ ), while 14 indicated that a significant difference existed. Again, as with the data from the samples split with EPA, the t-tests were inconclusive; however, least-squares regressions calculated for the TVA and State data for each year with the data for all species and stations combined (other pairing combinations were considered, such as by species comparison, but the lack of data precluded a powerful statistical test) resulted in significant ( $\alpha = 0.05$ ) predictive equations (see table 3) in six out of nine years. The  $r^2$  values, however, were much lower than those calculated for the EPA split sample data, indicating a higher degree of scatter between the TVA and State data sets. These models enable the confident prediction of mean mercury values for a species, but the probability of confidently predicting a mercury concentration in an individual fish would probably be so low as to make such an effort a waste of time.

These analyses indicate that the amount of variability between the TVA and State data is greater than the variability associated with either the TVA/EPA or State/EPA split sample data. This could be intuitively suspected when one considers that the comparison of the TVA and

Table 3

LINEAR REGRESSIONS OF MERCURY CONCENTRATIONS MEASURED BY TVA  
VERSUS THE STATE OF TENNESSEE FOR 1971 THROUGH 1979

(All Species, All Stations--Except 240, Combined)

Year	N	F-value	$\alpha$	$r^2$	$y = mx+b$
1971	280	27.5	0.01	0.09	$y = 0.3x + 0.4$
1972	235	6.9	0.01	0.03	$y = 0.23x + 0.43$
1973	155	11.6	0.01	0.07	$y = 0.37x + 0.53$
1974	165	13.6	0.01	0.08	$y = 0.47x + 0.47$
1975	105	1.7	0.20	0.02	$y = 0.25x + 0.48$
1976	52	15.6	0.01	0.23	$y = 0.94x + 0.17$
1977	10	11.9	0.01	0.57	$y = 1.08x + 0.02$
1978	62	0.84	0.40	0.01	$y = 0.13x + 0.28$
1979	56	3.0	0.09	0.05	$y = 0.24x + 0.22$

x = State of Tennessee mercury concentration ( $\mu\text{g/g}$ )

y = TVA mercury concentration ( $\mu\text{g/g}$ )

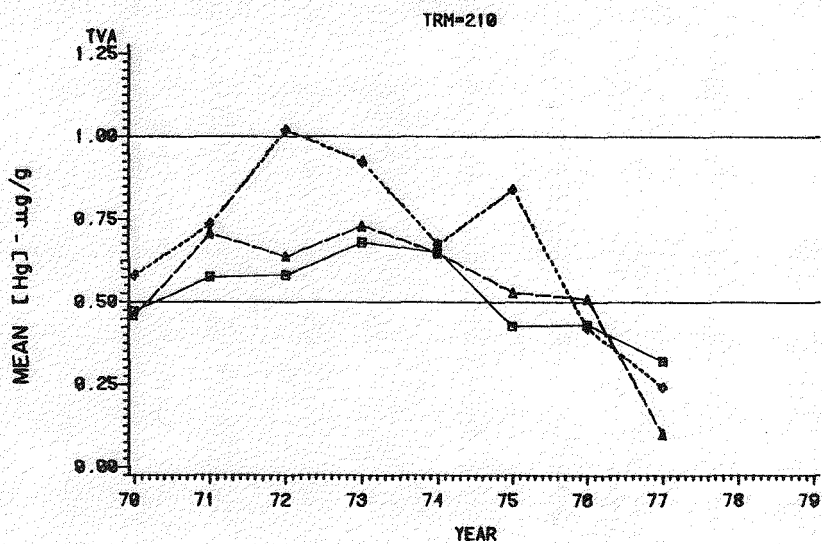
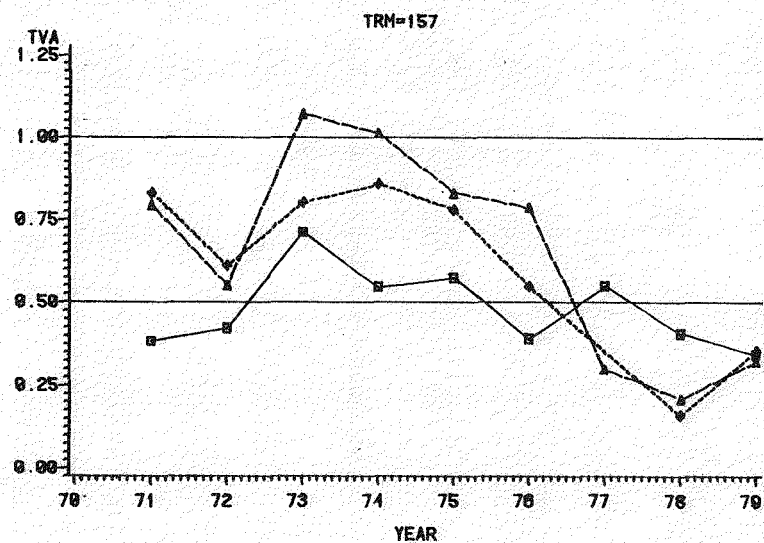
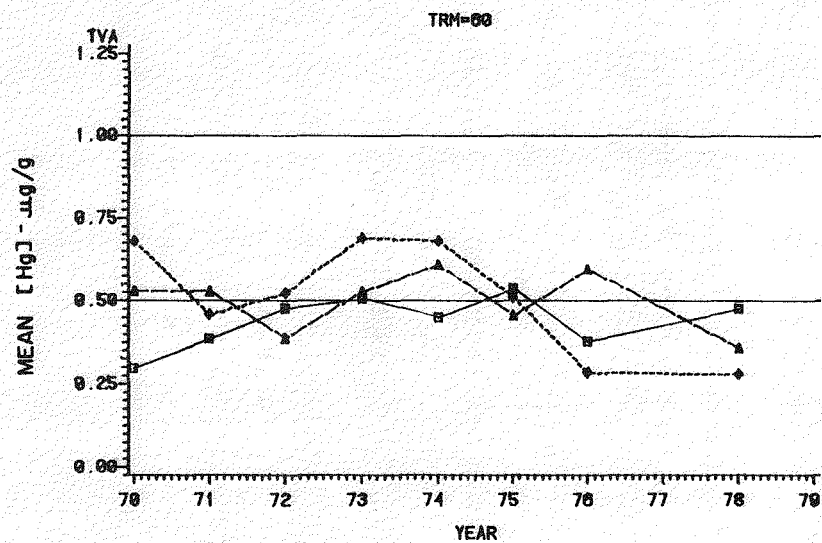
State data were on different fish, while the samples split between TVA and EPA and the State and EPA were from the same fish specimen. The data analyses suggest, however, that overall generalizations regarding trends in TVA's data set may confidently be applied to the State's.

#### Data Summary and Trends

Summary statistics of the total mercury concentrations measured in largemouth bass, carp, and drum collected from 1970 to 1979, at each of the five (TRMs 60, 157, 210, 240, and 490) sampling stations, by TVA, the State of Tennessee, and EPA are shown in the tables in Appendix B. The data presented include the mean ( $\bar{x}$ ), the standard deviation (S.D.), the maximum (max.), the minimum (min.), and the number of measurements (n). The trends in the TVA and State data from those tables are shown in figures 3 and 4, which are plots of the mean mercury concentration in each fish species versus year. For reference, horizontal lines have been drawn at 0.5 and 1.0  $\mu\text{g/g}$  to show the former and current FDA guidelines. As is evidenced from the figures, the mean mercury concentration in largemouth bass, carp, and drum never exceeded the 0.5  $\mu\text{g/g}$  level in any year for either the TVA or State data at TRM 490, the upstream control station.

The mean mercury concentrations measured in fish collected from the four impacted stations (TRM 60, 157, 210, and 240) by TVA generally increased from 1970 to a maximum in 1972 or 1973 (depending on the species) after which the concentrations declined to levels less than 0.5  $\mu\text{g/g}$ . The average mercury concentration in carp never exceeded 1.0  $\mu\text{g/g}$ , while the mean value for largemouth bass exceeded 1.0  $\mu\text{g/g}$  in 1973 at TRMs 157 and 240, and in 1974 at TRM 157. The mean concentration in drum exceeded 1.0  $\mu\text{g/g}$  in 1972 and 1973 at TRMs 210 and 240, respectively.

