

ORDER FROM CHAOS?
HISTORY OF CHLORINATED PESTICIDE CONTAMINATION OF
THE U.S. COASTAL FAUNA

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ABSTRACT

Since 1965 nearly one quarter of the U.S. marine fish fauna and over 100 species of mollusks and crustaceans have been surveyed for chlorinated pesticide and PCB contamination. These data are now centralized. A detailed review of over 25,000 records from 150 separate surveys confirm that DDT contamination has declined dramatically, but was once widespread in estuarine and coastal fish and shellfish of the northeast coast, in specific estuaries of the Gulf of Mexico coast and Caribbean Islands, and in the pelagic food webs of the entire Pacific shelf. Severe PCB contamination was, and continues to be restricted to large fauna of urban and industrial estuaries, but also occurs in low concentrations everywhere. Contamination of fish by chlordane, nonachlor and dieldrin continues. Renewed national surveillance is needed to determine whether toxaphene, endosulfan (Thiodan) and pentachlorophenol (PCP) are still present in past "hot spots. Some order is indeed coming from the monitoring chaos.

1. INTRODUCTION

Several years ago NOAA's Ocean Assessments Division (OAD) initiated a program to assess the status and trends in environmental quality around the sea coast of the U.S. This program, the National Status and Trends (NS&T) Program, measures contaminants in marine life and sediments, and the health of fish, at numerous coastal sites (1).

As part of the NS&T Program, we are gathering together existing and historical data on concentrations of polychlorinated biphenyls (PCBs) and chlorinated pesticides in coastal and estuarine fish and shellfish (2). The principal objective of this activity is to provide an historical basis for interpreting the new NS&T data. In so doing, however, the historical data is itself providing a wealth of information, sometimes inconsistent, on past trends in coastal resource contamination. Indeed, because of changes and shifts in monitoring programs, target species and chemical methods over the years it is a difficult - but not impossible - challenge to identify past "hot spots" and confirm decreasing and increasing trends. Following are

some examples of what we are learning about past conditions at the national and regional levels.

2. APPROACH

Existing data were identified and acquired from numerous private and academic organizations, and federal, state and local agencies. Data were extracted and entered into a computerized data base management system according to a specific set of protocols (2).

For this review, data from internally consistent past national surveys were isolated and mean values computed for specific chemicals, sites, and substrates (whole fish, fish muscle, fish liver and whole bivalve mollusks). In many cases chemical concentrations were reported as below analytical detection limits. For statistical reasons we halved these before computing site or regional means.

Next, we assembled a mix of national and local data for examining long-term trends in specific bays, estuaries and resource species.

A "preponderance-of-evidence" approach was used for identifying "hot spots" and temporal trends. That is, if several data sets agreed that marine life in a certain site or bay was highly contaminated relative to other sites, we so concluded that was the case. Likewise, if an increasing or decreasing temporal trend was common to several data sets, we so concluded that was the case. A more rigorous statistical approach is currently being evaluated.

All values are reported in ppm (mg/kg or ug/g) wet weight.

3. GEOGRAPHIC TRENDS FROM NATIONAL SURVEYS

Nearly a dozen surveys or monitoring activities qualify as "national" surveys - that is, samples were synoptically collected along all three major coasts (Atlantic, Gulf of Mexico and Pacific). Figures 1a through 1d show mean concentrations of 4 contaminants from original data supporting one of these surveys, the National Pesticide Monitoring Program (NPMP) juvenile estuarine fish surveys of 1972-76 (3). During this sampling period, juvenile estuarine fish were notably contaminated with PCBs (Aroclor 1254 > 1.0 ppm ww) in the upper Chesapeake Bay and in the Duwamish River, near

