Monitoring Fish and Wildlife for Environmental Contaminants: The National Contaminant Biomonitoring Program

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Monitoring Fish and Wildlife for Environmental Contaminants: The National Contaminant Biomonitoring Program

By

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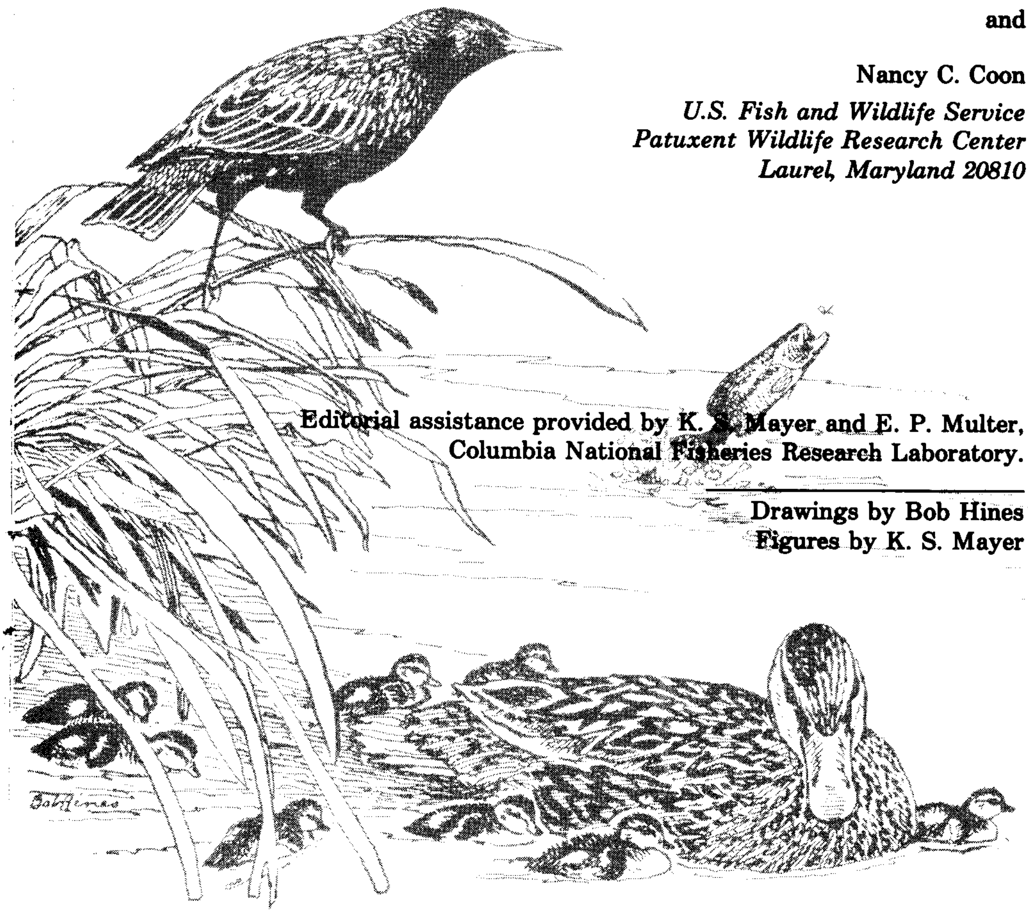

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Figures by K. S. Mayer

The National Contaminant Biomonitoring Program

The Problem

The birth of the modern pesticide era in the late 1940's was hailed as a major breakthrough for mankind. New chemical compounds, such as DDT, successfully controlled vectors of disease and pests of crops, forests, and rangelands. DDT and other persistent synthetic pesticides—members of a group of chemicals called organochlorines—were powerful weapons against mosquitoes, grasshoppers, weevils and other harmful insects. It was believed that organochlorines would stop such pests in their tracks, thereby eradicating diseases and eliminating crop reduction. This philosophy led to a progressive increase in the use of the chemicals; for example, the production of DDT in the United States rose from 78 million pounds in 1950 to a peak of 179 million pounds in 1963. Eventually, however, many pests became resistant to DDT, causing a demand for more effective synthetic organochlorine pesticides such as dieldrin, aldrin, and heptachlor.

