

National Contaminant Biomonitoring Program: Residues of Organochlorine Chemicals in U.S. Freshwater Fish, 1976-1984

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Abstract. The U.S. Fish and Wildlife Service periodically determines concentrations of organochlorine chemicals in freshwater fish collected from a nationwide network of stations as part of the National Contaminant Biomonitoring Program (NCBP, formerly a part of the National Pesticide Monitoring Program). From late 1984 to early 1985, a total of 321 composite fish samples were collected from 112 stations and analyzed for organochlorine chemical residues. The mean concentrations of total DDT did not change from 1980-81 to 1984, following a period of steady decline through the 1970's; however, the mean concentrations of *p,p'*-DDT declined significantly. The most persistent DDT homolog (*p,p'*-DDE) was detected at 98% of the stations sampled in 1984, and constituted 73% of total DDT residues, up from 70% in 1974-79. Collectively, these findings indicate a low rate of influx and continued weathering of DDT in the environment. Residues of polychlorinated biphenyls (PCBs) also remained widespread, but a significant downward trend in total PCBs was evident, and early eluting PCB components were present at fewer stations than in the past. Mean concentrations of dieldrin have not changed since 1978-79; concentrations remained highest in Hawaii and in the Great Lakes. Toxaphene concentrations declined from 1980-81 to 1984, especially in the Great Lakes, and the incidence of toxaphene declined from 88% of the stations sampled in 1980-81 to 69% in 1984. Mean chlordane concentrations did not change from 1980-81 to 1984, following a period of decline; however, *trans*-nonachlor replaced *cis*-chlordane as the most abundant component, suggesting a lower influx of chlordane to the aquatic environment. Residues of other organochlorines—mirex, pentachloroanisole (PCA), benzene hexachloride (BHC) isomers, endrin, heptachlor, hexachlorobenzene (HCB), and Dacthal® (DCPA)—were either found at relatively few (<25%) of the stations sampled in 1984 or were characterized by relatively low concentrations. In general, organochlorine concentrations were lower in 1984 than at any time reported previously.

to document temporal and geographic trends in concentrations of environmental contaminants that may threaten fish and wildlife resources. The NCBP also provides information on the success of regulatory actions intended to reduce environmental concentrations of toxic materials. The NCBP originated in 1967 as the FWS segment of the National Pesticide Monitoring Program, a multiagency monitoring effort by the member agencies of the Federal Committee on Pest Control. Since 1967, FWS has periodically analyzed residues of selected organochlorine contaminants and potentially toxic elements in samples of fish and wildlife collected from nationwide networks of stations. The results for organochlorines and elements in freshwater fish collected from 1967 to 1981 have been reported (Henderson *et al.* 1969, 1971, 1972; Lowe *et al.* 1985; May and McKinney 1981; Schmitt *et al.* 1981, 1983, 1985; Walsh *et al.* 1977). Here, we present analytical results for organochlorine chemical residues in freshwater fish collected in 1984 and evaluate temporal and geographic trends by comparison with earlier findings.

Materials and Methods

Sample Collection

Fish were collected from 112 stations at key points in major rivers throughout the United States and in the Great Lakes (Figure 1; Table 1). A total of 321 composite samples, each comprising 3-5 whole, adult specimens of a single species, were collected in fall and winter 1984 and early spring 1985 (Table 1). Collaborators were asked to collect three samples at each station—two of a representative bottom-feeding species, and one of a representative predatory species (Table 2). Methods of collecting, shipping, archiving, and preparing samples were described by Schmitt *et al.* (1981, 1983, 1985) except that collections were made at all the stations in the fall and winter of 1984-85. In previous years, collections were made at about half the stations in the fall of even-numbered years and the rest in the fall of odd-numbered years, thus requiring two full years for the completion of a collection cycle. Fish were shipped to the laboratory frozen in dry ice and stored in a freezer until prepared for analysis.

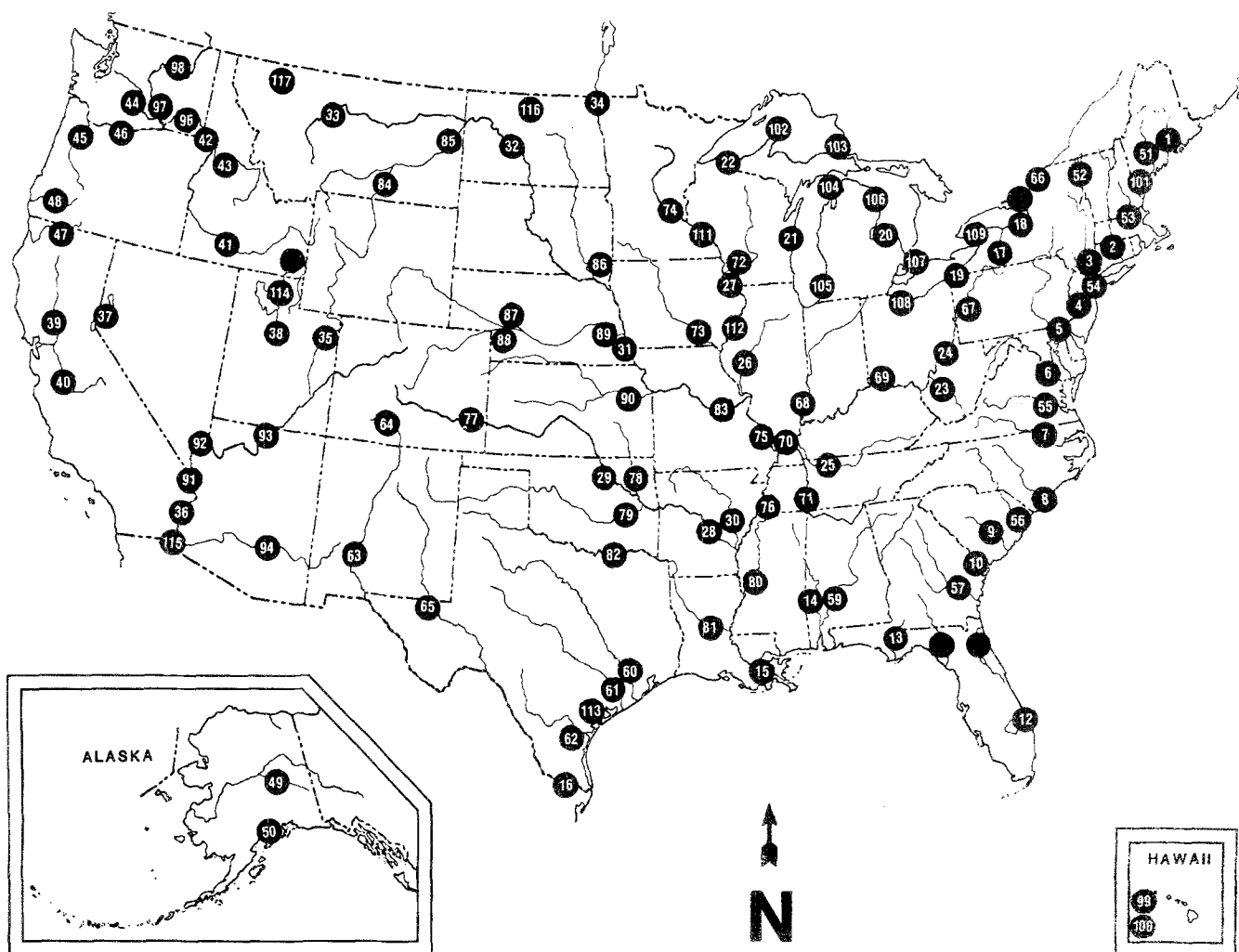


Fig. 1. National Contaminant Biomonitoring Program (NCBP) stations (numbered circles) where fish were collected for analysis in 1984. Solid circles represent inactive stations

Sample Preparation

Extraction, lipid determination, and cleanup and fractionation procedures have not changed since last described (Schmitt *et al.* 1985). Briefly, 10-g aliquots of fish tissue were mixed with anhydrous Na_2SO_4 , ground into a fine powder, and packed into a glass extraction column. The samples were extracted with dichloromethane. After solvent reduction by rotary evaporation in double-reservoir flasks, aliquots of the concentrated extracts were evaporated to constant weight and gravimetrically analyzed for lipid content. Automated gel permeation chromatography (GPC; S-X3 Bio-Beads® gel resin, Bio Rad, Inc.) was used to separate the organochlorine chemical residues from most of the fish lipids in the remaining portions (≤ 0.5 g lipid) of the concentrated extracts. In all extracts, the first fraction from the GPC column, containing the fish lipids, was discarded. The second fraction was collected and the solvent was exchanged to hexane prior to the initial fractionation with Florisil® adsorption chromatography.

The GPC concentrates were quantitatively transferred to 5-g Florisil® columns. The columns were first eluted with 5%-diethyl ether in petroleum ether and the eluate (5%-fraction) was collected for further fractionation. Subsequently, more polar compounds (δ -BHC, Dacthal®, dieldrin and endrin) were collected in a 40% solution of the same solvents (40%-fraction).

Polychlorinated biphenyls (PCBs) were separated from most of the remaining organochlorines by silica gel chromatography. The 5%-fraction concentrates were quantitatively transferred to 5-g silica gel columns. The silica gel columns were first eluted with 0.5% benzene in hexane (v/v%) to collect an eluate (PCB-fraction) containing the PCBs, HCB, heptachlor, aldrin, mirex and most of the *p,p'*-DDE. The second eluate (25% diethyl ether in hexane; Pesticide-fraction) contained residual *p,p'*-DDE, the other BHC isomers, toxaphene, DDT and its remaining homologs, chlordane (including the nonachlor isomers), oxychlordane, heptachlor epoxide, methoxychlor, and PCA. The eluate solvents from all three fractions (40% from Florisil®, and both fractions from silica gel) were exchanged to isooctane by rotary evaporation. The enriched samples in isooctane typically contained 1 g-equivalent of wet fish tissue/mL.

Residue Analysis

Gas Chromatography with Electron Capture Detection (GC/ECD): Portions (typically 1 μL) of enriched sample extracts in isooctane were analyzed by capillary-column GC/ECD to measure residues of the 27 organochlorine contaminants

Table 1. Freshwater fish collection stations. National Contaminant Biomonitoring Program (NCBP)

Station	River or Lake	Location
1	Penobscot River	Old Town, ME
2	Connecticut River	Windsor Locks, CT
3	Hudson River	Poughkeepsie, NY
4	Delaware River	Trenton, NJ
5	Susquehanna River	Conowingo Dam, MD
6	Potomac River	Little Falls, MD
7	Roanoke River	Roanoke Rapids, NC
8	Cape Fear River	Elizabethtown, NC
9	Cooper River	Lake Moultrie, SC
10	Savannah River	Savannah, GA
11 ^a	St. Johns River	Welaka, FL
12	St. Lucie Canal	Indiantown, FL
13	Apalachicola River	J. Woodruff Dam, FL
14	Tombigbee River	McIntosh, AL
15	Mississippi River	Luling, LA
16	Rio Grande	Mission, TX
17	Genessee River	Scottsville, NY
18	Lake Ontario	Port Ontario, NY
19	Lake Erie	Erie, PA
20	Lake Huron (Saginaw Bay)	Bay Port, MI
21	Lake Michigan	Sheboygan, WI
22	Lake Superior	Bayfield, WI
23	Kanawha River	Winfield, WV
24	Ohio River	Marietta, OH
25	Cumberland River	Clarksville, TN
26	Illinois River	Beardstown, IL
27	Mississippi River	Guttenburg, IA
28	Arkansas River	Pine Bluff, AR
29	Arkansas River	Keystone Reservoir, OK
30	White River	Devalls Bluff, AR
31	Missouri River	Nebraska City, NE
32	Missouri River	Garrison Dam, ND
33	Missouri River	Great Falls, MT
34	Red River of the North	Noyes, MN
35	Green River	Vernal, UT
36	Colorado River	Lake Martinez, AZ
37	Truckee River	Fernley, NV
38	Utah Lake	Provo, UT
39	Sacramento River	Knight's Landing, CA
40	San Joaquin River	Los Banos, CA
41	Snake River	Hagerman, ID
42	Snake River	Lewiston, ID
43	Salmon River	Riggins, ID
44	Yakima River	Granger, WA
45	Willamette River	Oregon City, OR
46	Columbia River	Cascade Locks, OR
47	Klamath River	Hornbrook, CA
48	Rogue River	Goldray Dam, OR
49	Chena River	Fairbanks, AK
50	Kenai River	Soldatna, AK
51	Kennebec River	Hinckley, ME
52	Lake Champlain	Burlington, VT
53	Merrimack River	Lowell, MA
54	Raritan River	Highland Park, NJ
55	James River	Richmond, VA
56	Pee Dee River	Johnsonville, SC
57	Altamaha River	Doctortown, GA
58 ^a	Suwannee River	Old Town, FL
59	Alabama River	Chrysler, AL
60	Brazos River	Richmond, TX

Table 1. (cont'd)

Station	River or Lake	Location
61 ^b	Colorado River	Wharton, TX
62	Nueces River	Mathis, TX
63	Rio Grande	Elephant Butte, NM
64	Rio Grande	Alamosa, CO
65	Pecos River	Red Bluff Lake, TX
66	St. Lawrence River	Massena, NY
67	Allegheny River	Natrona, PA
68	Wabash River	New Harmony, IN
69	Ohio River	Cincinnati, OH
70	Ohio River	Metropolis, IL
71	Tennessee River	Savannah, TN
72	Wisconsin River	Woodman, WI
73	Des Moines River	Keosauqua, IA
74	Mississippi River	Little Falls, MN
75	Mississippi River	Cape Girardeau, MO
76	Mississippi River	Memphis, TN
77	Arkansas River	John Martin Reservoir, CO
78	Verdigris River	Oologah, OK
79	Canadian River	Eufaula, OK
80	Yazoo River	Redwood, MS
81	Red River	Alexandria, LA
82	Red River	Lake Texoma, OK
83	Missouri River	Hermann, MO
84	Big Horn River	Hardin, MT
85	Yellowstone River	Sidney, MT
86	James River	Olivet, SD
87	North Platte River	Lake McConaughy, NE
88	South Platte River	Brule, NE
89	Platte River	Louisville, NE
90	Kansas River	Bonner Springs, KS
91	Colorado River	Lake Havasu, AZ
92	Colorado River	Lake Mead, NV
93	Colorado River	Lake Powell, AZ
94	Gila River	San Carlos Reservoir, AZ
95 ^a	Bear River	Preston, ID
96	Snake River	Ice Harbor Dam, WA
97	Columbia River	Pasco, WA
98	Columbia River	Grand Coulee, WA
99	Waialele Stream	Waipahu, HI
100	Manoa Stream	Honolulu, HI
101	Androscoggin River	Lewiston, ME
102	Lake Superior	Keeweenaw Point, MI
103	Lake Superior	Whitefish Point, MI
104	Lake Michigan	Beaver Island, MI
105	Lake Michigan	Saugatuck, MI
106	Lake Huron	Alpena, MI
107	Lake St. Clair	Mt. Clemens, MI
108	Lake Erie	Port Clinton, OH
109	Lake Ontario	Roosevelt Beach, NY
110 ^a	Lake Ontario	Cape Vincent, NY
111	Mississippi River	Lake City, MN
112	Mississippi River	Dubuque, IA
113	San Antonio River	McFaddin, TX
114	Bear River	Brigham City, UT
115	Colorado River	Yuma, AZ
116	Souris River	Upham, ND
117	Flathead River	Creston, MT

^a Inactive station^b Not collected in 1984

Table 2. Priority for collection of bottom-feeding and predatory species of fish^a

Bottom feeders (commercially or recreationally significant, if possible)
(1) Common carp (<i>Cyprinus carpio</i>)
(2) White sucker (<i>Catostomus commersoni</i>) or other catostomid
(3) Channel catfish (<i>Ictalurus punctatus</i>) or other ictalurid
(4) Other, with justification
Predators (recreationally significant, if possible)
(1) Cold-water stations: rainbow trout (<i>Oncorhynchus mykiss</i> , formerly <i>Salmo gairdneri</i>), brown trout (<i>Salmo trutta</i>), brook trout (<i>Salvelinus fontinalis</i>), lake trout (<i>Salvelinus namaycush</i>)
(2) Warm-water stations: largemouth bass (<i>Micropterus salmoides</i>) or other centrarchid such as crappie (<i>Pomoxis</i> sp.) or bluegill (<i>Lepomis macrochirus</i>), etc.
(3) Cool-water stations: walleye (<i>Stizostedion vitreum vitreum</i>) or other percid
(4) Other, with justification; should be representative of the entire drainage

^a From National Contaminant Biomonitoring Program, Freshwater Fish Collection Instructions (Internal memorandum issued to Environmental Contaminant Specialists of the U.S. Fish and Wildlife Service)

listed in Table 3 and methoxychlor (Chemical Abstracts No. 72-43-5). The capillary GC/ECD analyses were similar to those described by Schmitt *et al.* (1985) with several exceptions noted below. Briefly, all GC/ECD analyses were performed with a Varian 3700 gas chromatograph having a direct, splitless, capillary injection system and a standard ⁶³Ni electron capture cell with a constant current amplifier. The heated injection system was modified by incorporation of a customized, quartz, direct-injection insert designed and optimized at our laboratory for use with 0.32-mm i.d. capillary columns and similar to that manufactured by J&W Scientific¹, Inc. and others for use with 0.53-mm i.d. capillaries. The internal constriction at the outlet end of this liner allowed for the outside polyimide coating of the capillary column to form a press-fit seal, as described by Rohwer *et al.* (1986) for other capillary column connectors. The fused silica capillary (FSC) columns were 30 m × 0.25 mm i.d. DB-1 (0.25 μm thick cross-linked and bonded methyl silicone film, J&W Scientific, Inc.) and 25 m × 0.25 mm i.d. OV-17 (0.25 μm thick bonded 50% phenyl- + 50% methyl-silicone film, Quadrex Corp.). A 1-m length of 0.32-mm i.d. uncoated but deactivated (J&W Scientific, Inc.) "retention-gap" (Grob 1985) capillary was attached at the front of each analytical column by a butt connector (Supelco, Inc.). The detector temperature was 320°C; all other GC/ECD analytical conditions were as described previously (Schmitt *et al.* 1985). Capillary GC/ECD data were collected and analyzed with only slight modifications of the previous methods: Briefly, data were collected, peaks were detected and integrated, and the integrated data were stored with Sigma Model 10 and 15 Chromatography Data Stations (DS, Perkin-Elmer Corp.); programs were supplied by the vendor.

¹ Use of trade names does not constitute government endorsement of products.

Gas Chromatography with Photoionization Detection (GC/PID): Capillary GC/PID was performed with a Sigma 115 GC/DS equipped with an aromatic compound-selective, 9.5-eV lamp (Driscoll and Jaramillo 1980) in a Model P15202 PID (Perkin-Elmer Corp.). The use of direct-injection with our custom liner and a 1-m length of 0.32-mm i.d. retention gap was similar to that described for GC/ECD analysis. We analyzed 1-μL portions of concentrated extracts containing 5, 10 or 20 mg-equivalents wet tissue/μL. The FSC column was 30 m × 0.25 mm i.d. DB-5 (0.25 μm thick cross-linked and bonded 5% phenyl-silicone + 95% methyl-silicone film, J&W Scientific, Inc.). To minimize PID-associated dead volume, we inserted the outlet end of the analytical FSC column inside the detector to within 0.5 mm of the inlet to the PID detection chamber. The GC oven temperature was programmed at 20°C/min from 50°C to 185°C, 2°C/min to 230°C, and finally at 20°C/min to 250°C. The injector and detector temperatures were 180°C and 270°C, respectively. Hydrogen was used as carrier gas at a linear velocity of 50 cm/s at 50°C oven temperature, and the septum purge flow rate was 4 mL/min. The detector flow rate, including nitrogen make-up gas, was 30 mL/min. The GC/PID responses relative to the instrumental internal standard, benzo[*b*]naphtho[2,1-*d*]thiophene (Aldrich Chemical Co, Inc.), were calibrated by using 5-level calibration solutions spanning a 50-fold range in concentration for each compound determined. One additional analytical standard was analyzed for each three samples. Capillary GC/PID data were collected with a Model 763SB intelligent interface (Nelson Analytical, Inc.) and processed with Model 2600 chromatography software and Model 2670 batch reprocessing software (Nelson Analytical, Inc.) on a microcomputer.

We qualitatively identified DDT-related compounds on the basis of their adjusted retention times and quantitated them by internal standard techniques using relative response factors obtained from regression analyses of analytical standards.

