TECHNICAL MEMORANDUM

CHLORINATED HYDROCARBON PESTICIDE RESIDUES IN FRESHWATER FISHES WITHIN THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT

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(REVISED)

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ABSTRACT

Samples of fish were collected from freshwater habitats in central and south Florida from 1970 to 1978 for analysis of persistent pesticide residues. Residues of four chlorinated hydrocarbon insecticides (DDT, dieldrin, chlordane and toxaphene) and one industrial compound (PCB) were found in nearly all fish samples from almost every location. Pesticide residues were highest in fish collected from watersheds influenced by drainage water from agricultural areas. Fish collected from the Kissimmee River Basin contained extremely low levels of pesticides.

Concentrations of persistent chlorinated hydrocarbon compounds in whole fish from central and southern Florida freshwater habitats were considerably lower than in fish from many other watersheds in the United States. Pesticide concentrations reported from whole fish in this study were less than Food and Drug Administation tolerance levels established for edible portions of fish. DDT concentration in fish from agriculturally influenced areas in south Florida generally ranged from 0.2 to 0.8 ppm. Fish samples collected from the Kissimmee River Basin had DDT residues of 0.03 ppm or less. High toxaphene residues of 5.0 ppm were reported in some specimens from agriculturally influenced watersheds in 1971. By 1978 the highest toxaphene residue had declined to 2.7 ppm in the agriculturally influenced areas.

There was no other consistent increase or decrease in concentrations of pesticide residues in the areas examined between 1970 and 1978.

INTRODUCTION

Some of the effects attributed to the presence and accumulation of persistent, man-made chemical compounds on the environment were first brought to national attention in 1962 with the publication of Rachael Carson's Silent Spring.

One group of particularly persistent chemical compounds that are potentially hazardous and toxic to the environment and to humans are the synthetically produced chlorinated hydrocarbon pesticides. These compounds are relatively insoluble in water, but are highly soluble in animal fatty tissues. Chlorinated hydrocarbons are extremely stable, and as in the case of DDT, the breakdown metabolites, DDD and DDE, are also highly toxic. Additionally, these compounds are extremely mobile in the environment. Chlorinated hydrocarbons adhere to soil and dust particles, and therefore may be physically transported by wind and water. Chlorinated hydrocarbons are transmitted and concentrated through both aquatic and terrestrial food webs by a process called "biological magnification" or "bioaccumulation".

Chlorinated hydrocarbons have been widely used for the control of insect and rodent populations throughout agricultural and urban areas of the world for the past four decades. A National Pesticide Monitoring Program was established during the 1960's to provide a continuing nationwide assessment of the general levels of pesticide residues in the environment, and to locate possible problem areas within specific segments of the environment (Henderson, et al, 1969). Due to the integral relationships between natural ecosystems and agricultural and urban land uses in south Florida, the South Florida Water Management District (SFWMD) initiated a pesticide monitoring program in 1970.

This program was designed to gather baseline data concerning the presence

and abundance of persistent pesticides in selected freshwater fish species, and to determine the long term trends of these compounds in south Florida. This report presents the results of the pesticide residue monitoring program from 1970 through 1978. The pesticide monitoring program will be continued at approximately five year intervals. The data derived from future analyses will be included in subsequent reports.