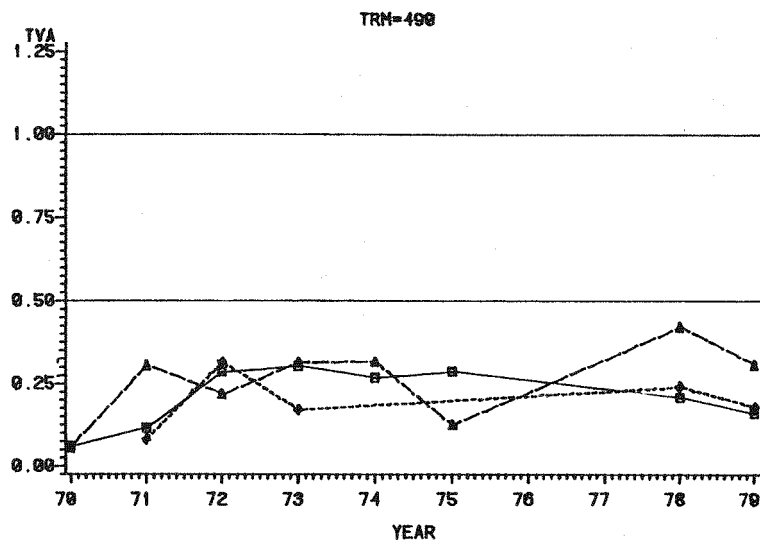
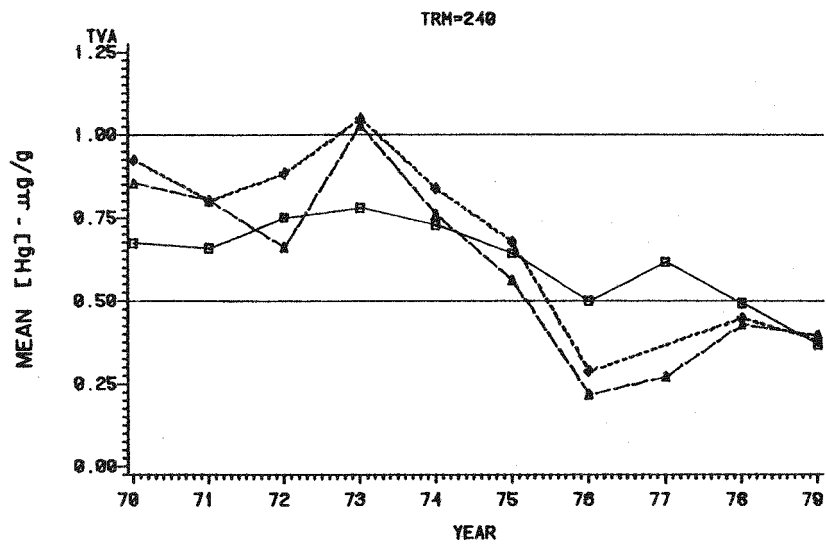
The State's data (figure 4) indicates a gradual decline in mean mercury values for all fish species at TRM stations 60, 157, and 210 (no State data was collected at TRM 240) to levels below 0.5  $\mu\text{g/g}$  by 1977. The only mean value shown to exceed 1.0  $\mu\text{g/g}$  was for drum collected in



LEGEND: SPECIES    □-□-□ CARP    ◆-◆-◆ DRUM  
 ▲-▲-▲ LARGEMOUTH BASS

1.0 µg/g IS CURRENT FDA GUIDELINE  
 0.5 µg/g IS FORMER FDA GUIDELINE

FIGURE 3. MEAN MERCURY CONCENTRATION MEASURED BY TVA IN LARGEMOUTH BASS, CARP, AND DRUM - 1970 THROUGH 1979. (values in µg/g)



LEGEND: SPECIES    □-□-□ CARP    ◆-◆-◆ DRUM  
 ▲-▲-▲ LARGEMOUTH BASS

1.0 µg/g IS CURRENT FDA GUIDELINE  
 0.5 µg/g IS FORMER FDA GUIDELINE

FIGURE 3. (cont.) MEAN MERCURY CONCENTRATION MEASURED BY TVA IN LARGEMOUTH BASS, CARP, AND DRUM - 1970 THROUGH 1979. (values in µg/g)

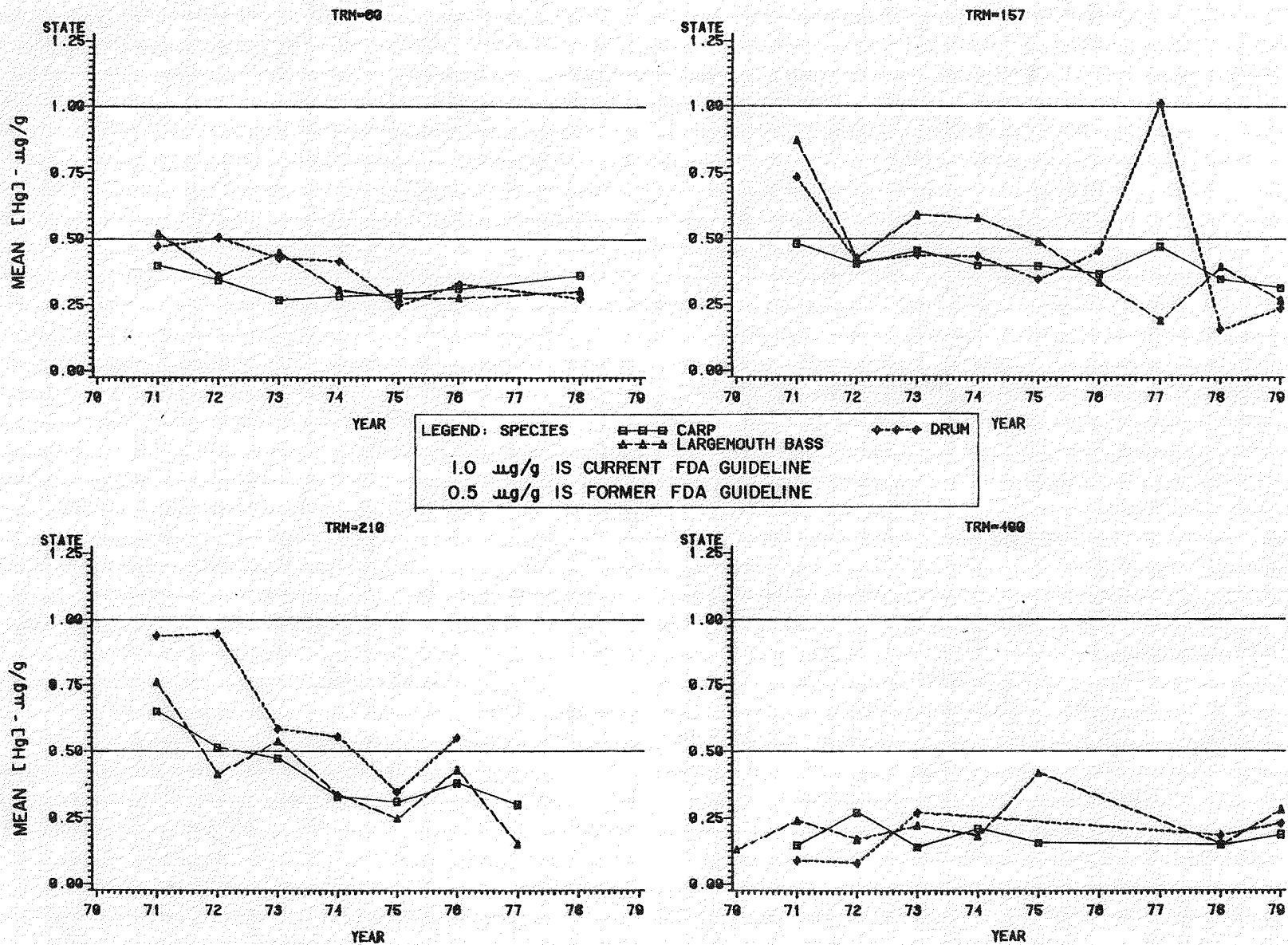


FIGURE 4. MEAN MERCURY CONCENTRATION MEASURED BY THE STATE IN LARGEMOUTH BASS, CARP, AND DRUM - 1970 THROUGH 1979. (values in  $\mu\text{g/g}$ )

1977 at TRM 157. This value, however, is of limited usefulness as only one drum was collected at that station in 1977.

Neither TVA's nor the State's data showed a consistent hierarchy in the mean mercury concentrations among the three fish species, although the concentration in drum generally tended to be higher than in either largemouth bass or carp.

A more detailed analysis of the data exceeding 0.5 and 1.0  $\mu\text{g/g}$  is presented in tables 4, 5, 6, and 7, which show, respectively, the percentage of largemouth bass, carp, drum, and all fish combined exceeding 0.5 and 1.0  $\mu\text{g/g}$  during each sampling year. Examination of the percentages for largemouth bass show that during the years 1970 to 1976 some percentage of fish exceeded the FDA guideline of 1.0  $\mu\text{g/g}$  at all impacted stations. After 1976 no largemouth bass which contained mercury in excess of the FDA guideline were collected by TVA or the State. No mercury concentrations measured in carp after 1974 exceeded the 1.0  $\mu\text{g/g}$  level, but for drum it was not until after 1978 that the levels dropped below 1.0  $\mu\text{g/g}$ . When all fish were combined, the 0.5  $\mu\text{g/g}$  level was exceeded as late as 1979, with TVA's data indicating that approximately 25 percent of all fish collected exceeded the former FDA limit. The State's data exceeded this value in approximately 15 percent of the samples. This, however, is more of academic interest, as the FDA guideline has been raised to the 1.0  $\mu\text{g/g}$  level.

#### Length/Mercury Content Relationship

The variability present in fish mercury data often casts uncertainty on the clear delineation of trends in time/concentration plots, such as those in figures 3 and 4. One factor contributing to the variability reported by various investigators<sup>23,24,25</sup> is fish age (or length, which is directly related). A high correlation between fish age and mercury concentration could result in erroneous conclusions when successive years of data are compared if some bias exists in the age range of the fish collected.