Gas Chromatography with Mass Spectrometry (GC/MS): All capillary GC/MS was performed with a Finnigan 4023 GC/MS with Inco 2300 DS acquiring electron ionization (EI) mass spectra. As previously described, direct-injection was used with a custom liner and a 1-m length of 0.32-mm i.d. retention gap. Portions of concentrated sample extracts (about 1 μL containing 20 to 50 mg-equivalents wet tissue) were analyzed by GC/MS with a 30-m DB-5 FSC column similar to that used for GC/PID analysis. Helium carrier was used with a linear velocity about 35 cm/s. Peak shapes and responses from a Grob test mixture (5 ng of each component/μL; Grob *et al.* 1978) were used to optimize chromatographic conditions. The initial GC/MS oven temperature of 50°C was held for 1 min, then programmed to 210°C at 7°C/min, and from 210°C to 300°C at 5°C/min. The injector temperature was 250°C. A comprehensive mixture of 60 organic compounds, including those targeted for the NCBP, was analyzed each day of analyses to calibrate chromatographic and mass spectral responses relative to the D₁₄-*p*-terphenyl internal standard. D₁₄-*p*-terphenyl was also added to extracts as an instrumental internal standard. During the acquisition of 70-eV EI spectra from *m/z* 35-650/s, the manifold pressure was approximately 4 × 10⁻⁷ mbar and the source temperature was 300°C. Other operating conditions

Table 3. Residues measured^a in NCBP fish samples collected in 1984

Residue	Chemical Abstracts No. ^b	Principal uses and occurrence
<i>p,p'</i> -DDE	72-55-9	DDT-metabolite
<i>p,p'</i> -DDD (TDE)	72-54-8	Insecticide; DDT-metabolite
<i>p,p'</i> -DDT	50-29-3	Insecticide
<i>o,p'</i> -DDE	3424-82-6	<i>o,p'</i> DDT-metabolite/degradation product
<i>o,p'</i> -DDD (TDE)	53-19-0	<i>o,p'</i> DDT-metabolite
<i>o,p'</i> -DDT	789-02-6	<i>p,p'</i> DDT-byproduct
Aroclor [®] 1242	53469-21-9	Dielectric fluids in capacitors; transformer fluids; vacuum pump lubricants; carbonless copy paper products ^c
Aroclor [®] 1248	12672-29-6	Gas turbine lubricants; hydraulic fluids; plasticizers; heat transfer fluids; wax,
Aroclor [®] 1254	11097-69-1	Pesticide, ink, lubricant, and cutting oil extenders; dedusting agents
Aroclor [®] 1260	11096-82-5	Dielectric fluids in transformers
Aldrin	309-00-2	Insecticide
Dieldrin	60-57-1	Insecticide; aldrin metabolite
Endrin	72-20-8	Insecticide
Heptachlor	76-44-8	Insecticide; minor constituent of technical chlordane
Heptachlor epoxide	1024-57-3	Heptachlor metabolite
<i>cis</i> -Chlordane	5103-71-9	Insecticide; constituent of technical chlordane
<i>trans</i> -Chlordane	5103-74-2	Insecticide; chlordane constituent
<i>cis</i> -Nonachlor	5103-73-1	Insecticide; chlordane constituent
<i>trans</i> -Nonachlor	39765-80-5	Insecticide; chlordane constituent
Oxychlordane (octachlor epoxide)	27304-13-8	Chlordane metabolite
Toxaphene	8001-35-2	Insecticide; herbicide
α -Benzene hexachloride (BHC)	319-84-6	Constituent of insecticide mixture containing various BHC isomers
γ -Benzene hexachloride (BHC; lindane)	58-89-9	Insecticide; BHC constituent
Hexachlorobenzene (HCB)	118-74-1	Fungicide; industrial intermediate
Mirex ^e	2385-85-5	Insecticide; fire retardant
Dacthal ^{®d}	1861-32-1	Herbicide
Pentachloroanisole (PCA)	1825-21-4	Pentachlorophenol metabolite

^a No quantifiable residues of Aroclor 1242 or aldrin have been found in NCBP fish samples since 1977; however all chromatograms were scanned for the presence of these residues

^b As listed in Chemical Abstracts

^c From Hutzinger *et al.* (1974)

^d DCPA; dimethyl 2,3,5,6-tetrachloro-1,4-benzenedicarboxylate

^e 1,1a,2,2,3,3a,4,5,5,5a,5b,6-dodecachlorooctahydro-1,3,4-metheno-1*H*-cyclobuta(cd)pentalene

included a manifold temperature of 100°C; a GC interface temperature of 275°C; and an emission current of 0.3 mA. Masses were calibrated with perfluorotributylamine (FC43).

Quality Control Procedures: The normalized response (peak area/pg injected) and the chromatographic peak quality (Bidlingmeyer and Warren 1984) for a 33-pg aldrin standard (Varian Associates) were systematically used to optimize and verify the autosampler-capillary GC/ECD performance prior to analyses of each new block of samples. Replicate GC/ECD analyses ($n = 4$) of a 40-fold dilution of SRM 1583, "Chlorinated Pesticides in 2,2,4-Trimethylpentane" (U.S. Department of Commerce, National Bureau of Standards) gave excellent recoveries (mean \pm relative SD) of lindane (104 \pm 1%), *p,p'*-DDE (102 \pm 3%), and *p,p'*-DDT (103 \pm 6%). These recoveries verified the four-level GC/ECD calibrations for three compounds. Recovery of aldrin was 90 \pm 6%, based on only single-level calibration. Recovery of δ -BHC showed a positive bias (131 \pm 6%) due to partial breakdown of our δ -BHC standard to a pentachlorocyclohexene; the breakdown product was characterized by

GC/MS analysis of one of our analytical calibration standards.

Capillary GC/ECD residue identities and concentrations were confirmed by capillary GC/MS in about 2% of the PCB- and Pesticide-fraction samples. For individual component residues, a comparison of GC/MS concentration results ($n = 195$) with corresponding GC/ECD results by linear regression gave a highly correlated ($r = 0.97$) relation:

$$[\text{Compound}]_{\text{GC/MS}} = 0.005 + 1.148 [\text{Compound}]_{\text{GC/ECD}}$$

where $[\text{Compound}]_{\text{GC/MS}}$ and $[\text{Compound}]_{\text{GC/ECD}}$ represent the residue concentrations for each compound as measured by GC/MS and GC/ECD, respectively. Residue concentrations quantitated by GC/MS ranged from 0.005 to 1.10 $\mu\text{g/g}$. The concentrations determined by GC/MS were about 15% higher than the corresponding GC/ECD concentrations. This agreement is quite good given that we used only a one-level (instrumental) internal standard calibration for GC/MS analyses compared with four-level calibration for GC/ECD. As judged by GC/MS results, no false positive or negatives were detected. Toxaphene, which requires negative ion

chemical ionization GC/MS to obtain adequate sensitivity (Ribick *et al.* 1982), methoxychlor, and the compounds recovered in the 40%-fraction from Florisil®, were not analyzed by GC/MS. Additional Pesticide-fraction samples (representing about 5% of all samples) were selectively analyzed by capillary GC/PID for DDT and its metabolites, DDD and DDE (including *o,p'*- and *p,p'*-homologs), and *p,p'*-methoxychlor. Capillary GC/PID results for these samples were similar to the GC/ECD results for DDT and its metabolites. However, methoxychlor residues initially measured by capillary GC/ECD (from ≤ 10 ng/g to 830 ng/g) were not detected by capillary GC/PID. The method limit of detection (LOD) derived by GC/PID for methoxychlor was 12 ng/g based on the analysis of 20 mg-equivalents/ μ L. The GC/ECD analyses showed that of 130 samples that contained detectable methoxychlor residues, 126 (97%) also had detectable toxaphene residues. Capillary GC/PID analysis of separate standard solutions of toxaphene and technical chlordane, each at a concentration equivalent to 8,000 ng/g, gave no interference for methoxychlor. It is possible (but not yet confirmed by GC/MS) that a component of environmentally weathered toxaphene biased positively our capillary GC/ECD determinations of methoxychlor. Due to this bias, we have not reported methoxychlor residues.

A method blank analyzed with each block of samples verified that solvents, reagents, apparatuses, and instrumentation did not add detectable positive biases to the residue concentrations. According to procedures outlined by Keith *et al.* (1983), mean method blank values plus 3- and 10-times their standard deviations were used to estimate both the method LOD and the method limit of quantitation (LOQ) for each residue determined. The experimentally determined method LOD ranged from < 1 ng/g to 5 ng/g for individual compounds. For multicomponent residues the LODs were toxaphene, 60 ng/g; Aroclor® 1248, 62 ng/g; Aroclor® 1254, 41 ng/g; and Aroclor® 1260, 61 ng/g. The corresponding estimated method LOQs ranged from 2 ng/g to 15 ng/g for individual compounds and for the same multicomponent residues it was 153 ng/g for toxaphene, 167 ng/g for Aroclor® 1248, 111 ng/g for Aroclor® 1254, and 155 ng/g for Aroclor® 1260.

To facilitate statistical evaluations of the data for individual compounds from field samples, we used a generic method LOD of 10 ng/g (0.01 μ g/g) wet weight that maintained continuity with results reported in previous years (Schmitt *et al.* 1981, 1983, 1985). For PCBs and toxaphene, multiresidue contaminants for which individual components were not quantified, a generic LOD of 100 ng/g (0.1 μ g/g) wet weight was used. These generic method LODs ranged from 3 to 0.6 times the estimated method LOQs, the quality assurance measure recommended for the "quantitative interpretation" of data (Keith *et al.* 1983).

Background residues in hatchery-raised fish used for recovery studies were all below the method LODs. As in previous years, systematic recovery studies were made with tissue from hatchery fish spiked with 14 C-dieldrin, 14 C-*p,p'*-DDT and 14 C-2,4,5,2',4',5'-hexachlorobiphenyl (hot spikes). Recovery studies with nonradiolabeled compounds (cold spikes) were also made; all individual components were spiked at 40 ng/g (wet weight) except for *p,p'*-DDE which was spiked at 100 ng/g. Aroclor® 1254 was spiked at 550

ng/g. Separate fish tissue samples were fortified with toxaphene to give a concentration of 500 ng/g. On the basis of recoveries of hot ($n = 23$) and cold ($n = 23$) spikes, we determined that recovery efficiency exceeded 84% for all compounds and mixtures measured except HCB ($68 \pm 18\%$, relative SD), PCA ($73 \pm 22\%$), α -BHC ($82 \pm 14\%$), and β -BHC ($79 \pm 11\%$), volatile compounds for which recovery has been poor in the past (Schmitt *et al.* 1985). Results were not adjusted for percent recovery, in accordance with previous reports (Schmitt *et al.* 1981, 1983, 1985).

To estimate the analytical variability between replicate analyses in each sample block, we analyzed 37 NCBP samples in duplicate; duplicate tissue aliquots were individually carried through extraction, cleanup, fractionation, and GC/ECD analysis. The mean absolute differences between replicate analyses within sample blocks were small—e.g., less than the generic methods LOD (0.01 μ g/g and 0.1 μ g/g)—for all compounds except *p,p'*-DDE (0.02 μ g/g).

To estimate the analytical variability of environmentally incorporated residues across analytical blocks, organochlorine residues were also measured over a period of nearly two years in 46 replicate, 10.0-g portions of an in-house reference fish sample, a composite sample of frozen whole striped bass (*Morone saxatilis*) collected from the Hudson River, NY in 1981. This material contained environmentally incorporated residues of PCBs and other compounds. Measured mean residue concentrations for individual compounds ranged from ≤ 0.01 μ g/g for endrin, α -BHC, heptachlor epoxide, HCB, and Dacthal® to 0.43 μ g/g for *p,p'*-DDE. Multicomponent residues included 6.55 μ g/g of total PCBs and 0.32 μ g/g of toxaphene. Lipid content averaged 9.4%. The relative SD was between 10% and 20% for lipid content and all compounds, with three exceptions: compounds that had mean concentrations at or near the generic method LOD (heptachlor, HCB, Dacthal® and endrin); *o,p'*-DDE (38%) and *o,p'*-DDT (27%); and that portion of the PCBs measured as Aroclor® 1254 (23%).

Data Analysis and Data Set Composition

For analyses of temporal and geographic trends, results for the 1984 collection were pooled with previously reported data for 1976–81 (Schmitt *et al.* 1983, 1985). To illustrate temporal trends, we compared the following descriptive statistics for each compound, by collection periods: mean (after appropriate transformation), maximum concentration, and incidence (percentage of stations at which each compound was detected). Least-squares means, adjusted for the number of observations in each station-collection period cell, were examined throughout. Concentrations below the generic method LOD are reported as "not detected" in Appendix A; however, for statistical computations, a value of half the generic method LOD was used, as suggested by Kushner (1976). Residue concentrations were transformed [\log_e (residue concentration + 1.0)] before computation of means and further statistical analyses. Transformed values of residue concentrations were analyzed by analysis of variance (ANOVA) with a mixed two-way model. We used Fischer's protected least-significant-difference (LSD) test to examine and test differences among the collection-period means, and the Mann-Kendall test for trend to examine and test the significance of changes in residue concentrations at individual stations. The Mann-Kendall test was selected on the basis of its relative insensitivity to: missing observations, deviations from assumptions re-

garding distributions, and presence of many zero or non-detected values (Gilbert 1987). Schmitt (1981) and Schmitt *et al.* (1981) described the other procedures in more detail and discussed their applicability to residue monitoring data. Both product-moment (based on log-transformed concentrations) and rank correlation coefficients were examined for trends in the co-occurrence of contaminants. A significance level of $P \leq 0.05$ was used for all statistical tests, unless otherwise indicated.

The 321 samples collected in 1984 represented 47 taxa (Table 4). As in previous years (Schmitt *et al.* 1981, 1983, 1985), common carp (*Cyprinus carpio*), white sucker (*Catostomus commersoni*), and largemouth bass (*Micropterus salmoides*), and their respective families (Cyprinidae, Catostomidae, and Centrarchidae), were the most frequently collected taxa. Data from 97 stations spanned four collection periods (1976–77, 1978–79, 1980–81, and 1984). The 1124 samples in this subset of stations, which contained representatives of 63 taxa (Table 4), were used in most of the analyses of temporal trends; 98 stations were tested individually for trends. In species composition, the 97- and 98-station subsets were similar to the complete data set, and samples from 63 of the stations included at least one species that was collected in each of the four collection periods (Table 5). At 89% of the 113 stations sampled since 1976, five or fewer species have been collected (Table 6).

Results and Discussion

Trends in the Concentrations of Specific Contaminants

DDT and its Metabolites: Geometric mean concentrations of total DDT (the sum of *p,p'*-homologs) were greatest ($>5 \mu\text{g/g}$) in samples from Station 80 (Yazoo River, MS; Figure 2), as they have been in previous years. Similarly, geometric mean concentrations $>4 \mu\text{g/g}$ remained evident at Station 14 (Tombigbee R., AL), near the site of a pesticide manufacturing facility. Geometric mean concentrations $>1.0 \mu\text{g/g}$ were also found in samples from the intensively farmed valleys of the lower Colorado River (Station 115) and Rio Grande (Station 16), and in the Delaware River (Station 4) and Lake Michigan (Station 105; Figure 2). Total DDT residues $\geq 1.0 \mu\text{g/g}$ were also present in individual samples from other stations in the Great Lakes (Stations 18, 21, 105, and 106; Appendix A). These mean concentrations, as well as the maxima for individual samples (Table 7), have not changed appreciably since 1976–1977. Among the 10 stations with the greatest geometric mean total DDT levels (Figure 2), concentrations decreased significantly from 1976–77 through 1984 at only one (Station 21, Lake Michigan) and there was one increase (Station 46, Columbia R., WA; Table 8). Although statistically significant changes (both increases and decreases) in concentrations of total DDT and one or more homologs occurred at other stations, concentrations at these locations were generally low ($<0.5 \mu\text{g/g}$ total DDT; Table 8, Appendix A). Concentrations of total DDT, *p,p'*-DDD, and *p,p'*-DDE at Station 44 (Yakima R., WA) also declined (Table 8). The presence of these residues in this river has been attributed to previous use of DDT in the heavily irrigated Yakima watershed (Johnson *et al.* 1988). These findings, similar to our results for other agricultural areas where DDT was heavily used in the past (e.g., Stations 16, 40, 80, 99, and 115), highlight the significance of

erosion and pesticides associated with soils to the continuing presence of organochlorine chemical residues in fish.

Nationally, mean concentrations of total DDT and all *p,p'*-homologs declined significantly over the period 1976–1984; however, only for *p,p'*-DDT was the decline from 1980–81 to 1984 significant (Table 9, Figure 3). Residues derived from DDT were present at 98% of the stations sampled in 1984, representing the first time since 1974 that the incidence of DDT (as *p,p'*-DDE) was not ubiquitous at NCBP stations (Schmitt *et al.* 1981, 1983, 1985). No DDT-derived residues were present in any of the six samples (three per site) collected from Stations 50 (Kenai R., AK) and 116 (Souris R., ND; Appendix A). Each of the three samples collected from Station 63 (Colorado R., NM) also contained only traces ($0.01 \mu\text{g/g}$) of DDE, and no DDD or DDT.

The proportional composition of the DDT mixture typically encountered in fish changed little from 1976–1977 to 1980–1981, consisting of about 70% *p,p'*-DDE, 20% *p,p'*-DDD, and 10% *p,p'*-DDT (Schmitt *et al.* 1985); in 1984, the DDE proportion increased to 73% (Figure 3), indicating an overall continued weathering of the DDT present in North America. Conversely, because DDT is metabolized to DDD and DDE (Menzie 1978), proportionately high concentrations of *p,p'*-DDT in fish suggest recent or continuing inputs of DDT to the aquatic ecosystem (Aguillar 1984). In 1980–81, at least one sample contained $>0.5 \mu\text{g/g}$ *p,p'*-DDT or constituted an unusually high percentage of total DDT at each of nine stations: 99 in Hawaii, where the percentages were greatest (54–61%); 103, 105, and 106 in the Great Lakes; and 14, 28, 59, 80 and 81 in the South (Schmitt *et al.* 1985). In 1984, no stations met these criteria; *p,p'*-DDT residues of $\geq 0.5 \mu\text{g/g}$ were present only at Stations 14 (Tombigbee R., AL) and 80, and at no station did *p,p'*-DDT constitute more than 20% of total DDT (Figure 2). Even at Station 115 (Colorado R. at Yuma, AZ), where it was previously reported that striped mullet (*Mugil cephalus*) showed evidence of having been exposed to unweathered DDT (Schmitt *et al.* 1985), residues of *p,p'*-DDT constituted only 10–12% of the $2 \mu\text{g/g}$ total *p,p'*-homologs present in this species in 1984 (Appendix A).

Most of the stations included in Figure 2 were highlighted as problem spots for DDT in previous NCBP reports (Schmitt *et al.* 1981, 1983, 1985). In contrast, Stations 46 (Columbia R.), and 24 (Ohio R.) were not previously identified. Moreover, there has been a significant upward trend at these stations (Table 8). Also present in one sample of common carp from Station 24 were residues of *o,p'*-DDD ($0.86 \mu\text{g/g}$) and *o,p'*-DDT ($0.2 \mu\text{g/g}$), the total of which ($1.06 \mu\text{g/g}$) is almost the same as the total for all *p,p'*-DDT homologs ($1.34 \mu\text{g/g}$, Appendix A). As noted in previous NCBP reports, the presence of higher than expected proportions ($\geq 20\%$) of *o,p'*-residues suggests a source other than insecticidally applied DDT, such as a site of manufacture, formulation, or chemical waste storage (Schmitt *et al.* 1985). Other sites at which *o,p'*-homologs were present at higher than expected concentrations included those identified previously as being affected by point sources of DDT: Station 28, Arkansas R. at Pine Bluff, AR, site of the Pine Bluff Arsenal; Station 14, site of major commercial pesticide facilities that manufactured DDT; and Station 71, Tennessee

Table 4. Occurrence of fish species at all stations where collections were made and at 97 stations with continuous data from 1976-84, by sample and by station-year, for the 1984 collection period and for the period 1976-84. Data for 1976-77 and 1978-79 from Schmitt *et al.* (1983) and data for 1980-81 from Schmitt *et al.* (1985). (Continued on pp. 756-757)