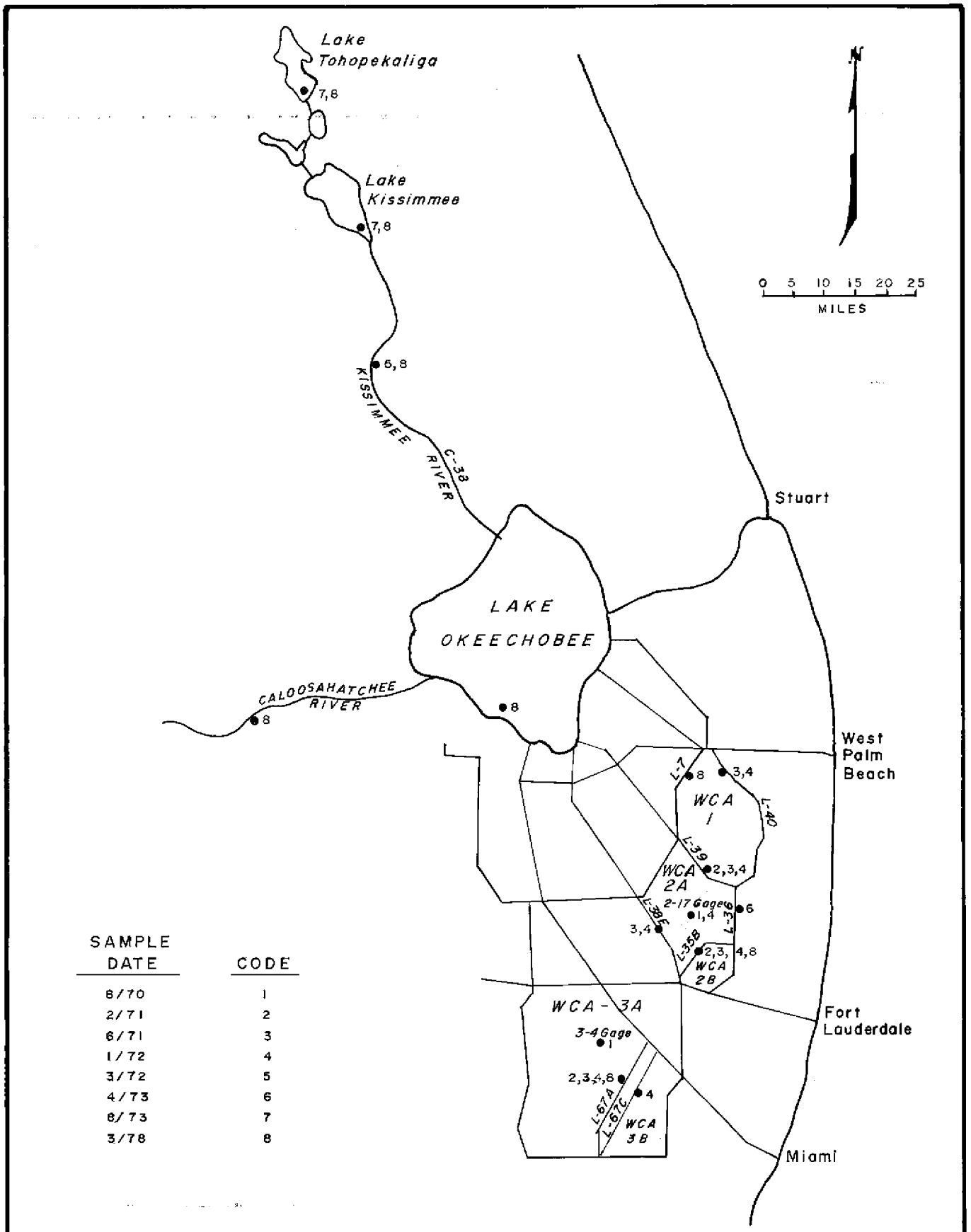
MATERIALS AND METHODS

Samples of freshwater fish for analyses of pesticide residues have been collected from various locations throughout the District since August 1970. Figure 1 shows the locations and dates of sampling. The earliest samples were collected from the water conservation area system, while later sampling efforts included the Kissimmee River, Kissimmee chain of lakes, Lake Okeechobee, and the Caloosahatchee River.

Fish were collected from canal and lake sites by electroshocking with a 240 volt generator and two, six foot long electrodes extending into the water from the bow of a boat. Stunned fish were netted and placed into a shallow water-filled box until selection of individuals for analysis. Fish from the interior marshes of the water conservation areas were collected by fly-fishing. An attempt was made to sample fish species that represented three different trophic levels at each location. The largemouth bass, Micropterus salmoides, was present in 100 percent of the samples submitted. The redear sunfish, Lepomis microlophus, and the lake chubsucker, Erimyzon sucetta, were present in about half of the samples submitted.

Usually, five specimens of each species were composited for one sample. An effort was made to obtain fish of each species that were approximately equal in length from all areas. Largemouth bass were generally 8 to 12 inches in length, redear sunfish 4 to 7 inches in length, and chubsucker 10 to 11 inches in length. Because of some sampling difficulties there were occasionally some individuals included in the composite samples which were larger and/or smaller than the desired range. The selected specimens were wrapped in aluminum foil, frozen, packed in dry ice, and shipped to the laboratory for analyses.

Analyses of the August 1970, February 1971, June 1971, January 1972,



SAMPLE DATE	CODE
8/70	1
2/71	2
6/71	3
1/72	4
3/72	5
4/73	6
8/73	7
3/78	8

Figure 1 LOCATION AND DATES OF FISH PESTICIDE SAMPLING PROGRAM

March 1972, and April 1973 samples were performed by the U.S. Geological Survey (USGS), Water Quality Laboratory in Washington, D.C. The August 1973 samples were analyzed by the Department of Health, Education and Welfare, Public Health Service, FDA Laboratory in Atlanta. The USGS Atlanta Central Water Quality Laboratory in Doraville, Georgia performed the analysis of the March 1978 samples. The composite samples of fish were ground whole in a laboratory blender, and analyzed using the laboratory methods presented in Appendix I.

Samples from August 1970 and February 1971 were analyzed for the following chlorinated hydrocarbon compounds: aldrin, dieldrin, endrin, heptachlor, lindane and the DDT compounds (DDT, DDD, DDE). Toxaphene and polychlorinated biphenyl (PCB) analyses were performed beginning with the June 1971 samples, and chlordane was added with the January 1972 analyses. The 1978 samples were analyzed for a total of 15 chlorinated hydrocarbon insecticides, plus PCB and polychlorinated napthalenes (PCN).

Results are presented in µg/kg (micrograms of pesticide per kilogram whole fish, wet weight), or ppb (parts per billion). One thousand µg/kg is equivalent to one mg/kg or one ppm (parts per million). The sum of DDT and the metabolite product residues is reported as total DDT-R.

RESULTS AND DISCUSSION

I. Pesticides

Analysis of pesticide residues in the fish samples collected from the SFWMD indicated that five major chlorinated hydrocarbon compounds were present regularly in the samples. These included four insecticides, DDT and its metabolites DDD and DDE, dieldrin, toxaphene and chlordane, and a widely used industrial chemical, PCB. (Endrin was present in 21% of the 1978 samples).

a. DDT, dichloro-diphenyl-trichloroethane, $(ClC_6H_4)_2CHC\ Cl_3$, gained wide use as a pesticide in the middle and late 1940's throughout many parts of the world, particularly for the control of malaria breeding mosquito populations. DDT became such a popular pesticide that by 1958 production of the compound in the United States was seven times that of a decade earlier (Ehrlich and Ehrlich, 1970). Breakdown of DDT in the environment is slow with an estimated half life exceeding 10 years. Unfortunately, two of the breakdown products of DDT; DDE (dichloro-diphenyl-dichloroethylene) and DDD (dichloro-diphenyl-dichloroethane), are also extremely stable chemical compounds.

b. Dieldrin $C_{12}H_8Cl_6$, considered to be four times as toxic as DDT (Ehrlich and Ehrlich, 1970), was used in south Florida primarily for the control of sweet potato weevil (Higer and Kolipinski, 1970).

c. Toxaphene, a chlorinated camphene containing 67-69% chlorine, replaced DDT when its use was restricted in south Florida in 1969 (Courtney and Roberts, 1973) and is widely used on corn, beans, cabbage, peas, tomatoes and sod.

d. Chlordane, $C_{10}H_6Cl_8$, was extensively used in this country for control of fire ants and subterranean termites.

Chlorinated hydrocarbons act primarily on the central nervous system. The ability of these compounds to affect the production of enzymes may account for a wide range of detrimental effects. Chlorinated hydrocarbons are more toxic to insects than to mammals due to the ease with which the chemical is absorbed through insect cuticles.

e. PCB's, compounds produced by the chlorination of biphenyls, are used in a variety of industrial processes, including the manufacture of plastic and synthetic rubber compounds, and may be applied with pesticides to extend the "kill life" of the poisons.

