NATIONAL WATER-QUALITY ASSESSMENT PROGRAM: PESTICIDE OCCURRENCE AND TEMPORAL DISTRIBUTION IN STREAMS DRAINING URBAN AND AGRICULTURAL BASINS IN GEORGIA AND FLORIDA, 1993-94

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ABSTRACT

Six streams located in Georgia and Florida were sampled intensively from March 1993 through April 1994 to assess the occurrence and temporal distribution of pesticides in streams representative of small urban and agricultural drainage basins. A total of 25 of the 47 pesticides and pesticide degradation products analyzed were detected in samples collected from the sites. Maximum measured concentrations of most pesticides coincided with the princpal application periods in both urban and agricultural drainage basins. Existing standards and guidelines for pesticides in drinking water were exceeded in only 1 of 217 samples. However, in the urban drainage basins, maximum concentrations of from one to three insecticides exceeded existing guidelines for protection of aquatic life during all but one month of sample collection.

INTRODUCTION

With improved control of industrial and municipal point discharges, the emerging issues and challenges for additional improvement of Georgia's water quality are related to toxics reduction and control of nonpoint source contaminants (Georgia Department of Natural Resources, 1994). The U.S. Geological Survey (USGS) National Water-Quality Assessment studies of the Apalachicola-Chattahoochee-Flint River basin (ACF) and the Georgia-Florida Coastal Plain began in 1991 (fig. 1), and included intensive surface-water sampling to assess the occurrence and temporal distribution of pesticides in streams representative of urban and agricultural drainage basins. Results from these assessments provide valuable information about many of the pesticides in current use during 1993 and 1994, and can be used to guide water-quality management of Georgia's streams.

This report describes the occurrence and distribution of dissolved pesticides in streams draining basins located in urban and agricultural areas of the Piedmont and Coastal Plain of Georgia and the Florida panhandle, and the possible implications of these findings for water-quality management. This assessment is based on analyses performed at six sites from March 1993 through April 1994. Two sites were on streams draining basins with mostly urban land use, and four sites were on streams draining basins with mostly agricultural land use.

METHODS

The predominant use of pesticides in the ACF and GAFL study areas occurs on agricultural and urban land. The six basins (figure 1 and table 1) were selected because they represent relatively homogeneous land use and physiographic conditions and because no known point sources of pesticides were identified within the basins. The four agricultural sites also were selected to represent a mixture of the types of crops

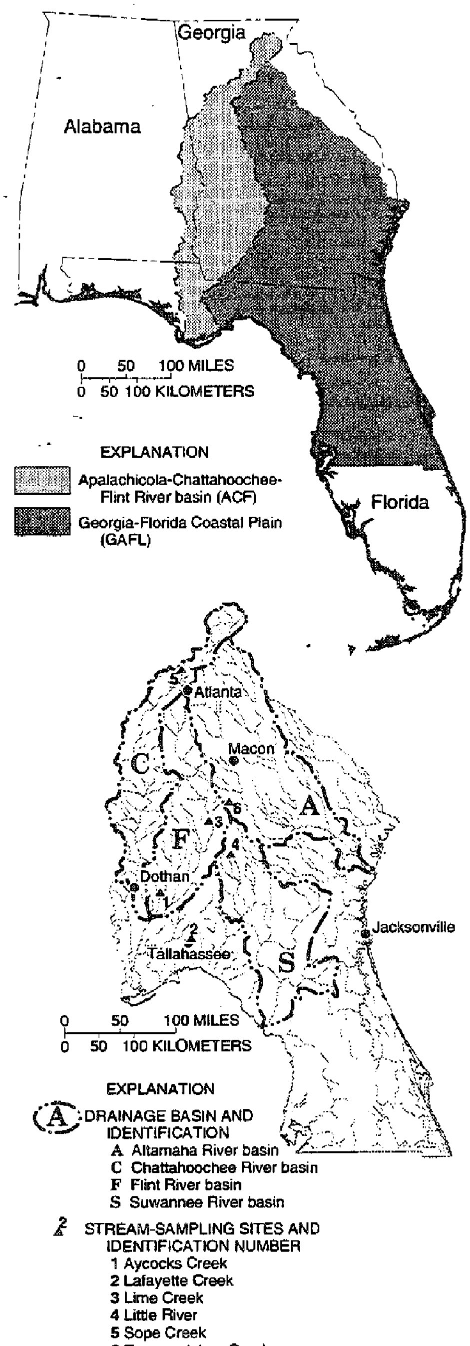

Figure 1. Location of six surface-water sampling sites in the Apalachicola-Chattahoochee-Flint (ACF) and Georgia-Florida Coastal Plain (GAFL) study units of the National Water-Quality Assessment program.