Family (no. taxa) and common name ^a	Scientific name (genus and species) ^b	Station-years															
		1984			1976-84			1984			1976-84						
		All Stations	97 Stations	All Stations	97 Stations	All Stations	97 Stations	All Stations	97 Stations	All Stations	97 Stations	All Stations	97 Stations				
#	% ^b	#	% ^c	#	% ^d	#	% ^e	#	% ^f	#	% ^g	#	% ^h	#	% ⁱ		
Lepidosteidae (3)	—	1	0.3	0	0.0	6	0.6	1	0.1	1	0.9	0	0.0	6	1.5	1	0.2
Alligator gar	<i>Lepidosteus osseus</i>	0	0.0	0	0.0	2	0.2	0	0.0	0	0.0	0	0.0	2	0.5	0	0.0
Longnose gar	<i>L. spatula</i>	1	0.3	0	0.0	3	0.2	0	0.0	1	0.9	0	0.0	3	0.7	0	0.0
Spotted gar	<i>L. occulatus</i>	0	0.0	0	0.0	1	0.1	1	0.1	0	0.0	0	0.0	1	0.2	1	0.2
Amiidae (1)	—	0	0.0	0	0.0	2	0.2	2	0.2	2	0.0	0	0.0	2	0.5	2	0.5
Bowfin	<i>Amia calva</i>	0	0.0	0	0.0	2	0.2	2	0.2	2	0.0	0	0.0	2	0.5	2	0.5
Clupeidae (1)	—	9	2.8	6	2.2	32	2.5	21	1.9	5	4.6	3	3.1	17	4.0	10	2.6
Gizzard shad	<i>Dorosoma cepedianum</i>	9	2.8	6	2.2	32	2.5	21	1.9	5	4.6	3	3.1	17	4.0	10	2.6
Hiodontidae (2)	—	2	0.6	2	0.7	15	1.3	15	1.4	2	1.8	2	2.1	15	3.5	15	3.8
Goldeye	<i>Hiodon alosoides</i>	2	0.6	2	0.7	14	1.2	14	1.3	2	1.8	2	2.1	14	3.3	14	3.6
Mooneye	<i>H. tergisus</i>	0	0.0	0	0.0	1	0.1	1	0.1	0	0.0	0	0.0	1	0.2	1	0.2
Salmonidae (9)	—	26	8.1	21	8.5	95	7.6	77	6.9	20	18.5	16	16.5	72	16.8	58	14.9
Arctic grayling	<i>Thymallus arcticus</i>	1	0.3	1	0.4	2	0.2	2	0.2	1	0.9	1	1.0	2	0.5	2	0.5
Bloater	<i>Coregonus hoyi</i>	8	2.5	6	2.2	31	2.5	26	2.3	4	3.7	3	3.1	16	3.7	13	3.4
Brown trout	<i>Salmo trutta</i>	3	0.9	3	1.1	10	0.8	9	0.8	3	2.8	3	3.1	10	2.3	9	2.3
Dolly Varden	<i>Salvelinus malma</i>	0	0.0	0	0.0	2	0.2	0	0.0	0	0.0	0	0.0	2	0.0	0	0.0
Lake trout	<i>S. namaycush</i>	8	2.5	6	2.2	29	2.3	24	2.1	7	6.5	5	5.2	27	6.3	22	5.7
Lake whitefish	<i>Coregonus clupeaformis</i>	2	0.6	2	0.7	10	0.8	10	0.9	1	0.9	1	1.0	6	1.4	6	1.5
Rainbow trout	<i>Oncorhynchus mykiss</i> ^j	2	0.6	2	0.4	7	0.6	4	0.4	2	1.8	1	1.0	7	1.6	4	1.0
Round whitefish	<i>Prosopium cylindraceum</i>	0	0.0	0	0.0	2	0.2	0	0.0	0	0.0	0	0.0	2	0.5	0	0.0
Mountain whitefish	<i>P. williamsi</i>	2	0.6	2	0.7	2	0.2	2	0.2	2	1.8	2	2.1	2	0.5	2	0.5
Esocidae (2)	—	4	1.3	4	1.4	14	1.1	14	1.3	4	3.7	4	4.1	14	3.2	10	2.5
Northern pike	<i>Esox lucius</i>	4	1.3	4	1.4	13	1.0	13	1.2	4	3.7	4	4.1	13	3.0	9	2.3
Redfin pickerel	<i>E. americanus</i>	0	0.0	0	0.0	1	0.1	1	0.1	0	0.0	0	0.0	1	0.2	1	0.2
Cyprinidae (7)	—	89	27.7	81	29.0	328	26.1	309	27.5	47	43.5	43	44.3	183	42.7	172	44.3
Chiselmouth	<i>Arocheilus alutaceus</i>	0	0.0	0	0.0	6	0.5	0	0.0	0	0.0	0	0.0	3	0.7	3	0.9
Common carp	<i>Cyprinus carpio</i>	82	25.6	74	26.5	289	23.0	270	24.0	42	38.9	38	39.2	154	35.9	143	43.1
Goldfish	<i>Carassius auratus</i>	0	0.0	0	0.0	7	0.6	7	0.6	0	0.0	0	0.0	4	0.9	4	1.0
Northern squawfish	<i>Ptychocheilus oregonensis</i>	3	0.9	3	1.1	17	1.4	17	1.5	3	2.8	3	3.1	17	4.0	17	4.4
Redside dace	<i>Clinostomus elongatus</i>	0	0.0	0	0.0	1	0.1	1	0.1	0	0.0	0	0.0	1	0.2	1	0.2
Sacramento blackfish	<i>Orthodon microlepidotus</i>	0	0.0	0	0.0	4	0.3	4	0.4	0	0.0	0	0.0	2	0.5	2	0.5
Peamouth	<i>Mylocheilus carinus</i>	4	1.3	4	1.4	4	0.3	4	0.4	2	1.8	2	2.1	2	0.5	2	0.5
Catostomidae (11)	—	68	21.2	58	20.8	299	23.8	272	24.2	37	34.3	31	32.0	161	37.5	145	37.4
Bigmouth buffalo	<i>Ictiobus bubalus</i>	2	0.6	2	0.7	6	0.5	6	0.5	1	0.9	1	1.0	3	0.7	3	0.8
Bridgeliip sucker	<i>Catostomus columbianus</i>	0	0.0	0	0.0	4	0.3	4	0.4	0	0.0	0	0.0	2	0.5	2	0.5
Carp sucker	<i>Carpoides</i> sp.	7	2.1	4	1.4	3	12.5	27	2.5	4	3.7	2	2.1	19	4.4	5	3.9
Klamath sucker	<i>Catostomus snyderi</i>	0	0.0	0	0.0	7	0.6	7	0.6	0	0.0	0	0.0	4	0.9	4	1.0
Largescale sucker	<i>C. macrocheilus</i>	17	5.3	17	6.1	57	4.5	57	5.1	9	8.3	9	9.3	29	6.8	29	7.5
Longnose sucker	<i>C. catostomus</i>	6	1.9	5	1.8	15	1.2	14	1.3	4	3.7	3	3.1	11	2.6	10	2.6
Redhorse	<i>Moxostoma</i> sp.	6	1.9	4	1.4	32	2.6	24	2.1	3	2.8	2	2.1	15	3.5	12	3.1

Table 4. (cont'd)

Family (no. taxa) and common name ^a	Scientific name (genus and species) ^a	Samples						Station-years									
		1984			1976-84			1984			1976-84						
		All Stations #	% ^b	97 Stations #	% ^c	All Stations #	% ^d	97 Stations #	% ^e	All Stations #	% ^f	97 Stations #	% ^g	All Stations #	% ^h	97 Stations #	% ⁱ
Smallmouth buffalo	<i>Ictiobus cyprinellus</i>	1	0.3	1	0.4	24	1.9	20	1.8	1	0.9	1	1.0	13	3.0	10	2.6
Spotted sucker	<i>Minytrema melanops</i>	4	1.3	4	1.4	16	1.3	16	1.4	2	1.8	2	2.1	9	2.1	9	2.3
Tahoe sucker	<i>Catostomus tahoensis</i>	2	0.6	0	0.0	6	0.5	0	0.0	1	0.9	0	0.0	3	0.7	0	0.0
White sucker	<i>C. commersoni</i>	23	7.2	21	7.5	101	8.1	97	8.6	12	11.1	11	11.3	53	12.4	51	13.1
Ictaluridae (7)	—	25	7.8	22	7.9	111	8.8	97	8.6	14	13.0	12	12.4	70	16.3	65	16.8
Black bullhead	<i>Ictalurus melas</i>	0	0.0	0	0.0	4	0.4	0	0.4	0	0.0	0	0.0	2	0.5	2	0.5
Blue catfish	<i>I. furcatus</i>	0	0.0	0	0.0	6	0.5	6	0.5	0	0.0	0	0.0	4	0.9	4	1.0
Brown bullhead	<i>I. nebulosus</i>	0	0.0	0	0.0	7	0.6	7	0.6	0	0.0	0	0.0	5	1.2	9	2.3
Channel catfish	<i>I. punctatus</i>	19	5.9	16	5.7	60	4.8	50	4.5	11	10.2	9	9.3	41	9.6	34	8.8
Flathead catfish	<i>Pylodictis olivaris</i>	0	0.0	0	0.0	1	0.1	1	0.1	0	0.0	0	0.0	1	0.2	1	0.2
White catfish	<i>Ictalurus catus</i>	4	1.3	4	1.4	27	2.2	25	2.2	2	1.8	2	2.1	15	3.5	14	3.6
Yellow bullhead	<i>I. natalis</i>	2	0.6	2	0.7	4	0.3	4	0.4	1	0.9	1	1.0	2	0.5	2	0.5
Clariidae (1)	—	1	0.3	1	0.4	2	0.4	2	0.2	1	.09	1	1.0	2	0.5	2	0.5
Chinese catfish	<i>Clarias fuscus</i>	1	0.3	1	0.4	2	0.4	2	0.2	1	.09	1	1.0	2	0.5	2	0.5
Gadidae (1)	—	0	0.0	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0	1	0.2	1	0.2
Burbot	<i>Lota lota</i>	0	0.0	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0	1	0.2	1	0.2
Poeciliidae (1)	—	2	0.6	2	0.7	14	1.1	14	1.3	2	1.8	2	2.1	8	1.9	8	2.1
Cuban limia	<i>Poecilia vittata</i>	2	0.6	2	0.7	14	1.1	14	1.3	2	1.8	2	2.1	8	1.9	8	2.1
Percichthyidae (3)	—	7	2.2	6	2.2	34	2.5	26	2.3	6	5.5	5	5.1	31	7.3	25	6.4
Striped bass	<i>Morone saxatilis</i>	2	0.6	2	0.7	9	0.7	7	0.6	1	0.9	1	1.0	8	1.9	6	1.5
White bass	<i>M. chrysops</i>	4	1.3	3	1.1	15	1.2	11	1.0	4	3.7	3	3.1	15	3.5	11	2.8
White perch	<i>M. americana</i>	1	0.3	1	0.4	8	0.6	8	0.7	1	0.9	1	1.0	8	1.9	8	2.1
Centrarchidae (12)	—	58	18.1	51	18.3	186	14.8	166	14.8	55	50.9	49	50.5	180	42.0	164	42.3
Black crappie	<i>Pomoxis nigromaculatus</i>	8	2.5	5	1.8	23	1.8	23	1.8	7	6.5	5	5.2	22	5.1	20	5.2
Bluegill	<i>Lepomis macrochirus</i>	0	0.0	0	0.0	4	0.3	4	0.4	0	0.0	0	0.0	4	0.9	4	1.0
Green sunfish	<i>L. cyanellus</i>	2	0.6	1	0.4	5	0.4	3	0.3	2	1.8	1	1.0	5	1.2	3	0.8
Largemouth bass	<i>Micropterus salmoides</i>	30	9.4	27	9.7	97	7.7	89	7.9	28	25.9	25	25.8	95	21.9	87	22.4

Orangespotted sunfish	<i>Lepomis humilis</i>	0	0.0	0	0.0	1	0.1	0	0.1	0	0.0	0	0.0	1	0.2	1	0.2
Pumpkinseed	<i>L. gibbosus</i>	0	0.0	0	0.0	3	0.2	0	0.0	0	0.0	0	0.0	2	0.5	0	0.0
Rock bass	<i>Ambloplites rupestris</i>	0	0.0	0	0.0	8	.64	4	0.4	0	0.0	0	0.0	6	1.4	4	1.0
Smallmouth bass	<i>Micropterus dolomieu</i>	5	1.6	5	1.8	22	1.8	22	2.0	5	4.6	5	5.2	22	5.1	22	5.7
White crappie	<i>Pomoxis annularis</i>	10	3.1	10	3.6	20	1.6	20	1.8	10	9.2	10	10.3	20	4.7	20	5.2
Longear sunfish	<i>Lepomis megalotis</i>	1	0.3	1	0.4	1	0.1	1	0.1	1	0.9	1	1.0	1	0.2	1	0.2
Redear sunfish	<i>L. microlophus</i>	1	0.3	1	0.4	1	0.1	1	0.1	1	0.9	1	1.0	1	0.2	1	0.2
Spotted bass	<i>Micropterus punctatus</i>	1	0.3	1	0.4	1	0.1	1	0.1	1	0.9	1	1.0	1	0.2	1	0.2
Percidae	—	19	5.9	18	6.5	83	6.6	80	7.1	19	17.6	18	18.6	78	18.2	75	19.3
Sauger	<i>Stizostedion canadense</i>	5	0.6	5	1.8	23	1.8	23	2.1	5	4.6	5	5.2	21	4.9	21	5.4
Walleye	<i>S. vitreum vitreum</i>	7	2.2	7	2.5	27	2.2	27	2.4	7	6.5	7	7.2	27	6.3	27	7.0
Yellow perch	<i>Perca flavescens</i>	7	2.2	6	2.2	33	2.6	30	2.7	7	6.5	6	6.2	30	7.0	27	7.0
Sciaenidae (1)	—	1	0.3	0	0.0	14	1.1	10	0.9	1	0.9	0	0.0	9	2.1	6	1.5
Freshwater drum	<i>Aplodinotus grunniens</i>	1	0.3	0	0.0	14	1.1	10	0.9	1	0.9	0	0.0	9	2.1	6	1.5
Cichlidae (1)	—	3	0.9	3	1.1	7	0.6	7	0.6	2	1.8	2	2.1	6	1.4	6	1.5
Mozambique tilapia	<i>Tilapia mossambica</i>	3	0.9	3	1.1	7	0.6	7	0.6	2	1.8	2	2.1	6	1.4	6	1.5
Cottidae (1)	—	2	0.6	1	0.4	2	0.2	1	0.1	2	1.8	1	1.0	2	0.5	1	0.2
Slimy sculpin	<i>Cottus cognatus</i>	2	0.6	1	0.4	2	0.2	1	0.1	2	1.8	1	1.0	2	0.5	1	0.2
Mugilidae (1)	—	3	0.9	2	0.7	9	0.7	6	0.5	2	1.8	1	1.0	6	1.4	4	1.0
Striped mullet	<i>Mugil cephalus</i>	3	0.9	2	0.7	9	0.7	6	0.5	2	1.8	1	1.0	6	1.4	4	1.0
Mixed species	—	1	0.3	1	0.4	3	0.2	3	0.3	1	0.9	1	1.0	3	0.7	3	0.8
Total samples or station years	—	321	26.6 ^d	79	86.9 ^e	1255	100 ^d	1124	90.0 ^d	108	24.2 ^b	97	89.8 ^b	429	100 ^b	388	90.4 ^b
Total taxa	—	47	—	44	—	69	—	63	—	47	—	44	—	69	—	63	—

^a From American Fisheries Society Committee on Names of Fishes (1980), except for *Poecilia vittata* and *Clarias fuscus*

^b Percentage of 279

^c Percentage of 279

^d Percentage of 1255

^e Percentage of 1124

^f Percentage of 108

^g Percentage of 97

^h Percentage of 429

ⁱ Percentage of 388

^j Formerly *Salmo gairdneri*

Table 5. Stations (97 total) having 0, 1, or 2 species common among all collection periods (1976–77, 1978–1979, 1980–1981, and 1984)

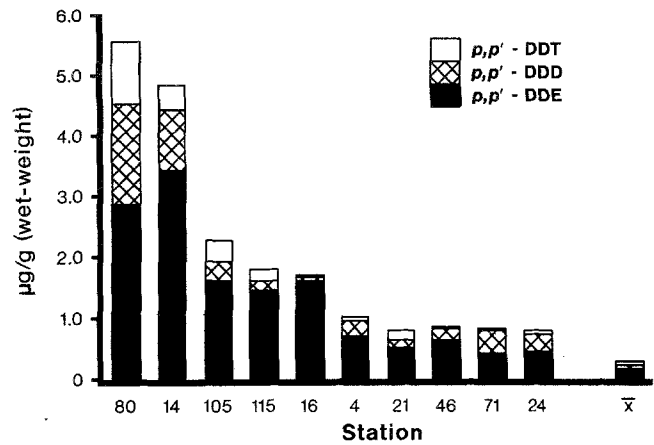
Number of common species	Number of stations	Stations
0	34	6,7,8,10,14,15,18,23, 24,30,32,33,39,40,43,44, 45,54,57,59,62,63,66,74, 76,79,80,81,82,84,88,97, 111,117
1	48	1,2,3,4,9,16,22,25, 27,28,29,31,34,35,36,38, 42,47,48,49,52,53,67,68, 69,70,72,73,75,78,85,86, 89,90,91,96,98,99,100, 102,103,105,106,108,112, 114,115,116
2	15	5,12,13,20,21,26,41,46, 51,55,64,87,93,101,107

Table 6. Cumulative distribution of species reported from stations 1976–84

	Cumulative number of species						
	2	3	4	5	6	7	8
Number of stations	22	35	30	13	8	4	1
Cumulative total	22	57	87	100	108	112	113
Cumulative percentage of total	19	50	77	89	96	99	100

River at Pickwick Landing Reservoir, TN, which is downstream from the widely publicized DDT contamination remaining from the former operation of Red Stone Arsenal (now Wheeler National Wildlife Refuge) in Alabama (O'Shea *et al.* 1980). Residues of *o,p'*-DDT homologs were also present in samples from most stations in the Great Lakes and from the Delaware River (Station 4). Stations 59 (Alabama R., AL) and 8 (Cape Fear R., NC), where concentrations of total DDT were high in previous collections, were absent from the 1984 list of high total DDT stations; however, no significant trend has yet been established at these sites (Table 8).

The metabolism of DDT in fish is generally accomplished through dehydrodechlorination to DDE; reductive dechlorination to DDD also occurs in some species, but to a lesser extent (Edwards and Millburn 1985; Uchida *et al.* 1988). There is also evidence suggesting that although some fish can metabolize DDT to DDD, much of the reductive dechlorination that occurs in fish is actually accomplished by the gut microflora (Wedemeyer 1968; Cherrington *et al.* 1969). Consequently, DDD has typically been a minor component of total DDT in most NCBP fish samples collected since 1970; when present in any quantity, other homologs (DDE, DDT or both) were always present as well (Schmitt *et al.* 1981, 1983, 1985), indicating previous insecticidal use of DDT. According to Uchida *et al.* (1988), common carp metabolize *p,p'*-DDT to DDE, but not to DDD, and tilapia (*Oreochromis niloticus*) hardly metabolize DDT at all. Compared to these documented patterns, the three 1984 samples from Station 100 (Manoa Stream, HI) were highly unusual,

**Fig. 2.** Geometric mean concentrations of *p,p'*-DDT homologs for NCBP stations at which the mean for total DDT equaled or exceeded the 90th percentile concentration in 1984. Also shown is the national geometric mean for 1984 (\bar{x})

containing the following concentrations ($\mu\text{g/g}$, wet weight) of the indicated *p,p'*-homologs:

Species	<i>p,p'</i> -Homolog			Total
	DDT	DDE	DDD	
Mozambique tilapia (<i>Tilapia mossambica</i>)	0.02	0.05	0.33	0.40
Cuban limia (<i>Poecilia vittata</i>)	0.05 (0.06) ^a	0.06 (0.08) ^a	0.50 (0.45) ^a	0.61 (0.59) ^a
Chinese catfish (<i>Clarias fuscus</i>)	0.04 (0.06) ^b	0.09 (NA) ^c	0.50 (0.45) ^b	0.63

^a by GC/MS; ^b by GC/PID; ^c not analyzed by GC/PID

In these samples, *p,p'*-DDD constituted 79–83% of total DDT; *p,p'*-DDT, 5–8%; and *p,p'*-DDE, 10–14%. Historically, Mozambique tilapia, Cuban limia, and Chinese catfish from Station 100 contained substantial (>1.0 $\mu\text{g/g}$ total) residues of DDT, but mostly as *p,p'*-DDT and *p,p'*-DDE; in 1981, *p,p'*-DDT constituted 55–76% of total DDT, but the total DDT concentrations were lower (0.11–0.21 $\mu\text{g/g}$; Schmitt *et al.* 1985). The anomalous homolog distribution detected in 1984, which was remarkably consistent among samples of three species, suggest direct inputs of *p,p'*-DDD. DDD (TDE) was once marketed under the tradename Rothane[®], primarily for the control of insects on fruits and vegetables (Anon 1987).

PCBs: Similar to DDT, PCB residues were widespread in 1984; they were present at 91% of the stations sampled, a percentage that has remained fairly stable since 1976–77 (Table 7). As also reported for the 1980–81 collection period (Schmitt *et al.* 1981), the maximum total PCB concentration encountered, as well as the maximum concentrations of the Aroclor[®] mixtures quantified, continued to decline through the 1984 collection (Table 7; Figure 4). Moreover, 1984 means for residues that chromatograph similar to Aroclors[®] 1248 and 1260, and for total PCBs, were significantly lower than the respective means for 1980–81; there was no change in the mean for residues that resemble Aroclor[®] 1254 since

Table 7. Maximum wet weight residue concentrations ($\mu\text{g/g}$), and percentage of stations where detectable residues were present (%) for 1976–77, 1978–79, 1980–81 and 1984 collection periods. Data for 1976–77, 1978–79, and 1980–81 from Schmitt *et al.* (1983, 1985). (NA = not analyzed)

Residue	Collection Period							
	1976–77		1978–79		1980–81		1984	
	$\mu\text{g/g}$	%	$\mu\text{g/g}$	%	$\mu\text{g/g}$	%	$\mu\text{g/g}$	%
<i>p,p'</i> -DDE	5.21	100.0	6.76	100.0	2.57	100.0	4.74	98.2
<i>p,p'</i> -DDD	1.77	99.1	3.01	100.0	3.43	97.2	2.55	97.3
<i>p,p'</i> -DDT	1.99	83.0	1.95	74.1	2.69	79.4	1.79	88.4
Total DDT ^a	6.54	100.0	10.62	100.0	6.50	100.0	9.08	98.2
Aroclor [®] 1248	51.9	38.7	66.9	41.7	8.5	75.7	4.3	42.9
Aroclor [®] 1254	16.4	84.0	22.1	98.1	4.2	88.8	4.0	65.2
Aroclor [®] 1260	5.6	84.0	7.6	88.0	2.6	93.5	2.3	86.6
Total PCBs ^b	70.6	91.5	92.8	98.1	11.3	94.4	6.7	91.1
Dieldrin ^c	5.01	93.4	3.72	80.6	0.72	74.8	1.39	74.1
Endrin	0.40	47.2	0.11	32.4	0.30	22.4	0.22	28.6
Heptachlor ^d	0.78	52.8	1.17	54.6	0.27	38.3	0.29	49.1
<i>cis</i> -Chlordane	0.93	92.5	2.53	94.4	0.36	73.8	0.66	84.8
<i>trans</i> -Chlordane	0.32	84.0	0.54	70.4	0.22	72.0	0.35	68.8
<i>cis</i> -Nonachlor	0.49	46.2	0.71	73.1	0.27	72.9	0.45	82.1
<i>trans</i> -Nonachlor	0.95	70.8	2.17	92.6	0.77	85.0	1.00	89.3
Oxychlordane	NA	NA	0.74	39.8	0.33	39.0	0.29	44.6
Toxaphene	12.7	58.5	18.7	61.1	21.0	87.9	8.2	68.8
γ -BHC	0.30	89.6	0.04	53.7	0.04	54.2	0.04	47.3
α -BHC	0.28	31.1	0.02	8.3	0.03	15.9	0.01	15.2
HCB	0.70	45.2	0.13	21.3	0.12	24.3	0.41	18.8
Mirex	NA	NA	NA	NA	0.21	17.8	0.44	13.4
Dacthal [®]	NA	NA	1.22	34.3	0.40	28.0	0.45	45.5
PCA	NA	NA	NA	NA	0.07	24.3	0.10	30.4

^a *p,p'*-homologs^b May include traces of Aroclor[®] 1242 for 1976–77^c May include traces of aldrin for 1976–77^d As heptachlor epoxide plus traces of heptachlor

last reported (Table 9). The PCB concentrations in 1984 continued to be highest where they were highest in other years (Figure 5, Appendix A)—in the industrialized regions of the Northeast (Stations 3, 4, and 53), Great Lakes (Stations 20, 21, 104, 105, 106, 107, 108, and 109), and in the Upper Mississippi (Station 111) and Ohio River systems (Stations 23, 24, and 69); however, total PCB concentrations were ≥ 2 $\mu\text{g/g}$ at only 12 stations in 1984, compared with 21 in 1980–81 (Schmitt *et al.* 1985). Most of the nine stations identified as PCB problem spots as recently as 1980–81, but not in 1984, are those that showed significant downward trends from 1976–77 to 1984 (Table 8). These downward trends were observed for total PCBs or for residues that resembled one or more PCB mixtures. Conversely, most stations at which PCB concentrations remained high through 1984 (Figure 5) showed no evidence of change (Table 8). Total PCB concentrations were low at other stations where the changes were statistically significant.