As the dangers of some of these compounds have become further understood, action has been taken by the Federal Government to ban their use in this country. Use of DDT and dieldrin was outlawed by the United States Environmental Protection Agency (EPA) in the early 1970's. Chlordane was classified in 1979 by EPA as "restricted", with its use limited to the control of subterranean termites. Toxaphene is still recommended for use in south Florida in controlling cattle hornflies, bean leaf rollers, and several types of corn infesting larvae.

II. Species of Fish Sampled

Thirty sets of fish samples have been submitted for pesticide analysis since August 1970. Each set was from a specific location on a specific date, and consisted of samples of one to six species of fish. Largemouth bass (*M. salmoides*), redear sunfish (*L. microlophus*), and lake chubsucker (*E. sucetta*) were the most frequently sampled fish. Table 1 lists all species of fish analyzed for pesticide residues, and the relative frequency of analysis.

Largemouth bass greater than six inches in length are primarily piscivorous (Chew, 1968) but also eat considerable amounts of decapods

TABLE 1. FISH SPECIES ANALYZED FOR PESTICIDE RESIDUES FROM THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Common Name	Scientific Name	Area Sampled*	Frequency N=30
Largemouth bass	Micropterus salmoides	1-8	100%
Redear sunfish	Lepomis microlophus	1-8	57
Lake chubsucker	Erimyzon sucetta	1-7	47
Bluegill	Lepomis macrochirus	1,2,3,7,8	23
Gizzard shad	Dorosoma petenense	1,3,7	10
Warmouth	Lepomis gulosus	3	7
Golden shiner	Notemigonus crysoleucas	3	7
American eel	Anguilla rostrata	2	7
Spotted sunfish	Lepomis punctatus	1	3
Black crappie	Pomoxis nigromaculatus	3	3
White catfish	Ictalurus catus	2	3
Brown bullhead	Ictalurus nebulosus	7	3
Walking catfish	Clarias batrachus	2	3
Bowfin	Amia calva	2	3

*Code

1 = WCA 1
2 = WCA 2
3 = WCA 3
4 = Lake Okeechobee
5 = Kissimmee River
6 = Lake Kissimmee
7 = Lake Tohopekaliga
8 = Caloosahatchee River

(McLane, 1955; Dineen, personal communication). Bass occupy a high trophic level in the aquatic ecosystem and should accumulate high concentrations of pesticide residues due to biological magnification. The diet of redear sunfish consists primarily of diptera larvae, copepods, other insect larvae as available, and gastropods (Wilbur, 1969). The lake chubsucker is omnivorous, and its diet consists of algae, plant matter, detritus, and diptera larvae (McLane, 1955). In instances where comparisons among species from the same location were possible, pesticide concentrations in redear sunfish were usually less than largemouth bass and greater than lake chubsuckers.

III. Pesticide Residues in Fish

The results presented in this report are subject to several types of variability. The most recent pesticide results from the USGS were prefaced with the statement, "Due to the complexity of the gas chromatographic curves and unusually high levels of toxaphene found, it became very difficult to interpret the curves accurately. Therefore, we wish to qualify the data reported on samples that contained toxaphene, chlordane, and the DDT's by status that the precision is estimated to be 20%" (Higer, 1978). Occasionally the results indicated that interference by some compounds in the analyses masked the presence of dieldrin or DDT (See Table 3 or Appendix II).

The size and age of the fish analyzed can affect the accumulation of pesticide residues. Pesticide residues in fish specimens can vary during the year since seasonal changes reflect surrounding agricultural land use practices and climatic conditions. Additionally, there can be considerable variability in the accumulation of pesticides among individuals from a small population. All of these variables, analytical and biological,

should be considered when comparing the pesticide residue results among species, locations, and dates.

Each sample was usually a composite of five individual specimens. Table 2 shows the variation in DDT residues attributed to five largemouth bass, analyzed individually. These fish were of approximately the same size, and were taken from the same location, but exhibited a wide range of concentrations for DDT and derivative products. It should be noted that all other composite samples to be discussed in this report may represent a similar wide range of variability from the component individuals.

The concept that largemouth bass represent a higher trophic level than redear sunfish, and consequently should accumulate higher concentrations of pesticide residues, was usually valid although several exceptions occurred. The reason for these exceptions may be related to the variables discussed above.

Table 3 summarizes the pesticide residue data for largemouth bass, redear sunfish and lake chubsucker. The data for all other species of fish is presented in Appendix II.

IIIa. Water Conservation Areas

All of the sampling efforts from August 1970 to January 1972 were conducted in the water conservation area (WCA) system.[1] These results and the 1978 data generally showed that the highest concentrations of pesticides were found in fish from WCA 1, followed by WCA 2 and WCA 3. Within WCA 1, samples from L-40 in the north end had higher pesticide residues than samples taken along the southwest side in L-39.

[1]The results of most analyses from 1971 and 1972 were published by McPherson (1973).

TABLE 2. CONCENTRATION OF DDT AND DERIVATIVES FROM FIVE INDIVIDUAL LARGEMOUTH BASS (MICROPTERUS SALMOIDES) OBTAINED FROM WATER CONSERVATION AREA 1 (L-39) ON FEBRUARY 16, 1971

	Total Length of Fish		Pesticide Residues µg/kg			
	mm	Inches	DDD	DDE	DDT	Total DDT-R
	132	5.2	100	140	3.6	243.6
	160	6.3	58	55	4.4	117.4
	149	5.9	56	130	13.0	199.0
	142	5.6	120	170	9.7	299.7
	121	4.8	59	78	4.4	141.4
$\bar{x}$	141	5.6	78.6	114.6	7.0	200.2
s	15.1	0.6	29.5	47.0	4.1	74.3
coefficient of variation*	11%	11%	38%	41%	59%	37%