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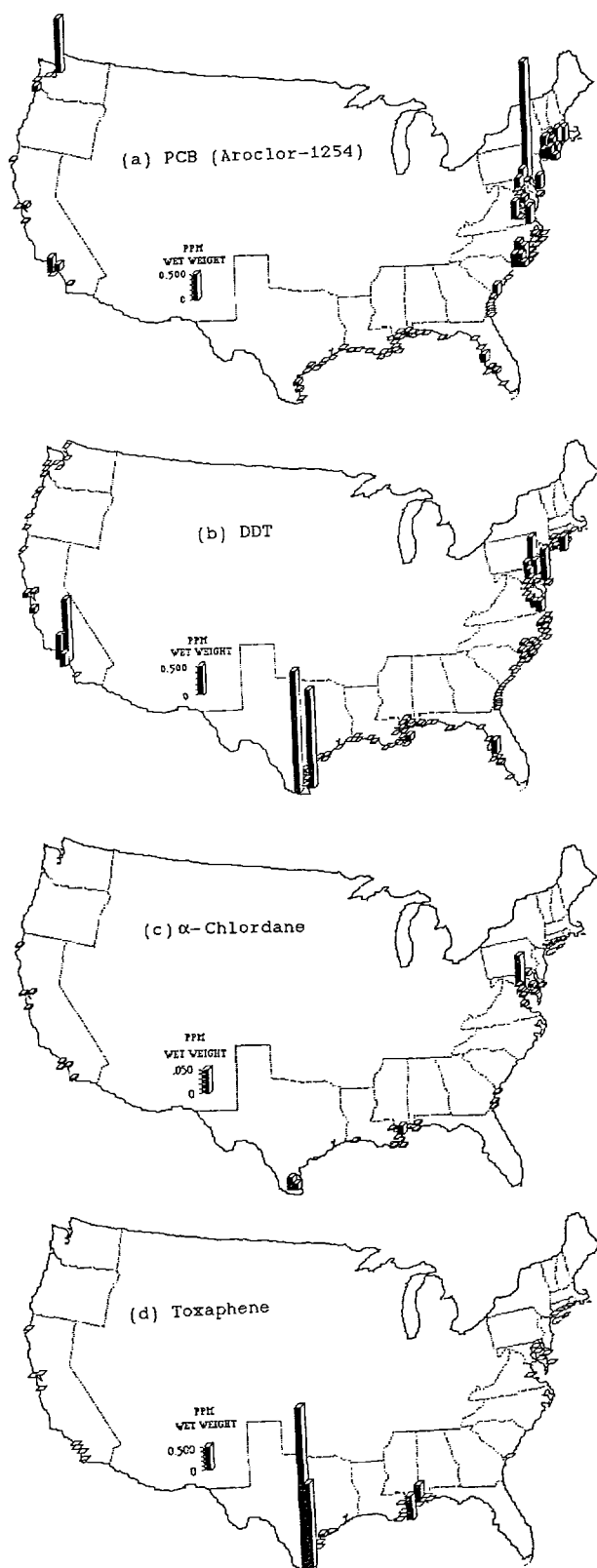


Figure 1. Mean concentrations of PCBs and three pesticides in juvenile estuarine fish, 1972-1976. From data supporting (3).

Seattle, Washington, and moderately contaminated (>0.2 ppm) at other sites in New York, southern Chesapeake Bay, southern North Carolina and near Los Angeles in southern California. By comparison, young fish of Gulf of Mexico estuaries were relatively uncontaminated (Figure 1a). DDT was a prominent contaminant (> 2.0 ppm) of juvenile fish in the Arroyo Colorado near lower Laguna Madre in southern Texas. Moderate concentrations (> 0.5 ppm) were found in two other epicenters: Delaware Bay and near Los Angeles (Figure 1b). Chlordane had three relative "hot spots" (>0.02 ppm): the upper Chesapeake, near Baltimore, the Arroyo Colorado, Texas, and a site in Mississippi Sound (Figure 1c). Finally, the national estuarine "hot spot" for toxaphene (>2.0 ppm) was also in the Arroyo Colorado: two additional sites occurred along the Louisiana-Mississippi coast (Figure 1d).

From this single, 4-year long national monitoring effort it can be concluded that 10 to 15 years ago there were at least a dozen chlorinated hydrocarbon "hot spots" in U.S. estuaries along all three coasts and that the Arroyo Colorado of southern Texas was by far the "number one" site in terms of both total chlorinated hydrocarbon concentration and diversity of contaminants.