Table 4

PERCENTAGE OF LARGEMOUTH BASS COLLECTED BY TVA AND THE STATE OF TENNESSEE  
 IN PICKWICK AND KENTUCKY RESERVOIRS WITH MEASURED MERCURY  
 CONCENTRATIONS EXCEEDING 0.5  $\mu\text{g/g}$  AND 1.0  $\mu\text{g/g}$ <sup>a</sup>

Year	%	Tennessee River Mile									
		60		157		210		240		All stations	
		TVA	State	TVA	State	TVA	State	TVA	State	TVA	State
1970	>0.5	64.7	NS <sup>b</sup>	NS	NS	38.5	NS	62.0	NS	56.9	NS
	>1.0	0	NS	NS	NS	7.7	NS	38.1	NS	17.6	NS
1971	>0.5	47.5	54.3	77.0	86.1	60.6	69.4	69.0	NS	64.1	70.0
	>1.0	5.0	5.7	15.4	33.3	21.2	27.8	27.6	NS	18.2	22.4
1972	>0.5	30.6	25.0	33.3	40.0	45.2	27.6	61.4	NS	46.2	30.8
	>1.0	5.6	0	13.9	0	19.4	3.4	11.4	NS	12.1	1.0
1973	>0.5	33.3	33.3	87.5	69.6	56.5	36.4	84.4	NS	69.0	46.4
	>1.0	4.2	4.2	50.0	8.7	26.1	22.7	40.0	NS	31.9	11.6
1974	>0.5	44.4	18.5	100.0	52.2	47.6	22.7	70.4	NS	66.1	30.6
	>1.0	18.5	0	36.4	0	14.3	0	18.5	NS	21.0	0
1975	>0.5	35.3	11.1	90.0	36.4	33.3	0	52.6	NS	50.0	13.3
	>1.0	5.9	5.6	30.0	0	20.0	0	5.3	NS	11.3	2.2
1976	>0.5	37.5	22.2	60.0	10.0	28.6	14.3	0	NS	29.7	15.4
	>1.0	25.0	0	30.0	0	14.3	14.3	0	NS	16.2	3.8
1977	>0.5	NS	NS	0	0	0	0	0	NS	0	0
	>1.0	NS	NS	0	0	0	0	0	NS	0	0
1978	>0.5	25.0	0	0	16.7	NS	NS	13.3	NS	12.0	8.3
	>1.0	0	0	0	0	NS	NS	0	NS	0	0
1979	>0.5	NS	NS	10.0	10.0	NS	NS	40.0	20.0	20.0	13.3
	>1.0	NS	NS	0	0	NS	NS	0	0	0	0

a. FDA Guideline = 1.0  $\mu\text{g/g}$ .

b. NS = no sample collected.

Table 5

PERCENTAGE OF CARP COLLECTED BY TVA AND THE STATE OF TENNESSEE  
 IN PICKWICK AND KENTUCKY RESERVOIRS WITH MEASURED MERCURY  
 CONCENTRATIONS EXCEEDING 0.5 µg/g AND 1.0 µg/g<sup>a</sup>

		Tennessee River Mile									
		60		157		210		240		All stations	
Year	%	TVA	State	TVA	State	TVA	State	TVA	State	TVA	State
1970	>0.5	0	NS <sup>b</sup>	NS	NS	36.4	NS	65.7	NS	46.9	NS
	>1.0	0	NS	NS	NS	0	NS	20.0	NS	10.6	NS
1971	>0.5	26.9	31.8	22.2	36.4	63.9	79.2	83.7	NS	58.1	50.0
	>1.0	0	0	0	4.5	0	0	4.1	NS	1.6	1.5
1972	>0.5	40.0	11.5	15.0	27.3	59.3	45.0	84.8	NS	58.4	26.5
	>1.0	0	0	0	0	0	0	17.4	NS	7.1	0
1973	>0.5	40.0	6.7	68.8	26.7	93.8	38.9	83.3	NS	74.0	25.0
	>1.0	0	0	18.8	0	0	0	23.3	NS	12.9	0
1974	>0.5	42.9	6.7	60.0	33.3	81.3	0	93.3	NS	74.7	13.6
	>1.0	0	0	6.7	0	0	0	10.0	NS	5.3	0
1975	>0.5	40.0	0	50.0	20.0	40.0	6.7	84.0	NS	60.0	8.6
	>1.0	0	0	0	0	0	0	0	NS	0	0
1976	>0.5	20.0	0	20.0	20.0	25.0	16.7	50.0	NS	33.3	12.5
	>1.0	0	0	0	0	0	0	0	NS	0	0
1977	>0.5	NS	NS	66.7	33.3	0	0	88.9	NS	71.4	25.0
	>1.0	NS	NS	0	0	0	0	0	NS	0	0
1978	>0.5	28.6	14.3	16.7	0	NS	NS	35.0	NS	30.3	8.3
	>1.0	0	0	0	0	NS	NS	0	NS	0	0
1979	>0.5	NS	NS	30.0	0	NS	NS	26.7	40.0	28.0	14.3
	>1.0	NS	NS	0	0	NS	NS	0	0	0	0

a. FDA Guideline = 1.0 µg/g.

b. NS = no sample collected.

Table 6

PERCENTAGE OF DRUM COLLECTED BY TVA AND THE STATE OF TENNESSEE  
IN PICKWICK AND KENTUCKY RESERVOIRS WITH MEASURED MERCURY  
CONCENTRATIONS EXCEEDING 0.5 µg/g AND 1.0 µg/g<sup>a</sup>

Year	%	Tennessee River Mile									
		60		157		210		240		All stations	
		TVA	State	TVA	State	TVA	State	TVA	State	TVA	State
1970	>0.5	75.0	NS <sup>b</sup>	NS	NS	66.7	NS	100.0	NS	84.6	NS
	>1.0	0	NS	NS	NS	0	NS	16.7	NS	7.7	NS
1971	>0.5	32.0	47.1	60.0	64.3	75.9	78.3	75.0	NS	60.6	64.8
	>1.0	8.0	5.9	25.0	35.7	10.3	30.4	25.0	NS	16.0	24.1
1972	>0.5	41.2	46.7	33.3	25.0	80.0	90.0	81.3	NS	54.7	51.4
	>1.0	5.9	0	13.3	0	20.0	30.0	25.0	NS	15.1	8.1
1973	>0.5	71.4	28.6	80.0	25.0	70.0	54.5	85.0	NS	78.6	40.9
	>1.0	14.3	14.3	20.0	0	30.0	9.1	50.0	NS	35.7	9.1
1974	>0.5	62.5	30.0	76.9	30.8	71.4	33.3	83.3	NS	76.1	31.3
	>1.0	25.0	0	23.1	0	14.3	11.1	16.7	NS	19.6	3.1
1975	>0.5	57.1	0	100.0	16.7	50.0	28.6	78.9	NS	73.0	15.8
	>1.0	14.3	0	20.0	0	33.3	0	10.5	NS	16.2	0
1976	>0.5	0	25.0	100.0	33.3	25.0	50.0	0	NS	21.4	33.3
	>1.0	0	0	0	0	0	0	0	NS	0	0
1977	>0.5	NS	NS	NS	100.0	0	NS	NS	NS	0	100.0
	>1.0	NS	NS	NS	100.0	0	NS	NS	NS	0	100.0
1978	>0.5	0	0	0	0	NS	NS	26.1	NS	18.8	0
	>1.0	0	0	0	0	NS	NS	4.3	NS	3.1	0
1979	>0.5	NS	NS	33.3	0	NS	NS	20.0	60.0	25.9	18.8
	>1.0	NS	NS	0	0	NS	NS	0	0	0	0

a. FDA Guideline = 1.0 µg/g.

b. NS = no sample collected.

Table 7

PERCENTAGE OF ALL FISH COLLECTED BY TVA AND THE STATE OF TENNESSEE  
 IN PICKWICK AND KENTUCKY RESERVOIRS WITH MEASURED MERCURY  
 CONCENTRATIONS EXCEEDING 0.5 µg/g AND 1.0 µg/g<sup>a</sup>

Year	%	Tennessee River Mile									
		60		157		210		240		All stations	
		TVA	State	TVA	State	TVA	State	TVA	State	TVA	State
1970	>0.5	46.6	NS <sup>b</sup>	NS	NS	39.4	NS	67.7	NS	54.6	NS
	>1.0	0	NS	NS	NS	2.6	NS	25.8	NS	13.1	NS
1971	>0.5	37.3	45.9	59.7	66.7	66.3	74.7	75.6	NS	61.3	62.9
	>1.0	4.3	4.1	14.2	25.0	10.2	20.5	18.1	NS	12.2	16.6
1972	>0.5	35.6	24.7	28.1	33.3	53.9	44.1	71.9	NS	51.6	33.0
	>1.0	4.1	0	9.8	0	11.1	6.8	15.1	NS	10.9	1.9
1973	>0.5	41.3	23.9	80.0	50.0	71.4	41.2	84.2	NS	72.3	38.1
	>1.0	4.3	4.3	35.5	4.8	18.3	11.8	36.8	NS	26.3	7.2
1974	>0.5	46.9	17.3	82.0	41.2	63.6	17.8	79.4	NS	70.6	25.7
	>1.0	14.3	0	24.0	0	9.1	2.2	15.7	NS	15.9	0.7
1975	>0.5	41.2	5.9	76.0	25.9	38.9	7.9	68.3	NS	58.2	12.1
	>1.0	5.9	2.9	16.0	0	13.9	0	4.9	NS	8.5	1.0
1976	>0.5	25.0	16.7	52.9	16.7	26.7	20.0	18.5	NS	29.3	17.6
	>1.0	12.5	0	17.6	0	6.7	6.7	0	NS	8.0	2.0
1977	>0.5	NS	NS	33.3	28.6	0	0	42.1	NS	33.3	18.2
	>1.0	NS	NS	0	14.3	0	0	0	NS	0	9.1
1978	>0.5	18.7	5.6	6.3	6.3	NS	NS	25.9	NS	21.1	5.9
	>1.0	0	0	0	0	NS	NS	1.7	NS	1.1	0
1979	>0.5	NS	NS	25.0	3.3	NS	NS	25.7	40.0	25.4	15.6
	>1.0	NS	NS	0	0	NS	NS	0	0	0	0

a. FDA Guideline = 1.0 µg/g.

b. NS = no sample collected.