As the use of pesticides reached massive proportions, the movement and persistence of the chemicals in the environment became apparent. Carried by natural forces such as wind, rain, and water currents, organochlorine residues began to appear throughout the globe, from tropical forests to remote antarctic snows. Worse still, the slowly decomposing chemicals were causing widespread mortality of nontarget fish and wildlife. It became clear from the residues found in the bodies of dead or dying birds, for example, that pesticides were directly responsible for many deaths.

As alarming as these direct kills were, the gradual buildup of organochlorines in fish and wildlife posed an even greater long-term threat. Scientists found that organochlorine residues linger in the environment for years after their application has ceased. Their persistence and high solubility in body fat causes them to bioaccumulate and finally to concentrate in animals at the top of the food chain. For example, birds of prey that have high concentrations of pesticides in their bodies produce thin-shelled eggs, which may be crushed beneath the weight of an incubating parent or fail to hatch normally. DDT has been shown to be responsible for population declines in birds such as bald eagles, brown pelicans, and peregrine falcons as a direct result of eggshell thinning.

Harmful chemicals can enter the environment from sources other than pesticide application. The persistent and widespread polychlorinated biphenyls (PCBs) are an example of these pollutants. PCBs have entered the environment from various industrial sources: they have been the principal fluid in hydraulic systems, capacitors and transformers, as well

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Harmful chemicals can enter the environment from sources other than pesticide application. The persistent and widespread polychlorinated biphenyls (PCBs) are an example of these pollutants. PCBs have entered the environment from various industrial sources: they have been the principal fluid in hydraulic systems, capacitors and transformers, as well as ingredients in certain paints, inks, and plastics. Fish in most rivers and lakes throughout the country are now contaminated with PCBs. In the Great Lakes, for example, PCB concentrations in three-fourths of the fish of certain species tested exceeded 1 part per million (ppm). Much higher PCB levels have been reported in fish-eating birds and mammals. Although the implications of the presence of these residues are not yet fully understood, some detrimental effects can be expected. Female mink that eat fish contaminated with even less than 1 ppm PCBs are incapable of producing healthy offspring. In fish, exposures to PCB concentrations similar to those found in some lakes and streams cause bone deformities and abnormal growth and development, and ultimately reduce survival.

The Monitoring Program

Publication of the book *Silent Spring* by biologist Rachel Carson in 1962 focused nationwide attention on the problems associated with the increasing use of persistent chemicals. The National Pesticide Monitoring Program was begun in 1964 as a result of this heightened public concern, to monitor levels of organochlorine pesticides in the Nation's water, soil, air, food, plants, animals, and people. Twelve networks were divided among several Federal agencies, of which three were managed by the U.S. Fish and Wildlife Service. The program later was given legislative status under the Federal Insecticide, Fungicide, and Rodenticide Act of 1972.

In recent years, the entire program has been expanded to include industrial chemicals and metals, as well as pesticides. Because of these changes, the networks composing the U.S. Fish and Wildlife Service program were recently renamed the National Contaminant Biomonitoring Program (NCBP). The purpose of the monitoring program is to answer two basic questions: How do levels of pollutants in fish and wildlife vary according to geographic region? And, what changes are occurring over time?

Detecting trends in levels of contaminants in fish and wildlife might seem fairly simple: collect animals, analyze them to determine the kinds and amounts of contaminant residues present, and evaluate and publish the results. However, many variables are involved that require careful scientific planning, scrutiny, and strict control to enable investigators to draw accurate conclusions. For example, contaminant levels may vary greatly among species in the same location or exposure. Within a species they often vary with age, sex, or time of year. Selection of representative animals and sites for monitoring thus requires many considerations: Which species should be chosen? Where should they be collected? How often and during what seasons?

Ideally, samples over time or space should be from the same species if they are to provide scientifically comparable information. This is not always possible, however, because most species are not evenly distributed throughout the country. In some areas this problem is resolved by substituting similar or ecologically related species. In addition, animals must be collected at the same times of the year from predetermined sampling sites that have been carefully selected. Finally, species chosen for monitoring must be plentiful enough to be collected easily and without jeopardizing the populations sampled. All of these criteria have been considered in the design of NCBP.