Other surveys, using other species (bivalves) and tissues, agree with the patterns expressed in this survey, both before (1965-72) and after (1977-) this particular sampling period. For example, past or recent PCB "hot spots" also include New Bedford and Boston Harbors (4), Escambia Bay, Florida (5), and San Diego Bay, California (6). Severe toxaphene contamination also occurred near Brunswick, Georgia (7). Endosulfan is a significant contaminant of estuarine fishes and bivalves in Elkhorn Slough near Monterey, California (8). The herbicide DCPA (dacthal) was an additional prominent contaminant of Arroyo Colorado and Laguna Madre fishes (9).

4. TEMPORAL TRENDS FROM NATIONAL SURVEYS

Several national surveys taken at various periods can be compared to reveal something about long term changes in contamination at the national level.

As shown in Figure 2a, estuarine mollusks (oysters, mussels and clams) during 1965-72 surveys were notably contaminated with DDT along large stretches of coastline in the northeast, the southwest, southern Florida, Mississippi Sound and at several sites in Georgia and Texas (10). The grand national median DDT concentration was 0.02 ppm ww. By 1977 (Figure 2b), DDT concentrations had declined everywhere leaving only one outstanding contaminated site each in Delaware Bay and near Los Angeles in southern California (11). Further, the grand national estuarine shellfish mean was below the 0.01 ppm ww detection limit (d.l.) used in this survey. Indeed, an overlapping US Mussel Watch survey (12) produced a grand national median DDT concentration at their d.l. of 0.001 ppm ww. In short, the preponderance of evidence indicates that DDT concentrations decreased by as much as 20-fold between the period 1965-72 and 1976-77.

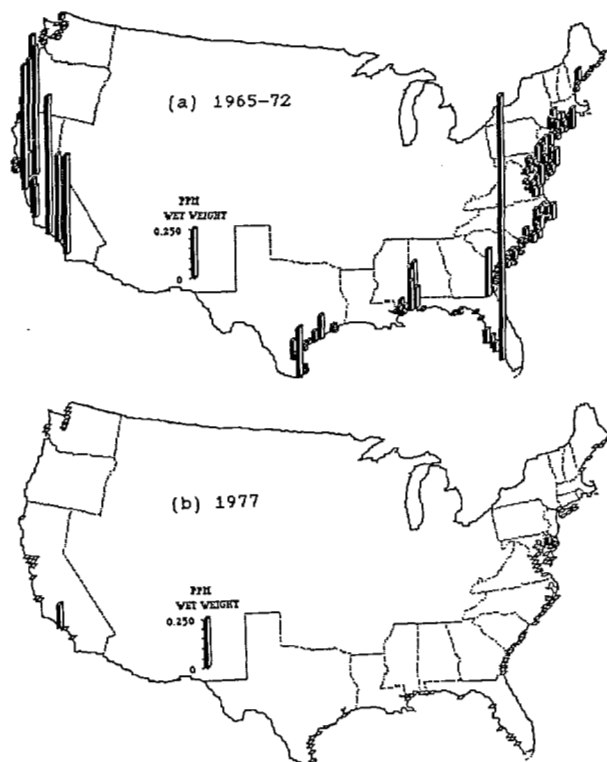


Figure 2. Mean concentrations of total DDT in bivalves from two National Pesticide Monitoring Program survey periods. From data supporting (10) and (11).

Data from other national surveys, using other species (fish) and organs (liver, muscle) result in a long-term matrix from which one can infer a 100-fold decline in DDT contamination of fish and shellfish at the national level. For example, as shown in Table 1, DDT concentrations in estuarine fish livers appeared to be 4 to 5 times lower at 42 sites sampled during the 1984 Benthic Surveillance surveys than 19 overlapping localities sampled during two federally-sponsored surveys in 1976-77. Coupled with the apparent 20-fold DDT

Table 1

MEDIAN OR GEOMETRIC MEAN DDT CONCENTRATIONS FOR 9 NATIONAL SURVEY EVENTS

ORGANISM SUBSTRATE	TDDT OF DDE, PPM W.W. BY SAMPLING PERIOD			
	1965-72	1972-75	1976-77	1984-86
BIVALVES	0.02 ¹		<0.01 ² -0.001 ³	NA
FISH, WHOLE JUVENILE		0.014 ⁴	ND	ND
FISH, MUSCLE		0.110 ⁵	0.012 ⁶	ND
FISH, LIVER			0.220 ⁶	0.054 ⁷
FISH, WHOLE F.W.	0.7-1.1 ⁸	0.4-0.6 ⁸	0.370 ⁸	

1 From Butler 1973 (10), median of 89 site means composited from 7839 samples
2 From original data supporting Butler et al 1978 (11); median of 89 site means composited from 188 samples.