To test this relationship for its degree of significance in this investigation, least-squares regressions were performed on fish length versus mercury content for each species using TVA and State data and both data sets combined (not enough data existed to warrant modeling by species, for each year and station, which would have been the optimum approach for predictive purposes). The results presented in table 8 indicate a significant regression in all instances except the State's data for carp. The best overall models, however, are for the largemouth bass which indicate a high degree of relationship between largemouth bass length (age) and total mercury content. For example, using TVA's data, the regression for largemouth bass is significant at the 0.01 level with 31.7 percent of the variation accounted for by the model ( $r^2$  for carp and drum are less than 0.05). The State's data resulted in a regression significant at 0.01 which accounted for 40.7 percent of the variation in the largemouth bass data. The regression lines with 95 percent confidence intervals about the data for TVA and the State's data are illustrated in figures 5 and 6. Although scattered, the data indicate a significantly positive relationship in length versus mercury concentrations for largemouth bass.

Some of the variation in the mercury data could have conceivably been accounted for by modeling length versus mercury concentration for each species by sampling station for each year. Not enough data existed, however, to warrant using this approach. In fact, little improvement in the regression was realized when mercury and length were modeled by sampling station with the data for all years combined.

#### Largemouth Bass - Age/Class Trends

The results of the preceding data analysis suggest that a clarification of temporal trends may be accomplished by reducing the variability in the mercury data through an evaluation of the mercury concentrations in a specific age-class of largemouth bass on a year-to-year basis. Three-year-old bass were selected for such an analysis because of their abundance in sample collections. Their length range was determined by comparing lengths of the sampled fish with growth tables developed by Hubert<sup>26</sup> for largemouth bass in Pickwick Reservoir.

Table 8

LINEAR REGRESSIONS OF MERCURY CONCENTRATIONS ON FISH LENGTH  
FOR TVA, THE STATE OF TENNESSEE, AND ALL DATA COMBINED

(All Years, All Stations--Except 490, Combined)

		N	F-value	$\alpha$	$r^2$	$y = mx+b$
Largemouth bass	TVA	802	373.2	0.01	0.32	$y = 0.07x - 0.27$
	State	445	305.7	0.01	0.41	$y = 0.07x - 0.40$
	Combined	1247	624.7	0.01	0.33	$y = 0.07x - 0.33$
Carp	TVA	612	7.1	0.01	0.01	$y = 0.01x + 0.70$
	State	298	0.2	0.70	0.0005	$y = 0.002x + 0.44$
	Combined	910	10.0	0.01	0.01	$y = 0.008x + 0.70$
Drum	TVA	357	5.5	0.02	0.02	$y = 0.01x + 0.51$
	State	189	8.2	0.01	0.04	$y = 0.02x + 0.27$
	Combined	546	11.1	0.01	0.02	$y = 0.02x + 0.44$

Note:  $x$  = Fish length (in)  
 $y$  = Mercury concentration ( $\mu\text{g/g}$ )

FIGURE 5. REGRESSION OF MERCURY CONCENTRATION ON LENGTH  
FOR LARGEMOUTH BASS ANALYZED BY TVA  
1970-1979

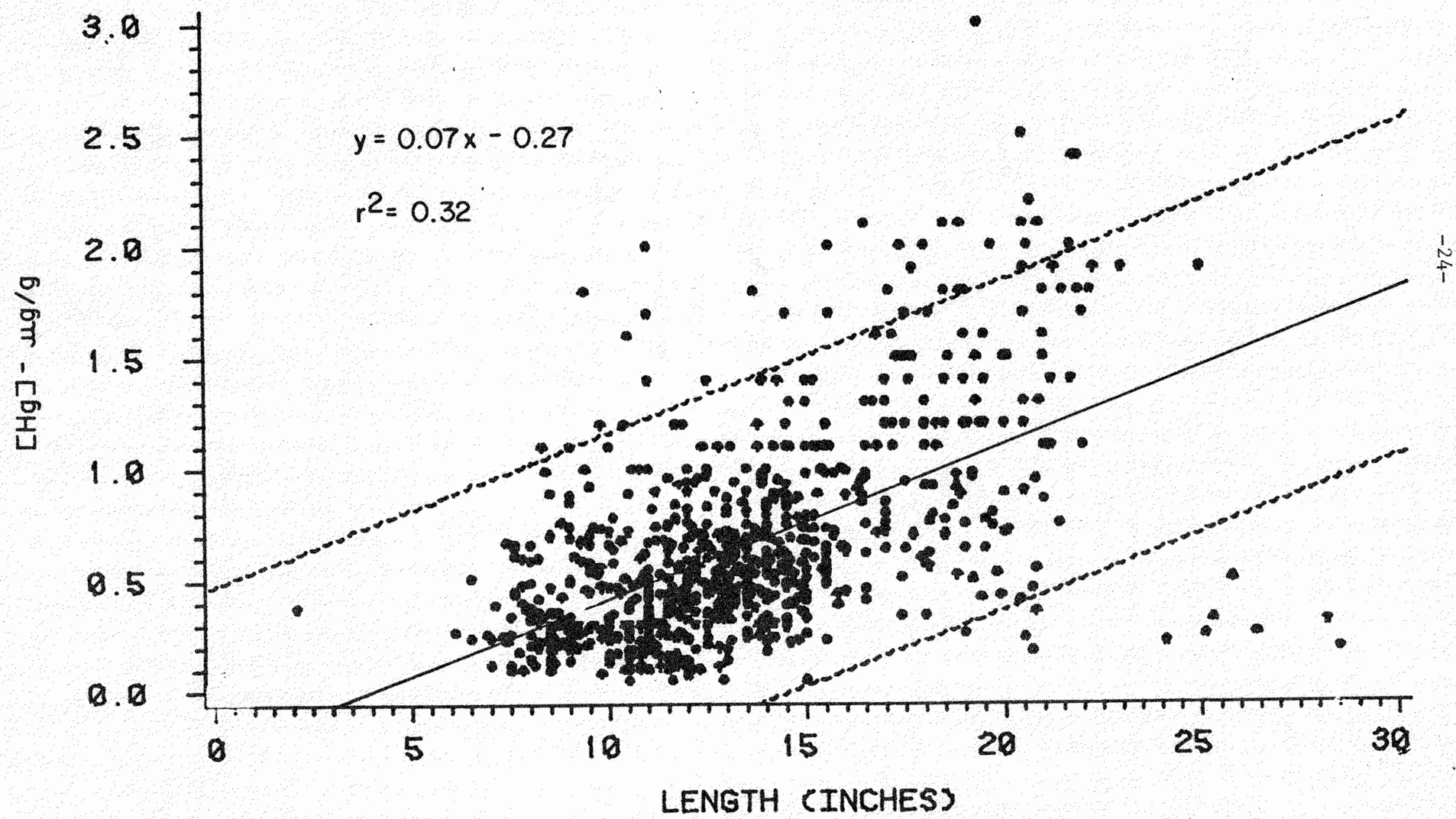
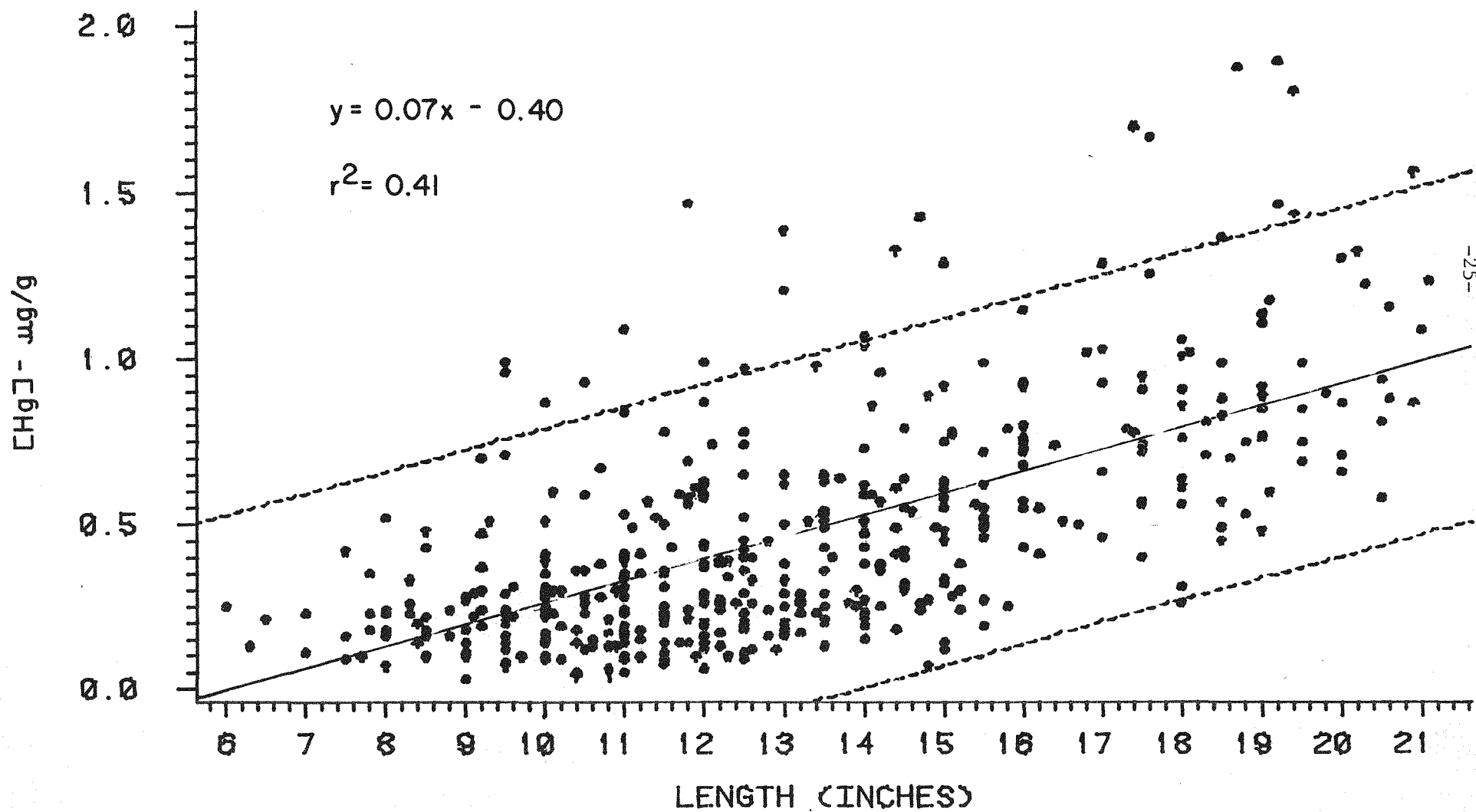