grown in the ACF and GAFL study areas. The urban basins, Sope Creek and Lafayette Creek, are located in the Atlanta and Tallahassee metropolitan areas, respectively (fig. 1). Sope Creek is a tributary to the Chattahoochee River. Lafayette Creek is part of the Apalachee Bay coastal drainages. Of the four agricultural basins, Lime Creek, Little River, and Tucsawhatchee Creek are located south of Macon, Georgia and Aycocks Creek is east of Dothan, Alabama (fig. 1). Lime and Aycocks Creek are located in the Flint River basin. Tucsawhatchee Creek and Little River are located in the Altamaha and Suwanee River basins, respectively. Although each basin has a mixture of land uses (table 1), the urban basins include a high percentage of urban land use; whereas, the agricultural basins include agricultural land mixed with substantial areas of forested land or wetlands. The agricultural land in Sope Creek drainage basin is principally small tracts of pasture and fallow fields. About 75 percent of the acreage for the major crops grown in the counties encompassing each of the four agricultural basins was planted in peanuts, cotton, and small grains during the study period (Georgia Agricultural Statistics Service, 1994; Hubbard and others, 1988, 1990). Smaller and more variable percentages of cropland in the agricultural basins were planted in corn, soybeans, sorghum, tobacco, and orchards.

Sampling was performed at regularly scheduled intervals at each site except when streams had little or no flow. In the ACF study area, stream-water samples were collected weekly from March 1993 through April 1994 for a total of 28 samples at Aycocks Creek, 49 at Lime Creek, and 46 at Sope Creek. In the GAFL study area, stream-water samples were collected weekly from March through October 1993 and monthly from November 1993 through April 1994 for a total of 29 samples at Lafayette Creek, 24 at Little River, and 41 at Tucsawhatchee Creek. Samples were not collected at Lafayette Creek during September and December 1993, at Aycocks Creek from June through November 1993, and at Little River from August through October 1993.

Stream-water samples were collected from multiple verticals in the stream channel using either an isokinetic sampler having a teflon collection bottle and nozzle or an open bottle, depending on flow conditions (Shelton, 1994). Composited samples were subsampled using a teflon cone-splitter. One-liter (L) samples are filtered using 0.7 micron nominal pore diameter glass-fiber filters and extracted through sorbent cartridges for subsequent elution and pesticide analysis. Samples were analyzed for 47 pesticides and pesticide degradation products using a gas chromatography/mass spectrometry method (S.D. Zaugg, USGS, written commun., 1993). The method detection limit (MDL) for targeted analytes is between 0.002 and 0.046 micrograms per liter (µg/L) (table 2). The MDL values for this analytical method typically are two or more orders of magnitude less than existing U.S. Environmental Protection Agency (USEPA) drinking-water standards or guidelines for most analytes. Analytes include about 68 percent of the herbicides and 66 percent of the insecticides by weight applied to agricultural land in Georgia (Gianessi and Puffer, 1990, 1992) and an unknown percentage of the pesticides applied on other land. Some heavily-used pesticides, such as 2,4-D, chlorothalonil, MSMA, glyphosate, and paraquat, were not included because they can not be analyzed using gas chromatography/mass spectrometry methods.

PESTICIDE OCCURRENCE AND TEMPORAL DISTRIBUTION

A total of 25 of the 47 pesticides and pesticide degradation products analyzed were detected in one or more of the 217 surface-water samples collected from the six sites (table 2). The 22 pesticides analyzed for, but not detected, also are listed in table 2.

Table 1. Land use in six basins in the Apalachicola-Chattahoochee-Flint River basin and Georgia-Florida Coastal Plain study areas
[mi^2, square miles; ACF, Apalachicola-Chattahoochee-Flint River basin study area; GAFL, Georgia-Florida Coastal Plain study area; <, less than]

Basin name	Study area	Drainage area (mi^2)	Land use, in percent				
			Agricultural	Forested	Urban	Wetland	Water
Aycocks Creek[1/]	ACF	105	46	43	0	9	2
Lafayette Creek[2/]	GAFL	10	<1	8	91	0	<1
Lime Creek[1/]	ACF	62	46	34	0	20	<1
Little River[3/]	GAFL	129	67	12	1	20	<1
Sope Creek[4/]	ACF	30	5	12	83	0	<1
Tucsawhatchee Creek[3/]	GAFL	163	56	41	2	1	<1

[1/] Digital data from the Georgia Department of Natural Resources, with 1988-90 land-cover classification from ERDAS, Inc.
[2/] Digital data from U.S. Geological Survey (Anderson and others, 1976), updated with 1990 population data (Kerie Hitt, written commun., 1994)
[3/] Digital data from U.S. Geological Survey (Anderson and others, 1976)
[4/] Digital data from U.S. Geological Survey (Anderson and others, 1976), update with 1990 land use by the Atlanta Regional Commission.