3 From Farrington et al 1982 (12); median of 80 site values or site means.

4 From original data supporting Butler and Schuttmann 1978 (3); median of 144 site means composited from 1524 composites.

5 From original data supporting Stout and Beezhold (1981) and Stout (1980) cited in (14).

6 From original data supporting Butler 1978 (16) and Sherwood 1982 (17); median of 19 site means.

7 From original data supporting OAD 1987 (1); median of 42 sites medians from 126 composites.

8 From Schmitt et al 1985 (15) and supporting reports.

decline in estuarine mollusks between 1965-72 and 1977, one may infer a nearly 99% decline in estuarine DDT contamination on a nationwide basis during the past two decades.

A similar piecemeal, but challenging strategy is proposed for inferring trends at the national level for PCBs and other contaminants.

5. GEOGRAPHIC AND TEMPORAL TRENDS IN BAYS, ESTUARIES AND SPECIFIC RESOURCE SPECIES

How are contaminants distributed in the biota of specific bays and estuaries and do site-specific long-term trends reflect national trends? Data from both federal and local sources were selected to explore these questions. Examples for 4 are presented below.

Chesapeake Bay. Over 4000 samples of shellfish and fish have been sampled from the Chesapeake since 1965. The "bay-wide" average DDT content in oysters decreased at least 10-fold from the late 1960's into the mid 1970's (Figure 3). However, oysters from only a few segments of the Bay were substantially contaminated and it is the data from these sites that dominates the "bay-wide" averages. Thus it is clear that there has been a dramatic decline but also that one or a few stations cannot adequately characterize a bay or estuary.

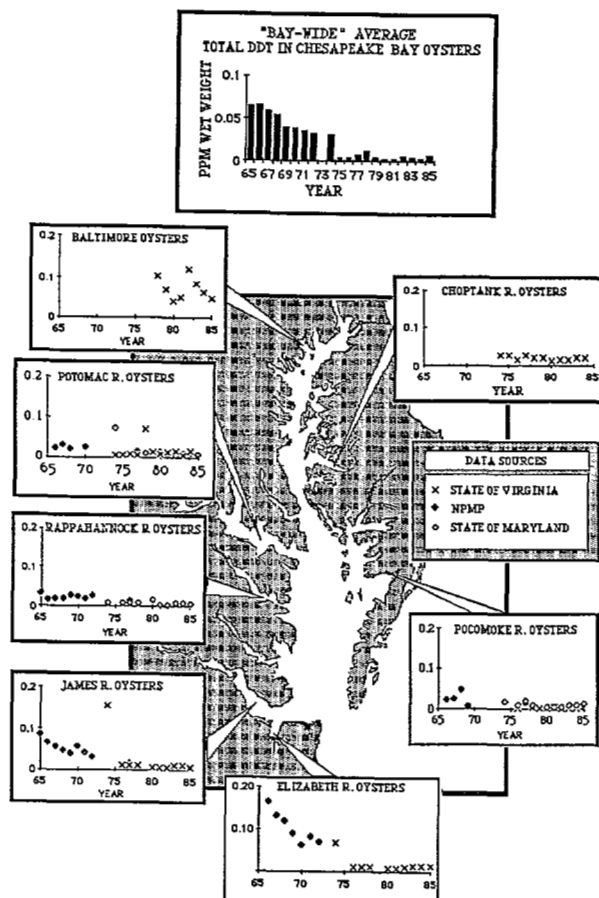


Figure 3. Long-term trends in DDT contamination of oysters in Chesapeake Bay.