FIGURE 6. REGRESSION OF MERCURY CONCENTRATION ON LENGTH  
FOR LARGEMOUTH BASS ANALYZED BY THE STATE OF TENNESSEE  
1970 - 1979



Once the length range of three-year-old bass was determined (9.7 to 12.2 inches), a least-squares regression was performed using mercury concentration versus year for the years 1973 to 1979; 1973 was selected as the beginning year because it was considered the peak year for mercury values. Prior to 1973 the mercury values were increasing. Including the data for 1970-1972 in the regression calculations would dampen the model's effectiveness in delineating a significant decreasing trend.

Regressions for the combined TVA and State three-year-old bass data at TRMs 60, 157, 210, and 240 (only TVA data at 240), for years 1973-1979, are presented in figure 7. As the slopes of the regression equations indicate, mean mercury concentrations are decreasing in three-year-old bass at the rate of -0.02, -0.09, -0.05, and -0.1  $\mu\text{g/g}$  per year, respectively, at TRMs 60, 157, 210, and 240. This data provides much firmer evidence of a decreasing trend in the mercury content in fish in Pickwick and Kentucky Reservoirs as well as supporting previous data analysis which indicated, more generally, a decreasing trend in the mercury content in largemouth bass, drum, and carp from these reservoirs.

### Conclusions

When TVA's mercury monitoring investigation was initiated in 1970, the analytical techniques for the analysis for total mercury in fish were newly developed. Because of this, and the degree of public concern regarding the health aspects of consuming mercury contaminated fish, it was believed that a thorough quality control effort was needed to reduce the possibility of obtaining erroneous or misleading information on the mercury content in fish from Pickwick and Kentucky Reservoirs. The preceding data analysis has resulted in the following conclusions regarding the quality control scheme used in this investigation:

1. No significant difference was found between the TVA/EPA and State/EPA split sample mercury data.

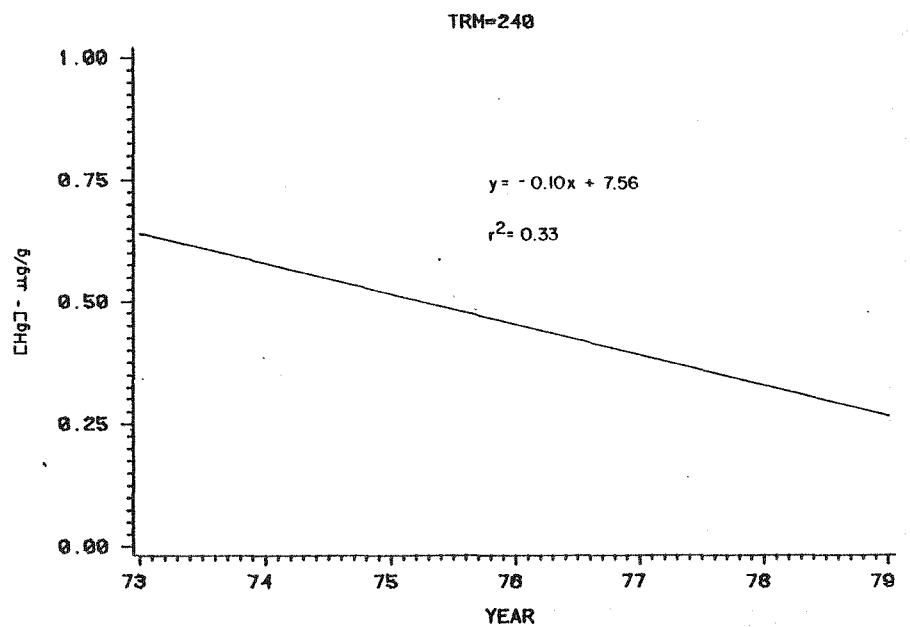
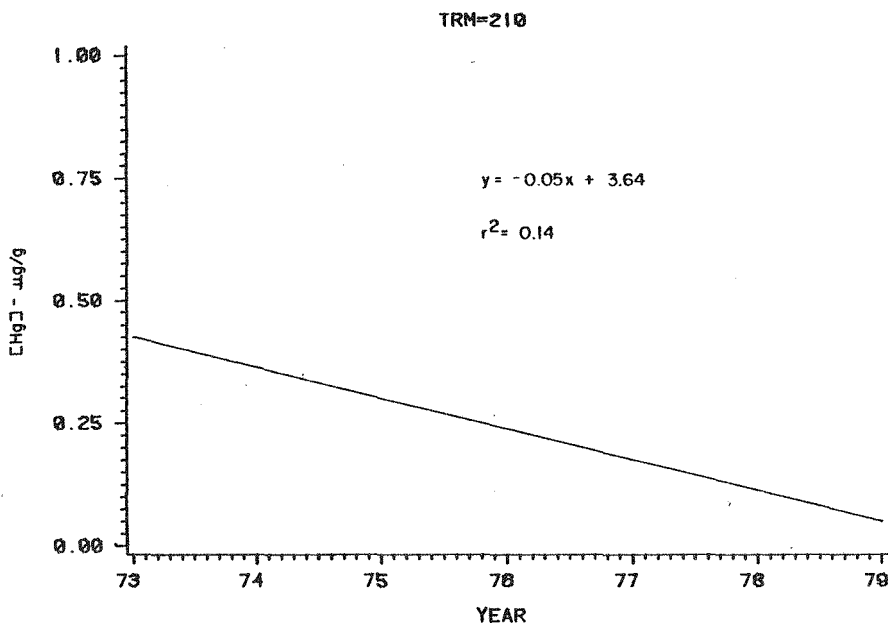
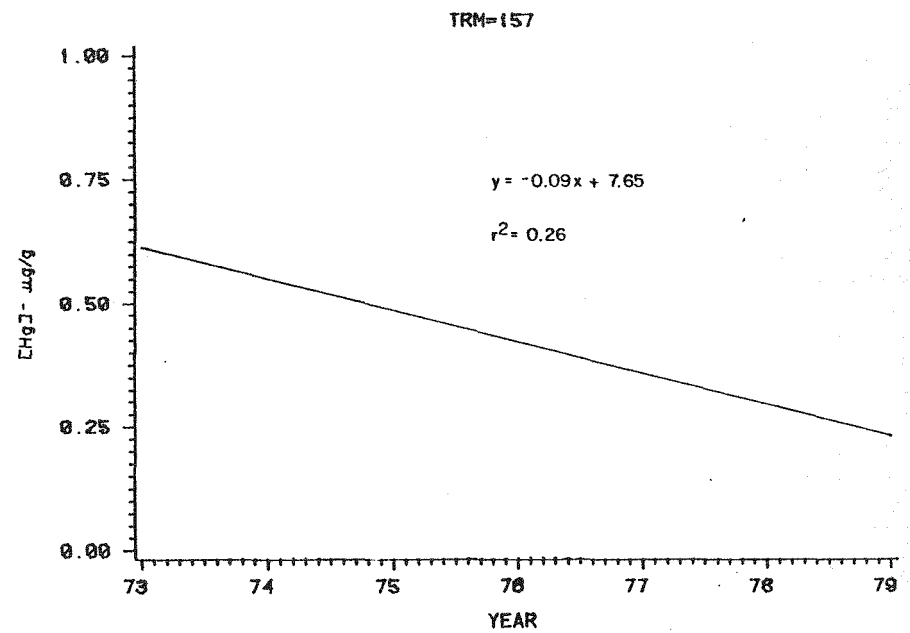
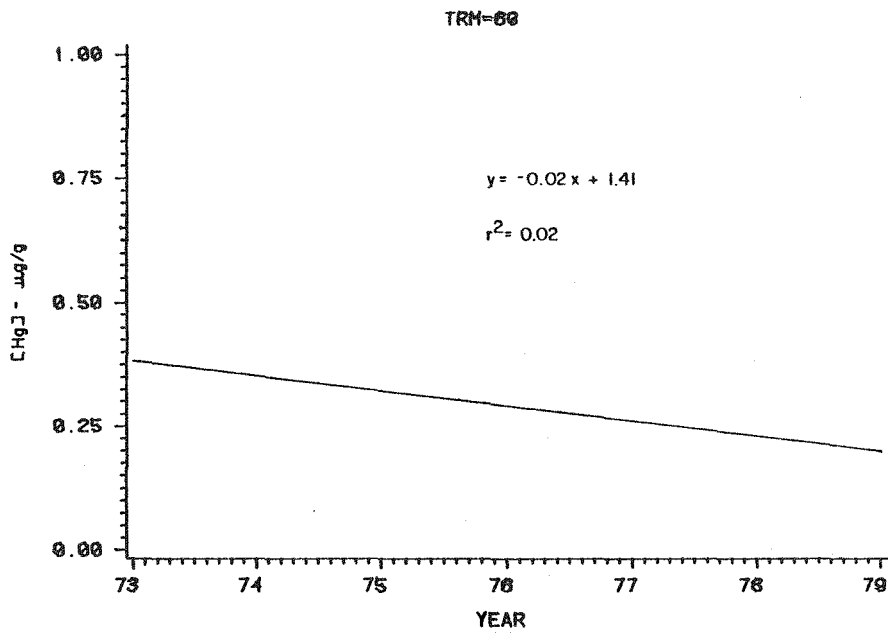


FIGURE 7. LINEAR REGRESSIONS OF MERCURY CONCENTRATIONS IN THREE-YEAR OLD LARGEMOUTH BASS vs. SAMPLING YEAR - TVA AND STATE DATA COMBINED (values in µg/g)

2. TVA and State of Tennessee data are in agreement to the extent that conclusions regarding general trends based on the analysis of one agency's data can be generalized to the other.