How Monitoring Works

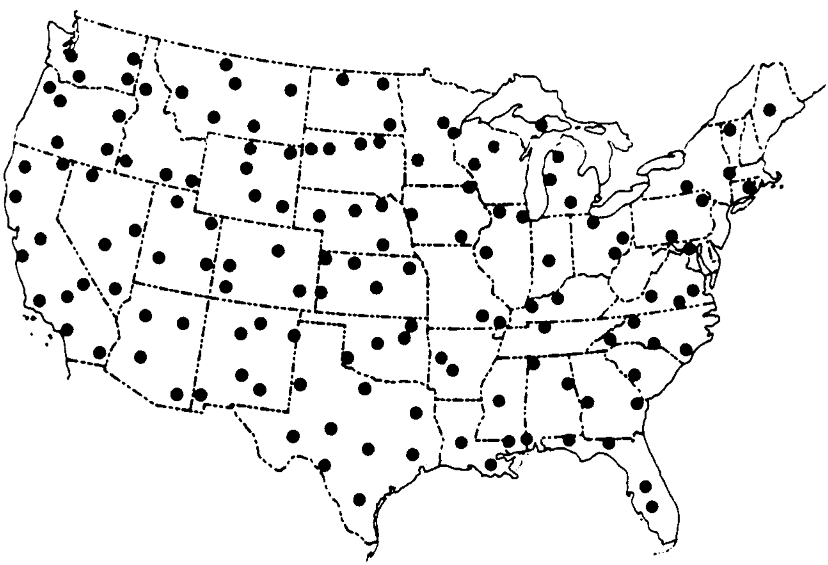
Birds

Two bird species, the terrestrial European starling and the aquatic mallard, were chosen for monitoring chemical residues in wildlife. The closely related black duck was included in a few Northeastern States where the mallard is less abundant.

Starlings are collected every third year by the Service's regional field personnel and other cooperators at 110 predetermined locations throughout the lower 48 States. Composite samples of 10 birds are analyzed from each site. The monitoring of starlings began in 1967.

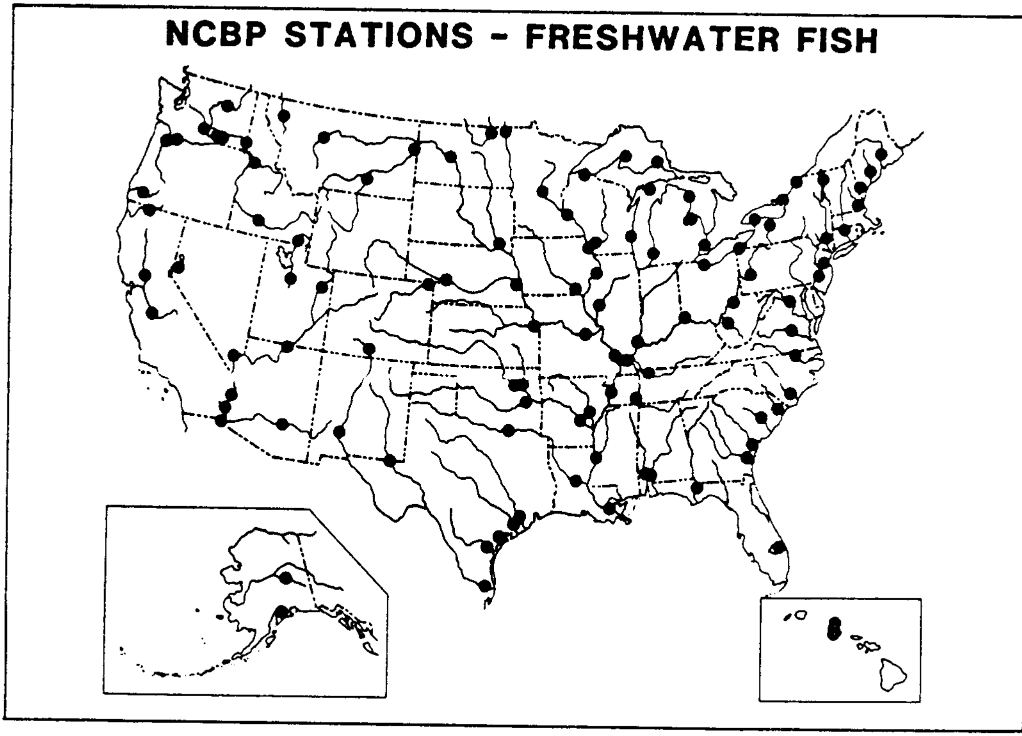
Samples of mallards (or black ducks) are obtained differently. For years, hunters throughout the country have sent wings to the Fish and Wildlife Service as part of a program to assess waterfowl productivity. Thousands of wings are submitted each year, along with information on the migration route where each was collected. Because research has shown that residue levels in wings correlate with those found in the rest of the body, these wings are used in the monitoring program. Duck wings are analyzed every 3 years as composite samples of 25 wings each, of which several come from each State. Sampling began in 1965.

