# Persistent Environmental Contaminants in Fish and Wildlife

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The publication of *Silent Spring* (Carson 1962) highlighted the potential for dichlorodiphenyl trichloroethane (DDT) and other pesticides that persist in the environment to accumulate in and to harm fish, wildlife, and the ecosystems upon which they depend. The federal government responded in the mid-1960's by establishing a multi-agency program to monitor the concentrations of pesticides and, later, other long-lived toxic contaminants in all segments of the environment.

The U.S. Fish and Wildlife Service (USFWS) participated in this program by periodically measuring contaminant concentrations in freshwater fish and birds (Johnson et al. 1967). Fish were selected for monitoring aquatic ecosystems because of their tendency to accumulate pesticides and other contaminants. The European starling (*Sturnus vulgaris*) was selected for monitoring contaminant levels in terrestrial habitats because of its varied diet and wide geographic distribution. Following a successful pilot study (Heath and Prouty 1967), the wings of hunter-killed ducks were used to monitor contaminants in duck populations of the major flyways, and thereby to also provide an assessment of contaminant levels in wetlands. The USFWS maintained this National Contaminant Biomonitoring Program into the 1980's, with the objective of continuing the documentation of temporal and geographic trends in contaminant concentrations (Prouty and Bunck 1986; Bunck et al. 1987; Schmitt and Brumbaugh 1990; Schmitt et al. 1990).

## Status and Trends

During the two decades spanned by USFWS contaminant monitoring, the use of persistent insecticides such as DDT was greatly curtailed, and concentrations in fish and wildlife declined. In the environment, DDT breaks down gradually into several different toxic metabolites, of which dichlorodiphenylethylene (DDE) is the most stable and most toxic. A downward trend was clearly evident for DDE in all three networks (Fig. 1), indicating that the total DDT burden in North America declined. In fish, DDE increased from about 70% of total DDT in 1976 to about 74% in 1986 (Fig. 2).

As existing DDT is metabolized, DDE increases proportionally if DDT inputs are reduced; the proportional change evident in fish therefore provides additional evidence of reduced inputs to North American ecosystems. A similar trend toward increasing percentages of DDE relative to DDT has been noted elsewhere (Aguillar 1984), indicating that the global DDT burden is also declining.

In the United States, the bioaccumulation (*see* glossary) of DDT led to eggshell thinning in fish-eating birds such as the bald eagle (*Haliaeetus leucocephalus*). The resulting decline in recruitment of young to bald eagle populations caused the near extirpation and subsequent listing of this species as endangered in the conterminous states (Federal Register 1978). The downward trend of DDT concentrations documented in fish, starlings, and duck wings (Figs. 1 and 2) was paralleled by declining DDE concentrations in bald eagle eggs, and eagle eggshell thickness increased (Wiemeyer et al. 1993). Corresponding increases in recruitment have led to bald eagles repopulating many areas (Fig. 2), and reclassification of the bald eagle from endangered to threatened has been proposed for most of the conterminous states (Federal Register 1994).

In addition to the effects of DDT and its metabolites on eggshell thickness, these compounds, as well as PCBs (polychlorinated biphenyls) and other contaminants, are reported to interfere with other reproductive and maturation processes in fish and wildlife (e.g., Fry and Toone 1981). Although overall concentrations have declined, residues of DDT, other insecticides, and PCBs remain widespread, and problem areas are still evident. In the United States, concentrations of DDT (mostly as DDE) remain highest in fish and wildlife from areas in the South, Southwest, and Northwest where DDT was used to protect cotton and orchards from insects; in the Northeast, where it was used to control mosquitos; and near former centers of DDT production and formulation. Areas affected by former production centers include northern Alabama, near the former Red Stone Arsenal—now Wheeler National Wildlife Refuge (O'Shea et al. 1980); and the Arkansas, Tombigbee, Alabama, and Tennessee rivers (Fig. 3).

Concentrations of other persistent insecticides that are no longer in widespread use, such as heptachlor, dieldrin, endrin, and chlordane, have also declined in all three networks (Prouty and Bunck 1986; Bunck et al. 1987; Schmitt et al. 1990). Nevertheless, residues of chlordane remain sufficiently high in fish from some areas of the Midwest to warrant the issuance of human consumption advisories by state health agencies. Concentrations are also high in Hawaii, where chlordane and other chemically similar compounds were used against termites and agricultural pests, as they were in the Midwest.