Analysis of the TVA and State data to determine whether a relationship existed between fish age (length) and its mercury content demonstrated the existence of a significant positive relationship for largemouth bass by both agencies' data. This relationship enabled an analysis of the mercury data in three-year-old largemouth bass for temporal trends. The results of this analysis, along with the time-concentration plots for all three species and the tables showing the percentages of samples exceeding the 1.0  $\mu\text{g/g}$  FDA guideline, indicated that:

1. The average mercury content in fish downstream from the chlor-alkali plant discharge increased from 1970 to a maximum in 1972 and 1973.
2. The mean mercury concentrations in largemouth bass, carp, and drum from Pickwick and Kentucky Reservoirs have been steadily decreasing since 1973 with concentrations in three-year-old largemouth bass decreasing at an average rate of approximately 0.06  $\mu\text{g/g}$  per year.
3. The percentage of fish collected with mercury concentrations exceeding 1.0  $\mu\text{g/g}$  has decreased steadily since 1973 to less than 2 percent in 1978, and in 1979 no fish sampled contained mercury concentrations exceeding the FDA guideline of 1.0  $\mu\text{g/g}$ .

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APPENDIX A

Interlaboratory Data Comparisons  
Using Students' t-Tests

PAIRED t-TEST OF TVA AND EPA DATA

<u>Year</u>	<u>n</u>	<u>t</u>	<u>Probability</u> <u>&gt;  t </u>
1970	9	-1.26	0.2445
1971	71	-3.11	0.0027
1972	72	-0.57	0.5703
1973	26	3.81	0.0008
1974	26	5.57	0.0001
1975	16	2.01	0.0631
1976	8	0.35	0.7378
1977	4	6.95	0.0061
1978	7	-2.81	0.0309
1979	11	-0.93	0.3760

PAIRED t-TEST OF TVA AND EPA DATA  
(ALL YEARS)

<u>Year</u>	<u>n</u>	<u>t</u>	<u>Probability</u> <u>&gt;  t </u>
All years combined	250	0.74	0.4625

PAIRED t-TEST OF EPA AND STATE DATA

<u>Year</u>	<u>n</u>	<u>t</u>	<u>Probability</u> <u>&gt;  t </u>
1970	0	-	-
1971	53	2.84	0.0065
1972	50	3.68	0.0006
1973	20	3.83	0.0011
1974	20	1.16	0.2621
1975	14	2.29	0.0397
1976	6	1.91	0.1143
1977	2	-1.40	0.3949
1978	6	4.19	0.0086
1979	11	1.30	0.2227

PAIRED t-TEST OF EPA AND STATE DATA  
(ALL YEARS)

<u>Year</u>	<u>n</u>	<u>t</u>	<u>Probability</u> <u>&gt;  t </u>
All years combined	182	6.36	0.0001

UNPAIRED t-TEST OF TVA AND STATE DATA

Year	Station	n		t		Probability >  t	
		TVA	State	TVA	State	TVA	State
1971	TRM 60.0	91	74	-0.1212	-0.1196	0.9037	0.9049
	TRM 157.0	77	72	-0.2687	-0.2676	0.7885	0.7894
	TRM 210.0	98	83	-1.9006	-1.9362	0.0592	0.0544
	TRM 240.0	NS <sup>a</sup>	NS	NS	NS	NS	NS
	TRM 490.0	8	7	-0.1853	-0.1860	0.8559	0.8553
1972	TRM 60.0	73	81	1.4004	1.4158	0.1636	0.1589
	TRM 157.0	71	69	1.9283	1.9138	0.0064	0.0577
	TRM 210.0	63	59	1.4428	1.4359	0.1517	0.1536
	TRM 240.0	NS	NS	NS	NS	NS	NS
	TRM 490.0	9	11	1.0707	1.1167	0.3033	0.2788
1973	TRM 60.0	46	46	2.7418	2.7418	0.0074	0.0074
	TRM 157.0	45	42	5.2358	5.1207	0.0001	0.0001
	TRM 210.0	49	51	2.7208	2.7269	0.0077	0.0076
	TRM 240.0	NS	NS	NS	NS	NS	NS
	TRM 490.0	12	7	1.0452	0.9762	0.3121	0.3427
1974	TRM 60.0	49	52	4.0683	4.1351	0.0001	0.0001
	TRM 157.0	50	51	6.0145	6.0377	0.0001	0.0001
	TRM 210.0	44	45	3.8948	3.9165	0.0002	0.0002
	TRM 240.0	NS	NS	NS	NS	NS	NS
	TRM 490.0	12	16	1.6411	1.8337	0.1240	0.0782
1975	TRM 60.0	34	34	3.5318	3.5318	0.0008	0.0008
	TRM 157.0	25	27	3.9519	4.0257	0.0003	0.0002
	TRM 210.0	36	38	3.2960	3.3672	0.0020	0.0012
	TRM 240.0	NS	NS	NS	NS	NS	NS
	TRM 490.0	5	5	-0.8070	-0.8070	0.4552	0.4430
1976	TRM 60.0	16	18	1.4971	1.5560	0.1494	0.1295
	TRM 157.0	17	18	2.3790	2.4335	0.0275	0.0205
	TRM 210.0	15	15	0.2405	0.2405	0.8121	0.8117
	TRM 240.0	NS	NS	NS	NS	NS	NS
	TRM 490.0	NS	NS	NS	NS	NS	NS

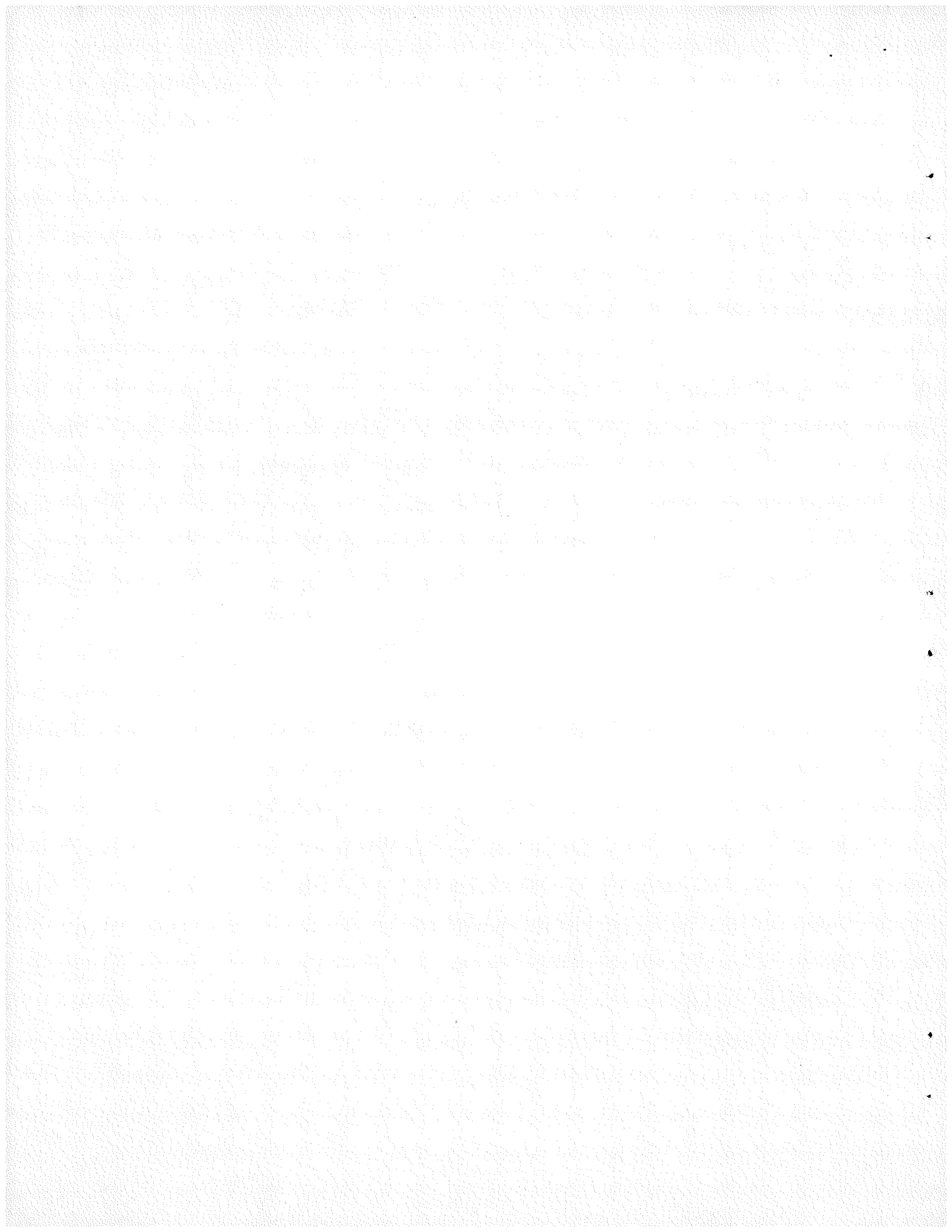
a. NS = no sample collected.