Table 2. Method detection limits and water-quality standards and criteria for pesticides in streams draining urban and agricultural basins, in Georgia and Florida, March 1993 through April 1994
[based on S.D. Zaugg, U.S. Geological Survey, written commun., 1993; L.H. Nowell and E.A. Resek, 1994; National Acedemy of Sciences and National Academy of Engineers, 1973; Environment Canada, 1992; mg/l, micrograms per liter; -- not determined]

Pesticides detected in one or more samples[1/]	Method detection limit (µg/L)	Primary drinking water standard (µg/L)	Lifetime health advisory level (µg/L)	Ambient water-quality creteria for protection of freshwater aquatic organisms (µg/L)	NAS/NAE guidelines for protection of freshwater aquatic life (µg/L)	Environment Canada, guidelines for protection of freshwater aquatic life (µg/L)
			Herbicides			
Alachlor	0.009	2	--	--	--	--
Atrazine	.017	3	3	--	--	2
Benfluralin	.013	--	--	--	--	--
Butylate	.008	--	700	--	--	--
Cyanazine	.013	--	1	--	--	2
DCPA	.004	--	4,000	--	--	--
Ethafluralin	.013	--	--	--	--	--
Metolachlor	.009	--	100	--	--	8
Metribuzin	.012	--	200	--	--	1
Napropamide	.010	--	--	--	--	--
Pendimethalin	.018	--	--	--	--	--
Prometon	.008	--	100	--	--	--
Pronamide	.009	--	50	--	--	--
Propachlor	.015	--	90	--	--	--
Simazine	.008	4	4	--	10	10
Tebuthiuron	.015	--	500	--	--	--
Trifluralin	.012	--	2	--	--	--
			Insecticides			
Carbaryl	.046	--	700	--	.02	--
Carbofuran	.013	40	36	--	--	--
Chlorpyrifos	.005	--	20	.041	.001	.001
Diazinon	.008	--	.6	--	.009	.08
Ethoprop	.012	--	--	--	--	--
Fonofos	.008	--	10	--	--	--
Lindane	.011	.2	2	--	.02	--
Malathion	.014	--	200	--	--	--

[1/]The following pesticides and pesticide degradation products were analyzed, but were not detected in surface-water samples from the six sites: azinphos-methyl, *p,p'*-DDE, deethylatrazine, dieldrin, diethylanaline, dimethoate, disulfoton, EPTC, alpha-HCH, linuron, molinate, ethyl-parathion, methyl-parathion, pebulate, *cis*-permethrin, phorate, propanil, propargite, terbacil, terbufos, thiobencarb, and triallate.

SOPE CREEK

Pesticide	Years; months; and number of samples analyzed													
	1993										1994			
	M	A	M	J	J	A	S	O	N	D	J	F	M	A
	4	4	4	4	3	2	3	3	3	4	4	4	4	0
Herbicides														
Alachlor								**.052**						-
Atrazine	.082	.088	.031	.027	.020	.015	.013	.015	.015	.013	.11	**.18**	.082	-
Benfluralin	**.008**	**.008**												-
DCPA			**.003**	.002										-
Metolachlor		**.068**	.003	.003										-
Napropamide		**.021**												-
Pendimethalin	.041	.039	.014	.012								.031	**.14**	-
Prometon	.004	**.11**	.008	.023	.021	.016	.009	.024	.021	.010		.009	.017	-
Pronamide												**.014**	.007	-
Simazine	.16	.11	.039	.033	.075	.17	.014	.55	.59	**8.2**	1.1	.34	.31	-
Tebuthiuron	.019	.012	.027	.017	.011	.030	.022	.028	.030	.028	.014	.022	**.034**	-
Trifluralin	**.007**	**.007**										.004		-
Insecticides														
Carbaryl	.020	.058	.010	.054	.041		.061	**.11**	.012	.030	.012	.017	.065	-
Chlorpyrifos	.021	**.034**	.016	.011			.003			.014	.012	.012	.011	-
Diazinon	.020	**.18**	.028	.034	.037	.027	.031	.14	.082	.029	.033	.018	.063	-
Malathion	.009		.005	.007			**.045**	.008	.010					-