NCBP COLLECTION SITES - STARLINGS



Fish

Chemical residues in freshwater fish have been monitored since 1967. Currently, fish are sampled biennially by field personnel and cooperators at 112 stations throughout the United States, generally in alternate years. The monitoring sites were selected to represent watersheds, and include all the major river basins in the continental United States. Three composite samples of no fewer than five fish each are analyzed from each station. Two of the samples are of bottom-dwelling fishes such as common carp, suckers, or catfish, and the third is of predators such as trout, walleyes, or black bass.



Chemicals

Fish and bird samples are examined for a wide variety of contaminants, including the following organochlorine chemicals (most of which are pesticides) or their metabolites:

Aldrin	Heptachlor
α-BHC	Heptachlor epoxide
Chlordane	Hexachlorobenzene
Dacthal	Lindane
DDD	Mirex
DDE	Nonachlor
DDT	Oxychlordane
Dieldrin	PCBs
Endrin	Toxaphene

Fish monitoring has been expanded to include seven inorganic contaminants: arsenic, cadmium, copper, lead, mercury, selenium, and zinc.

Other chemicals are monitored when their use increases, when new dangers are uncovered, or when methods of chemical analysis become sufficiently refined to detect them. In addition, samples are sometimes screened for other pollutants that are not regularly measured. For example, mercury has been monitored in duck wings; and lead, cadmium, arsenic, mercury, and selenium have been monitored in starlings.

Results of the Program: Birds

National Overview

In general, organochlorine compounds have been uncommon in bird samples or, if detected, have occurred only at low levels. Hexachlorobenzene, mirex, dieldrin, and heptachlor epoxide have been detected in composite samples of duck wings, but concentrations have rarely exceeded 0.02 ppm and the frequency of detection has been decreasing. No toxaphene has been reported in recent samples of either starlings or waterfowl. The maximum concentration and frequency of occurrence of oxychlordane (the most common and persistent chlordane-related compound) in starlings decreased from 0.37 ppm and 60% in 1979 to 0.14 ppm and 54% in 1982. Waterfowl wings appear to be progressively less contaminated by chlordane compounds; only 3 of 256 samples contained residues in 1981–82, and the concentrations were low, averaging only 0.04 ppm.

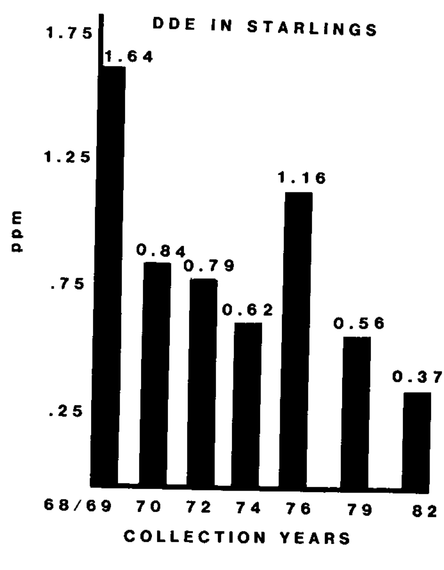
In contrast, certain other organochlorine compounds have increased in concentration and have continued to occur in nearly all samples analyzed.

DDT

The pesticide DDT is a striking example. As recently as 1981, relatively high levels of "total" DDT (DDT plus its two metabolites DDD and DDE) occurred in the Southeast and Southwest, where application of the insecticide was greatest before its use was banned in the United States in 1972. A separate study confirmed these high values in the Upper Rio Grande/Pecos River area in 1983.