UNPAIRED t-TEST OF TVA AND STATE DATA

(Continued)

Year	Station	n		t		Probability > t	
		TVA	State	TVA	State	TVA	State
1977	TRM 60.0	NS <sup>a</sup>	NS	NS	NS	NS	NS
	TRM 157.0	6	7	-0.0378	-0.0368	0.9705	0.9713
	TRM 210.0	5	4	0.4377	0.4149	0.6753	0.6906
	TRM 240.0	NS	NS	NS	NS	NS	NS
	TRM 490.0	NS	NS	NS	NS	NS	NS
1978	TRM 60.0	16	18	1.5198	1.5187	0.1385	0.1387
	TRM 157.0	16	16	-0.6189	-0.6189	0.5406	0.5406
	TRM 210.0	NS	NS	NS	NS	NS	NS
	TRM 240.0	NS	NS	NS	NS	NS	NS
	TRM 490.0	26	28	3.8727	3.9800	0.0005	0.0002
1979	TRM 60.0	NS	NS	NS	NS	NS	NS
	TRM 157.0	32	30	2.1936	2.1736	0.0323	0.0337
	TRM 210.0	NS	NS	NS	NS	NS	NS
	TRM 240.0	35	15	-0.6316	-0.6360	0.5331	0.5278
	TRM 490.0	25	25	-0.6670	-0.6670	0.5086	0.5080

a. NS = no sample collected.



APPENDIX B

Summary Statistics of Total Mercury Concentrations  
Measured in Largemouth Bass, Carp, and Drum

STATISTICAL SUMMARY OF MERCURY CONCENTRATIONS MEASURED IN LARGEMOUTH BASS  
BY TVA, THE STATE OF TENNESSEE, AND EPA

		Tennessee River Mile														
		60			157			210			240			490		
Year	Statistics	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA
1970	$\bar{x}$	0.53		0.55				0.46		0.64	0.85		0.86	0.06	0.13	
	S.D.	0.14		0.08				0.40		0.32	0.57		0.60	0.01	-	
	Max.	0.76	NS <sup>a</sup>	0.62	NS	NS	NS	1.40	NS	0.96	2.10	NS	1.28	0.07	0.13	NS
	Min.	0.25		0.45				0.05		0.32	0.08		0.43	0.05	0.13	
	n	17		4				13		3	21		2	3	1	
1971	$\bar{x}$	0.53	0.52	0.78	0.79	0.87	1.15	0.70	0.76	1.06	0.80		1.24	0.31	0.24	0.30
	S.D.	0.33	0.31	0.42	0.36	0.36	0.45	0.49	0.49	0.62	0.52		0.62	1.12	0.27	0.14
	Max.	1.90	1.15	2.09	1.90	1.90	2.24	1.90	1.88	2.59	2.10	NS	2.30	0.39	0.43	0.47
	Min.	0.07	0.03	0.11	0.23	0.28	0.24	0.12	0.13	0.15	0.10		0.32	0.22	0.05	0.13
	n	40	35	36	39	36	36	33	36	34	58		16	2	2	4
1972	$\bar{x}$	0.39	0.36	0.56	0.55	0.43	0.67	0.64	0.41	0.65	0.66		0.78	0.22	0.17	0.23
	S.D.	0.28	0.28	0.36	0.40	0.26	0.42	0.51	0.28	0.47	0.38		0.27	0.15	0.16	0.16
	Max.	1.20	0.99	1.50	1.80	0.99	1.96	2.00	1.37	1.76	2.10	NS	1.39	0.39	0.28	0.35
	Min.	0.05	0.09	0.14	0.16	0.13	0.06	0.18	0.10	0.15	0.21		0.37	0.11	0.06	0.04
	n	36	40	31	36	35	32	31	29	33	70		17	3	2	3
1973	$\bar{x}$	0.53	0.45	0.60	1.07	0.59	0.83	0.73	0.54	0.80	1.03		1.02	0.31	0.22	0.35
	S.D.	0.32	0.27	0.45	0.43	0.22	0.38	0.53	0.54	0.66	0.58		0.64	0.17	0.11	0.10
	Max.	1.40	1.14	1.36	2.00	1.09	1.39	2.00	1.81	2.06	3.00	NS	2.18	0.54	0.32	0.43
	Min.	0.11	0.10	0.21	0.34	0.28	0.16	0.15	0.04	0.14	0.11		0.38	0.09	0.08	0.20
	n	24	24	12	24	23	12	23	22	12	45		6	7	4	4
1974	$\bar{x}$	0.61	0.30	0.56	1.01	0.58	0.66	0.65	0.34	0.44	0.76		0.47	0.32	0.18	0.21
	S.D.	0.43	0.24	0.32	0.26	0.20	0.20	0.53	0.22	0.35	0.46		0.28	0.26	0.08	0.04
	Max.	1.80	0.91	1.08	1.80	0.96	1.04	2.40	0.88	1.26	2.40	NS	0.95	0.94	0.32	0.25
	Min.	0.17	0.06	0.24	0.67	0.29	0.40	0.21	0.09	0.04	0.27		0.20	0.16	0.06	0.17
	n	27	27	12	22	23	12	21	22	12	54		6	8	10	4

a. NS = no samples collected.

		Tennessee River Mile														
		60			157			210			240			490		
Year	Statistics	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA
1975	$\bar{x}$	0.45	0.27	0.61	0.83	0.49	0.75	0.53	0.25	0.29	0.56		0.43	0.13	0.42	0.36
	S.D.	0.30	0.26	0.43	0.37	0.20	0.54	0.47	0.14	0.19	0.27		0.19	0.04	0.26	0.24
	Max.	1.20	1.11	1.56	1.40	0.85	1.87	1.80	0.49	0.56	1.40	NS <sup>a</sup>	0.60	0.15	0.71	0.70
	Min.	0.10	0.05	0.25	0.10	0.28	0.30	0.10	0.05	0.08	0.11		0.15	0.10	0.23	0.18
	n	17	18	8	10	11	8	15	16	6	38		4	2	3	4
1976	$\bar{x}$	0.59	0.27	0.84	0.79	0.33	1.03	0.51	0.43	0.21	0.22		0.22			
	S.D.	0.56	0.19	0.51	0.55	0.15	0.54	0.76	0.36	0.12	0.07		0.03			
	Max.	1.60	0.61	1.33	1.80	0.55	0.76	2.20	1.16	0.38	0.34	NS	0.24	NS	NS	NS
	Min.	0.10	0.11	0.28	0.19	0.11	0.18	0.13	0.10	0.12	0.10		0.20			
	n	8	9	4	10	10	4	7	7	4	12		2			
1977	$\bar{x}$				0.30	0.19	0.10	0.10	0.15		0.27		0.10			
	S.D.				0.06	0.20	0.10	0.00	0.01		0.07		0.00			
	Max.	NS	NS	NS	0.34	0.30	0.10	0.20	0.16	NS	0.38	NS	0.10	NS	NS	NS
	Min.				0.23	0.11	0.10	0.10	0.14		0.18		0.10			
	n				3	3	4	2	3		10		2			
1978	$\bar{x}$	0.36	0.30	0.37	0.21	0.39	0.55				0.43		0.53	0.42	0.15	0.20
	S.D.	0.13	0.08	0.11	0.07	0.18	0.22				0.12		0.03	0.18	0.06	0.02
	Max.	0.54	0.43	0.49	0.31	0.71	0.87	NS	NS	NS	0.70	NS	0.55	0.71	0.30	0.22
	Min.	0.24	0.23	0.28	0.11	0.23	0.40				0.20		0.51	0.15	0.07	0.18
	n	4	6	3	6	6	4				15		2	10	10	4
1979	$\bar{x}$				0.32	0.27	0.34				0.39	0.29	0.47	0.31	0.28	0.45
	S.D.				0.13	0.12	0.18				0.21	0.18	0.37	0.11	0.06	0.01
	Max.	NS	NS	NS	0.55	0.53	0.52	NS	NS	NS	0.63	0.60	0.73	0.46	0.38	0.45
	Min.				0.15	0.15	0.10				0.14	0.17	0.21	0.18	0.24	0.44
	n				10	10	6				5	5	2	5	5	2

a. NS = no samples collected.