Chlordane is a mixture of structurally similar compounds that decompose at different rates over time. The composition of the chlordane mixture present in fish has changed during the 1980's in a manner indicative of an overall

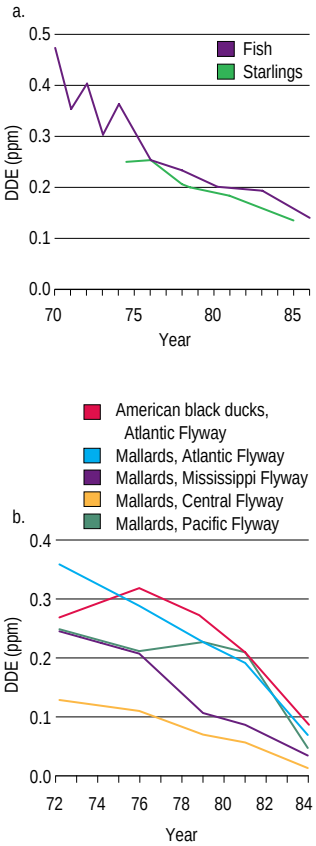


**Fig. 1.** Mean concentrations of DDE in U.S. Fish and Wildlife Service monitoring networks: (a) fish and starlings and (b) flyway populations of mallards and American black ducks.

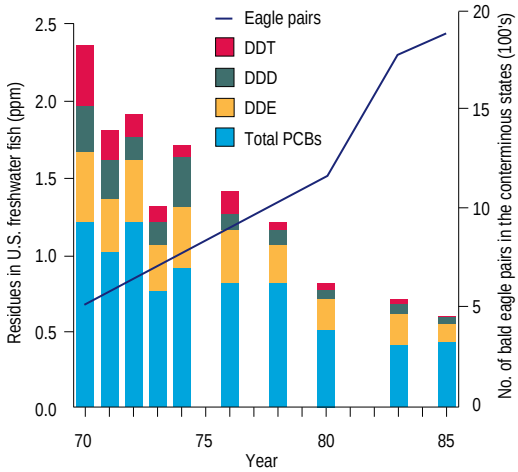


**Fig. 2.** Mean concentrations of DDT and its primary metabolites, DDE and DDD (TDE—dichlorodiphenyldichloroethane), and of total polychlorinated biphenyls (PCBs), in fish,1970-86. Also shown are the estimated number of bald eagle pairs in the conterminous United States during the same period (Federal Register 1994).

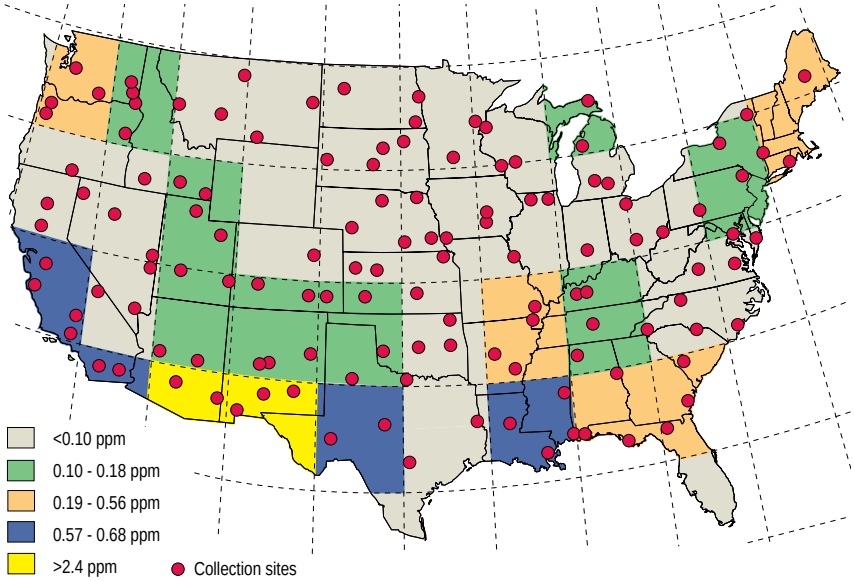


**Fig. 3.** Geographic distribution of DDE residues in starlings collected in 1985. Also shown are boundaries of the 5-degree (latitude and longitude) sampling blocks and collection sites.

decline (Schmitt et al. 1990). Concentrations of toxaphene, an insecticide that replaced DDT in cotton farming and many other applications, have also declined in fish since 1980, when its registration was canceled (Schmitt et al. 1990). Toxaphene does not accumulate in birds and was not measured in either starling or duckwing samples.