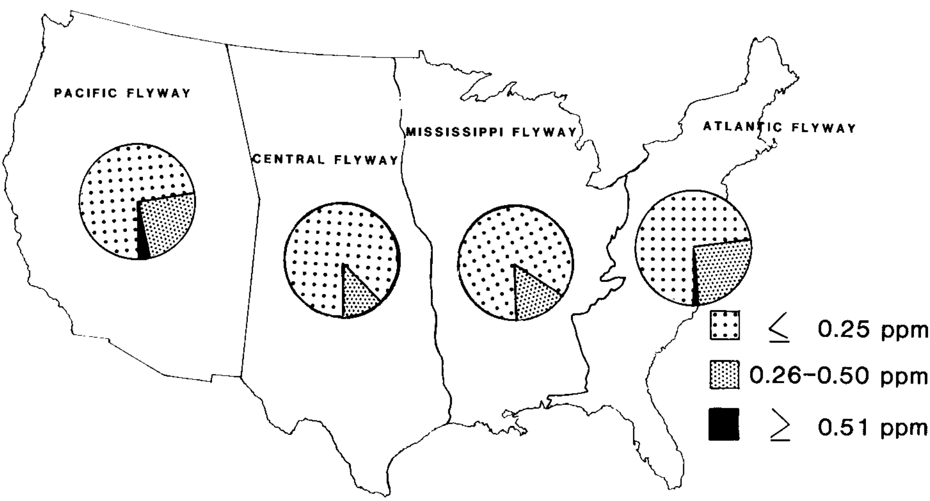
DDE residues were found in all of the 129 starling samples collected in 1982, but DDT itself was found in only 3 samples—1 each from Oregon, Tennessee, and North Carolina. Pooled samples of starlings from 11 sites, including 5 in the Southwest and 4 in the Southeast, contained more than 1 ppm DDE.

Since waterfowl migrate over wide areas, residues reported in one



State's samples may actually indicate exposure at other points along the migration route. Although mean DDE residues declined significantly between the 1979-80 and 1981-82 collections, from a nationwide average of 0.14 ppm to 0.11 ppm, there was a marked pattern of regional differences. Samples from the Eastern and Western States were still more contaminated than those from the interior of the country. DDE was detected in over 90% of the duck wing samples representing the 1981-82 harvest in each geographic area except the Central Flyway, where the percentage was 69%. Even so, the mean levels were 0.5 ppm or higher in only three States—Delaware, Alabama, and Arizona. The occurrence of DDT, the parent compound of DDE, has declined in duck wings in recent years. In 1981-82 only 7 of the more than 200 samples of waterfowl wings contained DDT. The highest level recorded was 0.35 ppm, in a sample from Alabama.

DDE RESIDUES IN WATERFOWL WINGS (NCBP, 1981-82)

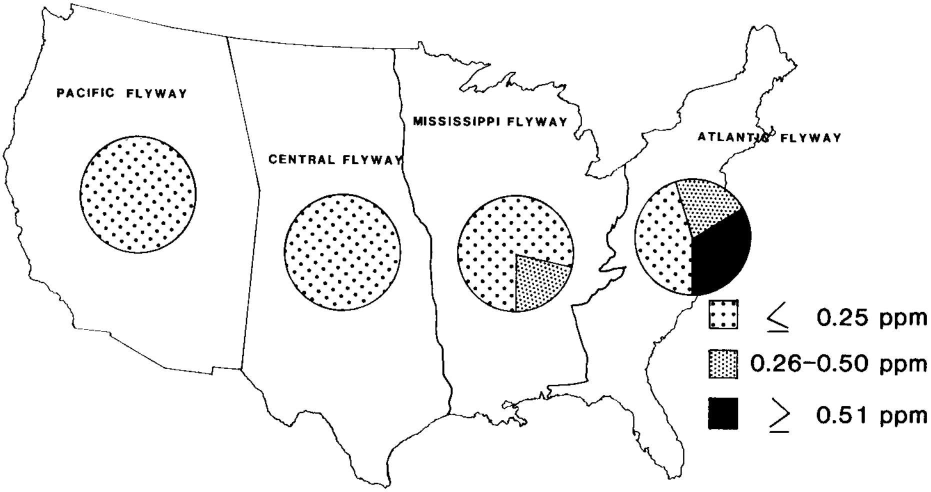


PCBs

Residues of some pollutants have not declined in birds despite restrictions on use and disposal. Although key industries have voluntarily restricted their use of PCBs, and regulations have been instituted that limit PCB discharges into the nation's lakes and streams, concentrations of these chemicals in fish and wildlife tissues have not yet shown consistent declines. In fact, PCB contamination remains widespread in birds. In both 1979 and 1982, 83% of the starling samples contained detectable PCB residues. The highest reported concentration of PCBs in 1982 was 4.0 ppm—somewhat higher than the 2.3 ppm maximum reported in 1979.