As in previous years, residues that were chromatographically similar to Aroclor[®] 1260 were the most widespread, being detected at 86% of the stations sampled, down from 94% in 1980–81 (Table 7). Residues that resembled Aroclors[®] 1254 and 1248 were present at fewer stations (65% and 43%, respectively), down from 89% and 76% in 1980–81. This distribution of PCB mixtures differs from that reported for 1978–79, when residues that were chromato-

graphically similar to Aroclor[®] 1254 were the most widespread, and those that resembled Aroclor[®] 1248 were found at fewer stations (Table 7). As previously noted, however (Schmitt *et al.* 1985), the dramatic change in the percentages of stations evidencing residues that resembled Aroclors[®] 1248 and 1254 between 1976–79 and 1980–81 probably reflects the introduction of capillary-column GLC in 1980–81. This technique provides better resolution of individual components (Duinker *et al.* 1980; Bush *et al.* 1982; Schwartz *et al.* 1984; Mullin *et al.* 1984) than is provided by packed-column GLC, especially in the early portion of the chromatogram, where many of the peaks typical of the Aroclor[®] 1248 mixture occur. Although quantitation of total PCBs by packed- and capillary-column methods is usually equivalent, and either technique can distinguish among PCB mixtures when the early eluting components are abundant, the capillary technique is more likely to detect low concentrations of the less chlorinated components (Duinker *et al.* 1980). The changes in the composition of PCB residues from 1980–81 to 1984, however, contain no such ambiguities; residues resembling Aroclors[®] 1248 and 1254 were present at fewer stations in 1984 than in 1980–81 (Table 7).

Some early eluting PCB congeners, such as those present in Aroclor[®] 1248, are more toxic (but less persistent) than the later eluting, more chlorinated PCBs that dominate mixtures that are chromatographically more similar to Aro-

Table 8. Numbers and, in parentheses, identity of stations at which geometric mean residue concentrations have increased or decreased significantly ($P \leq 0.05$, $N = 98$, Mann-Kendall test for trend) since 1976

Residue	Changes since 1976-77	
	Increases (Stations)	Decreases (Stations)
<i>p,p'</i> -DDE	4 (12,24,46,25)	17 (3,5,15,27,33,38, 40,44,54,55,57,63, 68,69,86,112,117)
<i>p,p'</i> -DDD	1 (46)	18 (5,7,12,15,20,27, 29,38,42,44,48,52, 54,64,68,76,96,107)
<i>p,p'</i> -DDT	2 (32,86)	4 (5,49,89,91)
Total DDT ^a	1 (46)	20 (5,15,21,27,29,33, 38,40,44,49,63,64, 68,73,78,86,89,107, 112,117)
Aroclor [®] 1248	4 (10,35,36,112)	8 (3,31,46,51,54,57, 67,68)
Aroclor [®] 1254	0	33 (2,3,10,26,29,30, 31,33,38,40,44,45, 48,51,55,57,63,64, 67,68,70,74,76,78, 89,93,96,111, 112,114,117)
Aroclor [®] 1260	0	24 (1,3,5,7,10,21,22,26, 31,33,34,38,49,55, 59,67,70,74,86,89, 96,103,111,112)
Total PCBs ^b	0	28 (3,5,10,21,22,27, 30,31,33,34,38,45, 48,51,54,55,63,64, 67,68,69,70,89,96, 99,101,111,117)
Dieldrin	2 (84,88)	10 (5,7,9,22,30,38, 53,66,90,112)
Endrin	0	9 (14,22,30,46, 70,80,90,100,103)
Heptachlor ^c	0	1 (42)
<i>cis</i> -Chlordane	2 (28,86)	23 (2,7,13,15,24,27, 29,30,34,45,46,53, 54,68,70,73,74,81, 97,101,107,111,117)
<i>trans</i> -Chlordane	3 (20,28,29)	11 (5,24,27,38, 44,45,53, 54,72,99,114)
<i>cis</i> -Nonachlor	4 (14,18,20,46)	1 (99)
<i>trans</i> -Nonachlor	3 (82,85,86)	8 (5,29,40,48,55,67, 74,117)
Toxaphene	0	12 (7,13,14,21,22,29, 55,73,76,79,103,115)

^a *p,p'*-homologs

^b Sum of Aroclors 1248, 1254, and 1260

^c As heptachlor epoxide plus traces of heptachlor

clors[®] 1254 and 1260 (Stalling *et al.* 1979, 1980). Consequently, Schmitt *et al.* (1983, 1985) argued that the occurrence of significant concentrations of PCBs that resemble Aroclor[®] 1248 indicates either recent inputs of Aroclor[®] 1248 or the degradation of less-persistent mixtures such as Aroclor[®] 1242 mixtures; both mixtures are relatively toxic (Mayer *et al.* 1977; Stalling and Mayer 1972; Stalling *et al.*

1979, 1980). In the early portion of chromatograms, only four capillary GC/ECD peaks distinguish Aroclor 1242[®] from Aroclor[®] 1248 mixtures (Mullin 1985; Mullin *et al.* 1984). These four peaks comprise four to six di- and mono-ortho-chlorine-substituted-Cl₂-PCB isomers: IUPAC Nos. 004 and/or 010, 007, 006, and 005 and/or 008. When these Cl₂-PCB isomers are eliminated by environmental factors, our capillary technique can no longer distinguish PCB mixtures as Aroclor[®] 1242 residues. In previous years, high concentrations of residues resembling Aroclor[®] 1248 were present in at least one sample from the Merrimack, Connecticut, Hudson, and Delaware rivers in the Northeast (Stations 53, 2, 3, and 4, respectively); at two stations in the Ohio River system (68 and 69); and at Station 21, in Lake Michigan (Schmitt *et al.* 1985). In 1984, residues that resembled Aroclor[®] 1248 were present at relatively high concentrations (≥ 0.5 $\mu\text{g/g}$) at only five sites—Stations 3, 53, 69, 105, and 107 (Appendix A); among these the trend has been downward only at Station 3 (Table 8). At this station (Hudson R.), the reduction is due to the continued weathering and transport of PCBs that originated primarily as Aroclor[®] 1242 (Brown *et al.* 1987). No residues resembling Aroclor[®] 1242 have been found in NCBP samples since 1976-77. Aroclor[®] 1248 was the primary mixture released into southern Lake Michigan (Brown *et al.* 1987), where residues resembling this mixture remain evident in fish from Station 105 (Figure 5), and where fish have also been shown to contain relatively high concentrations of toxic PCB congeners (Huckins *et al.* 1988).

Brown *et al.* (1987) recently reported selective microbial degradation of the most toxic PCB congeners in anaerobic sediments, which suggests that environmentally weathered PCBs—even those that are chromatographically similar to Aroclor[®] 1248—may not constitute the same degree of hazard as the original mixtures. Conversely, Huckins *et al.* (1988) reported that there was little, if any, evidence of reductive dechlorination of Aroclor[®] 1248 in sediment samples from Waukegan Harbor, IL, a major source of PCBs for Lake Michigan, and that the most toxic PCB congeners appeared to bioaccumulate in fish. Sonstegard *et al.* (1988) also reported that potentially toxic PCB congeners were preferentially accumulated by mice fed coho salmon (*Oncorhynchus kisutch*) from the Great Lakes. Although our methods are adequate for the estimation of total PCB concentrations, these and other findings suggest that it is not appropriate to speculate as to the toxicological significance of PCB residues without either the resolution of isomer-specific PCB characterization of toxic isomers or associated impurities (Schwartz *et al.* 1987) or a bioassay (Safe 1987). Previously stated caveats (Schmitt *et al.* 1985) regarding the potential toxicological significance of polychlorinated dibenzofurans also remain; these compounds, which are present in commercial PCB mixtures and in environmental samples that are heavily contaminated with PCBs (Rappe and Buser 1980; Stalling *et al.* 1983), should be considered in the assessment of PCB threats to piscivorous wildlife.

Cyclodiene Insecticides: Mean concentrations of dieldrin have not changed since 1976-77 (Table 9). The maximum concentration in 1984 (1.39 $\mu\text{g/g}$ at Station 100 in Hawaii) was slightly greater than in 1980-81, but was less than half

Table 9. Geometric mean residue concentrations ($\mu\text{g/g}$) for the 1976–77, 1978–79, 1980–81, and 1984 collection periods, and significance tests for time-period main effects (as ANOVA F -values^a). Within each group of four means (columns), values containing the same subscript are not significantly different ($P > 0.05$, Fischer's protected LSD). Data for 1976–77, 1978–79, and 1980–81 from Schmitt *et al.* (1983, 1985). (NA = not analyzed)

Residue	Collection period				F^a
	1976–77	1978–79	1980–81	1984	
<i>p,p'</i> -DDE	0.26 _a	0.24 _a	0.20 _b	0.19 _b	6.18**
<i>p,p'</i> -DDD	0.08 _a	0.08 _a	0.07 _b	0.06 _b	3.96**
<i>p,p'</i> -DDT	0.05 _a	0.04 _b	0.05 _b	0.03 _c	4.63**
Total DDT ^b	0.37 _a	0.34 _a	0.29 _b	0.26 _b	8.40**
Aroclor® 1248	0.14 _a	0.14 _a	0.11 _a	0.06 _b	5.21**
Aroclor® 1254	0.49 _a	0.46 _a	0.24 _b	0.21 _b	48.83**
Aroclor® 1260	0.37 _a	0.37 _a	0.25 _b	0.15 _c	32.73**
Total PCBs ^c	0.89 _a	0.84 _a	0.53 _b	0.39 _c	57.41**
Dieldrin ^d	0.06 _a	0.05 _a	0.04 _a	0.04 _a	2.04
Endrin	0.01 _a	<0.01 _b	<0.01 _b	<0.01 _b	6.25**
Heptachlor ^e	0.01 _a	0.02 _b	0.01 _a	0.01 _a	4.61**
<i>cis</i> -Chlordane	0.06 _a	0.07 _a	0.03 _b	0.03 _b	14.43**
<i>trans</i> -Chlordane	0.02 _a	0.02 _b	0.02 _b	0.02 _b	5.21**
<i>cis</i> -Nonachlor	0.01 _a	0.03 _b	0.02 _c	0.02 _c	13.15**
<i>trans</i> -Nonachlor	0.03 _a	0.05 _b	0.04 _a	0.03 _a	8.29**
Oxychlordane	NA	0.01 _a	0.01 _a	0.01 _a	1.11
Toxaphene	0.34 _a	0.28 _b	0.28 _b	0.14 _c	17.91**
α -BHC	0.02 _a	<0.01 _b	<0.01 _b	<0.01 _b	22.55**
γ -BHC	0.01 _b	<0.01 _a	<0.01 _a	<0.01 _a	2.83*
HCB	0.01 _a	<0.01 _b	<0.01 _b	<0.01 _b	3.08*
Mirex	NA	NA	<0.01 _a	<0.01 _a	0.08
Dacthal®	NA	0.01 _a	<0.01 _a	<0.01 _a	0.87
PCA	NA	NA	<0.01 _a	<0.01 _a	0.04

^a $df = 2, 192$ for Dacthal® and oxychlordane, 1, 96 for mirex and PCA, and 3, 234 for all other tests; * = $P \leq 0.05$; ** = $P \leq 0.01$

^b *p,p'*-homologs

^c May include traces of Aroclor® 1242 for 1976–77

^d May include traces of aldrin for 1976–77

^e As heptachlor epoxide plus traces of heptachlor

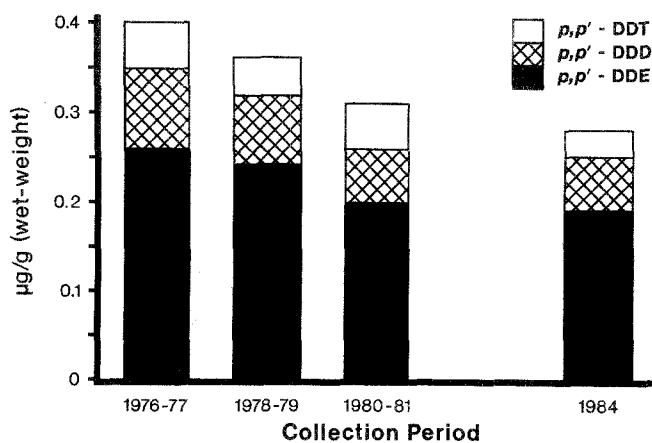


Fig. 3. Geometric mean concentrations of *p,p'*-DDT homologs, 1976–84

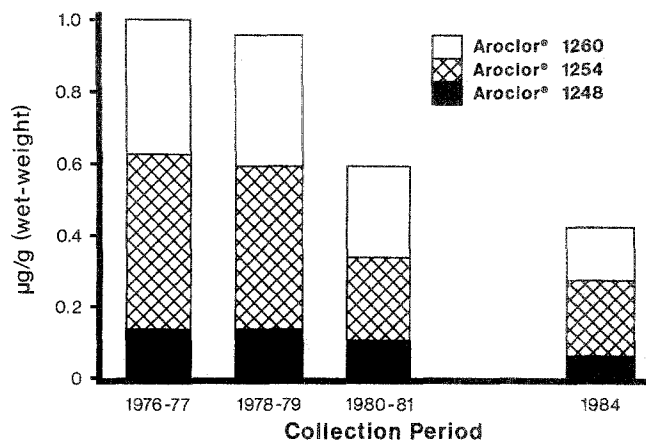


Fig. 4. Geometric mean concentrations of polychlorinated biphenyls (as Aroclor® mixtures), 1976–84

the 3–5 $\mu\text{g/g}$ typical of this station in 1976–79 (Figure 6, Table 7). The geographic distribution of stations with the greatest dieldrin concentrations has remained unchanged since 1970–79 (Schmitt *et al.* 1983); in addition to samples from Station 100, which contained 0.92–1.39 $\mu\text{g/g}$ of dieldrin, concentrations of 0.1–0.5 $\mu\text{g/g}$ remained typical of samples from Lakes Michigan, Huron, and Ontario, and

from most of the major rivers that drain the Corn Belt (Figure 6, Appendix A).

Among the stations with the greatest dieldrin concentrations in 1984 or in previous collection periods, a statistically significant downward trend in concentrations from 1976–77 to 1984 has occurred only at Station 90 (Kansas R., KS); at the two stations that have shown evidence of increases

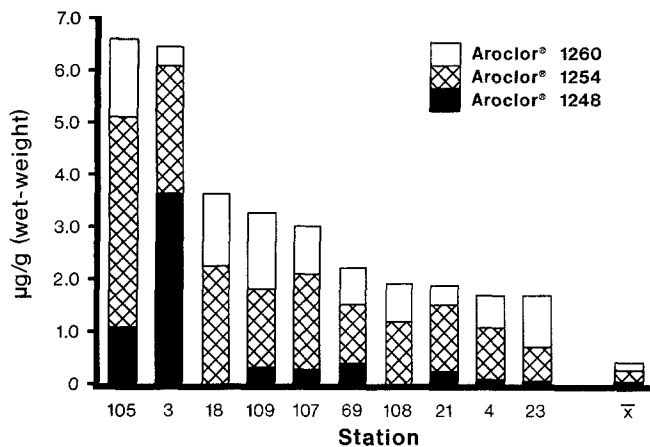


Fig. 5. Geometric mean concentrations of polychlorinated biphenyls (as Aroclor® mixtures) for NCBP stations at which the mean for total PCB equaled or exceeded the 90th percentile concentration in 1984. Also shown is the national geometric mean for 1984 (\bar{x})

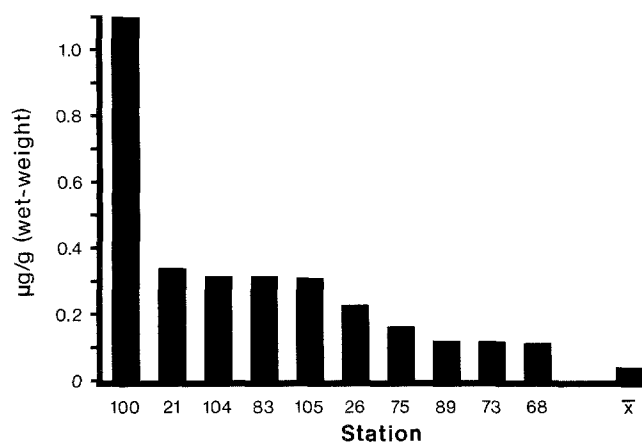


Fig. 6. Geometric mean concentrations of dieldrin for NCBP stations at which the mean equaled or exceeded the 90th percentile concentration in 1984. Also shown is the national geometric mean for 1984 (\bar{x})

(Table 8), concentrations were low (0.02–0.04 µg/g, Appendix A). Schmitt *et al.* (1985) cited evidence (Leung *et al.* 1981; Ricci *et al.* 1983) indicating that dieldrin was still being carried into receiving waters from fields in the Midwest, despite the fact that no aldrin (the source of most environmental dieldrin residues) had been used in agriculture since 1974 (Schnoor 1981). The lack of appreciable change in dieldrin concentrations in fish from the Great Lakes and the major rivers of the Midwest since 1978–79 suggests that dieldrin residues in soils remain a threat to fish and wildlife (Clark *et al.* 1983).

As reported previously (Schmitt *et al.* 1985), mean concentrations of endrin in NCBP samples have always been low (Table 9); because this compound is relatively short-lived and was used on comparatively few crops, it has usually been detected at fewer stations than most of the more persistent and widely used organochlorine insecticides. The maximum concentration and the percentage of stations at which endrin was detected declined from 1976–77 to 1980–81; for 1984, the maximum concentration (0.22 µg/g) was lower than in 1980–81, but the incidence increased from 22% to 28% (Table 7). As has been typical of endrin, samples containing >0.01 µg/g came from only eight stations in 1984. As in previous years, concentrations were highest at Station 76, on the Mississippi R. at Memphis, TN (Figure 7). Endrin was manufactured near Memphis; in the past, spills of cyclodiene insecticides caused massive fish kills (Public Health Service 1964), and fish from the Mississippi River contained residues of cyclodiene insecticide precursors (Yurawecz and Roach 1978). In previous years, concentrations were also elevated at Station 15, farther downstream on the Mississippi River. In 1984, however, the three samples from Station 15 each contained only 0.01 µg/g of endrin. Although endrin was once found at high concentrations at many of the stations in the Cotton Belt, levels at all of these stations were <0.05 µg/g in 1980–81 (Schmitt *et al.* 1985) and fell to ≤0.03 µg/g in 1984 (Figure 7), having declined significantly since 1976–77 (Table 8). In 1978–79, the endrin concentration was highest (0.11 µg/g) in Lake Mich-

igan (Schmitt *et al.* 1983); endrin levels were lower in Lake Michigan in 1980–81 and 1984, but nevertheless remained greater than concentrations at most other stations (Figure 7). Endrin is still used in many areas of the United States to protect orchards from rodent damage, and remained registered for insect control on some crops as recently as 1987 (Anon 1987). Endrin is among the organochlorine insecticides most toxic to fish (Grant 1976; Grant and Mehrle 1970, 1973; Johnson and Finley 1980).

A controversial issue in 1981 was the use of endrin to protect small grains from an infestation of army cutworms (*Euxoa auxiliaris*) that occurred in some areas of the Northern Great Plains (Anon 1981a). Residues were later detected in waterfowl and other wildlife that frequented treated areas, prompting concern among wildlife and public health agencies (Anon 1981a, 1981b). Detectable, but extremely low (0.01 µg/g) concentrations of endrin were present in only three of the samples collected in 1981 from the Missouri River system (one each from Stations 88, 89, and 90); none was found in any of the 1981 samples from the Missouri River watershed upstream from its confluence with the Platte River, in eastern Nebraska (Schmitt *et al.* 1985). In 1984, only one sample from the Missouri River system, collected at Station 32 (Missouri R. at Garrison Dam, ND), contained detectable (0.01 µg/g) endrin residues (Appendix A).

Following a period of steady decline from 1976 to 1981, mean concentrations of chlordane did not change from 1980–81 to 1984 (Table 9). Residues of *cis*-chlordane and *trans*-nonachlor, the most abundant and persistent of the chlordane components measured, were present at 85% and 89%, respectively, of the stations sampled in 1984; in 1980–81, *cis*-chlordane was detected at 74% of the stations sampled, and *trans*-nonachlor at 85%, having declined from 93% in 1978–79 (Table 7). As in previous years, the other chlordane components were present at fewer stations in 1984. The maximum chlordane concentration also occurred where it has in the past—in Hawaii at Station 100 (Figure 8)—but remained far lower than in 1978–79 (Table 7), when

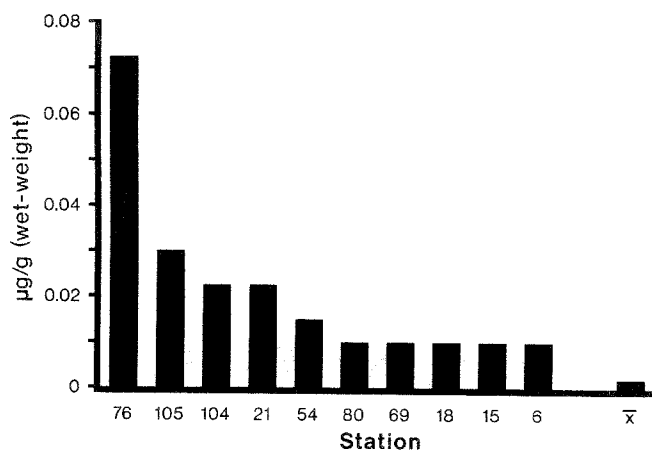


Fig. 7. Geometric mean concentrations of endrin for NCBP stations at which the mean equaled or exceeded the 90th percentile concentration in 1984. Also shown is the national geometric mean for 1984 (\bar{x})

residues of *cis*-chlordane and *trans*-nonachlor both exceeded 2.0 µg/g. Relatively high concentrations of one or more chlordane-related compounds (*cis*- or *trans*-chlordane or nonachlor; oxychlordane; heptachlor epoxide) also remained in the Great Lakes (Stations 21, 104, 105, 106, 107, and 109), and in the watersheds of the Ohio R. (Stations 23, 24, 26, 68, 69, and 70), Missouri R. (Station 83), and Mississippi R. (Stations 75, 76, and 80), and in the Delaware and Raritan rivers (Stations 4 and 54, respectively), in the Northeast (Figures 8 and 9; Appendix A). Oxychlordane, a major toxic metabolic of *cis*-chlordane, and heptachlor epoxide were present at most of these sites as well, but at lower concentrations than the other chlordane components (Figures 8 and 9).