*c v $= \frac{s}{\bar{x}} \times 100$

TABLE 3. PESTICIDE RESIDUES IN LARGEMOUTH BASS, REDEAR SUNFISH, AUGUST 1970 - MARCH 1978

Date	Location Species	Number Individuals	Size Range Total Length
8-70	WCA2A - 2-17 gauge		
	Largemouth bass	5	9 - 10"
	WCA3A - 3-4 gauge		
	Largemouth bass	5	9 - 11"
2-71	WCA 1 - L-39		
	Largemouth bass	5	8.5 - 10"
	Redear	5	4 - 7"
	Chubsucker	5	8 - 9"
	WCA 2 - L-35B		
	Largemouth bass	6	8 -10"
	Redear	7	6 - 8.5"
	Chubsucker	5	9 - 10"
	WCA 3 - L-67A		
	Largemouth bass	5	5.5 - 9"
	Redear	5	4.5 - 8"
	Chubsucker	5	8 - 9.5"
6-71	WCA 1 - L-40		
	Largemouth bass	5	10 - 12"
	Redear	5	7 - 8"
	L-39		
	Largemouth bass	5	10 - 12"
	Chubsucker	5	10 - 11"
	WCA2A L-35B		
	Largemouth bass	5	5 - 13"
	Redear	5	8 - 9"
	Chubsucker	5	10 - 11"
	L-38E		
	Largemouth bass	5	7 - 11"
	Redear	5	6 - 8"
	WCA3A L-67A		
	Largemouth bass	5	8 - 10"
	Chubsucker	5	10 - 11"

AND LAKE CHUBSUCKER FROM SOUTH FLORIDA WATER MANAGEMENT DISTRICT WATERS,

Pesticide Residues µg/kg								
DDD	DDE	DDT	Total DDT-R	Dieldrin	Endrin	Chlordane	Toxaphene	PCB
39	120	50	209	-				
23	93	38	154	0.4				
36	39	25	100	-	-			
24	31	9.4	64	-	-			
8.9	7.7	-	17	-	-			
38	160	52	250	-	-			
53	62	54	169	-	-			
6.9	7	8.5	22	-	-			
1.3	4.9	4	10	-	-			
11	12	20	43	-	-			
2.0	4.3	2.0	8.3	-	-			
480	320	-	800	130	-		5000	50
350	280	-	630	5.7	-		5000	40
290	220	-	510	4.6	-		500	40
250	140	-	390	6.0	-		-	40
23	17	24	64	0.6	-		300	40
190	220	40	450	2.3	-		50	-
5.2	22	-	27	-	-		-	-
68	110	-	178	3.4	-		5000	40
33	28	-	61	2.1	-		1300	50
6.6	6.4	6.8	20	*	-		20	100
4.0	2.0	-	6.0	*	-		60	30

TABLE 3. Cont.

Date	Location Species	Number Individuals	Size Range Total Length
1-72	WCA 1 - L-39		
	Largemouth bass	5	6 - 9"
	Redear	5	3 - 8"
	L-40		
	Largemouth bass	1	10"
	WCA2A L-35B		
	Largemouth bass	5	7 - 10"
	Chubsucker	5	5 - 13"
	L-38E		
	Largemouth bass	5	6 - 14"
	2-17 gauge		
	Largemouth bass	2	6 - 7"
	WCA 3 L-67A		
	Largemouth bass	5	5.5 - 14"
	L-67C		
	Largemouth bass	5	8 - 12"
3-72	C-38 Pool B		
	Largemouth bass	5	6 - 10"
	Redear	5	4 - 7"
4-73	L-36 - East of WCA2A		
	Largemouth bass	4	11 - 15"
	Redear	5	4 - 10"
8-73	Lake Tohopekaliga		
	Largemouth bass	n.a.	4 - 13"
	Largemouth bass	n.a.	4 - 13"
	Lake Kissimmee		
	Largemouth bass	n.a.	4 - 9"
3-78	WCA 1 - L-7		
	Largemouth bass	5	7 - 12"
	Redear	5	6 - 8"
	Chubsucker	5	5 - 13"

Pesticide Residues µg/kg								
DDD	DDE	DDT	Total DDT-R	Dieldrin	Endrin	Chlordane	Toxaphene	PCB
48	160	-	208	2.6	-	-	150	50
92	130	-	222	2.5	-	-	150	35
230	160	-	390	29	-	-	2200	15
6.1	29	4.5	40	1.4	-	-	30	15
1.1	4.9	-	6	0.3	-	-	5	10
140	410	74	624	6.3	-	-	450	70
8.3	33	5.3	47	0.8	-	-	40	15
38	150	30	218	2.1	-	-	80	50
4.4	19	4.7	28	1.1	-	-	30	10
0.6	3.0	1.0	5	0.3	-	-		6
0.4	1.2	-	2	0.3	-	-		<5
80	380	25	485	2.1	-	170	200	26
52	120	8.2	180	2.0	-	85	260	20
-	20	-	20	-		-	-	
-	30	-	30	-		-	-	
20	10	-	30	-		-	-	
-	78	-	78	27	52	-	2700	-
820	830	-	1650	18	-	300	750	-
400	250	-	650	8.5	24	240	1030	-

TABLE 3. Cont.

Date	Location Species	Number Individuals	Size Range Total Length
3-78	WCA 2 - L-35B		
	Largemouth bass	5	7 - 13"
	Redear**	5	6 - 7"
	Chubsucker	5	5 - 12"
	WCA 3 - L-67A		
	Largemouth bass	5	7 - 13"
	Redear**	5	5 - 9"
	Chubsucker	5	6 - 12"
	Lake Okeechobee		
	Largemouth bass	5	5 - 13"
	Redear	5	6 - 8"
	Chubsucker	5	10 - 13"
	C-38 - Pool B		
	Largemouth bass	5	7 - 14"
	Redear	5	5 - 9"
	Chubsucker	5	6 - 12"
	Lake Tohopekaliga		
	Largemouth bass	5	5 - 13"
	Redear	5	4 - 9"
	Chubsucker	3	8 - 11"
	Lake Kissimmee		
	Largemouth bass	5	10 - 13"
	Redear	5	7 - 9"
	Chubsucker	5	11 - 12"
	Caloosahatchee River		
	Largemouth bass	5	6 - 14"
	Redear	5	4 - 11"

- indicates not detected in analysis
blank indicates no analysis made
* interference
** samples may be reversed
n.a. data not available