Boston Harbor and Massachusetts. Surveys by the Massachusetts Division of Marine Fisheries have documented a steep gradient of PCB contamination in lobster. As shown in Figure 4, the gradient decreases sharply from a possible epicenter in Boston Harbor. It is not yet clear whether PCB concentrations in this region are increasing or decreasing: limited time-series data from mussels in the Boston area do not indicate a consistent change in either direction.

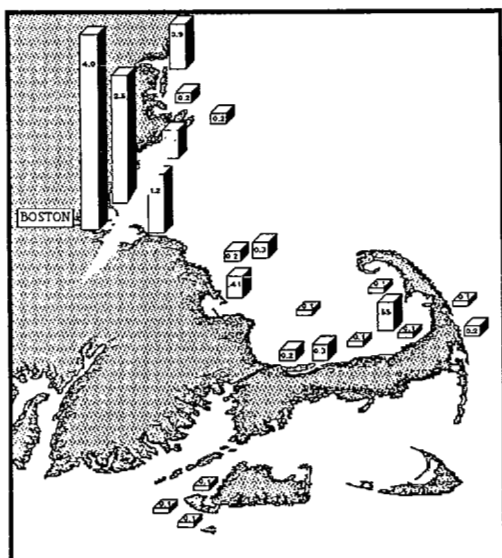


Figure 4. PCB Concentrations in Massachusetts American lobster (*Homarus americanus*) samples collected in 1983. Data from- Massachusetts Division of Marine Fisheries.

Hudson River Striped Bass. Since 1976 it has been known that the Hudson River was heavily contaminated with PCB's. Annual and seasonal surveys by the New York Department of Environmental Conservation have documented the extremely high (over 20 ppm ww) PCB levels in flesh of striped bass in the mid-1970's. By the mid 1980's, concentrations decreased dramatically to the range of 3 to 5 ppm (Figure 4). However, these concentrations are still above the 1983 FDA action limit of 2.0 ppm ww. As a consequence, it is illegal to possess striped bass in New York State waters.

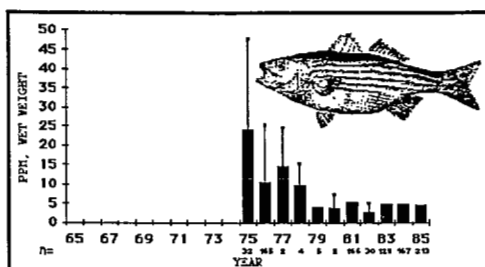
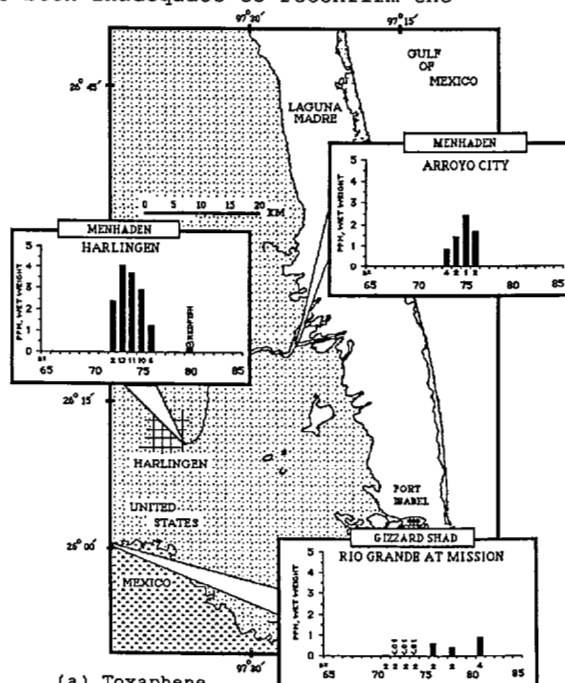
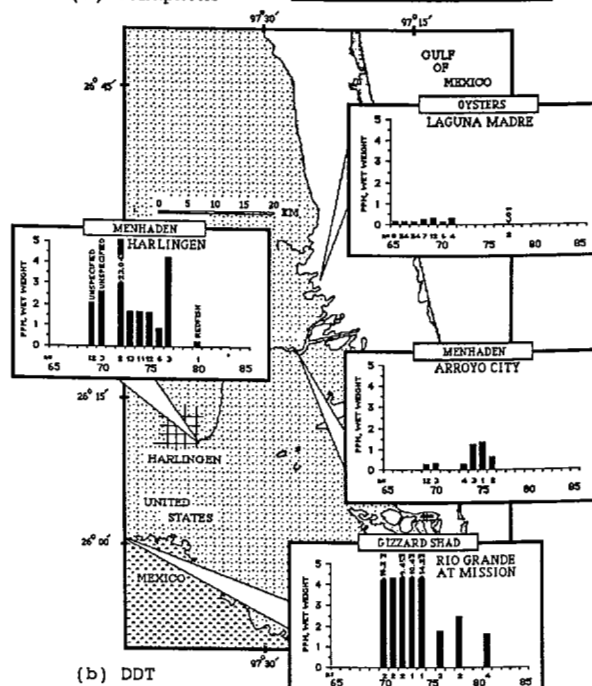