Polychlorinated biphenyls (PCBs) are also complex mixtures of chemicals. Comprising as many as 209 different compounds, various PCB formulations were used historically as lubricants, hydraulic fluids, and fire retardants; as heat transfer agents in electrical equipment, including fluorescent light ballasts; and as a component of carbonless copy papers. Much like DDT, many PCBs are persistent and toxic. Large quantities were discharged directly to waterways, including Lakes Michigan and Ontario and the Hudson, Mississippi, Kanawha, and Ohio rivers. PCBs are also often present in landfills and urban runoff. These discharge and disposal patterns are reflected in the geographic trends evident for PCBs in fish and wildlife; greatest concentrations generally occur in the urban-industrial regions of the Midwest and Northeast (Fig. 4). By 1980, the direct discharge of PCBs to waterways had been greatly restricted, and total PCB concentrations generally declined in U.S. fish and wildlife (Bunck et al. 1987; Schmitt et al. 1990). Residual PCBs nevertheless remain a problem in some areas, as evidenced by human consumption advisories in effect for fish from the Great Lakes, Lake Champlain, the Hudson River, and elsewhere.

Some highly toxic PCBs are long-lived and are selectively accumulated by aquatic organisms. Fish samples collected in 1988 from some regions, especially the Great Lakes, still contained toxic PCBs at concentrations great enough to be harmful to fish-eating birds (C.J. Schmitt, National Biological Service, unpublished data, 1993). Indeed, PCBs and other contaminants in Great Lakes fish are believed to limit the reproduction of bald eagles and other fish-eating birds, mink (*Mustela vison*), and river otters (*Lutra canadensis*) in coastal areas of the Great Lakes (Wren 1991; Giesy et al. 1994). PCBs, along with DDE and other contaminants, including chlorinated dioxins, may also be involved in the failure of lake trout (*Salvelinus namaycush*) to reproduce naturally in Lake Michigan (USFWS 1981; Spitsbergen et al. 1991). In spite of discharge restrictions, the concentrations of PCBs and chemically similar compounds in the Great Lakes will likely remain elevated because of atmospheric transport and the internal cycling of contaminants already present in the lakes.

The primary sources of mercury to U.S. waters were discharges from chemical facilities that manufactured caustic soda (sodium hydroxide). These discharges have been regulated since the 1970's. Other historical sources included paper mills, gold and silver mines, and the production and use of mercury-containing pesticides. Concentrations of mercury in fish declined significantly from 1969 through 1974 as a result of restrictions on these historical uses, but concentrations have not changed appreciably since 1974. Concentrations in fish from heavily contaminated waters, such as Lake St. Clair, declined the most (Schmitt and Brumbaugh 1990). Despite these declines, fish consumption advisories remain in effect for some waters. Recent findings have highlighted the importance of atmospheric transport and the accumulation of mercury in natural sinks, such as Lake Champlain (e.g., Driscoll et al. 1994) and the Everglades, in the maintenance of elevated concentrations (Zillioux et al. 1993).

Lead concentrations in fish declined from 1976 to 1986 (Schmitt and Brumbaugh 1990),

paralleling a trend reported for U.S. rivers (Smith et al. 1987). This decline has been attributed to reductions in the lead content of gasoline and to discharge restrictions at smelters and other industrial sources (Smith et al. 1987).

Selenium is a trace element required by plants and animals; it is toxic at high concentrations. Concentrations of selenium in fish declined in some areas of the United States. In some parts of the West, however, where concentrations were historically elevated, levels either increased or remained unchanged (Schmitt and Brumbaugh 1990). Selenium is a natural component of soils and is present at high concentrations in some arid areas of the U.S. West. The dissolution of selenium and other potentially toxic elements from soils and their accumulation in ecosystems are accelerated by irrigation. Elevated selenium concentrations, induced by irrigation, are responsible for the widely publicized wildlife deaths and deformities at Kesterson National Wildlife Refuge in California (Lemly 1993).

In general, U.S. concentrations of persistent contaminants that accumulate in fish and wildlife are lower now than at any time for which accurate data exist, although problem areas remain. These results imply that direct inputs of many toxic substances to the environment have been reduced through the regulation of industrial discharges and pesticide use. Declining concentrations of DDT and other contaminants in North America have permitted the return of predatory birds, such as bald eagles, to some areas from which they had been eliminated (Fig. 2).

The persistence of contaminant problems, despite curtailment of direct discharges to waterways and restrictions on the uses of persistent pesticides, has highlighted the importance of global and ecosystem processes such as atmospheric transport and internal cycling. The accumulation of selenium in California, and mercury in the Everglades, has resulted from natural processes—the leaching of elements from soils and vegetation. The rates of these processes have been accelerated by irrigation and other activities associated with agriculture. Atmospheric transport also represents an important source of PCBs to the Great Lakes; it has also been linked to the accumulation of mercury in Lake Champlain (*see* Glaser, this section; Baker et al. 1993) and other northeastern lakes (Driscoll et al. 1994).