Overall, the relative abundance of the major components of technical chlordane present in fish changed over the period 1976–1984 (Figure 10). Before 1980, *cis*-chlordane, the active ingredient of technical chlordane, was the most abundant component; however, concentrations of *trans*-nonachlor, the most persistent component, have equaled or exceeded those of *cis*-chlordane since 1980–81 (Table 9, Figure 10). The general distribution of chlordane components for freshwater fish in 1984 (Figure 10) is nearly identical to that reported for marine fish from the northern North Pacific, Bering Sea, and Antarctica by Kawano *et al.* (1988). *Trans*-nonachlor and *cis*-chlordane were also the prevalent components at all of the stations at which chlordane concentrations were highest (Figure 8), except Station 76, where *trans*-chlordane was most abundant. At Station 76 (Mississippi R. at Memphis, TN), the unusually high proportion of *trans*-chlordane probably derives from the proximity of the collection site to the facility that produces most of the cyclodiene insecticides used in the United States. It also may indicate that the proportional composition of the chlordane mixture in fish can be used to differentiate among point sources of chlordane, especially if additional components are measured. For example, Ribick and Zajicek (1983) found that the pattern of chlordane residues in NCBP fish from Hawaii was different than the pattern typical of fish from other locations.

Collectively, the lower overall concentrations of chlor-

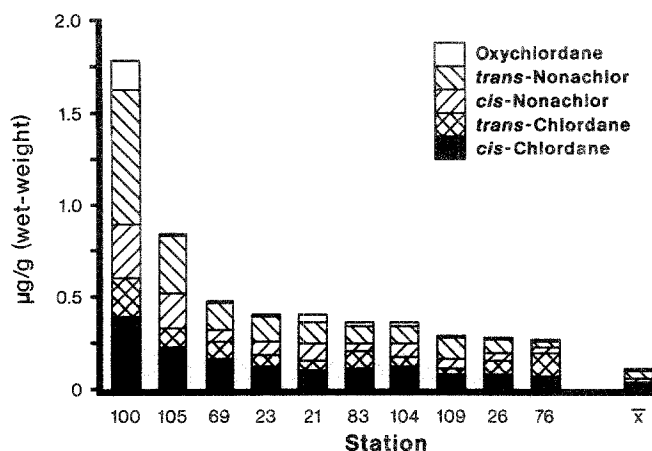


Fig. 8. Geometric mean concentrations of chlordane-related compounds for NCBP stations at which the mean sum of these residues equaled or exceeded the 90th percentile concentration in 1984. Also shown is the national geometric mean for 1984 (\bar{x})

dane in fish and the proportional increase in concentrations of *trans*-nonachlor suggested that the rate of chlordane influx to the aquatic environment has been reduced since the mid-1970's, when chlordane use in agriculture was terminated. The findings of Arruda *et al.* (1987) suggest that urban areas now constitute the main source of chlordane to aquatic ecosystems, even in watersheds that received significant agricultural inputs in the past. In Hawaii, Station 100 (Manoa Stream) drains a suburban watershed. Elevated concentrations of chlordane, dieldrin, and other organochlorine insecticides at this station (Figures 8–10) are also indicative of termite control efforts, as subterranean and dry-wood termites constitute a major problem in Hawaii (Bevenue *et al.* 1972; Tanita *et al.* 1976). Recently imposed restrictions on the use of chlordane for termite control, based in part on the occurrence of unacceptably high residues in the edible parts of fish, should result in a further decline in concentrations.

Heptachlor, aldrin, dieldrin, and chlordane were used as soil insecticides until rather recently. Heptachlor also occurs as a minor component ($\leq 10\%$) of technical chlordane (NRCC 1974), which makes it difficult to differentiate the source of heptachlor epoxide residues (Schmitt *et al.* 1985). Heptachlor is rapidly converted to heptachlor epoxide and other metabolites by many organisms; consequently, little unmetabolized heptachlor has been detected in NCBP fish samples since 1976–77. Both the occurrence and the concentrations of heptachlor epoxide seemed to be declining slightly (Tables 7 and 8). Concentrations remained highest in Hawaii (Station 100) and in the Midwest, especially in Lake Michigan and in the Mississippi, Missouri, Ohio, and Illinois rivers (Figure 9).

Toxaphene: Mean concentrations of toxaphene in NCBP freshwater fish samples plateaued in 1970–76 after a period of steady increase through the 1970's (Tables 7 and 8). The national mean was significantly lower in 1984 than in 1981 (Table 9), and the 1984 maximum (8.2 µg/g) is the lowest maximum concentration yet encountered in the NCBP (Table 7). As in all previous collections except 1978–79 (Schmitt *et al.* 1981, 1983, 1985), the maximum was at Station 80, in Mississippi (Figure 11). In 1978–79, toxaphene

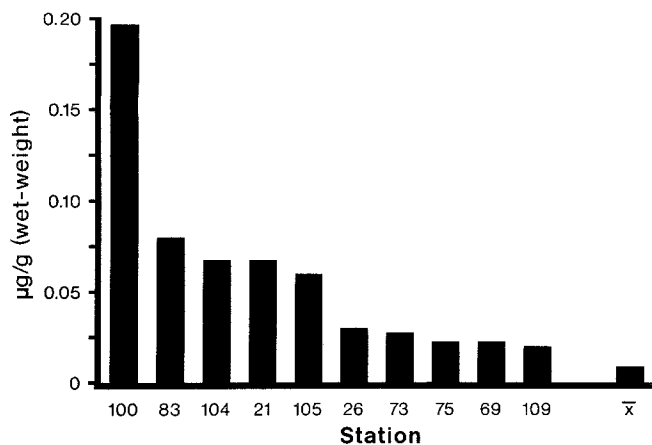


Fig. 9. Geometric mean concentrations of heptachlor epoxide for NCBP stations at which the mean sum of these residues equaled or exceeded the 90th percentile concentration in 1984. Also shown is the national geometric mean for 1984 (\bar{x})

concentrations were highest in lake trout samples from Lakes Michigan and Superior (Schmitt *et al.* 1983). Concentrations in the Upper Great Lakes were generally lower (2.5 µg/g) in 1980–81 than in 1978–79, when residues in Lakes Michigan and Superior were typically 5–10 µg/g. For 1984, concentrations in the Great Lakes declined further, to about 1–2 µg/g in Lakes Michigan, Superior, and Huron (Figure 11, Appendix A). A significant downward trend since 1976–79 has been evident at Stations 21 (Lake Michigan) and 22 (Lake Superior), at two stations in the South (7 and 14), and at Station 115, where concentrations were high in earlier years (Table 8). Although concentrations were much lower in 1984, the downward trend for toxaphene residues at other stations with high concentrations in the past (Stations 80, 102, 103, 104, 105, and 106) was not statistically significant; however, in contrast to previous years, there were no significant increases for 1984 (Table 8). The incidence of toxaphene residues increased from about 60% of the stations sampled in 1976–77 and 1978–79 to 88% in 1980–81. In 1984, however, toxaphene was detected at only 69% of the stations sampled (Table 7).

As discussed previously for PCBs, the dramatic change in the percentages of stations that yielded fish containing residues that resemble toxaphene between 1976–79 and 1980–81 probably reflected the introduction of capillary-column GC in 1980–81. This technique provides better resolution of components than does packed-column GLC (Ribick *et al.* 1982). Although the quantification of toxaphene by packed- and capillary-column methods is usually equivalent (Ribick *et al.* 1982), the capillary technique is more likely to detect low concentrations. The change in the occurrence of toxaphene residues from 1980–81 through 1984, however, is not confounded by analytical inconsistency; toxaphene residues were present at fewer stations in 1984 than in 1980–81.

Partly as a consequence of the ban on the use of DDT imposed in 1972, toxaphene was for many years the insecticide used most heavily in the United States (Andrilenus 1974; Eichers *et al.* 1978). During 1976, over 15 kilotonnes (kt) were used in agriculture, of which 10 kt were applied to cotton (Eichers *et al.* 1978). After 1976, toxaphene became

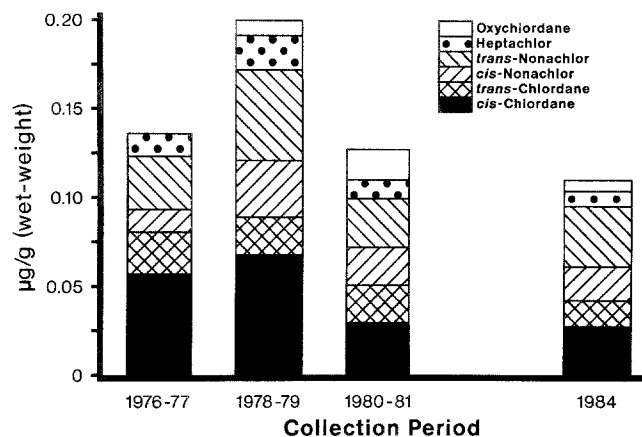


Fig. 10. Geometric mean concentration of chlordane-related compounds, 1976–1984. (Oxychlordane was not determined in 1976–77)

less popular with cotton farmers; by 1982, less than 1.1 kt were used on cotton, total U.S. use declined to 7.3 kt (USEPA 1982a), and toxaphene's registration for most uses was subsequently cancelled (USEPA 1982b). Schmitt *et al.* (1985) noted declining concentrations at several NCBP stations in the Great Lakes and in the South in 1980–81, paralleling the decline of toxaphene use, and hypothesized that cancellation would result in further declines. Results for 1984, showing significantly lower concentrations, support that hypothesis. According to Gooch and Matsamura (1987), however, concentrations of the most toxic components of the toxaphene mixture present in Great Lakes lake trout did not change from 1982 to 1985. Our analytical procedure does not have sufficient resolution to enable quantitation of individual components. Moreover, as we outlined previously for PCBs, it appears that the toxicological significance of toxaphene residues in fish cannot be evaluated by estimating the total toxaphene concentration, even with the resolution afforded by present capillary GC methods.

Other Compounds: Mirex was used as an insecticide to control red imported fire ants (*Solenopsis invicta*) in the South, and more widely as a flame retardant and polymerizing agent in plastics (Kaiser 1978). The commercial synthesis of mirex at Niagara Falls and Volney, NY was responsible for the mirex pollution of Lake Ontario (Kaiser 1978). Mirex was present at 18% of the stations sampled in 1980–81 and 13% in 1984. As in 1981, concentrations were greatest for 1984 in Lake Ontario (Stations 18 and 109) and the St. Lawrence River (Station 66), and in the Southeast (Stations 10, 13, 14, 57, and 59). Traces (0.01 µg/g) were also present in the Ohio R. at Cincinnati, OH (Station 69; Figure 12, Appendix A). Mirex concentrations at the two Lake Ontario stations were two- to four-fold higher in 1984 than in 1981, and were also two-fold greater than other reported values for Lake Ontario (NYSDEC 1981, Lum *et al.* 1987). As in 1980–81 (Schmitt *et al.* 1985), trace concentrations (0.01 µg/g) were also detected in samples from Lake Michigan (Station 105) and Lake Superior (Station 102).

Pentachlorophenol (PCP) is widely used as a wood preservative and as a slimicide by the forest products and

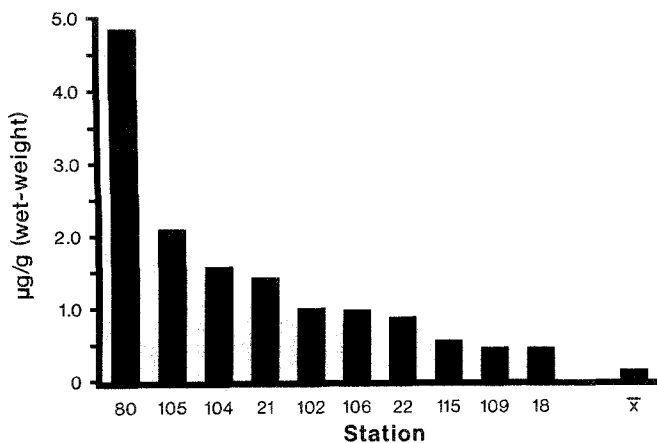


Fig. 11. Geometric mean concentrations of toxaphene for NCBP stations at which the mean equaled or exceeded the 90th percentile concentration in 1984. Also shown is the national geometric mean for 1984 (\bar{x})

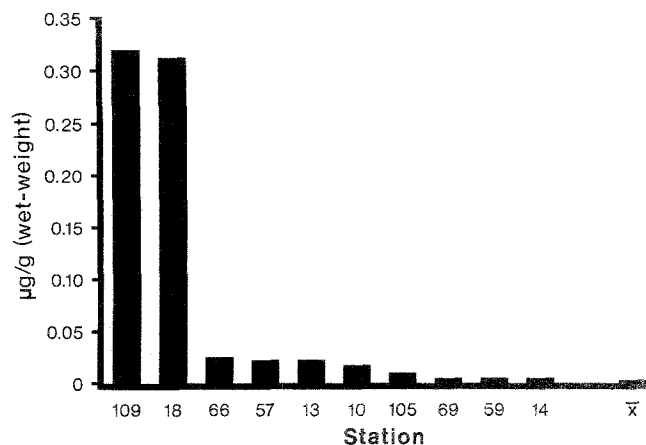


Fig. 12. Geometric mean concentrations of mirex for NCBP stations at which the mean equaled or exceeded the 90th percentile concentration in 1984. Also shown is the national geometric mean for 1984 (\bar{x})

leather industries (NRCC 1982). It is also a metabolite of HCB, which was formerly used widely as a fungicide (Vizethum and Goerz 1979). Residues of PCA, a methylated degradation product of PCP, were present at 30% of the stations sampled in 1984, up from 24% in 1980–81 (Table 7); however, concentrations remained generally low (≤ 0.02 $\mu\text{g/g}$) except at Stations 59 (Alabama R.), 53 (Merrimack R., MA), and 28 (Arkansas R.). Residues of PCA were detected in 1984 samples from stations at which concentrations were also high in 1980–81: 54 (Raritan R., NJ), 8 (Cape Fear R., NC), 1 (Penobscot R., ME), 69 (Ohio R. at Cincinnati, OH), 15 (Mississippi R., LA), and 45 (Willamette R., OR), but the concentrations were lower in 1984 (0.01–0.02 $\mu\text{g/g}$; Appendix A). PCA is relatively short-lived; its half-life in fish lipid is only 23 days (Glickman *et al.* 1977). Therefore, residues in environmental samples indicate recent inputs of PCP or another parent material. PCA is also comparatively volatile; based on recovery data, concentrations in fish are probably somewhat higher than the values reported.

Residues of HCB, which have become virtually ubiquitous (Zell and Ballschmiter 1980), occur in the environment as a result of this compound's wide use as a fungicide, and because it is a by-product of the production of other chlorinated hydrocarbons (Villanueva *et al.* 1974). Compared with DDT and other persistent organochlorine compounds, HCB is less persistent in (and less toxic to) fish; however, similar to PCP, commercial formulations once contained toxic impurities, including polychlorinated dibenzo-*p*-dioxins and PCDFs (Villanueva *et al.* 1974). The greatest HCB concentration (0.4 $\mu\text{g/g}$) in the 1984 samples came from the Tombigbee River, AL (Station 14), where concentrations have historically been highest (Schmitt *et al.* 1981, 1983, 1985) because of the aforementioned insecticide production facilities. Relatively high concentrations (≥ 0.04 $\mu\text{g/g}$) of HCB were also evident in samples from Lakes Ontario and St. Clair (Stations 18, 107, and 109), the Ohio River (Stations 24 and 69), and the Mississippi River (Station 15). The co-occurrence of octachlorostyrene (Chemical Abstracts No. 29082-74-4, confirmed by GC/MS) in 1984 samples from Stations 18, 107, 109, 24, 69, and 15 (U.S. Fish and Wildlife Service, unpublished) suggests that the source of HCB at

these stations is from the production (Kuehl *et al.* 1981) or incineration (Lohse 1988) of other chlorinated hydrocarbons, rather than from HCB use as a fungicide. Similar to PCA, HCB is relatively volatile; based on recovery data, HCB concentrations were probably higher than the values reported.

BHC, an insecticidal mixture of five hexachlorocyclohexane isomers, was once used extensively on cotton and other crops in the USA (and is still used elsewhere in the world); the purified γ -isomer (lindane) was the more widely used and is still registered for a variety of applications (Anon 1987). The BHC isomers are relatively short-lived compared with some organochlorine compounds; their occurrence at more than trace levels (≥ 0.01 $\mu\text{g/g}$) in environmental samples therefore indicates recent inputs. α -BHC was detected at 47% of the stations sampled in 1984, and γ -BHC at 15%—percentages that have not changed appreciably since 1980–81 (Table 7). However, BHC residues had declined in both concentration and occurrence between 1976–77 and 1980–81 (Tables 7 and 9). In 1980–81, residues of γ -BHC exceeded 0.01 $\mu\text{g/g}$ only at Station 99 (in Hawaii), and even there the concentrations were low (0.02–0.03 $\mu\text{g/g}$); in 1984, concentrations did not exceed 0.01 $\mu\text{g/g}$ at any station (Appendix A). Mean concentrations of α -BHC were greatest (0.02–0.04 $\mu\text{g/g}$) at stations in the Great Lakes (18, 21, 22, 102, 104, 105, and 106) and at Stations 32 (Missouri R., ND) and 14 (Tombigbee R., AL; Figure 13). Because of their volatility, α - and γ -BHC were also difficult to accurately quantify; consequently, the concentrations may be slightly higher than the values reported.

Residues of Dacthal® declined slightly in both concentrations and occurrence from 1978–79 to 1980–81, but increased in 1984 (Tables 7 and 8). Measurable residues were present at 46% of the stations sampled in 1984 (Table 7). Dacthal® is a popular broad-spectrum herbicide that is registered for use on ornamental plants, turf, and certain vegetable and field crops (Anon 1987). Greatest concentrations (0.07–0.45 $\mu\text{g/g}$) and occurrence in the 1984 NCBP collections were nearly identical to those reported previously; the maximum was at Station 16, in the lower Rio Grande, TX (Figure 14, Appendix A), an area that is intensively farmed.

Greater than trace (0.01 $\mu\text{g/g}$) concentrations were also detected in samples from the Mississippi River at Cape Girardeau, MO (Station 75), Delaware River (Station 4), Raritan River, NJ (Station 54), Columbia River (Station 46), Rogue River, OR (Station 48), Snake River (Stations 42 and 96), Wisconsin River (Station 72), lower Colorado River (Station 115), and in Lakes Michigan, Huron, and Erie (Stations 21, 106, and 108, respectively; Figure 14, Appendix A).

Co-occurrences and Correlations Among Contaminants

As in past years, concentrations of the contaminants measured in 1984 were highest at relatively few stations; consequently, the residues were highly correlated (Table 10). These correlations represent significant co-occurrences of contaminants that are related to common use patterns and persistence, and are similar to those reported for 1980–81 (Schmitt *et al.* 1985). Dieldrin, for example, remained highly correlated with chlordane and heptachlor (Table 10). The co-occurrence of high concentrations of these contaminants in the Midwest and in Hawaii presumably resulted from their use on the same crops and to control insects in and near buildings. The correlation between chlordane components and PCBs resulted primarily from joint contamination of fish from the Great Lakes and Ohio River systems by these residues (Figures 5 and 8). The correlation between DDT and toxaphene (Table 10) reflects the presence of these insecticides in fish from the South and the Great Lakes (Figures 2 and 10), as well as similar use patterns. HCB and DDT were correlated (Table 9) because both compounds occur in fish from the Great Lakes, the Lower Mississippi River Valley, and Station 14.

Lipid-Normalization of Residue Concentrations

In previous NCBP reports, lipid-normalized residue concentrations were computed, compared, and published along with wet-weight concentrations, even though statistical analysis of these data had shown that little or no precision was gained by this adjustment, and that differences in residue concentrations among species collected from any given site could not be explained solely on the basis of their differing lipid content (Schmitt *et al.* 1981, 1983). Similarly, Huckins *et al.* (1988) recently found that lipid-normalization of total PCB concentrations increased variability among fish samples by five-fold instead of reducing it. Consequently, we have neither computed nor analyzed lipid-weight residue concentrations for this report; however, the lipid values are reported in Appendix A.