PCB residues in mallard wings remained unchanged between the 1979-80 and 1981-82 collections. Concentrations continued to be higher in wings collected in the Atlantic Flyway than in those collected from other areas of the Nation, and frequency of occurrence was also greater there (about 90%). In both 1979-80 and 1981-82, every black duck sample from the highly industrialized Northeast contained PCBs.

PCB RESIDUES IN WATERFOWL WINGS (NCBP, 1981-82)



Results of the Program: Fish

National Overview

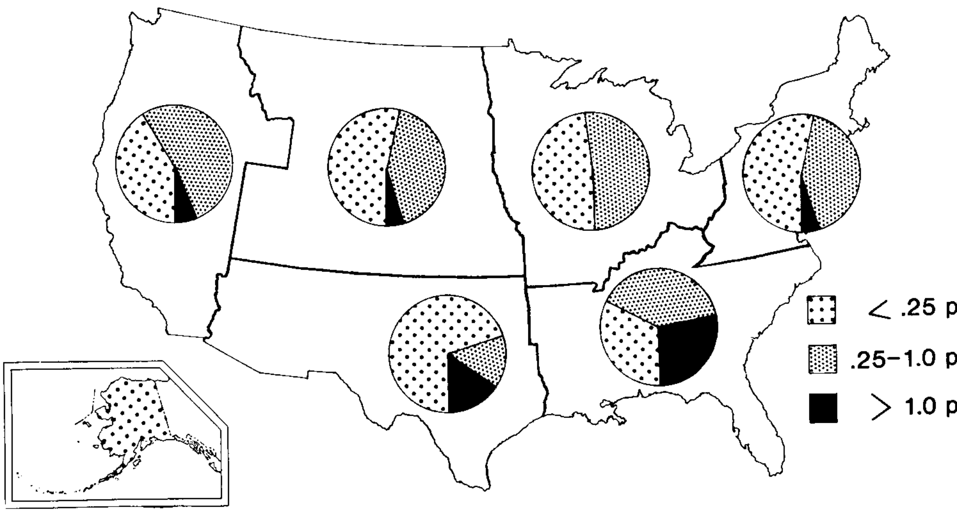
In general, organochlorine pesticide residues in fish have declined nationwide since the early 1970's. Although some organochlorines—dacthal, dieldrin, heptachlor epoxide, hexachlorobenzene, lindane, and mirex—have not changed appreciably, they have usually occurred only at very low levels in fish since the mid-1970's, and are therefore of only minor concern. Those of greater concern are DDT (though it is declining in occurrence) and PCBs and toxaphene which have become more widespread in some areas of the country.

DDT

The average total DDT in fish has decreased nationwide from 1 ppm in 1970 to about 0.3 ppm in 1981. In addition, DDT decreased from about 25% of the total DDT to only 10%, indicating a continued biochemical degradation of the product, as well as a decline in the release of DDT into the environment.

Although DDT itself is no longer considered a major threat to our nation's fishery resources, DDE residues are still high enough to cause concern in certain areas. In 1981, total DDT was highest in the Southeast and Southwest (from past agricultural use) and in Lake Michigan (from aerial transport and deposition).