STATISTICAL SUMMARY OF MERCURY CONCENTRATIONS MEASURED IN CARP  
BY TVA, THE STATE OF TENNESSEE, AND EPA

		Tennessee River Mile														
		60			157			210			240			490		
Year	Statistics	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA
1970	$\bar{x}$	0.30						0.47			0.67			0.06		
	S.D.	0.09						0.20			0.39			-		
	Max.	0.45	NS <sup>a</sup>	NS	NS	NS	NS	0.95	NS	NS	1.80	NS	NS	0.06	NS	NS
	Min.	0.15						0.07			0.06			0.06		
	n	9						22			35			1		
1971	$\bar{x}$	0.39	0.40		0.38	0.48		0.58	0.65		0.66			0.12	0.15	
	S.D.	0.18	0.18		0.16	0.29		0.20	0.16		0.25			0.09	0.05	
	Max.	0.72	0.87	NS	0.69	1.37	NS	0.96	0.89	NS	1.50	NS	NS	0.24	0.20	NS
	Min.	0.11	0.13		0.16	0.12		0.21	0.35		0.14			0.05	0.08	
	n	26	22		18	22		36	24		49			4	4	
1972	$\bar{x}$	0.48	0.34	0.83	0.42	0.41	0.41	0.58	0.51		0.75		0.41	0.29	0.27	
	S.D.	0.18	0.13	-	0.17	0.15	0.23	0.20	0.21		0.28			0.17	0.05	
	Max.	0.83	0.69	0.83	0.92	0.72	0.69	0.88	0.97	NS	1.40	NS	0.41	0.45	0.34	NS
	Min.	0.23	0.14	0.83	0.16	0.19	0.15	0.13	0.21		0.24		0.41	0.14	0.20	
	n	20	26	1	20	22	4	27	20		46		1	4	6	
1973	$\bar{x}$	0.51	0.27		0.71	0.46		0.68	0.47		0.78			0.30	0.14	
	S.D.	0.25	0.12		0.35	0.17		0.13	0.17		0.25			0.22	-	
	Max.	1.00	0.57	NS	1.50	0.85	NS	0.98	0.76	NS	1.10	NS	NS	0.62	0.14	NS
	Min.	0.19	0.06		0.26	0.16		0.47	0.17		0.30			0.11	0.14	
	n	15	15		16	15		16	18		30			4	1	
1974	$\bar{x}$	0.45	0.28		0.54	0.40		0.65	0.33		0.73			0.27	0.21	
	S.D.	0.24	0.13		0.24	0.17		0.21	0.09		0.24			0.12	0.08	
	Max.	0.82	0.61	NS	1.10	0.64	NS	0.97	0.49	NS	1.40	NS	NS	0.40	0.31	NS
	Min.	0.10	0.10		0.10	0.14		0.15	0.18		0.24			0.13	0.06	
	n	14	15		15	15		16	14		30			4	6	

a. NS = no samples collected.

		Tennessee River Mile														
		60			157			210			240			490		
Year	Statistics	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA
1975	$\bar{x}$	0.54	0.29		0.57	0.40		0.43	0.31		0.64			0.29	0.16	
	S.D.	0.27	0.07		0.26	0.17		0.25	0.13		0.15			0.02	0.04	
	Max.	0.93	0.45	NS <sup>a</sup>	1.00	0.69	NS	0.98	0.52	NS	0.85	NS	NS	0.30	0.18	NS
	Min.	0.24	0.22		0.22	0.18		0.12	0.10		0.30			0.27	0.13	
	n	10	10		10	10		15	15		25			3	2	
1976	$\bar{x}$	0.38	0.31		0.39	0.37		0.43	0.38		0.50					
	S.D.	0.19	0.09		0.14	0.16		0.11	0.24		0.11					
	Max.	0.69	0.44	NS	0.63	0.60	NS	0.51	0.78	NS	0.71	NS	NS	NS	NS	NS
	Min.	0.29	0.20		0.27	0.23		0.26	0.13		0.36					
	n	5	5		5	5		4	6		10					
1977	$\bar{x}$				0.55	0.47		0.32	0.30		0.62					
	S.D.				0.26	0.09		0.08	-		0.13					
	Max.	NS	NS	NS	0.81	0.57	NS	0.38	0.30	NS	0.90	NS	NS	NS	NS	NS
	Min.				0.29	0.40		0.26	0.30		0.48					
	n				3	3		2	1		9					
1978	$\bar{x}$	0.48	0.36		0.41	0.35					0.49			0.21	0.15	
	S.D.	0.05	0.14		0.19	0.07					0.10			0.13	0.07	
	Max.	0.54	0.64	NS	0.79	0.44	NS	NS	NS	NS	0.78	NS	NS	0.47	0.30	NS
	Min.	0.41	0.20		0.28	0.24					0.35			0.09	0.06	
	n	7	7		6	5					20			10	10	
1979	$\bar{x}$				0.34	0.31	0.52				0.37	0.45	0.54	0.16	0.19	0.16
	S.D.				0.15	0.11	0.04				0.16	0.11	0.12	0.07	0.10	0.08
	Max.	NS	NS	NS	0.57	0.43	0.54	NS	NS	NS	0.59	0.57	0.62	0.29	0.35	0.28
	Min.				0.13	0.16	0.49				0.12	0.28	0.45	0.10	0.02	0.07
	n				10	9	2				15	5	2	10	10	5

a. NS = no samples collected.

STATISTICAL SUMMARY OF MERCURY CONCENTRATIONS MEASURED IN DRUM  
BY TVA, THE STATE OF TENNESSEE, AND EPA

Year	Statistics	Tennessee River Mile														
		60			157			210			240			490		
		TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA
1970	$\bar{x}$	0.68						0.58					0.92			
	S.D.	0.25						0.15					0.30			
	Max.	0.92	NS <sup>a</sup>	NS	NS	NS	NS	0.70	NS	NS	NS	NS	1.50	NS	NS	NS
	Min.	0.33						0.41					0.68			
	n	4						3					6			
1971	$\bar{x}$	0.46	0.47		0.83	0.73		0.73	0.94			0.80		0.08	0.09	
	S.D.	0.34	0.25		0.61	0.43		0.28	0.51			0.41		0.04	-	
	Max.	1.60	1.07	NS	2.50	1.37	NS	1.50	2.15	NS	NS	1.70	NS	NS	0.11	0.09
	Min.	0.08	0.11		0.34	0.12		0.30	0.34			0.12		0.05	0.09	NS
	n	25	17		20	14		29	23			20		2	1	
1972	$\bar{x}$	0.52	0.51	0.52	0.61	0.41		1.02	0.95			0.88		0.32	0.08	
	S.D.	0.43	0.27	-	0.61	0.27		0.68	0.56			0.49		0.28	0.05	
	Max.	1.90	0.91	0.52	2.60	0.89	NS	2.20	1.92	NS	NS	2.00	NS	NS	0.51	0.14
	Min.	0.07	0.06	0.52	0.20	0.06		0.49	0.19			0.24		0.12	0.05	NS
	n	17	15	1	15	12		5	10			16		2	3	
1973	$\bar{x}$	0.69	0.43		0.80	0.44		0.92	0.58			1.05		0.17	0.27	
	S.D.	0.30	0.38		0.56	0.16		0.52	0.30			0.55		-	0.25	
	Max.	1.10	1.09	NS	1.80	0.66	NS	1.70	1.16	NS	NS	2.70	NS	NS	0.17	0.45
	Min.	0.31	0.13		0.48	0.27		0.22	0.16			0.31		0.17	0.09	NS
	n	7	7		5	4		10	11			20		1	2	
1974	$\bar{x}$	0.68	0.42		0.86	0.43		0.67	0.56			0.84				
	S.D.	0.42	0.22		0.34	0.27		0.36	0.35			0.41				
	Max.	1.40	0.78	NS	1.40	0.97	NS	1.40	1.14	NS	NS	1.90	NS	NS	NS	NS
	Min.	0.15	0.09		0.25	0.08		0.31	0.18			0.18				
	n	8	10		13	13		7	9			18				

a. NS = no samples collected.

		Tennessee River Mile														
		60			157			210			240			490		
Year	Statistics	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA	TVA	State of Tenn.	EPA
1975	$\bar{x}$	0.51	0.25		0.78	0.35		0.84	0.35		0.68					
	S.D.	0.35	0.11		0.26	0.21		0.58	0.20		0.29					
	Max.	1.20	0.41	NS <sup>a</sup>	1.10	0.62	NS	1.60	0.63	NS	1.40	NS	NS	NS	NS	NS
	Min.	0.07	0.14		0.53	0.10		0.28	0.19		0.20					
	n	7	6		5	6		6	7		19					
1976	$\bar{x}$	0.28	0.33		0.55	0.45		0.42	0.55		0.29					
	S.D.	0.09	0.33		0.04	0.24		0.08	0.20		0.22					
	Max.	0.34	0.82	NS	0.57	0.71	NS	0.52	0.69	NS	0.46	NS	NS	NS	NS	NS
	Min.	0.18	0.11		0.52	0.24		0.35	0.41		0.17					
	n	3	4		2	3		4	2		5					
1977	$\bar{x}$					1.01		0.24								
	S.D.					-		-								
	Max.	NS	NS	NS	NS	1.01	NS	0.24	NS	NS	NS	NS	NS	NS	NS	NS
	Min.					1.01		0.24								
	n					1		1								
1978	$\bar{x}$	0.28	0.27		0.16	0.16					0.45			0.24	0.18	
	S.D.	0.13	0.17		0.10	0.06					0.27			0.10	0.08	
	Max.	0.42	0.49	NS	0.31	0.24	NS	NS	NS	NS	1.50	NS	NS	0.39	0.31	NS
	Min.	0.10	0.12		0.10	0.07					0.11			0.11	0.10	
	n	5	5		4	5					23			6	8	
1979	$\bar{x}$				0.35	0.24	0.25				0.38	0.49		0.18	0.23	0.12
	S.D.				0.16	0.10	0.10				0.16	0.14		0.09	0.23	-
	Max.	NS	NS	NS	0.58	0.43	0.32	NS	NS	NS	0.76	0.62	NS	0.39	0.87	0.12
	Min.				0.13	0.11	0.18				0.14	0.28		0.10	0.07	0.12
	n				12	11	2				15	5		10	10	1

a. NS = no samples collected.