The basic assumption underlying lipid-normalization is that non-polar organic compounds partition into and are distributed among the extractable lipids in the fish. Some evidence, however, suggests that non-polar organic compounds are not distributed uniformly among extractable fish lipids. Schneider (1982) stated that the lipid material extractable by solvent from fish tissues constitutes a complex mixture composed mainly of "fats" (esters of fatty acids and glycerol), cholesterol and its esters, free fatty acids, and polar (e.g.,

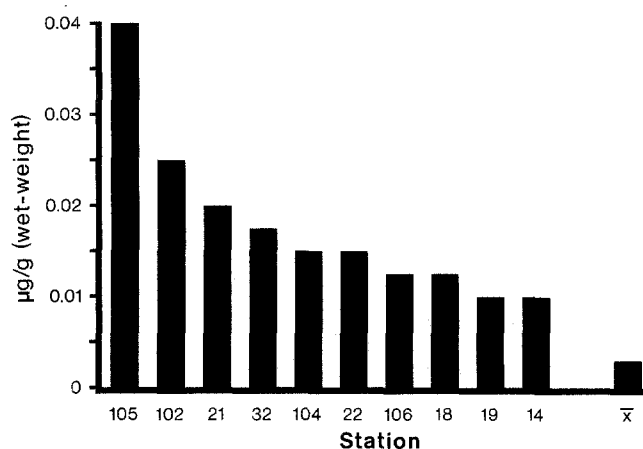


Fig. 13. Geometric mean concentration of α -BHC for NCBP stations at which the mean equaled or exceeded the 90th percentile concentration in 1984. Also shown is the national geometric mean for 1984 (\bar{x})

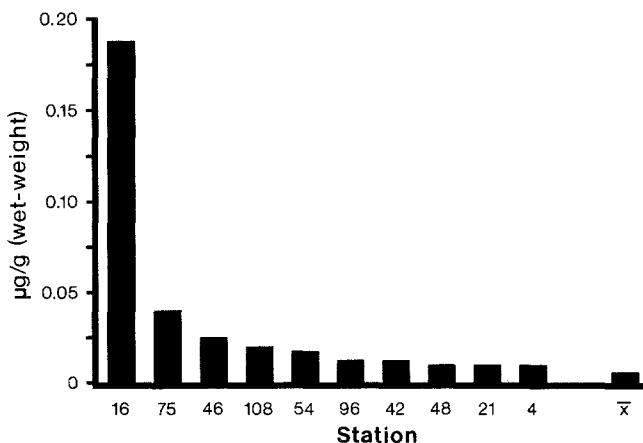


Fig. 14. Geometric mean concentrations of Dacthal[®] for NCBP stations at which the mean equaled or exceeded the 90th percentile concentration in 1984. Also shown is the national geometric mean for 1984 (\bar{x})

"phospho") lipids, which include phospho-, sphingo-, and glycolipids; and that the proportion of these constituents varies among tissues and, presumably, individuals and species. Using a PCB mixture as an example, Schneider (1982) showed that some non-polar organic compounds are less soluble in polar lipids than in other constituents of the lipid pool, which he termed fats (the "phospholipid-free" component of the lipid). Schneider (1982) isolated the polar lipids from the total lipid extract and compared both lipid- (total extract) and fat- (phospholipid-free extract) normalized PCB concentrations in the livers, gonads, and edible tissues of Atlantic cod (*Gadus morhua*) from the Baltic Sea, and found that in contrast to lipid-normalization, the fat-normalized PCB concentrations in tissues from individual fish and from prey species were nearly identical. Kawai *et al.* (1988) provided more direct evidence for the differential distribution of organochlorines among organs and lipid types by measuring contaminant concentrations in five lipid fractions obtained from various tissues of striped dolphins (*Stenella coeruleoalba*). Kawai *et al.* reported, in agreement

Table 10. Correlations $|r|$ between concentrations of organochlorine residues, 1984 ($N = 321$). Product-moment correlations above the principal diagonal, rank correlations below. If $|r| \geq .18$, $P < 0.05$; if $|r| \geq 0.21$, $P < 0.01$

	Lipid	Total DDT ^a	Total PCB ^b	Toxaphene	Dieldrin	Endrin	α -BHC	Dacthal	Mirex	HCB	γ -BHC	Chlordanes ^c	PCA
Lipid	—	.24	.42	.52	.38	.16	.67	.07	.18	-.03	.30	.42	.15
Total DDT ^a	.30	—	.30	.61	.18	.14	.22	.27	.16	.42	.06	.28	.08
Total PCBs ^b	.40	.35	—	.32	.23	.18	.38	-.03	.39	.26	.16	.49	.15
Toxaphene	.50	.54	.35	—	.36	.29	.49	.14	.15	.14	.15	.38	.10
Dieldrin	.61	.35	.47	.52	—	.19	.31	.02	.07	.03	.17	.85	.07
Endrin	.25	.28	.27	.41	.34	—	.26	.11	.09	.07	.06	.30	.06
α -BHC	.61	.14	.34	.31	.44	.30	—	-.01	.18	.19	.35	-.01	.15
Dacthal	.27	.27	.11	.28	.33	.10	.18	—	.01	-.01	-.01	.02	-.04
Mirex	.16	.09	.17	.28	.13	.17	.14	.06	—	.30	.10	.16	.04
HCB	.34	.35	.41	.39	.36	.41	.47	.18	.26	—	.06	.13	.04
γ -BHC	.26	.11	.14	.14	.22	.11	.28	.07	.12	.17	—	.21	.08
Chlordanes ^c	.59	.56	.65	.58	.75	.34	.42	.27	.17	.43	.26	—	.17
PCA	.25	.24	.30	.27	.21	.13	.05	-.05	.07	.19	.13	.37	—

^a *p,p'*-homologs^b Sum of Aroclors 1248, 1254, and 1260^c Sum of *cis* and *trans* isomers of chlordane and nonachlor, oxychlordane, heptachlor, and heptachlor epoxide

with Schneider (1982), that non-polar organochlorines were associated with the triglyceride fraction of the lipid extract; however, they also found that the more polar organochlorines, such as γ -BHC, tended to accumulate in tissue such as brain, which contains proportionately high concentrations of phospholipids, in agreement with previous findings for other cetaceans (Tanabe *et al.* 1981). In their classic study of DDT in lake trout sac fry, Burdick *et al.* (1964) hypothesized that the near total mortality observed at the time of yolk-sac absorption was due to the mobilization of DDT contained in triglycerides, which are used for energy as the fry begin to feed. The findings of Kawai *et al.* (1988) supported that hypothesis; it appears that non-polar organic contaminants are stored in the triglycerides, becoming available during the mobilization of energy reserves.

On the basis of his work with PCBs in various lipid fractions, Schneider (1982) recommended the standardization of lipid determination procedures among monitoring programs, a recommendation with which we concur. These findings also suggest that it is not advisable to follow the now common practice of using percent extractable lipid to estimate the concentrations of organic contaminants in the edible parts of fish on the basis of residue analyses performed on whole fish (Connor 1984).

Summary and Conclusions

Concentrations of some of the most persistent organochlorine compounds were lower in 1984 than at any time since the early 1970s. Average concentrations of DDT, PCBs, chlordane, dieldrin, and toxaphene, the contaminants occurring at the highest concentrations and at the most stations, declined significantly from 1976–77 to 1984, especially at the stations where concentrations were the highest. Among the multi-component mixtures, however, there appear to be mixed toxicological implications within these findings: for PCBs, there have been recent conflicting reports as to the degree to which the most toxic congeners are being degraded by microbial activity; for toxaphene, it appears that

the most toxic components present in fish are also the most persistent, and that the potential hazard of these accumulated residues in Great Lakes fishes has not declined to the same extent as the total toxaphene concentration.

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Appendix A. Organochlorine residues ($\mu\text{g/g}$, wet weight) and percent lipid in composite samples of whole fish, National Contaminant Bio-monitoring Program, 1984. See Figure 1 and Table 1 for station locations (nd, not detected).

Station	Species	<i>p,p'</i> DDE	<i>p,p'</i> DDD	<i>p,p'</i> DDT	PCBs (Aroclors®)			Dieldrin	Endrin	Heptachlor ^a	<i>cis</i> Chlordane
					1248	1254	1260				
1	Smallmouth bass	0.01	nd	nd	0.1	nd	0.1	nd	nd	nd	nd
1	White sucker	0.02	0.01	0.01	0.1	0.1	nd	nd	nd	nd	0.01
1	White sucker	0.01	0.01	0.01	nd	0.1	nd	nd	nd	nd	nd
2	White catfish	0.11	0.03	0.03	nd	0.7	0.8	0.01	nd	nd	0.03
2	White catfish	0.14	0.03	0.02	0.1	0.5	0.4	0.01	nd	0.01	0.03
2	Yellow perch	0.17	0.08	0.06	0.2	0.6	0.7	0.04	nd	0.01	0.07
3	Common carp	0.13	0.08	0.01	4.3	2.4	nd	0.02	nd	0.01	0.02
3	Largemouth bass	0.19	0.06	0.01	3.0	2.5	0.7	0.01	nd	nd	0.01
4	Largemouth bass	0.83	0.27	0.02	0.3	1.3	0.8	0.04	nd	0.01	0.04
4	Smallmouth bass	0.90	0.36	0.09	nd	1.2	0.9	0.02	nd	0.01	0.07
4	White sucker	0.30	0.11	0.04	nd	0.5	0.2	0.02	nd	0.01	0.04
4	White sucker	0.41	0.11	0.06	nd	0.3	0.2	0.02	nd	0.01	0.03
5	Common carp	0.22	0.06	0.01	nd	0.3	1.5	0.01	nd	nd	0.03
5	Common carp	0.05	0.01	0.01	nd	nd	0.6	nd	nd	nd	0.01
5	White perch	0.12	0.03	0.02	nd	0.2	0.7	0.01	nd	nd	0.02
6	Common carp	0.31	0.13	0.02	nd	0.5	0.3	0.03	0.01	0.01	0.05
6	Common carp	0.19	0.04	0.01	0.1	0.1	0.1	0.02	0.01	0.01	0.02
6	Largemouth bass	0.09	0.02	0.01	nd	0.1	0.1	0.01	0.01	nd	0.01
7	Channel catfish	0.12	0.06	0.02	0.3	0.4	nd	0.01	nd	0.01	0.02
7	Channel catfish	0.13	0.06	0.02	0.3	0.7	nd	nd	nd	nd	0.02
7	Largemouth bass	0.23	0.05	0.03	0.1	0.3	0.1	nd	nd	nd	0.02
8	Channel catfish	0.06	0.04	0.02	nd	nd	0.1	0.01	nd	0.01	0.02
8	Largemouth bass	0.06	0.02	0.01	nd	0.1	0.1	0.01	nd	nd	0.01
9	Channel catfish	0.11	0.03	nd	nd	0.1	0.2	nd	nd	nd	0.01
9	Channel catfish	0.06	0.01	0.02	nd	nd	nd	nd	nd	nd	0.01
9	Largemouth bass	0.05	0.01	nd	0.1	nd	0.1	nd	nd	nd	nd
10	Channel catfish	0.02	nd	nd	nd	nd	nd	0.01	nd	nd	0.01
10	Channel catfish	0.01	0.01	nd	0.1	nd	0.1	nd	nd	nd	nd
10	Largemouth bass	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
12	Largemouth bass	0.28	nd	0.01	nd	nd	0.1	nd	nd	nd	0.01
12	Largemouth bass	0.29	0.01	0.01	nd	nd	0.1	nd	nd	nd	0.01
12	Largemouth bass	0.28	0.01	0.01	nd	nd	nd	nd	nd	nd	nd
12	White catfish	0.37	0.05	nd	nd	0.1	nd	0.01	nd	nd	0.01
12	White catfish	0.21	0.03	nd	0.1	nd	nd	0.01	nd	nd	0.01
13	Largemouth bass	0.82	0.15	0.07	nd	0.3	0.5	0.06	nd	0.01	0.03
13	Spotted sucker	0.25	0.05	0.02	nd	0.1	0.1	0.01	nd	0.01	0.01
13	Spotted sucker	0.28	0.07	0.02	nd	0.2	0.1	0.01	nd	0.01	0.02
14	Channel catfish	2.05	0.67	0.52	nd	nd	0.4	nd	nd	nd	0.06
14	Channel catfish	2.26	0.98	0.56	nd	nd	0.3	nd	nd	nd	0.08
14	Largemouth bass	4.71	1.16	0.28	nd	0.3	0.4	nd	nd	nd	0.04
15	Gizzard shad	0.04	0.05	0.01	nd	0.1	0.1	0.04	0.01	0.01	0.02
15	Gizzard shad	0.07	0.08	0.02	nd	0.1	0.1	0.06	0.01	0.01	0.03
15	White bass	0.06	0.06	0.03	nd	0.1	0.2	0.08	0.01	0.01	0.02
16	Channel catfish	1.55	0.03	0.02	nd	nd	nd	nd	nd	nd	nd
16	Channel catfish	1.21	0.03	0.02	nd	nd	nd	nd	0.01	nd	0.01
16	Gizzard shad	1.44	0.09	0.03	nd	nd	nd	0.01	0.03	nd	0.02
16	Gizzard shad	1.27	0.08	0.03	nd	nd	0.1	0.02	0.01	0.01	0.03
16	Largemouth bass	2.09	0.04	0.04	nd	nd	nd	0.01	nd	nd	0.01
17	Largemouth bass	0.10	0.02	0.01	nd	0.2	0.1	nd	nd	nd	nd
17	Redhorse	0.03	0.01	0.01	nd	0.2	0.1	nd	nd	nd	nd
17	Redhorse	0.03	0.01	0.01	0.1	nd	0.1	nd	0.01	nd	nd
18	Lake trout	0.65	0.09	0.08	nd	2.4	1.2	0.07	0.01	0.01	0.05
18	Lake trout	1.03	0.22	0.19	nd	3.6	2.3	0.11	0.01	0.02	0.11
18	Slimy sculpin	0.16	0.08	0.12	nd	1.5	1.0	0.09	0.01	0.02	0.02

<i>trans</i> Chlordane	<i>cis</i> Nonachlor	<i>trans</i> Nonachlor	Oxy- chlordane	Toxaphene	α - BHC	γ - BHC	HCB	Mirex	Dacthal®	PCA	Lipid
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	3.7
nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	0.01	6.4
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	3.6
0.01	0.01	0.04	nd	nd	nd	nd	nd	nd	nd	0.01	4.0
0.02	0.02	0.05	0.01	0.1	nd	nd	nd	nd	nd	0.01	6.1
0.03	0.03	0.06	0.01	0.1	nd	nd	nd	nd	0.01	0.01	5.4
0.01	0.01	0.02	0.07	nd	nd	nd	nd	nd	nd	nd	9.3
nd	0.01	0.02	nd	nd	nd	nd	nd	nd	nd	nd	2.5
0.03	0.04	0.10	0.01	0.2	nd	nd	nd	nd	0.01	nd	4.0
0.03	0.05	0.15	0.03	0.2	nd	nd	nd	nd	0.01	nd	4.9
0.02	0.01	0.03	0.01	0.1	nd	nd	nd	nd	0.01	nd	5.1
0.01	0.01	0.03	0.01	0.1	nd	nd	nd	nd	0.01	nd	4.8
0.02	0.02	0.04	nd	0.1	nd	nd	nd	nd	nd	nd	2.7
0.01	0.01	0.01	nd	nd	nd	nd	nd	nd	0.01	nd	1.5
0.01	0.02	0.03	0.01	0.1	nd	nd	nd	nd	nd	nd	3.3
0.03	0.03	0.07	0.01	0.5	nd	nd	nd	nd	nd	0.01	10.7
0.01	0.01	0.02	nd	0.2	nd	nd	nd	nd	nd	nd	6.2
nd	0.01	0.01	nd	0.1	nd	nd	nd	nd	nd	nd	1.6
0.01	0.01	0.03	nd	0.2	0.01	nd	nd	nd	nd	0.01	10.3
0.01	0.01	0.02	nd	0.1	nd	nd	nd	nd	nd	0.01	10.8
0.01	0.01	0.02	0.01	0.2	nd	nd	nd	nd	0.01	nd	5.9
0.02	0.01	0.02	0.01	0.1	nd	0.01	nd	nd	nd	0.01	5.4
nd	0.01	0.01	0.01	0.1	nd	nd	nd	nd	nd	nd	1.6
0.01	0.01	0.01	nd	0.1	nd	nd	nd	nd	nd	nd	5.8
nd	0.01	0.01	nd	0.1	nd	nd	nd	nd	nd	nd	3.9
nd	0.01	0.01	nd	0.1	nd	nd	nd	nd	nd	nd	2.2
0.01	nd	0.01	nd	0.1	nd	nd	nd	0.02	nd	nd	4.5
nd	nd	0.01	nd	0.1	nd	nd	nd	0.01	nd	0.01	3.3
nd	nd	nd	nd	nd	nd	nd	nd	0.02	0.01	nd	4.6
nd	0.01	0.01	0.01	nd	nd	nd	nd	nd	nd	nd	2.7
nd	0.01	0.02	0.01	0.01	nd	nd	nd	nd	nd	nd	2.8
nd	0.01	0.01	nd	nd	nd	nd	nd	nd	nd	nd	3.6
0.01	0.01	0.01	nd	0.1	nd	nd	nd	nd	nd	nd	8.2
0.01	0.01	0.01	nd	nd	nd	nd	nd	nd	nd	nd	5.6
0.01	0.06	0.07	0.01	0.6	nd	nd	nd	0.04	nd	nd	8.9
0.01	0.01	0.02	nd	0.3	nd	nd	nd	nd	nd	0.01	8.0
0.01	0.02	0.02	nd	0.3	nd	nd	nd	0.01	nd	nd	9.1
0.01	0.02	0.01	nd	0.4	0.01	nd	0.10	nd	nd	0.01	5.4
nd	0.02	nd	nd	0.1	0.01	nd	0.04	nd	nd	0.01	3.5
nd	0.01	nd	nd	0.3	0.01	nd	0.41	0.01	nd	nd	3.0
0.01	0.01	0.01	nd	0.1	nd	nd	0.02	nd	nd	0.01	7.2
0.02	0.02	0.03	0.01	0.2	0.01	nd	0.05	nd	nd	0.02	8.2
0.01	0.01	0.02	0.01	0.2	0.01	nd	0.03	nd	nd	0.01	7.1
nd	nd	0.01	nd	0.3	nd	nd	nd	nd	0.07	nd	1.5
0.01	nd	0.01	nd	0.2	nd	nd	nd	nd	0.11	nd	2.1
0.01	0.01	0.03	nd	0.6	nd	nd	nd	nd	0.45	nd	8.1
0.02	0.01	0.03	nd	0.6	nd	nd	nd	nd	0.34	nd	7.1
nd	0.01	0.01	nd	0.2	nd	nd	nd	nd	0.08	nd	2.8
nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	2.7
nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	1.6
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.0
0.01	0.05	0.10	0.02	0.3	0.01	nd	0.02	0.21	0.01	nd	13.7
0.03	0.11	0.19	0.03	0.5	0.02	0.01	0.05	0.44	0.01	0.01	20.1
0.04	0.04	0.07	0.01	0.5	0.01	nd	0.06	0.30	nd	nd	4.5

Appendix A. (cont'd)

Station	Species	<i>p,p'</i> DDE	<i>p,p'</i> DDD	<i>p,p'</i> DDT	PCBs (Aroclors®)			Dieldrin	Endrin	Heptachlor ^a	<i>cis</i> Chlordane
					1248	1254	1260				
19	White sucker	0.06	0.04	0.01	nd	0.5	0.3	0.03	nd	0.01	0.02
19	White sucker	0.04	0.01	nd	nd	0.2	0.3	0.01	nd	nd	0.01
19	Yellow perch	0.03	0.02	0.01	nd	0.2	0.2	0.02	nd	nd	0.01
20	Common carp	0.11	0.05	nd	nd	0.6	1.2	0.02	nd	nd	0.01
20	Common carp	0.15	0.06	0.01	0.1	0.8	0.2	0.01	nd	nd	0.01
20	Yellow perch	0.09	0.02	0.01	0.2	0.7	0.1	0.02	nd	0.01	0.01
21	Bloater	0.63	0.17	0.17	0.3	1.2	0.3	0.66	0.04	0.11	0.15
21	Bloater	0.47	0.11	0.12	0.1	0.9	0.3	0.32	0.03	0.08	0.09
21	Lake trout	0.86	0.14	0.12	0.3	1.5	0.4	0.19	0.01	0.04	0.08
22	Bloater	0.12	0.02	0.04	nd	0.2	0.1	0.04	0.01	0.01	0.02
22	Bloater	0.05	0.03	0.03	nd	0.1	0.1	0.03	nd	0.01	0.02
22	Lake trout	0.14	0.02	0.03	nd	0.3	0.2	0.03	nd	0.01	0.02
23	Channel catfish	0.07	0.05	0.02	nd	0.9	1.2	0.03	0.01	0.01	0.17
23	Sauger	0.06	0.05	0.02	0.2	0.8	1.5	0.03	nd	0.02	0.20
23	Striped bass	0.04	0.03	0.01	nd	0.4	1.0	0.02	0.01	0.01	0.08
23	Striped bass	0.04	0.03	0.02	nd	0.5	0.6	0.02	0.01	0.01	0.08
23	White crappie	0.02	0.02	0.01	nd	0.4	0.5	0.01	nd	0.01	0.03
24	Common carp	0.81	0.48	0.05	nd	1.2	0.4	0.01	nd	0.01	0.10
24	White crappie	0.08	0.12	0.03	0.2	0.7	0.2	0.01	nd	0.01	0.05
25	Common carp	0.10	0.04	nd	nd	0.2	0.2	0.01	nd	nd	0.02
25	Common carp	0.15	0.03	nd	nd	0.2	0.5	0.01	nd	nd	0.02
25	Spotted bass	0.06	0.02	0.01	nd	0.1	0.1	0.01	nd	nd	0.01
26	Black crappie	0.03	0.02	0.01	0.1	0.2	0.1	0.18	nd	0.02	0.04
26	Common carp	0.08	0.06	0.01	nd	0.8	0.3	0.24	nd	0.05	0.15
26	Common carp	0.09	0.04	0.01	0.2	0.4	0.1	0.31	nd	0.03	0.09
27	Black crappie	0.01	nd	nd	nd	0.2	nd	0.01	nd	nd	nd
27	Common carp	0.01	0.01	0.01	0.1	0.2	nd	0.03	nd	nd	0.01
27	Common carp	0.03	0.01	nd	nd	0.5	0.1	0.03	nd	nd	0.01
28	Common carp	1.07	0.30	0.03	nd	0.3	0.2	0.03	0.01	0.02	0.08
28	Common carp	0.49	0.15	0.01	nd	0.5	0.3	0.02	nd	0.02	0.06
28	Largemouth bass	0.16	0.10	0.04	nd	0.2	0.2	0.01	nd	0.01	0.02
29	Common carp	0.04	0.02	nd	nd	nd	0.1	0.01	nd	nd	0.01
29	Common carp	0.05	0.01	nd	nd	0.1	0.1	nd	nd	nd	0.01
29	Largemouth bass	0.02	nd	nd	nd	nd	0.1	0.01	nd	nd	0.01
30	Bigmouth buffalo	0.14	0.03	0.03	nd	nd	nd	0.01	nd	nd	0.01
30	Bigmouth buffalo	0.19	0.05	0.04	nd	nd	0.1	0.02	nd	0.01	0.01
30	Longear sunfish	0.05	0.01	0.01	nd	nd	nd	nd	nd	nd	nd
31	Common carp	0.04	0.01	nd	nd	0.1	nd	0.02	nd	0.01	0.01
31	Common carp	0.07	0.03	0.02	0.1	nd	0.1	0.14	nd	0.03	0.03
31	Sauger	0.04	nd	0.01	nd	nd	nd	0.03	nd	0.01	0.01
32	River carpsucker	0.02	0.02	0.02	nd	nd	0.1	0.01	nd	0.01	0.01
32	River carpsucker	0.04	0.02	0.02	nd	nd	nd	0.01	nd	0.01	0.01
32	Walleye	nd	0.02	0.02	nd	nd	0.1	0.01	0.01	0.01	0.01
33	Brown trout	0.03	0.01	nd	nd	0.2	nd	nd	nd	nd	nd
33	Longnose sucker	0.08	0.04	0.06	nd	0.3	0.1	nd	nd	0.02	0.01
33	Longnose sucker	0.04	0.01	0.02	nd	0.1	nd	nd	nd	nd	0.01
34	Common carp	0.09	0.04	nd	0.1	0.1	nd	0.01	nd	nd	nd
34	Common carp	0.09	0.03	nd	0.1	0.1	nd	0.01	nd	nd	nd
34	Sauger	0.06	0.04	0.02	nd	0.1	0.1	nd	nd	nd	0.01
35	Common carp	0.03	0.02	0.01	nd	nd	nd	nd	nd	0.01	0.01
35	Common carp	0.01	0.01	nd	0.1	nd	nd	nd	nd	nd	nd
35	Smallmouth bass	0.04	0.01	0.01	nd	nd	nd	nd	nd	nd	nd
36	Common carp	0.10	0.02	nd	nd	0.1	nd	nd	nd	nd	0.01
36	Common carp	0.06	0.02	nd	nd	nd	nd	nd	nd	nd	nd
36	Largemouth bass	0.10	0.01	0.01	0.1	nd	nd	0.01	nd	nd	0.01