LAFAYETTE CREEK

Pesticide	Years; months; and number of samples analyzed													
	1993										1994			
	M	A	M	J	J	A	S	O	N	D	J	F	M	A
	4	4	2	4	3	2	0	1	2	0	1	4	1	1
Herbicides														
Atrazine	.29	.28	.049	.17	.051	.018	-	.082	.032	-	.024	.093	**.49**	.30
DCPA				**.002**			-			-				
Metolachlor	**.035**	.010	.003	.003	.002		-		.020	-		.004	.005	.003
Metribuzin					**.012**		-			-				
Prometon	.007		.005	.020	.016	**.062**	-		.020	-				.010
Propachlor					**.004**		-			-				
Simazine	.093	.068	.019	.019	.010	.010	-		.026	-	.069	.093	**.26**	.12
Trifluralin							-			-			**.008**	
Insecticides														
Carbaryl	.005	.031		**.28**	.15	.016	-	.27		-		.016	.024	
Chlorpyrifos	.008			**.028**	.004		-			-		.006	.017	.007
Diazinon	.041	.035	.009	.069	**.28**	.16	-	.085	.081	-	.037	.086	.27	.089
Lindane				**.013**			-			-				
Malathion			.028	.027	.018	.029	-	.020		-				**.20**

EXPLANATION

.10 (boxed) Maximum measured concentration during sampling period

.010 (shaded) Maximum measured concentration during month

(empty box) Not detected during month

\- No samples collected during month

Figure 2. Monthly distribution of pesticide concentrations in streams draining two urban basins, March 1993 through April 1994.

Pesticides in streams draining urban basins. A total of 14 herbicides and 5 insecticides were detected in one or more samples collected from the urban basins, Sope Creek and Lafayette Creek (fig. 2). The larger number of pesticides detected at Sope Creek compared to Lafayette Creek may be related to the larger drainage area of Sope Creek (table 1), as well as differences in types of urban land use or pesticide-use practices between the two basins. Six herbicides (atrazine, DCPA, metolachlor, prometon, simazine, and trifluralin) and four insecticides (carbaryl, chlorpyrifos, diazinon, and malathion) were detected in both streams. Pesticides such as atrazine, prometon, simazine, tebuthiuron, carbaryl, and diazinon, were present throughout much of the sampling period (fig. 2). At Sope Creek, more pesticides were present and generally were at the maximum measured concentrations in samples collected from March through May 1993. At Lafayette Creek, more pesticides were present and generally were at the maximum measured concentrations in samples collected from June through August, 1993. The maximum measured concentration of simazine was 8.2 μg/L in a sample from Sope Creek, which exceeded the USEPA maximum contaminant limit (MCL) for drinking water (table 2 and fig. 2). Concentrations of other herbicides and insecticides in both streams were less than existing standards and guidelines for pesticides in drinking water. The maximum measured diazinon concentrations exceeded National Academy of Sciences and National Academy of Engineering (NAS/NAE) guidelines for protection of aquatic life for each of the 13 months sampled at Sope Creek and 11 of 12 months at Lafayette Creek (table 2 and fig. 2). Chlorpyrifos, when detected, also exceeded NAS/NAE guidelines for protection of aquatic life; this occurred in 9 of 13 months at Sope Creek and 6 of 12 months at Lafayette Creek. The maximum measured concentrations of carbaryl equaled or exceeded NAS/NAE guidelines for protection of aquatic life for 8 of 13 months at Sope Creek and 7 of 12 months at Lafayette Creek.

Most of the herbicides detected in the streams draining the urban basins probably were applied to turf for selective control of annual grasses and broadleaf weeds (Murphy, 1993). Whereas, prometon and tebuthiuron are used almost exclusively for nonselective vegetation control at industrial sites and along fences, roads, and rights-of-way for power lines, pipelines, and railroads (Delaplane, 1991). The insecticides detected commonly are used in urban settings with the exception of lindane which is restricted for many uses (U.S. Environmental Protection Agency, 1990).