Pesticide Residues µg/kg								
DDD	DDE	DDT	Total DDT-R	Dieldrin	Endrin	Chlordane	Toxaphene	PCB
33	150	-	183	1.4	-	46	220	-
7.2	29	7.1	43	-	-	16	23	8.3
-	8	-	8	0.7	-	5.9	-	4.9
6.0	45	7.0	58	0.8		14	-	23
6.7	17	-	24	1.1	0.5	11	30	5.9
3.8	13	-	17	0.3	-	7.7	9.9	7.8
42	160	-	202	1.5	-	30	103	6.8
430	410	-	840	7.4	-	170	260	-
55	96	12	163	1.5	0.5	34	-	2.7
0.8	13	-	14	0.3	-	6.7	-	4.8
0.3	5.8	1.6	8	2.6	0.6	-	-	2.8
0.4	3.1	-	4	-	-	3.8	-	2.4
1.1	17	-	18	-	-	17	-	11
-	5.4	-	5	0.6	-	5.4	6.9	3.8
-	2.6	-	3	0.4	-	6	-	3.3
1.3	16	-	14	0.8	-	2.8	-	4.8
2.4	14	-	16	2.6	-	14	-	5.8
0.6	2.8	-	3	0.3	-	4.3	-	-
48	110	35	193	37		48	37	100
59	79	19	157	71	-	42	-	37

In Water Conservation Area 2A, the fish taken from the southwest side, in L-38E, usually had higher concentrations of DDT-R than samples taken from the southeast side in L-35B. Total DDT-R values in largemouth bass from the central portion of WCA2A, near the 2-17 gauge, ranged from 47 µg/kg to 209 µg/kg. With the exception of the results from L-38E on January 1972, background levels from the interior of WCA2A were similar to the results from the canals. This indicates considerable areal movement of the pesticide residues through WCA2A food chains.

L-67A flows from the Miami Canal to Everglades National Park in the southern portion of WCA 3, and receives water from agricultural areas to the north and from urban and agricultural areas to the east. The data from January 1972 indicate considerably higher pesticide residues in fish collected from L-67A than in fish from L-67C, an isolated canal situated about a mile to the east. Generally, pesticide residues in fish from WCA 3 were much lower than in fish from WCA 1 and WCA 2.

Toxaphene and dieldrin concentrations were much higher at the north end of WCA 1 (L-40) and the southwest portion of WCA 2 (L-38E) than throughout the rest of the water conservation area system. Dieldrin was present in only one sample from WCA3A prior to June 1971. After June 1971, dieldrin was found, although usually in small amounts, in nearly every sample taken. The concentration of toxaphene, estimated at 5000 µg/kg (5.0 ppm), was high in some fish from WCA 1 and WCA 2 in June 1971. Subsequent samples from L-40 and L-7 in January 1972 and March 1978, respectively, show that toxaphene residues have decreased by about 50% or more, depending on the species of fish examined.

Samples were analyzed for chlordane beginning in January 1972. Redear sunfish and largemouth bass from L-36 canal, outside WCA 2 and adjacent to sod farms, contained chlordane residues of 85 and 170 µg/kg,

respectively in April 1973. Chlordane was not detected in any of the fish samples from within the WCA system until March 1978; however, nearly all fish from the WCA's contained chlordane residues in 1978. Chlordane concentrations of 240 µg/kg in lake chubsucker and 300 µg/kg in redear sunfish from WCA 1 were considerably higher than residues measured in fish from WCA 2 or WCA 3.

DDT was an identifiable component of the total DDT-R in fish analyzed in August 1970 and February 1971, and, with one exception, accounted for 15 to 47 percent of the total residue. From June 1971 to 1978 the amount of DDT in proportion to the total DDT-R generally declined in the fish analyzed, and 57% of the samples had no DDT. By 1978 only two of the nine fish samples from the WCA system contained any DDT at all. This data appears to document that DDT is being broken down into its derivative products in the environment since its use was banned in the early 1970's.

IIIb. Kissimmee River Basin

Pesticide residues in fish from Lake Tohopekaliga, Lake Kissimmee and the Kissimmee River were at least an order of magnitude less than residues in the fish from agriculturally impacted waters in WCA 1 and WCA 2. These low concentrations can be attributed to the lack of intensive crop agriculture in the Kissimmee drainage basins. Rather, much of the agricultural land use is range pasture which requires much less insect control treatment.

IIIc. Other Areas

Samples were obtained from Lake Okeechobee and the Caloosahatchee River for the first time in March 1978, so no comparison can be made with previous data. On a relative scale, total DDT residues in fish from these two areas were nearly as high as from the agriculturally influenced portions of the WCAs although levels of chlordane and toxaphene

were generally lower. Fish samples from the Caloosahatchee River still contained appreciable amounts of DDT, whereas in most other areas, DDT has almost entirely broken down to DDD and DDE. This may suggest that there is a continued use of DDT within the Caloosahatchee River drainage area.

Figures 2 and 3 graphically show the concentrations of DDT-R and dieldrin, respectively, in largemouth bass throughout the District. The numbers adjacent to each data point on these figures refer to the sampling date. These figures indicate that there has been no consistent increase or reduction of DDT-R and dieldrin residues in bass during the last eight years.

IV. Effects of Pesticide Residues on Fishes

Although many species of fish are able to tolerate relatively high residual concentration of pesticides in their body fats, other sub-lethal effects attributable to pesticides include birth defects, growth of tumors, genetic changes, altered behavior patterns, low adaptability to environmental stresses such as temperature and salinity, reproductive failures, mortality of fry, and changes in swimming ability and oxygen consumption (EPA, 1973; Menzie, 1972). Indirect effects of pesticide accumulation in aquatic ecosystems on fish include reduction in the food supply, reduced photosynthetic activity of aquatic plants and increased BOD from dying phytoplankton (EPA, 1973).