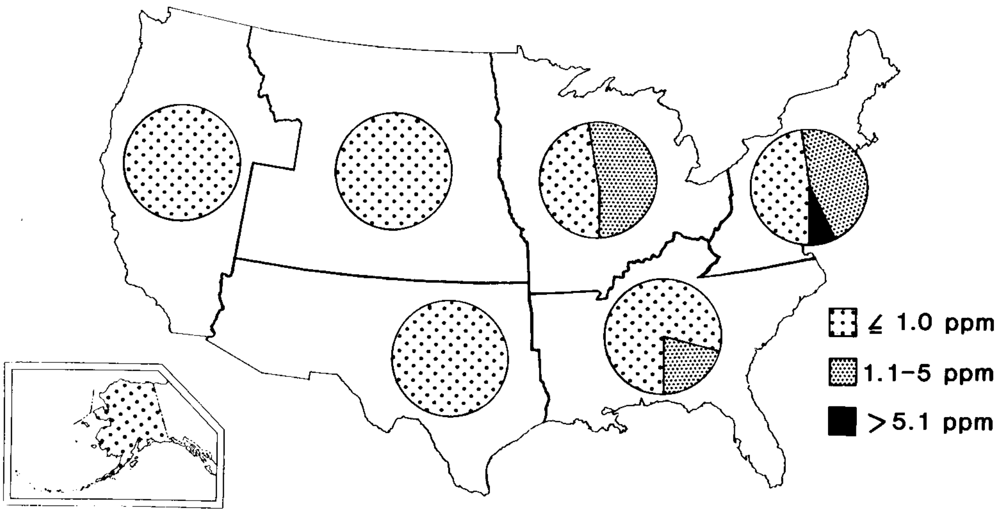
"TOTAL" DDT RESIDUES IN FRESHWATER FISH (NCBP, 1980-81)



PCBs

PCB residues in fish have decreased at locations where they were previously highest. For example, the maximum concentration of PCBs declined from 70.6 ppm in 1976-77 to 11.3 ppm in 1980-81. The PCB content in fish has been highest along the Ohio River system, in the Great Lakes, and in a few rivers in the Northeast. For the period 1976-81, at the 117 stations then sampled, PCB levels remained unchanged at 102, decreased at 14, and increased significantly at only 1 station.

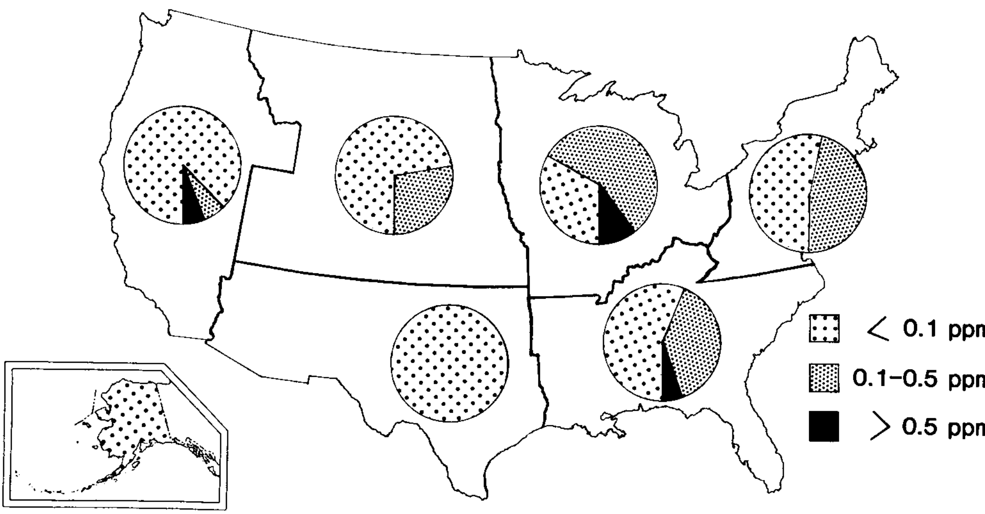
PCB RESIDUES IN FRESHWATER FISH (NCBP, 1980-81)



Chlordane and Toxaphene

Chlordane is a complex mixture of as many as 45 distinct compounds. *Cis*-chlordane and *trans*-chlordane were the most abundant and persistent of the chlordane components in fish and occurred at more than 90% of the stations in 1978–79 and 1980–81. *Cis*-chlordane, however, declined by about 50% between 1976 and 1981.