Pesticides in streams draining agricultural basins. A total of 14 herbicides and 7 insecticides were detected in one or more samples collected from the four streams draining agricultural basins during the sampling period (figs. 3 and 4). Six herbicides (alachlor, atrazine, butylate, metolachlor, prometon, and tebuthiuron), and one insecticide (carbaryl) were detected at least once in all four streams. Atrazine and metolachlor also were present throughout much of the sampling period (figs. 3 and 4). More pesticides were present and generally were at the maximum measured concentrations in samples collected from March through June 1993. This time period coincides with the planting periods of most of the row crops grown in these basins (Georgia Agricultural Statistics Service, 1994). More pesticides were detected in all four basins during March and April 1993 than during March and April 1994. This difference between the two years may be related to differences in crops planted, crop management, weather, or hydrologic conditions.

The maximum measured concentrations of herbicides in samples collected from each of the streams draining an agricultural basin were less than the existing standards and guidelines for drinking water and for protection of aquatic life (table 2 and figs. 3 and 4). During April 1993, maximum measured carbaryl concentrations at each of the agricultural basins exceeded NAS/NAE guidelines for protection of aquatic life (figs. 3 and 4 and table 2). Chlorpyrifos, when detected, also exceeded these guidelines; this occurred during June and July 1993 at Tucsawhatchee Creek and November 1993 at Little River. During June 1993, the maximum measured concentration of diazinon exceeded NAS/NAE guidelines for protection of aquatic life at Tucsawhatchee Creek.

Most of the herbicides detected in the streams draining the agricultural basins were probably applied to row cropland and orchard land (Delaplane, 1991). Two herbicides, prometon and tebuthiuron, are used almost exclusively for nonselective vegetation control along fences, roads, and rights-of-way for power lines, pipelines, and railroads (Delaplane, 1991). The insecticides detected are among those recommended for insect control on rowcrops or orchards in the basins (Delaplane, 1991).

Comparison of urban and agricultural basins. Three herbicides (benfluralin, napropamide, and pronamide) and one insecticide (lindane) were detected in streams draining urban basins, but not in streams draining agricultural basins (figs. 2, 3, and 4). In contrast, four herbicides (butylate, cyanazine, ethafluralin, and metribuzin) and three insecticides (carbofuran, fonofos, and ethoprop) were detected in streams draining agricultural basins, but not in streams draining urban basins. Maximum concentrations of insecticides detected in both urban and agricultural basins were higher in the urban basins. Pesticides in the urban basins generally were detected throughout the sampling period while pesticides in agricultural basins generally were detected more frequently earlier in the sampling period.

SUMMARY

Maximum measured concentrations of the 25 pesticides detected in six streams draining urban and agricultural basins in central Georgia and the Florida panhandle were low relative to existing standards and guidelines for drinking water. Of 47 pesticides analyzed in 217 stream-water samples, simazine (an herbicide) was the only pesticide measured at a maximum concentration greater than a drinking-water standard. No herbicides were detected at concentrations greater than existing guidelines for protection of aquatic life. Maximum measured concentrations of one or more insecticides exceeded existing guidelines for protection of aquatic life during all but one month of sample collection at the two urban basins. Maximum measured insecticide concentrations also exceeded existing guidelines for protection of aquatic life at each of the four agricultural basins, but for no more than

LIME CREEK

Pesticide	Years; months; and number of samples analyzed													
	1993										1994			
	M	A	M	J	J	A	S	O	N	D	J	F	M	A
	5	4	4	5	3	2	2	2	5	4	5	2	4	2
Herbicides														
Alachlor	.004	**.011**	.003	.004	.004					.002				
Atrazine	.038	**.093**	.050	.034	.012		.003			.002		.010	.016	.021
Butylate									**.002**					
Cyanazine			.013			**.022**					.020			
Ethafluralin				**.016**										
Metolachlor	.021	.012	.023	**.038**	.004		.002			.003	.010	.004	.005	
Metribuzin				**.016**										
Pendimethalin		**.009**	.007											
Prometon		.003	**.12**	.005	.004									
Simazine	.096	.031	.011									.046	**.16**	.027
Tebuthiuron	.007	.007	**.050**	.005					.011	.009		.010	.005	
Trifluralin				**.007**	.005									
Insecticides														
Carbaryl		**.021**		.003			.007							
Ethoprop			**.010**											
Fonofos				**1.2**	.007	.021								
Malathion				**.007**										