V. Comparisons

The EPA has established Federal Water Quality Criteria for concentrations of chlorinated hydrocarbon compounds in fresh water (DDT, 0.001 µg/l; PCB, 0.001 µg/l; toxaphene, 0.005 µg/l; chlordane, 0.01 µg/l). The

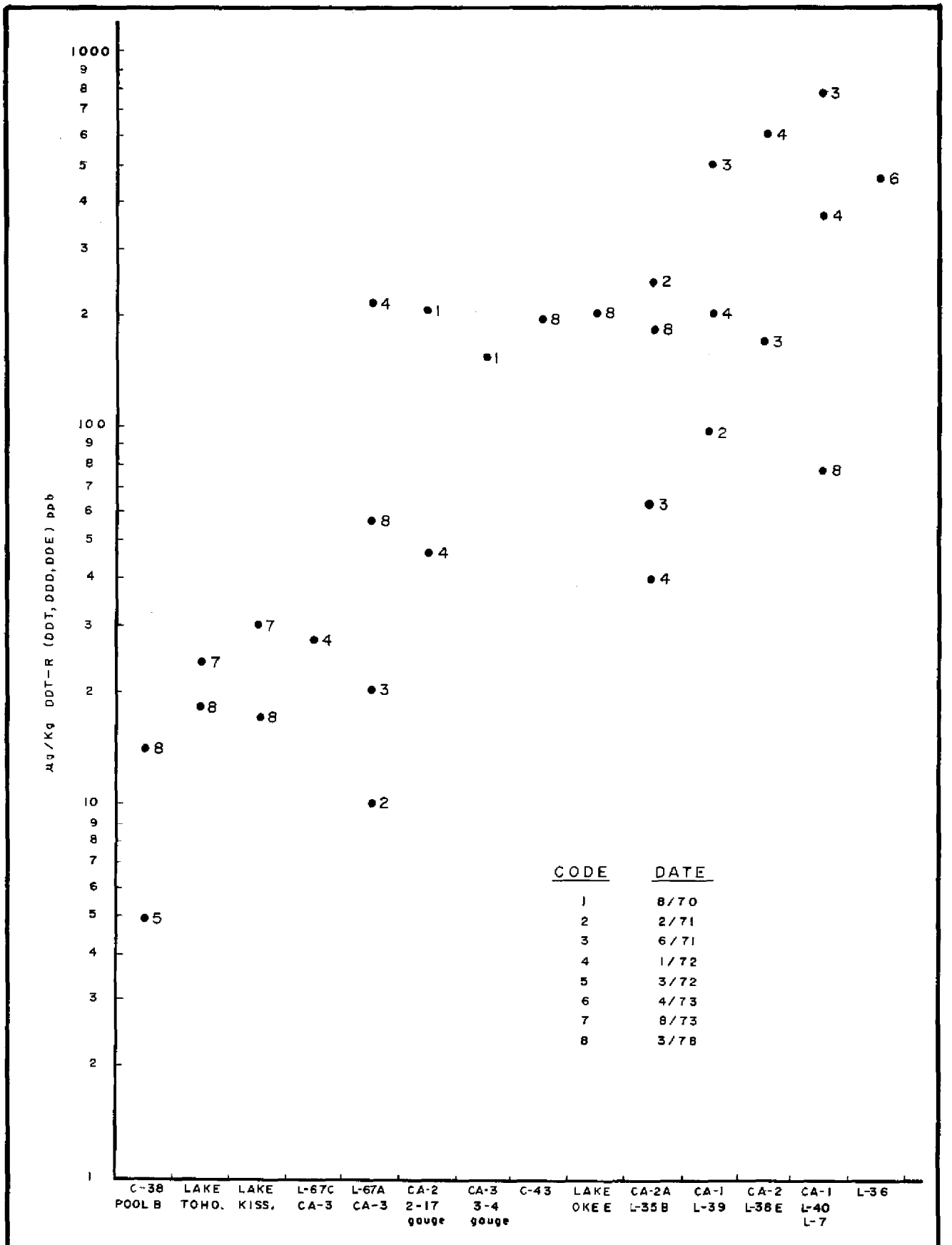


Figure 2 CONCENTRATION OF TOTAL DDT-R IN LARGEMOUTH BASS (µg/Kg) 1970–1978

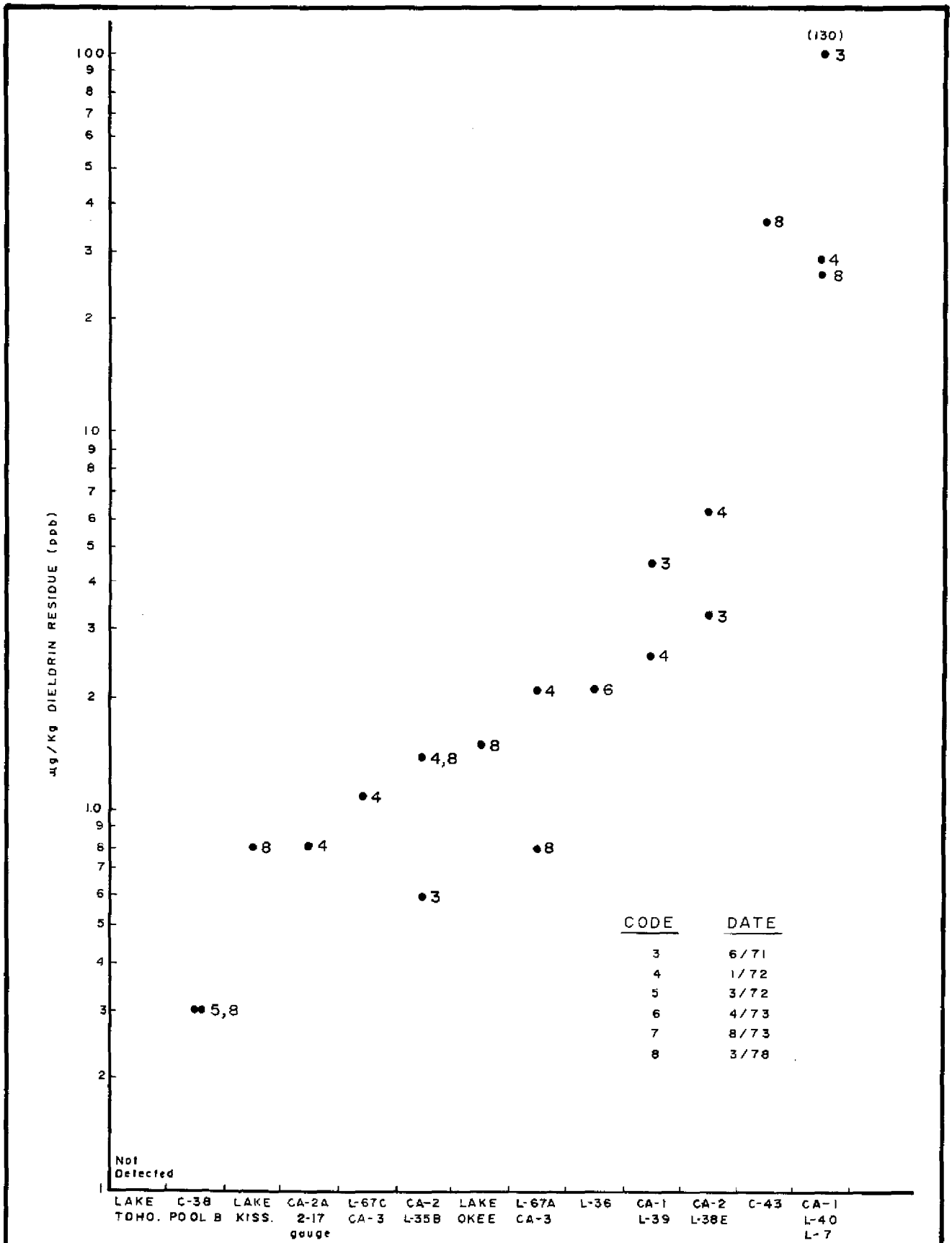


Figure 3 CONCENTRATION OF DIELDRIN IN LARGEMOUTH BASS (µg/Kg) 1971–1978

Food and Drug Administration (FDA), U.S. Department of Health, Education and Welfare, has tolerance levels for pesticides in edible portions of fish (DDT, 5.0 ppm; PCB, 5.0 ppm; toxaphene, 7.0 ppm; dieldrin, 0.3 ppm).

Pesticide residues in whole fish are an appropriate means of expressing environmental pesticide contamination and provide a gross means of comparison between locations and dates. Data interpretation and comparisons must be made with the numerous sources of variation kept in mind (food habits, size, age, species, fat content, etc.).

The levels of pesticide residues in freshwater fish from this study were considerably lower than FDA tolerance levels. This is impressive since these samples contain fatty tissues and internal organs, which tend to accumulate pesticides, that are not included with the edible portion for FDA limits.

In comparison, pesticide residues in whole fish from SFWMD watersheds were considerably lower than the values reported from many other areas of the United States. Table 4 provides some examples of pesticide residues in whole fish and indicates the wide range of values reported. Total DDT-R residues in fish from agriculturally influenced water bodies of south Florida generally ranged from 200 to 800 µg/kg (0.2 to 0.8 ppm). Table 4 shows total DDT-R values for fish in Lake Michigan from 2240 to 4230 µg/kg (2.2 to 4.2 ppm) and also reports a value of 10,150 µg/kg (10 ppm) total DDT-R in largemouth bass from the Tombigbee River, Alabama. In contrast, the total DDT-R in fish from the Kissimmee River and Kissimmee lakes were 30 µg/kg (0.03 ppm) or less, and rank among the least contaminated fish reported.

TABLE 4. SELECTED PESTICIDE RESIDUE DATA FOR WHOLE FISH FROM THROUGHOUT THE UNITED STATES

Species	Source	Location	µg/kg Total DDT-R	µg/kg Dieldrin	µg/kg PCB	Comments
Largemouth Bass	Henson (1973)	Reelfoot Lake, Tenn.	17	-	-	1 individual; 85 g
Bluegill	Henson (1973)	Reelfoot Lake, Tenn.	66	-	-	$\bar{x}$ of 14 individuals; 96-213 g
White Crappie	Henson (1973)	Reelfoot Lake, Tenn.	91	-	-	$\bar{x}$ of 11 individuals
Gizzard Shad	Henson (1973)	Reelfoot Lake, Tenn.	290	-	-	$\bar{x}$ of 5 individuals; 55-234 g