Appendix A. (cont'd)

Station	Species	<i>p,p'</i> DDE	<i>p,p'</i> DDD	<i>p,p'</i> DDT	PCBs (Aroclors®)			Dieldrin	Endrin	Heptachlor ^a	<i>cis</i> Chlordane
					1248	1254	1260				
37	Green sunfish	0.09	0.01	0.01	nd	nd	nd	nd	nd	nd	nd
37	Tahoe sucker	0.06	0.01	nd	nd	nd	0.1	nd	nd	nd	0.01
37	Tahoe sucker	0.02	0.01	nd	nd	nd	nd	nd	nd	nd	0.01
38	Common carp	0.03	0.01	nd	nd	0.1	nd	nd	nd	nd	0.01
38	Common carp	0.03	0.01	nd	nd	nd	nd	nd	nd	nd	0.01
38	White bass	0.03	0.01	nd	nd	nd	0.1	nd	0.01	nd	0.01
39	Common carp	0.22	0.05	nd	nd	nd	nd	nd	nd	nd	0.01
39	Common carp	0.50	0.06	nd	nd	nd	nd	nd	nd	nd	0.01
39	White crappie	0.31	0.08	0.01	nd	nd	nd	0.01	nd	nd	0.01
40	Common carp	0.04	0.01	nd	nd	nd	nd	nd	nd	nd	nd
40	Common carp	0.06	0.02	nd	nd	nd	nd	0.01	nd	nd	0.01
41	Largescale sucker	0.23	0.02	0.02	nd	nd	0.1	nd	0.01	nd	0.01
41	Largescale sucker	0.14	0.02	0.01	nd	nd	nd	nd	nd	nd	nd
41	Rainbow trout	0.34	0.04	0.02	nd	nd	0.1	nd	nd	nd	0.01
42	Largescale sucker	0.22	0.03	0.03	nd	nd	nd	0.01	nd	nd	nd
42	Largescale sucker	0.21	0.06	0.03	nd	nd	nd	0.02	nd	nd	0.01
42	Northern squawfish	0.51	0.05	0.01	nd	0.1	0.1	0.02	nd	nd	0.01
43	Largescale sucker	0.02	nd	0.01	nd	nd	0.1	nd	nd	nd	nd
43	Largescale sucker	0.01	0.01	0.01	0.1	nd	nd	nd	nd	nd	nd
43	Mountain Whitefish	0.02	nd	0.02	nd	nd	nd	0.01	nd	nd	nd
44	Black crappie	0.30	0.05	0.03	nd	nd	0.1	0.01	nd	nd	0.01
44	Largescale sucker	0.22	0.05	0.01	nd	nd	0.1	nd	nd	nd	nd
44	Largescale sucker	0.15	0.03	0.01	nd	nd	nd	nd	nd	nd	nd
45	Northern squawfish	0.13	0.02	0.01	nd	0.2	0.1	nd	nd	nd	0.01
45	Peamouth	0.03	0.01	0.01	nd	0.1	0.1	0.01	nd	nd	0.01
45	Peamouth	0.03	0.01	nd	nd	0.1	nd	nd	nd	nd	0.01
46	Largescale sucker	0.73	0.23	0.05	nd	0.4	0.1	0.01	nd	nd	0.01
46	Northern squawfish	0.56	0.12	nd	nd	0.5	0.1	0.01	nd	nd	0.01
47	Yellow bullhead	0.02	nd	nd	nd	nd	0.1	0.01	nd	nd	nd
47	Yellow bullhead	0.02	0.01	0.01	nd	nd	0.1	nd	nd	nd	nd
47	Yellow perch	nd	nd	nd	nd	nd	0.1	nd	nd	nd	nd
48	Black crappie	0.20	0.04	0.01	nd	0.1	nd	0.01	nd	nd	0.01
48	Largescale sucker	0.79	0.11	0.12	nd	0.1	nd	0.04	nd	nd	0.01
48	Largescale sucker	0.97	0.15	0.17	nd	nd	nd	0.05	nd	nd	0.01
49	Arctic grayling	0.09	0.01	0.01	nd	nd	0.1	nd	nd	nd	nd
49	Longnose sucker	0.01	0.01	0.01	nd	nd	0.1	nd	nd	nd	nd
50	Longnose sucker	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
50	Rainbow trout	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
51	White sucker	0.01	0.01	0.01	nd	nd	0.1	0.01	nd	nd	nd
51	White sucker	0.01	0.01	nd	nd	nd	0.1	nd	0.01	nd	nd
51	Yellow perch	0.01	0.01	0.01	nd	nd	0.1	nd	nd	nd	nd
52	Northern pike	0.11	0.01	0.02	0.1	0.3	0.1	nd	nd	nd	0.01
53	Smallmouth bass	0.06	0.07	0.02	0.4	0.7	0.2	nd	nd	nd	0.02
53	White sucker	0.07	0.06	0.03	0.3	0.8	0.2	0.01	0.01	0.01	0.04
53	White sucker	0.11	0.12	0.04	0.8	1.3	0.4	0.01	nd	0.01	0.06
54	Redear sunfish	0.06	0.04	0.03	nd	1.3	0.1	0.02	0.01	0.01	0.03
54	White sucker	0.13	0.09	0.09	0.2	0.9	0.3	0.03	nd	0.02	0.12
54	White sucker	0.16	0.07	0.09	nd	0.9	0.2	0.03	0.04	0.02	0.09
55	Largemouth bass	0.04	0.02	0.04	nd	0.1	0.1	0.10	nd	nd	0.01
55	Redhorse	0.03	0.02	0.01	nd	nd	0.1	0.01	nd	0.01	0.01
55	Redhorse	0.03	0.02	0.02	nd	0.1	0.1	0.01	0.01	0.01	0.01
56	Channel catfish	0.06	0.02	0.01	nd	nd	nd	nd	nd	nd	0.01
56	Channel catfish	0.03	0.02	0.01	nd	nd	0.1	nd	nd	nd	0.01
56	Largemouth bass	0.16	0.02	0.02	0.1	0.2	nd	0.01	nd	nd	0.01

<i>trans</i> Chlordane	<i>cis</i> Nonachlor	<i>trans</i> Nonachlor	Oxy- chlordane	Toxaphene	α - BHC	γ - BHC	HCB	Mirex	Dacthal®	PCA	Lipid
nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	4.1
0.01	nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	3.8
nd	0.01	0.01	nd	nd	nd	nd	nd	nd	nd	nd	2.8
nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	5.6
0.01	nd	0.01	nd	nd	0.01	nd	nd	nd	nd	nd	6.1
nd	0.01	0.01	nd	nd	nd	nd	nd	nd	nd	nd	2.2
nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	1.6
0.01	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.4
0.01	0.01	0.01	nd	0.1	nd	nd	nd	nd	nd	nd	1.9
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.3
nd	nd	nd	nd	nd	nd	nd	nd	nd	0.01	nd	1.5
nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	2.2
nd	nd	0.01	nd	nd	nd	nd	nd	nd	0.01	nd	2.4
nd	0.01	0.01	nd	nd	nd	nd	nd	nd	nd	nd	4.0
nd	nd	0.01	nd	0.2	nd	nd	nd	nd	0.01	nd	3.4
nd	0.01	0.01	nd	0.3	nd	nd	0.01	nd	0.02	nd	6.2
nd	0.01	0.01	nd	0.2	nd	nd	nd	nd	0.01	nd	4.8
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.0
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.9
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	3.1
nd	0.01	0.01	nd	nd	nd	nd	nd	nd	nd	nd	2.4
nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	3.3
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.6
nd	0.01	0.01	nd	nd	nd	nd	nd	nd	nd	0.01	3.9
nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	0.01	3.3
nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	0.01	3.3
0.01	0.01	0.02	0.01	0.1	0.01	nd	0.01	nd	nd	0.01	9.1
0.01	0.01	0.01	nd	0.1	nd	nd	nd	nd	0.05	0.01	9.1
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	6.0
nd	nd	0.01	nd	nd	nd	nd	nd	nd	0.01	nd	2.7
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	3.3
nd	nd	0.01	0.01	nd	nd	nd	nd	nd	nd	nd	4.7
0.01	0.01	0.01	nd	nd	nd	nd	nd	nd	0.02	nd	5.9
0.01	0.01	0.01	0.01	0.1	nd	nd	nd	nd	0.02	nd	4.4
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	3.3
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	1.8
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	3.1
nd	nd	nd	nd	nd	0.01	nd	nd	nd	nd	nd	4.8
nd	nd	nd	nd	0.1	nd	nd	nd	nd	nd	nd	3.7
nd	nd	nd	nd	0.1	nd	nd	nd	nd	nd	nd	4.9
nd	nd	nd	nd	0.1	nd	nd	nd	nd	0.01	nd	3.7
nd	0.01	0.01	nd	0.1	nd	nd	nd	nd	nd	nd	2.8
0.01	0.02	0.01	0.01	0.1	nd	nd	nd	nd	nd	0.01	6.4
0.03	0.01	0.03	0.01	nd	0.01	nd	nd	nd	nd	0.03	8.5
0.03	0.02	0.06	0.01	0.1	0.01	nd	nd	nd	nd	0.04	10.5
0.01	0.04	0.10	0.05	0.1	nd	nd	nd	nd	0.01	nd	2.2
0.05	0.03	0.08	0.01	0.1	nd	nd	nd	nd	0.03	nd	5.8
0.03	0.03	0.07	0.02	0.1	nd	nd	nd	nd	0.02	nd	6.2
0.01	0.01	0.02	0.01	0.1	nd	nd	nd	nd	nd	nd	3.6
0.01	0.01	0.01	nd	0.1	nd	nd	nd	nd	nd	nd	10.2
0.01	0.01	0.02	0.01	0.1	nd	nd	nd	nd	nd	0.01	8.5
nd	nd	0.01	nd	0.1	nd	nd	nd	nd	nd	nd	4.0
nd	0.01	0.01	nd	0.1	nd	nd	nd	nd	nd	nd	3.2
nd	0.01	0.01	nd	0.2	nd	nd	nd	nd	nd	nd	6.0

Appendix A. (cont'd)

Station	Species	<i>p,p'</i> DDE	<i>p,p'</i> DDD	<i>p,p'</i> DDT	PCBs (Aroclors®)			Dieldrin	Endrin	Heptachlor ^a	<i>cis</i> Chlordane
					1248	1254	1260				
57	Largemouth bass	0.03	0.01	0.01	nd	nd	0.1	0.01	nd	nd	0.01
57	Spotted sucker	0.06	0.02	0.01	nd	nd	0.1	0.01	nd	nd	0.01
57	Spotted sucker	0.06	0.03	0.02	nd	nd	0.1	0.01	nd	0.01	0.01
59	Channel catfish	0.13	0.04	0.01	nd	0.3	0.1	0.01	nd	nd	0.01
59	Channel catfish	0.06	0.02	0.01	nd	0.1	0.1	nd	nd	nd	0.01
59	Largemouth bass	0.25	0.05	0.02	nd	0.5	0.2	0.01	0.01	0.01	0.01
60	Carp sucker	0.24	0.03	0.02	nd	nd	nd	nd	nd	0.01	0.01
60	Channel catfish	0.17	0.03	0.01	nd	nd	nd	nd	nd	nd	0.01
60	Gizzard shad	0.33	0.06	0.02	nd	nd	nd	0.02	nd	0.02	0.03
60	Striped mullet	0.45	0.06	0.03	nd	nd	0.1	0.01	nd	0.01	0.01
62	Gizzard shad	0.17	0.02	nd	nd	nd	0.1	nd	nd	nd	0.01
62	Gizzard shad	0.14	0.02	0.01	nd	nd	nd	nd	nd	nd	nd
62	White bass	0.15	0.02	0.02	nd	nd	0.1	nd	nd	nd	0.01
63	Common carp	0.01	nd	nd	nd	nd	0.1	nd	nd	nd	nd
63	Common carp	0.01	nd	nd	0.1	nd	0.1	nd	nd	nd	nd
63	Largemouth bass	0.01	nd	nd	nd	nd	nd	nd	nd	nd	nd
64	Brown trout	0.19	0.09	0.02	nd	nd	nd	nd	nd	nd	nd
64	White sucker	0.05	0.01	nd	nd	nd	nd	nd	nd	nd	nd
64	White sucker	0.04	0.01	0.01	nd	nd	nd	nd	nd	nd	nd
65	Gizzard shad	0.13	0.01	nd	nd	nd	nd	nd	nd	nd	nd
65	Gizzard shad	0.09	0.01	nd	nd	nd	nd	nd	nd	nd	nd
65	White bass	0.08	0.01	nd	nd	nd	nd	nd	0.01	nd	nd
66	Northern pike	0.11	0.02	0.01	nd	0.5	0.3	nd	nd	nd	0.01
66	White sucker	0.03	0.01	0.01	nd	0.2	0.1	nd	nd	nd	nd
67	Largemouth bass	0.03	0.01	0.01	nd	0.2	0.2	0.01	nd	nd	0.01
67	Redhorse	0.02	0.01	0.01	nd	nd	0.1	nd	nd	nd	0.01
67	Redhorse	0.03	0.03	0.02	nd	0.2	0.2	nd	nd	nd	0.01
68	Common carp	0.05	0.02	nd	0.2	0.3	0.2	0.15	nd	0.02	0.08
68	Common carp	0.08	0.03	0.01	0.2	0.5	0.1	0.18	nd	0.02	0.08
68	White crappie	0.03	0.01	nd	0.1	0.1	0.1	0.06	nd	0.01	0.03
69	Common carp	0.05	0.04	nd	0.2	0.9	0.4	0.02	nd	0.01	0.10
69	Common carp	0.05	0.04	nd	0.2	1.4	1.0	0.02	nd	0.02	0.11
69	Sauger	0.05	0.07	0.03	0.6	1.1	0.7	0.05	0.02	0.03	0.22
70	Common carp	0.12	0.07	0.01	0.1	0.5	0.2	0.06	nd	0.01	0.07
70	Common carp	0.07	0.06	0.01	nd	0.3	0.2	0.07	nd	0.01	0.05
70	White crappie	0.07	0.03	0.02	nd	0.3	0.2	0.03	nd	0.01	0.03
71	Black crappie	0.30	0.25	0.02	nd	0.2	0.1	0.01	nd	nd	0.01
71	Common carp	0.39	0.46	0.01	nd	0.2	0.1	0.03	0.01	nd	0.01
71	Common carp	0.69	0.57	0.01	nd	0.4	0.3	0.01	nd	nd	0.02
72	Common carp	0.03	0.01	nd	0.1	0.2	0.1	0.01	nd	nd	0.01
72	Common carp	0.04	0.01	nd	0.2	0.2	nd	0.01	nd	nd	0.01
72	Smallmouth bass	0.01	0.01	0.01	0.1	0.1	nd	nd	nd	nd	nd
73	Common carp	0.05	0.02	nd	nd	0.1	0.1	0.13	nd	0.03	0.03
73	Common carp	0.06	0.02	0.01	nd	0.1	0.1	0.16	nd	0.06	0.03
73	Walleye	0.02	0.01	0.01	nd	nd	nd	0.09	nd	0.01	0.01
74	Northern pike	0.01	0.01	0.01	nd	nd	nd	nd	nd	nd	nd
74	White sucker	0.01	nd	0.01	nd	nd	0.1	nd	0.01	nd	nd
74	White sucker	0.01	0.01	0.01	nd	nd	nd	nd	nd	nd	nd
75	Common carp	0.30	0.07	0.01	nd	0.3	0.3	0.10	nd	0.02	0.06
75	Common carp	0.17	0.07	0.01	0.1	0.4	0.1	0.11	nd	0.03	0.06
75	White crappie	0.04	0.03	0.01	0.1	0.1	0.1	0.22	nd	0.02	0.04
76	Common carp	0.23	0.15	0.01	nd	0.2	0.2	0.08	0.01	0.02	0.06
76	Common carp	0.07	0.09	0.01	0.2	0.2	0.1	0.11	0.22	0.03	0.13
76	White crappie	0.06	0.03	0.02	nd	0.1	0.1	0.04	0.03	0.01	0.04

<i>trans</i> Chlordane	<i>cis</i> Nonachlor	<i>trans</i> Nonachlor	Oxy- chlordane	Toxaphene	α - BHC	γ - BHC	HCB	Mirex	Dacthal®	PCA	Lipid
nd	nd	0.01	nd	0.3	nd	nd	nd	0.01	nd	nd	6.2
0.01	0.01	0.01	nd	0.5	nd	nd	nd	0.02	nd	0.01	9.6
0.01	0.01	0.01	nd	0.6	nd	nd	nd	0.05	nd	0.01	9.3
0.01	0.01	0.01	nd	0.3	nd	nd	nd	nd	nd	0.10	7.2
nd	nd	0.01	nd	0.2	nd	nd	nd	nd	nd	0.04	2.6
0.01	0.01	0.02	0.01	0.4	nd	nd	nd	0.01	nd	0.05	7.1
0.01	0.01	0.01	nd	0.3	nd	nd	nd	nd	nd	nd	2.0
0.01	0.01	0.01	nd	0.3	nd	nd	nd	nd	nd	nd	1.9
0.02	0.01	0.02	nd	0.5	nd	nd	nd	nd	nd	0.01	4.4
0.01	0.01	0.02	nd	0.5	nd	0.01	nd	nd	nd	0.01	5.0
0.01	0.01	0.01	nd	0.1	0.01	nd	nd	nd	nd	nd	5.4
nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	3.3
nd	0.01	0.01	nd	nd	nd	nd	nd	nd	nd	nd	4.3
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.1
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	1.1
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	4.1
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	1.9
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.6
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	1.6
nd	nd	nd	nd	0.1	nd	nd	nd	nd	nd	nd	3.1
nd	nd	0.01	nd	0.1	nd	nd	nd	nd	0.01	nd	3.0
nd	nd	nd	nd	nd	0.01	nd	nd	nd	nd	nd	6.8
nd	0.01	0.01	nd	0.1	nd	nd	nd	0.04	nd	nd	2.5
nd	0.01	0.01	nd	nd	nd	nd	nd	0.01	nd	nd	1.6
0.01	0.01	0.02	nd	nd	nd	nd	nd	nd	nd	nd	2.0
0.01	0.01	0.01	nd	nd	nd	nd	nd	nd	nd	nd	1.7
0.01	0.01	0.01	nd	nd	nd	nd	nd	nd	nd	nd	2.4
0.05	0.04	0.06	0.01	0.1	nd	nd	nd	nd	0.01	nd	8.9
0.06	0.06	0.11	0.02	0.1	0.01	0.01	nd	nd	0.01	nd	10.0
0.01	0.02	0.06	0.01	nd	nd	nd	nd	nd	nd	nd	3.1
0.08	0.03	0.10	0.01	0.1	nd	nd	0.02	nd	nd	0.01	9.0
0.07	0.04	0.08	0.01	0.1	nd	nd	0.05	nd	0.01	0.01	8.1
0.11	0.09	0.19	0.02	0.4	0.01	0.01	0.09	0.01	0.01	0.02	9.3
0.05	0.03	0.08	0.01	0.1	0.01	nd	0.01	nd	0.01	nd	9.1
0.04	0.02	0.05	0.01	0.1	nd	nd	nd	nd	nd	nd	7.0
0.02	0.02	0.04	nd	0.1	nd	nd	nd	nd	nd	nd	2.2
nd	0.01	0.01	nd	0.1	nd	nd	nd	nd	nd	nd	1.5
0.01	0.01	0.01	nd	0.2	nd	nd	nd	nd	nd	nd	4.9
0.01	0.01	0.02	nd	0.2	nd	nd	nd	nd	nd	nd	4.3
nd	0.01	0.01	nd	nd	0.01	nd	nd	nd	nd	nd	6.3
nd	0.01	0.01	nd	nd	nd	nd	nd	nd	0.02	nd	7.5
nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	2.7
0.03	0.02	0.03	0.01	0.1	nd	nd	nd	nd	0.01	nd	7.4
0.04	0.02	0.05	0.02	0.1	0.01	nd	nd	nd	nd	nd	7.4
0.01	0.01	0.01	nd	nd	nd	nd	nd	nd	nd	nd	4.5
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	1.8
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	1.6
nd	nd	nd	nd	nd	nd	nd	nd	nd	0.01	nd	1.3
0.04	0.03	0.03	0.01	0.1	0.01	nd	nd	nd	0.01	0.01	11.2
0.04	0.02	0.05	0.01	0.1	0.01	nd	nd	nd	0.01	0.02	10.6
0.03	0.02	0.05	0.01	0.2	0.01	nd	nd	nd	0.07	nd	6.4
0.06	0.02	0.04	0.01	0.2	nd	nd	0.01	nd	nd	0.02	6.0
0.35	0.03	0.04	0.01	0.2	0.01	nd	0.01	0.01	nd	0.01	4.4
0.06	0.01	0.03	0.01	0.1	nd	nd	nd	nd	nd	0.01	1.3