CHLORDANE RESIDUES IN FRESHWATER FISH (NCBP, 1980-81)

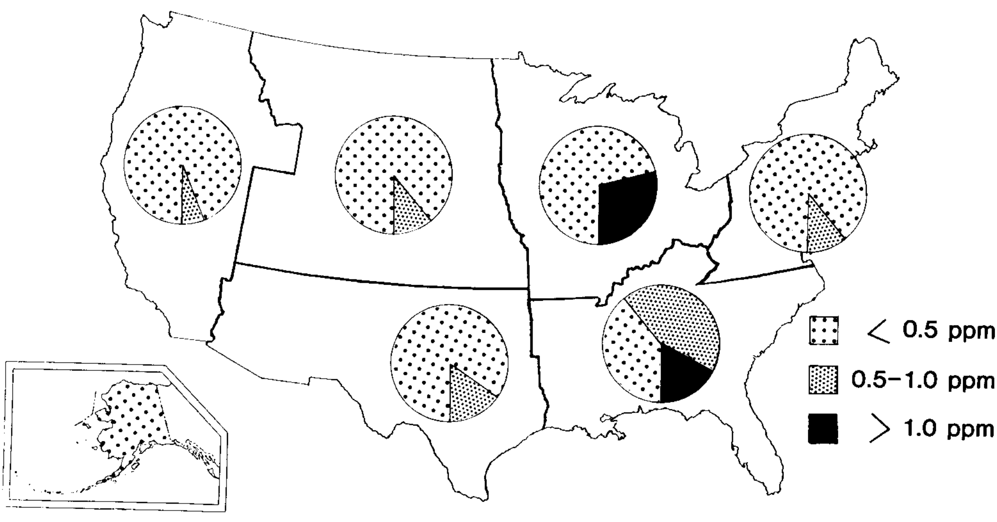


In contrast to the residues of *cis*-chlordane, those of toxaphene increased steadily in fish until about 1976, but have remained nearly constant since then. However, the frequency of occurrence of toxaphene nationwide has increased in recent years: residues were found in fish from 60% of the stations in 1976–79 and 88% in 1980–81. The increased occurrence has helped establish that toxaphene is atmospherically transported and may be deposited far from where it is applied—a phenomenon noted for DDT and similar to that associated with acid rain.

Inorganic Contaminants

The fish that were analyzed for organic contaminants in 1976–81 were also analyzed for seven inorganic contaminants: arsenic, cadmium, copper, lead, mercury, selenium, and zinc. Average concentrations of each of these contaminants except mercury and copper declined only slightly in 1980–81, compared with those in 1978–79; concentrations of copper decreased significantly and those of mercury remained unchanged. However, the monitoring period for inorganic contaminants has been too short to allow the establishment of conclusive long-term trends.

TOXAPHENE RESIDUES IN FRESHWATER FISH (NCBP, 1980-81)



Operational Implications

The monitoring program provides significant information for use in the assessment of contaminant effects on the nation's fish and wildlife. Increasing contaminant concentrations in a particular region have posed a clear warning; use patterns there must be analyzed, and detailed studies of impacts on nontarget organisms must be carried out.

In other situations the identification of compounds previously undetected in fish and wildlife may suggest a contamination problem, and should lead to concerted efforts to identify the source and scope of the problem. The information developed is always passed on to State and Federal regulatory agencies.

Research Implications

The National Contaminant Biomonitoring Program of the Fish and Wildlife Service is intended to identify temporal and geographic trends in the occurrence of chemical residues, detect upsurges of chemicals believed to be under control, monitor the effectiveness of the regulation of hazardous contaminants, and screen for selected chemicals or contaminants that may represent new hazards to the environment. Other questions related to contaminants and their impacts on fish and wildlife resources remain to be answered. For example, how widespread are contaminants in unstudied areas where heavy pollution is known or suspected? What residue levels are injurious to fish and birds? What are the effects of the many chemicals that are short-lived and difficult to detect? And, what effects in fish and birds should we emphasize that may provide early warning signals of impending danger to affected populations? Providing answers to these questions is an important role of research in the Fish and Wildlife Service. Controlled laboratory and field experiments, complemented by monitoring and surveys, are among the mechanisms the Service uses to provide answers to the many questions related to contaminant threats.

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Jacknow, Joel, J. Larry Ludke and Nancy C. Coon. 1986. **Monitoring Fish and Wildlife for Environmental Contaminants: The National Contaminant Biomonitoring Program**. U.S. Fish Wildl. Serv., Fish Wildl. Leafl. 4. 15 pp.

The National Contaminant Biomonitoring Program has been in existence since 1964. This pamphlet reports current data for residues of various contaminants in birds and fish and provides an overview of the results of the program.

Keywords: Monitoring, contaminants, residues, DDT, PCSs, chlordane, toxaphene, heavy metals.

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