Bluegill	Ogden et al (1974)	Shark Valley, Everglades National Park (ENP), Fla.	25	n.d.	47	composite of 4 individuals
Bluegill	Ogden et al (1974)	Taylor Slough, ENP, Fla.	91	6	75	composite of 4 individuals
Largemouth Bass	Ogden et al (1974)	Taylor Slough, ENP, Fla.	131	5	55	composite of 3 individuals
Yellow Perch	Henderson et al (1971)	Klamath River, Calif.	90	n.d.	280	composite of 5 individuals; avg. 8.9"
Lake Trout	Henderson et al (1971)	Kenai River, Alaska	90	n.d.	2640	composite of 5 individuals; avg. 14.6"
Largemouth Bass	Vanderford and Hamchink (1977)	Seven natural lakes in Northern Indiana	45-157	0-36	-	$\bar{x}$ of 2-4 individual fish from each lake
Largemouth Bass	Henderson et al (1971)	Potomac River, Md.	480	30	1040	composite of 5 individuals; avg 10.5"
Ten Pounder	Shultz (1971)	Hawaiian Estuary	614	110	-	muscle tissue only, $\bar{x}$ of 29-30 ind.
Alewife	Haile et al (1975)	Lake Ontario	947	35	2350	$\bar{x}$ of 6 samples; each sample composite of at least 8 individuals
Smelt	Haile et al (1975)	Lake Ontario	1396	44	2646	$\bar{x}$ of 5 samples; each sample composite of at least 8 individuals
Largemouth Bass	Henderson et al (1971)	Roanoke River, N.C.	1380	100	<100	composite of 4 individuals; avg. 9.7"
Largemouth Bass	Henderson et al (1971)	Apalachicola River, Fla.	2690	1590	<100	composite of 5 individuals; avg. 15.6"
Lake Trout	Lake Michigan Interstate Pesticide Commission (1972) (LMIPC)	Lake Michigan	2240	120	-	average value from numerous analyses from 1965-69 (DDT) and 1967-69 (dieldrin)
Smelt	LMIPC (1972)	Lake Michigan	2310	60	-	average value from numerous analyses from 1965-69 (DDT) and 1967-69 (dieldrin)
Yellow Perch	LMIPC (1972)	Lake Michigan	3160	70	-	average value from numerous analyses from 1965-69 (DDT) and 1967-69 (dieldrin)
Alewife	LMIPC (1972)	Lake Michigan	4230	100	-	average value from numerous analyses from 1965-69 (DDT) and 1967-69 (dieldrin)
Largemouth Bass	Henderson et al (1971)	Hudson River, N.Y.	3300	160	4820	composite of 5 individuals; avg. 9.2"
Largemouth Bass	Henderson et al (1971)	Cooper River, S.C.	3870	10	<100	composite of 5 individuals; avg. 13.4"
Largemouth Bass	Henderson et al (1971)	Ohio River, Ohio	4190	70	8070	composite of 5 individuals; avg. 11.3"
Largemouth Bass	Henderson et al (1971)	Tombigbee River, Ala.	10,150	30	<100	composite of 5 individuals; avg. 14.0"

- = analyses not reported
n.d. = residue not detected

SUMMARY

1. Pesticide residues in whole fish from within the South Florida Water Management District are lower than FDA tolerance levels for edible portions of fish, and less than the concentration in fish reported from many other parts of the country.