Figure 5. Annual averages and standard deviations of PCB concentrations in muscle of Hudson River striped bass (*Morone saxatilis*). Data from New York Dept. Env. Cons., Albany.

Arroyo Colorado and the Laguna Madre, Texas. As noted above, fish and shellfish of the Arroyo Colorado, Texas, were heavily contaminated with DDT, toxaphene, dieldrin and DCPA. A close-up view of the region (Figure 6a and b) reveals, again, a steep downstream gradient existed for DDT and toxaphene contamination and, further, that levels began to decline in the mid-1970's. Recent sampling has been inadequate to reconfirm the



(a) Toxaphene



(b) DDT

Figure 6. Annual average concentrations of (a) toxaphene and (b) DDT in fishes from several sites near lower Laguna Madre, Texas. From data supporting (3), (16) and unpublished reports from Texas Parks and Wildlife Department.

continuation of declining trends. Also, it is not clear that the contamination of fish was restricted to the Arroyo or also substantially extended into Laguna Madre.

These are a few examples of site- and resource-specific trends that can be documented from many local and regional monitoring surveys. Trends in other estuaries are being examined now. Data has already been presented and published that documents declining concentrations of DDT and PCBs in fish and shellfish from southern California and other Pacific coast sites (13).

6. DISCUSSION AND CONCLUSIONS

There is a wealth of existing data with which it is possible to infer and semi-quantify the history of pesticide and PCB contamination in coastal biota of the U.S. The problem is, there has been no long-term consistency in either national or local sampling objectives: target species and sampling sites seem to change at several-year intervals. A lot of inferences have to be made to reconstruct history. NOAA's National Status and Trends Program offers a unique opportunity to relate local and regional monitoring and trend results to a national background and data base. Hopefully, key elements of the program will remain unchanged over the long run.

Taken together, existing data point toward dramatic declines in DDT contamination of coastal fish and shellfish, both on a nationwide and local basis, including the Southern California Bight where concentrations nonetheless remain problematic. Additional review of data suggests this conclusion holds true for endrin and dieldrin. Chlordane concentrations have declined in some well-monitored areas such as San Francisco Bay, but it is still a problem in Baltimore Harbor.

PCB's have experienced dramatic declines where levels were once extremely high (Hudson River, Los Angeles), but it is not clear that concentrations have declined in less contaminated areas and species (14).

Several chemicals have not been adequately surveyed on a national basis during the 1980's. Among these are toxaphene, endosulfan and pentachlorophenol (PCP). Recent localized surveys in specific areas reveal continued or even increasing local contamination (eg., Elkhorn Slough near Monterey Bay, and the delta region inland of San Francisco Bay (8)).

How does estuarine contamination compare with inland areas? Based on data in Table 1, estuaries may have been cleaner than inland sites. A new survey of chlorinated hydrocarbon levels in whole estuarine fish (comparable to an ongoing inland program, 15), or of concentrations in livers of freshwater fish across the U.S., would allow a direct national comparison of coastal, estuarine and aquatic fish.

7. ACKNOWLEDGEMENTS

Many specific individuals assisted in this project. In addition to those previously cited (2) we thank L. Bridges (Massachusetts Division of Marine Fisheries).

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