AYCOCKS CREEK

Pesticide	Years; months; and number of samples analyzed													
	1993										1994			
	M	A	M	J	J	A	S	O	N	D	J	F	M	A
	4	3	4	2	0	0	0	0	0	2	4	3	4	2
Herbicides														
Alachlor	**.023**	.005			-	-	-	-	-					
Atrazine	.037	.037	.027	.008	-	-	-	-	-	.003			.099	**.12**
Butylate	**.022**				-	-	-	-	-					.007
Metolachlor	**.019**	.012	.012	.004	-	-	-	-	-	.005	.007	.004	.013	.005
Prometon			**.22**		-	-	-	-	-					
Tebuthiuron			**.007**		-	-	-	-	-					
Insecticides														
Carbaryl		**.033**			-	-	-	-	-					

EXPLANATION

- **.10** Maximum measured concentration during sampling period
- .010 Maximum measured concentration during month
- (blank) Not detected during month
- -- No samples collected during month

Figure 3. Monthly distribution of pesticide concentrations in streams draining two agricultural basins, March 1993-April 1994.

LITTLE RIVER

Pesticide	Years; months; and number of samples analyzed													
	1993										1994			
	M	A	M	J	J	A	S	O	N	D	J	F	M	A
	4	4	4	1	1	0	0	0	3	1	2	2	1	1
Herbicides														
Alachlor	.009	.004	.004	.006	**.11**	-	-	-						
Atrazine	.015	.022	**.071**	.014	.018	-	-	-					.008	.025
Butylate		**.006**				-	-	-						
DCPA	**.003**					-	-	-						
Ethafluralin				**.012**		-	-	-						
Metolachlor	.033	.036	**.091**	.074	.038	-	-	-	.010	.007	.012	.018	.016	.020
Pendimethalin			**.008**			-	-	-						
Prometon	.020	.071	.14	.074	.020	-	-	-	.020		.025	.021		**.15**
Propachlor			**.002**			-	-	-						
Simazine			**.007**			-	-	-						
Tebuthiuron	.005		.006	.007		-	-	-						**.20**
Trifluralin				**.006**		-	-	-						
Insecticides														
Carbaryl		**.025**		.007		-	-	-						
Carbofuran		**.030**				-	-	-						
Chlorpyrifos						-	-	-	**.021**					
Ethoprop	**.018**					-	-	-						
Malathion			.007	**.011**		-	-	-						

TUSCAWHATCHEE CREEK

Pesticide	Years; months; and number of samples analyzed													
	1993										1994			
	M	A	M	J	J	A	S	O	N	D	J	F	M	A
	4	4	4	5	4	4	4	4	1	1	1	2	1	2
Herbicides														
Alachlor			**.003**											
Atrazine	.010	.014	.012	.017	**.045**		.004	.001				.005		.005
Butylate	**.019**	.001												
Cyanazine					**.095**	.029								
DCPA				**.003**										
Ethafluralin				**.017**										
Metolachlor	.029	.020	.012	**.20**	.066	.030	.008	.005	.011	.009	.008	.016	.017	.012
Metribuzin			.006	**.008**	**.008**									
Prometon			.003	.015	**.016**									
Propachlor			**.001**											
Simazine		.011		**.027**										
Tebuthiuron		.008	.010	**.025**										
Trifluralin		.012		**.008**										
Insecticides														
Carbaryl		**.029**		.006			.005						.009	
Carbofuran				**.009**										
Chlorpyrifos				**.007**	.005									
Diazinon				**.010**										

.10 Maximum measured concentration during sampling period

.010 Maximum measured concentration during month

(blank box) Not detected during month

\- No samples collected during month

Figure 4. Monthly distribution of pesticide concentrations in streams draining two agricultural basins, March 1993-April 1994.

one month of the sampling period at Lime and Aycocks Creeks, two months at Little River, and 3 months at Tucsawhatchee Creek. Several pesticides detected in urban or agricultural basins currently (1994) do not have standards and guidelines for drinking-water quality, ambient surface-water quality, or for protection of aquatic life (Nowell and Resek, 1994).

Maximum measured concentrations of most pesticides detected in agricultural and urban basins coincided with the principal pesticide-application periods. However, some herbicides (atrazine and metolachlor) in agricultural basins, and some herbicides (atrazine, metolachlor, prometon, simazine, and tebuthiuron) and insecticides (carbaryl, chlorpyrifos, and diazinon) in urban basins were present throughout much of the year. The data presented also indicate some differences in pesticide occurrence among basins of similar land use and between successive spring high-application periods that can not be explained except possibly by analysis of additional data collection from more basins and for longer time periods.

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