2. Within the District, fish from areas most directly influenced by agricultural drainage waters exhibited the highest concentrations of pesticide residues. These areas included the canals in the northern portion of WCA 1 (L-40, L-7), the canal in southwest WCA 2 (L-38E), the canal on the outside eastern edge of WCA2A (L-36), Lake Okeechobee and the Caloosahatchee River.

3. Fish from areas less influenced by intensive agricultural practices (WCA 3, Kissimmee River, and Kissimmee basin lakes) had very low levels of pesticide residues.

4. Toxaphene, which replaced DDT around 1969 in south Florida, was present in relatively high levels in those areas influenced by agricultural runoff.

5. There has been no consistent decrease or increase in residues of DDT or dieldrin in fish during the first eight years of this sampling program.

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APPENDIX I - ANALYTICAL LABORATORY METHODS

Date	Analysis Performed By	Method	Citations
August, 1970 February, 1971 June, 1971	U.S. Geological Survey Water Quality Laboratory Washington, D.C.	electron-capture gas chromatograph	Kolipinski, M.C., Higer, A.L. and Yates, M.L. 1971, Pesticides in Water, Pesticide Monitoring Journal, Vol. 5, No. 3, Pg. 281-285. Onley, J.H. and Bertizzi, B.F., 1966, Rapid extraction procedure for chlorinated pesticide residues in raw animal tissues and fat and meat products. J. Assoc. Off. Anal. Chem. 49(2): 370-374.
January, 1972 March, 1972 April, 1973	U.S. Geological Survey Water Quality Laboratory Washington, D.C.	electron-capture gas chromatograph	Extraction procedure modified according to: U.S. Dept. of Health, Education and Welfare Food and Drug Administration, 1971, Pesticide Analytical Manual, Vol. 1
August, 1973	Dept. of Health, Education and Welfare Public Health Service Food and Drug Administration Atlanta, Georgia	electron-capture gas chromatograph	Pesticide Analytical Manual Volume 1, Sec. 212.13(a) and 211.14(d)
March, 1978	U.S. Geological Survey Altanta Central Water Quality Laboratory Doraville, Georgia	electron-capture gas chromatograph	Pesticide Analytical Manual Volume 1, Sec. 212.13(a) and 211.14(d)

APPENDIX II. RESULTS OF ANALYSIS FOR PESTICIDE RESIDUE IN FISH OTHER THAN LARGEMOUTH BASS, REDEAR SUNFISH AND LAKE CHUBSUCKER

Date	Location Species	Number Individuals	Size Range Total Length	Pesticide Residues µg/kg DDD	DDE	DDT	Total DDT-R	Dieldrin	Endrin	Chlordane	Toxaphene	PCB
2-71	WCA 1 - L-39											
	Bluegill	6	4.5 - 9.5"	340	280	130	750	-	-			
	Spotted Sunfish	6	4.5 - 7"	39	36	37	112	-	-			
	WCA 3 - L-67A											
	Golden Shiner	5	3.5 - 8.5"	2.7	3.0	-	5.7	-	-			
6-71	WCA 2 - L-35B											
	American Eel	5	13 - 18"	4.5	-	5.8	10	1.3	-		150	25
	WCA 3 - L-67A											
	Bluegill	5	6 - 8"	13	15	7.0	35	2.0			25	30
	Gizzard Shad	5	7 - 10"	5.9	-	-	5.9	1.0	-		20	35
1-72	WCA 1 - L-39											
	Bluegill	5	4 - 5"	36	100	3.7	140	1.1	-	-	40	30
	L-40											
	Gizzard Shad	5	9 - 10"	425	380	-	805	9.9	-	-	2700	20
	WCA 2 - L-38E											
	White Catfish	5	10 - 12"	300	500	-	800	16	-	-	1100	260
	WCA-3 - L-67A											
	Bluegill	5	5.5 - 7"	14	31	4.6	50	3.3	-	-	30	12
	Black Crappie	5	6 - 8.5"	6.2	29	4.3	40	1.0	-	-	10	15
	Golden Shiner	9	3.5 - 6"	2.6	12	-	15	0.2	-	-	10	4
	L-67C											
	Bluegill	4	4 - 6"	6.3	22	3.0	31	1.0	-	-	30	10
	Warmouth	4	3 - 6"	4.7	30	1.6	36	1.8	-	-	10	7
4-73	L-36 east of WCA 2											
	Bluegill	4	4 - 9"	51	96	13	160	2.3	-	90	310	20
	Walking Catfish	4	12 - 14"	28	115	*	143	2.9	-	70	170	24
	Bowfin	5	13 - 15"	2.5	54	3.2	60	0.3	-	3	tr	2
	American Eel	4	11 - 24"	610	1200	60	1870	17	-	650	2200	21
8-73	Lake Tohopekaliga											
	Bluegill	n.a.	4 - 7"	-	10	-	10	tr				
	Gizzard Shad	n.a.	4 - 12"	-	20	-	20	10				
	Gizzard Shad	n.a.	4 - 12"	-	20	-	20	10				
	Brown Bullhead	n.a.	11"	-	10	-	10	tr				
3-78	Caloosahatchee River											
	Bluegill	5	4 - 8"	56	120	28	204	54	-	27	60	55

Blank indicates no analysis
* Interference
- Not present in analysis
tr = Trace amount detected
n.a. data not available