Appendix A. (cont'd)

Station	Species	<i>p,p'</i> DDE	<i>p,p'</i> DDD	<i>p,p'</i> DDT	PCBs (Aroclors®)			Dieldrin	Endrin	Heptachlor ^a	<i>cis</i> Chlordane
					1248	1254	1260				
77	Black crappie	0.01	0.01	0.01	nd	nd	nd	0.01	nd	nd	nd
77	Black crappie	0.02	0.01	nd	nd	nd	0.1	0.01	nd	nd	0.01
77	Common carp	0.02	0.01	0.02	0.1	0.1	nd	0.01	nd	nd	0.01
77	Common carp	0.04	0.01	nd	0.1	0.1	nd	0.01	nd	nd	0.01
78	Common carp	0.02	0.01	nd	nd	nd	nd	nd	nd	nd	0.01
78	Common carp	0.03	0.01	0.01	nd	nd	nd	nd	nd	nd	0.01
78	Largemouth bass	0.05	0.02	nd	nd	nd	0.1	0.01	nd	nd	0.01
79	Common carp	0.38	0.03	0.01	nd	nd	0.1	nd	nd	nd	0.01
79	Common carp	0.27	0.02	nd	nd	nd	0.1	nd	nd	nd	0.01
79	Largemouth bass	0.20	0.01	nd	nd	nd	0.1	nd	nd	nd	0.01
80	Smallmouth buffalo	4.74	2.55	1.79	0.2	nd	0.2	0.04	0.01	0.01	0.03
80	White crappie	1.01	0.76	0.24	0.1	0.3	0.1	0.04	0.01	0.01	0.03
81	Channel catfish	0.10	0.02	0.01	nd	0.1	0.5	nd	nd	nd	0.01
81	Channel catfish	0.09	0.01	nd	nd	nd	0.2	0.01	nd	0.01	0.01
81	White crappie	0.30	0.04	0.02	0.1	nd	0.1	0.01	nd	nd	0.01
82	Common carp	0.11	0.01	nd	nd	nd	0.1	nd	nd	nd	0.01
82	Common carp	0.13	0.01	nd	nd	nd	0.1	nd	nd	nd	0.01
82	Largemouth bass	0.05	0.01	nd	nd	nd	nd	nd	nd	nd	0.01
83	Freshwater drum	0.05	0.03	0.02	0.1	0.2	0.2	0.31	nd	0.08	0.08
83	Quillback carpsucker	0.05	0.04	0.01	0.1	nd	0.1	0.31	nd	0.06	0.10
83	Quillback carpsucker	0.07	0.06	0.03	0.2	0.2	0.2	0.33	nd	0.10	0.18
84	Brown trout	0.02	0.02	0.01	nd	nd	nd	0.02	nd	0.02	nd
84	Longnose sucker	0.01	0.01	nd	nd	nd	nd	0.02	nd	0.01	0.01
84	Longnose sucker	0.01	nd	nd	nd	nd	nd	0.02	nd	0.01	nd
85	Common carp	0.04	0.01	nd	nd	nd	nd	0.01	nd	nd	nd
85	Common carp	0.03	0.01	0.01	nd	nd	nd	nd	nd	nd	nd
85	Sauger	0.02	0.01	nd	nd	nd	nd	0.01	nd	nd	nd
86	Common carp	0.02	0.01	0.01	nd	nd	nd	0.02	nd	nd	nd
86	Common carp	0.03	0.01	0.02	nd	nd	nd	0.06	nd	0.01	0.01
86	Goldeye	0.03	0.02	0.03	0.1	nd	0.1	0.09	nd	0.01	0.01
87	Common carp	0.33	0.04	0.01	nd	0.1	0.1	0.01	nd	nd	0.01
87	Common carp	0.05	0.01	nd	nd	nd	nd	0.01	nd	nd	nd
87	Walleye	0.07	nd	nd	nd	nd	0.1	nd	nd	nd	nd
88	Mixed species	0.16	0.03	0.01	nd	nd	0.1	0.04	nd	nd	nd
89	Carpsucker	0.03	0.01	0.01	nd	nd	nd	0.04	nd	0.01	0.01
89	Carpsucker	0.09	0.04	0.03	nd	nd	nd	0.10	nd	0.02	0.04
89	Goldeye	0.11	0.04	0.02	0.1	0.2	0.1	0.17	nd	0.02	0.04
90	Common carp	0.03	0.02	0.01	nd	0.1	nd	0.04	nd	0.01	0.04
90	Common carp	0.03	0.02	nd	nd	nd	0.1	0.04	nd	0.01	0.04
91	Common carp	0.17	nd	nd	nd	nd	nd	nd	nd	nd	0.01
91	Common carp	0.19	0.01	nd	nd	nd	nd	nd	nd	nd	0.01
91	Largemouth bass	0.06	0.01	nd	nd	nd	nd	nd	nd	nd	nd
92	Common carp	0.07	0.01	nd	nd	nd	0.1	nd	nd	nd	nd
92	Common carp	0.09	nd	nd	nd	nd	nd	nd	nd	nd	0.01
93	Common carp	0.02	nd	nd	nd	nd	nd	0.01	nd	nd	nd
93	Common carp	nd	0.01	nd	nd	nd	0.1	nd	nd	nd	0.01
93	Largemouth bass	0.02	nd	nd	0.1	nd	0.1	nd	nd	nd	nd
94	Common carp	0.10	0.01	nd	nd	nd	nd	nd	nd	nd	nd
94	Common carp	0.06	0.01	nd	0.1	nd	nd	nd	nd	nd	nd
94	Largemouth bass	0.11	nd	0.02	nd	nd	nd	nd	nd	nd	nd

<i>trans</i> Chlordane	<i>cis</i> Nonachlor	<i>trans</i> Nonachlor	Oxy- chlordane	Toxaphene	α - BHC	γ - BHC	HCB	Mirex	Dacthal®	PCA	Lipid
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	3.4
nd	nd	0.01	nd	0.1	0.01	nd	nd	nd	nd	nd	4.3
nd	0.01	nd	nd	0.1	0.01	nd	nd	nd	0.01	nd	6.0
0.01	0.01	0.01	nd	0.1	nd	nd	nd	nd	nd	nd	5.9
nd	0.01	0.01	nd	nd	nd	nd	nd	nd	nd	nd	3.0
0.01	0.01	0.01	nd	nd	nd	nd	nd	nd	nd	nd	3.0
0.01	0.01	0.01	nd	0.1	0.01	nd	nd	nd	nd	nd	6.3
0.01	0.01	0.01	nd	nd	nd	nd	nd	nd	0.01	nd	3.6
nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	2.1
nd	0.01	nd	nd	nd	nd	nd	nd	nd	0.01	nd	2.4
0.03	0.04	0.04	nd	8.2	0.01	nd	nd	nd	nd	0.01	10.0
0.01	0.02	0.02	0.01	1.5	nd	nd	nd	nd	nd	0.01	4.0
0.02	0.01	0.02	nd	0.1	0.01	nd	nd	nd	nd	0.01	7.4
0.01	0.01	0.01	nd	0.1	nd	nd	nd	0.01	nd	nd	5.3
0.01	0.01	0.02	0.01	0.2	0.01	nd	nd	nd	nd	0.01	7.0
0.01	0.01	0.01	nd	nd	nd	nd	nd	nd	nd	nd	6.6
0.01	0.01	0.01	nd	0.1	nd	nd	nd	nd	nd	nd	6.3
nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	1.1
0.06	0.03	0.08	0.03	0.2	nd	nd	nd	nd	0.01	0.01	11.4
0.08	0.04	0.08	0.02	0.2	nd	nd	nd	nd	0.01	0.01	12.7
0.16	0.05	0.16	0.02	0.2	0.01	nd	nd	nd	0.01	0.02	18.2
nd	0.01	0.01	0.01	nd	0.01	nd	nd	nd	nd	nd	8.3
nd	nd	0.01	nd	nd	0.01	nd	nd	nd	nd	nd	10.3
nd	nd	0.01	nd	nd	0.01	nd	nd	nd	0.01	nd	8.7
nd	0.01	nd	nd	0.1	nd	nd	nd	nd	nd	nd	4.4
nd	nd	0.01	nd	0.1	nd	nd	nd	nd	nd	nd	4.3
nd	nd	0.01	nd	0.1	0.01	nd	nd	nd	nd	nd	6.5
nd	nd	0.01	nd	nd	0.01	nd	nd	nd	nd	nd	6.6
0.01	0.01	0.01	0.01	0.1	0.01	nd	nd	nd	nd	nd	8.4
0.01	nd	0.01	0.01	0.1	0.01	nd	nd	0.01	nd	nd	16.0
nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	5.5
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.0
nd	nd	nd	nd	0.1	nd	nd	nd	nd	nd	nd	2.7
nd	0.01	nd	nd	0.1	nd	nd	nd	nd	nd	nd	4.6
0.01	0.01	0.01	nd	0.1	nd	nd	nd	nd	0.01	nd	9.4
0.04	0.02	0.03	nd	0.2	0.01	nd	nd	nd	0.01	nd	10.5
0.01	0.02	0.03	0.03	0.1	0.01	nd	nd	nd	0.01	0.01	12.6
0.03	0.01	0.02	0.01	nd	0.01	0.01	nd	nd	0.01	nd	7.7
0.03	0.01	0.01	0.01	0.1	0.01	0.01	nd	nd	0.01	nd	6.8
nd	0.01	0.01	nd	nd	nd	nd	nd	nd	nd	nd	5.1
nd	0.01	0.01	nd	nd	nd	nd	nd	nd	0.01	nd	4.0
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	3.5
nd	0.01	0.01	nd	0.1	nd	nd	nd	nd	nd	nd	3.6
nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.2
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	3.9
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	3.8
nd	nd	0.01	nd	0.1	nd	nd	nd	nd	nd	nd	4.2
nd	nd	nd	nd	0.1	nd	nd	nd	nd	nd	nd	2.9
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	1.2
nd	0.01	nd	nd	0.1	nd	nd	nd	nd	nd	nd	6.7

Appendix A. (cont'd)

Station	Species	<i>p,p'</i> DDE	<i>p,p'</i> DDD	<i>p,p'</i> DDT	PCBs (Aroclors®)			Dieldrin	Endrin	Heptachlor ^a	<i>cis</i> Chlordane
					1248	1254	1260				
96	Largescale sucker	0.15	0.04	0.02	nd	nd	nd	0.01	nd	nd	nd
96	Largescale sucker	0.14	0.04	0.01	nd	nd	nd	0.01	nd	nd	0.01
96	White crappie	0.22	0.05	0.02	nd	nd	nd	0.02	nd	nd	nd
97	Yellow perch	0.21	0.04	0.01	nd	nd	nd	0.02	nd	nd	nd
97	Peamouth	0.25	0.06	0.01	nd	0.1	0.1	nd	nd	nd	nd
97	Peamouth	0.34	0.05	nd	nd	0.1	nd	nd	nd	nd	nd
98	Largescale sucker	0.06	0.01	0.03	nd	0.1	0.1	nd	nd	nd	nd
98	Largescale sucker	0.01	nd	nd	nd	0.1	0.1	nd	nd	nd	nd
98	Walleye	nd	0.01	0.01	nd	nd	nd	nd	nd	nd	nd
99	Cuban limia	0.15	0.03	0.03	nd	nd	nd	0.03	nd	0.02	0.02
99	Mozambique tilapia	0.06	0.02	0.02	0.1	nd	0.1	0.02	nd	0.01	0.01
99	Mozambique tilapia	0.11	0.03	0.02	nd	nd	nd	0.03	nd	0.02	0.01
100	Cuban limia	0.06	0.50	0.05	nd	0.1	0.1	0.99	nd	0.18	0.44
100	Mozambique tilapia	0.05	0.33	0.02	0.1	nd	0.1	0.92	nd	0.12	0.11
100	Chinese catfish	0.09	0.50	0.04	0.1	0.2	0.1	1.39	nd	0.29	0.66
101	White sucker	0.02	0.01	0.01	nd	0.2	0.2	nd	nd	nd	nd
101	White sucker	0.02	0.01	nd	nd	0.3	0.2	nd	nd	nd	0.01
101	Yellow perch	0.07	0.01	0.01	nd	0.1	0.1	nd	nd	nd	nd
102	Bloater	0.12	0.04	0.05	nd	0.1	0.1	0.05	0.01	0.01	0.03
102	Bloater	0.09	0.02	0.03	nd	0.1	0.1	0.03	0.01	0.01	0.01
103	Lake whitefish	0.05	0.01	0.02	nd	nd	0.1	0.05	0.01	0.01	0.01
103	Lake whitefish	0.04	0.01	0.02	nd	0.1	0.1	0.02	nd	0.01	0.01
104	Bloater	0.39	0.15	0.11	0.1	0.7	0.3	0.36	0.03	0.10	0.12
104	Bloater	0.56	0.21	0.15	nd	1.1	0.3	0.46	0.04	0.11	0.15
104	Lake trout	0.47	0.10	0.11	0.2	0.9	0.4	0.22	0.01	0.03	0.10
105	Lake trout	1.61	0.33	0.34	1.1	4.0	1.5	0.31	0.03	0.06	0.23
106	Lake trout	0.83	0.12	0.25	0.1	2.0	0.6	0.21	0.02	0.02	0.10
106	White sucker	0.12	0.02	0.02	nd	0.2	0.4	0.01	nd	nd	0.01
106	White sucker	0.07	0.03	0.02	nd	0.2	0.4	0.02	nd	nd	0.01
107	Common carp	0.56	0.17	0.01	0.5	2.4	1.0	0.02	0.01	0.01	0.06
107	Common carp	0.33	0.13	0.02	nd	1.7	0.7	0.02	nd	0.01	0.03
107	Walleye	0.35	0.09	0.09	0.3	1.6	1.0	0.06	nd	0.01	0.06
108	Walleye	0.12	0.08	0.03	nd	1.2	0.7	0.05	nd	0.01	0.04
109	Lake trout	0.68	0.14	0.13	0.3	1.6	1.7	0.05	nd	0.01	0.06
109	Slimy sculpin	0.23	0.16	0.13	0.3	1.4	1.2	0.14	0.02	0.03	0.09
111	Common carp	0.03	0.01	nd	nd	0.7	nd	0.01	nd	nd	0.01
111	Common carp	0.03	0.01	nd	nd	0.6	nd	0.01	nd	nd	0.01
111	Walleye	0.07	0.02	nd	nd	1.9	nd	0.02	nd	0.01	0.01
112	Black crappie	0.01	nd	nd	nd	0.2	nd	0.01	0.01	nd	nd
112	Common carp	0.02	0.01	nd	0.9	0.1	nd	0.01	nd	nd	0.01
112	Common carp	0.03	0.01	nd	nd	0.5	0.1	0.02	nd	0.01	0.01
113	Longnose gar	0.26	0.04	0.02	nd	nd	0.5	nd	nd	nd	0.01
114	Common carp	0.08	0.04	0.01	nd	nd	nd	nd	nd	nd	0.01
114	Common carp	0.02	0.02	nd	nd	nd	nd	nd	nd	nd	nd
114	Green sunfish	0.07	0.01	nd	nd	nd	0.1	nd	nd	nd	nd
115	Largemouth bass	1.8	0.2	0.1	nd	nd	nd	nd	nd	nd	nd
115	Striped mullet	1.56	0.19	0.20	nd	nd	0.1	0.01	nd	nd	0.01
115	Striped mullet	0.56	0.07	0.09	nd	nd	0.1	0.02	0.01	0.01	0.01
116	Northern pike	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
116	White sucker	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
116	White sucker	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
117	Largescale sucker	0.01	0.01	0.01	nd	nd	nd	nd	nd	nd	nd
117	Largescale sucker	0.02	0.01	0.01	nd	0.1	nd	nd	nd	nd	nd
117	Mountain whitefish	0.03	nd	0.01	nd	nd	0.1	nd	nd	nd	nd

^a As heptachlor epoxide

<i>trans</i> Chlordane	<i>cis</i> Nonachlor	<i>trans</i> Nonachlor	Oxy- chlordane	Toxaphene	α - BHC	γ - BHC	HCB	Mirex	Dacthal®	PCA	Lipid
nd	nd	nd	nd	0.1	nd	nd	0.01	nd	0.02	0.02	4.1
nd	nd	0.01	nd	0.1	nd	nd	0.01	nd	0.01	nd	3.8
0.01	0.01	nd	nd	0.2	nd	nd	nd	nd	0.01	0.01	5.3
nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	2.9
nd	0.01	0.01	nd	nd	0.01	nd	nd	nd	nd	nd	9.2
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	6.4
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	4.6
nd	nd	nd	nd	0.1	nd	nd	nd	nd	nd	nd	4.5
nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	2.0
0.02	0.02	0.08	0.03	nd	nd	nd	nd	nd	nd	0.01	7.1
0.01	0.01	0.03	0.01	nd	nd	nd	nd	nd	nd	nd	4.6
0.01	0.02	0.05	0.01	nd	nd	nd	nd	nd	nd	nd	6.6
0.24	0.30	0.90	0.14	0.3	nd	nd	nd	nd	nd	nd	4.2
0.06	0.13	0.28	0.06	0.2	nd	nd	nd	nd	0.01	0.01	5.6
0.29	0.45	1.00	0.29	0.2	nd	nd	nd	nd	nd	0.01	6.0
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.1
nd	nd	0.01	nd	0.1	nd	nd	nd	nd	nd	nd	3.6
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.02	2.5
0.01	0.03	0.05	0.03	1.3	0.04	0.01	0.01	0.01	0.01	nd	14.1
0.01	0.03	0.03	0.01	0.7	0.01	nd	nd	nd	nd	nd	9.4
0.01	0.01	0.02	0.01	0.4	0.01	nd	nd	nd	nd	nd	7.5
nd	0.01	0.02	0.01	0.3	0.01	nd	nd	nd	nd	nd	6.7
0.08	0.04	0.09	0.02	1.7	0.02	nd	0.01	nd	0.01	nd	17.9
0.09	0.07	0.12	0.03	2.2	0.02	nd	0.01	nd	0.01	nd	17.0
0.04	0.07	0.08	0.02	1.2	0.01	nd	0.01	nd	nd	nd	13.9
0.10	0.19	0.31	nd	2.1	0.04	nd	0.01	0.01	0.01	nd	20.6
0.03	0.11	0.14	nd	1.9	0.02	nd	0.01	nd	nd	nd	19.2
nd	0.01	0.01	nd	0.1	nd	nd	nd	nd	0.02	nd	4.2
nd	0.01	0.01	nd	nd	0.01	nd	nd	nd	nd	nd	4.6
0.03	0.03	0.07	0.01	0.1	0.01	nd	0.03	nd	0.01	nd	10.4
0.01	0.02	0.04	0.01	0.1	0.01	nd	0.04	nd	nd	nd	9.2
0.02	0.05	0.11	0.01	0.7	0.01	nd	0.01	nd	nd	nd	9.3
0.02	0.02	0.04	0.01	0.1	0.01	nd	0.01	nd	0.02	nd	13.0
0.02	0.06	0.12	0.02	0.4	0.01	nd	0.04	0.24	0.01	nd	11.3
0.05	0.04	0.09	0.01	0.5	0.01	nd	0.11	0.40	0.01	nd	7.5
nd	nd	0.01	nd	nd	nd	nd	nd	nd	0.01	nd	4.7
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	4.2
0.01	0.01	0.01	nd	nd	nd	0.01	nd	nd	nd	nd	6.3
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.8
nd	nd	0.01	nd	nd	0.01	nd	nd	nd	nd	nd	6.0
0.01	0.01	0.01	nd	nd	0.01	nd	nd	nd	nd	nd	7.9
0.01	0.01	0.02	nd	0.1	nd	0.01	nd	nd	nd	0.01	3.9
0.01	nd	0.01	nd	nd	nd	nd	nd	nd	0.01	nd	2.4
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.7
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	1.5
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	9.3
0.01	0.01	0.01	nd	0.4	0.01	nd	nd	nd	0.01	nd	14.0
0.01	0.01	0.01	0.01	0.4	0.01	nd	nd	nd	0.02	nd	14.5
nd	nd	nd	nd	0.1	nd	nd	nd	nd	nd	nd	1.2
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.3
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	3.7
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	3.7
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	4.9
nd	nd	nd	nd	nd	0.02	nd	nd	nd	nd	nd	2.7