The exposure of migratory birds such as peregrine falcons (*Falco peregrinus*) to contaminants on their wintering grounds outside of the United States (Henny et al. 1982), where DDT and other persistent compounds are still used, also remains a problem. Moreover, the curtailment of organochlorine pesticide use in North America has led to increasing reliance on so-called soft pesticides—highly toxic organophosphate, carbamate, and synthetic pyrethroid compounds—that are difficult to monitor because they are short-lived and do not accumulate. Evidence of the increasing use and potential adverse effects of these chemicals is highlighted by increasing occurrences of wildlife mortality attributable to them (*see* Glaser, this section). Additionally, chemical analysis has demonstrated the presence of highly toxic contaminants such as the chlorinated dioxins. No long-term monitoring data exist for these compounds, which may affect fish and wildlife at extremely low concentrations (Giesy et al. 1994). New approaches and technologies, capable of detecting chemical exposure and its effects at all levels of biological organization, will be required to monitor and assess highly toxic chemicals and those that do not accumulate in fish and wildlife before concentrations reach harmful levels.

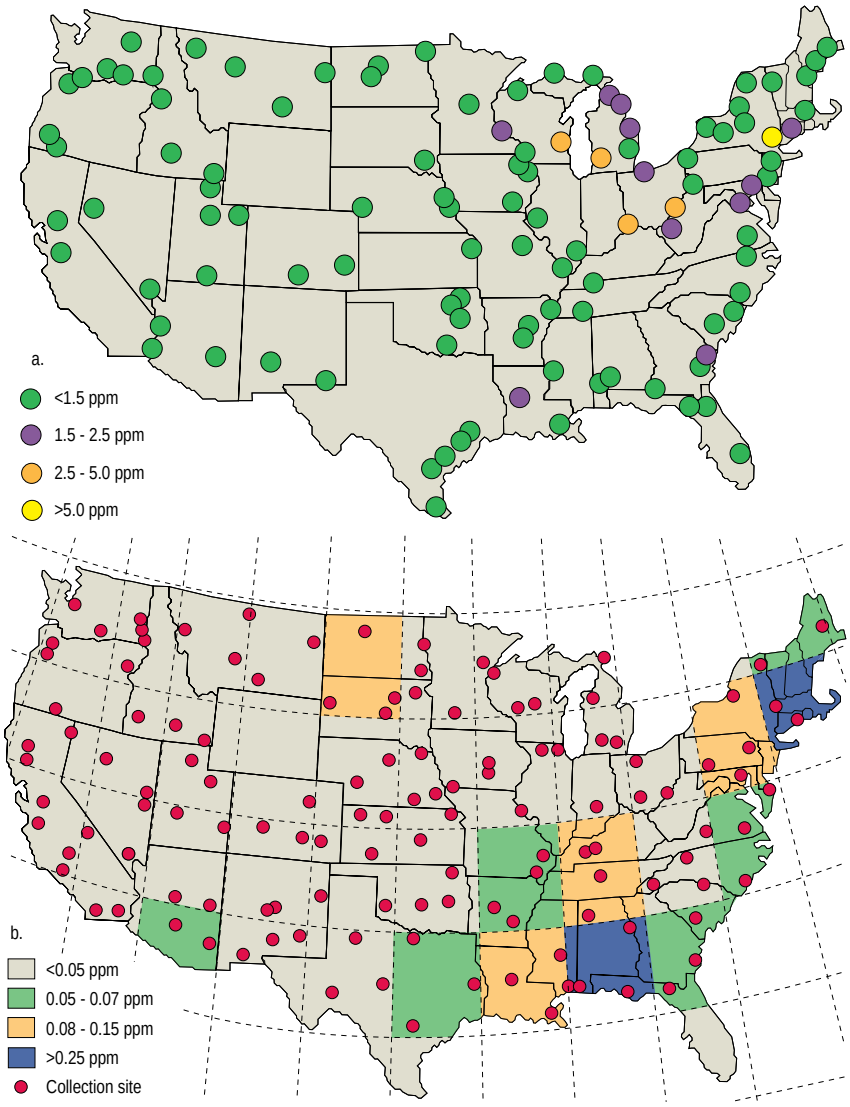


**Fig. 4.** Geographic distribution of PCB residues in U.S. Fish and Wildlife Service monitoring networks: (a) PCB concentrations in fish collected in 1986 from the indicated sites. Not shown are stations in Alaska and Hawaii, at which PCB concentrations were < 1.5 parts per million (ppm) at all sites; (b) PCBs in starlings collected in 1985. Also shown are boundaries of the 5-degree (latitude and longitude) sampling blocks and collection sites.

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