Report

of the

Interstate Workgroup on Evaluating Atlantic Coastal Advisories for Recreationally Caught Striped Bass and Bluefish based on PCBs

10/1/2008

Executive Summary

Fish consumption advisories for recreationally caught striped bass and bluefish vary among eastern coastal states. Although specific advice varies, polychlorinated biphenyls (PCBs) are consistently cited as a major risk driver leading to these advisories. The advisories vary from state to state due to differences in analytical methods, toxicological basis, risk management approaches, or actual differences in measured PCB levels. The differences in consumption advisories can be confusing for the public who may be receiving conflicting messages, i.e., if two states issue different advisories for the same water body as in Long Island Sound. The Eastern Coastal Striped Bass and Bluefish Consumption Advisory Workgroup was formed to explore the feasibility of developing a consistent advisory for recreationally caught migratory marine striped bass and bluefish. This Workgroup did not address subpopulations of landlocked striped bass , non-migratory populations of striped bass, or of commercially available or farm raised striped bass.

The objective of the Workgroup was to analyze the feasibility of a consistent advisory based on PCB contaminants for all of the Atlantic coastal states. Where consistent advisories are not possible, the report provides a rationale for this conclusion. Four sub-workgroups also compiled and described existing striped bass and bluefish data from the Atlantic coastal states and the biological and management aspects of striped bass and bluefish that impact decisions about coastal consumption advice. Lastly, they reviewed methodologies used in issuing state fish consumption advisories across the Atlantic coastal states, the toxicological basis used to develop this advice, and benefits and risks of PCBs vs. omega-3 fatty acids in striped bass and bluefish.

> The workgroup determined that it was feasible, with certain caveats to develop consistent advice along the Atlantic Coast for recreationally caught striped bass and bluefish based on PCBs. Resident striped bass in bays, harbors and riverine populations are not migrating, and hence consistent advice in these estuarine/inland waters are not supported. Additionally, PCB concentration is related to size in bluefish, hence smaller less contaminated bluefish require less stringent advice. Because of differences in the fishery from location to location, the size cut off should be based on local data. For migratory striped bass populations PCB levels support a 1 meal per month advisory and a 1 meal every other month advisory for large bluefish using EPA risk based approach for developing advisories. A majority of states, but not all, feel the new evidence regarding neurodevelopmental effects in children are compelling enough to recommend no consumption for the sensitive population. One purpose of this document is to provide the government agencies that develop state advisories with this compilation of data and information for their consideration. It is acknowledged that it is up to those agencies to decide whether the information in this report is compelling enough to implement or alter any current fish consumption advice.

Summaries of Subworkgroups

The Data Subworkgroup compiled available PCB data in striped bass and bluefish from State and Federal sources. These data were used to describe the levels of PCBs in these species along the Atlantic Coast, as well as descriptions of the fish collected (e.g., size and weight), analytical methods, and other information (e.g., percent lipids). The information compiled indicates the amount of data varies considerably by state. Limited data are available for bluefish coastwide with only eight of fourteen states reporting results. Moderate amounts of data for striped bass data are available for eleven coastal states, with extensive data available for coastal waters from Connecticut to New Jersey. The range of reported mean striped bass PCB levels was 10,500 ppb (NY, Hudson River) to 30 ppb (GA). The range of reported mean bluefish PCB levels was 2,670 ppb (NY, Hudson River) to < 13 ppb (NC). Direct comparisons of interstate data are difficult based on the observed variability and differences in collection methods (e.g., temporal and size differences). These factors need to be considered when interpreting the data including regional observations. However, distinguishing between populations of striped bass (migratory vs. breeding vs. estuarine) shows relative consistency among striped bass which are migrating vs. those which are resident. These data do indicate that PCB concentrations have declined in striped bass and bluefish since the 1980s. For striped bass there was no apparent length-PCB relationship for fish collected from Long Island Sound and the Hudson River. There was a strong positive length-PCB relationship for bluefish throughout much of the range in which they are found. Secondary objectives included analyzing the feasibility of a common database and analytical methodology for PCB concentrations in striped bass and bluefish.

The Biology Subworkgroup evaluated the life histories, migratory routes, dietary habits and recreational harvest and regulations associated with striped bass and bluefish. Striped bass have several breeding locations along the coast, with adult males and females migrating north during the summer and overwintering off North Carolina/Virginia. The major breeding locations include the Hudson River, the Delaware Estuary, the Chesapeake Bay and Albermarle Sound/Roanoke River. Southern striped bass (South Carolina to Florida) are generally riverine and do not migrate along the coast. Generally the minimum lengths for recreational harvest are such that it is the migratory females that can be kept. Striped bass diet is dominated by available prey at any particular location and the importance of the recreational fishery (relative to other species) increases north along the coast. From an absolute perspective, the numbers of striped bass recreationally harvested are greatest in the Mid Atlantic and southern New England states. Bluefish are generally considered one population along the Atlantic Coast. Like striped bass, they are opportunistic feeders and their diet is dominated by local resources. Their range stretches from Maine to Florida, but as a recreational fishery, they are not important in Georgia and South Carolina.

The Health Effects Subworkgroup evaluated the existing toxicological bases for developing advisories for PCBs, all of which were found to be outdated and do not take into account the several longitudinal prospective epidemiological studies published in the last 20 years. That said, the Health Effects Subworkgroup did use standard risk based methods to estimate “risk based decision criteria” for PCBs in fish using various consumption rates, estimates of cooking loss and a 1/100,000 cancer risk level. The one meal per week consumption rates range from 11 to 87 ug/kg and the one meal per month consumption rates range from 43 to 346 ug/kg.

Additionally, the recent epidemiological studies evaluating neuropsychological effects in children exposed to PCBs were evaluated. While characterization of the shape of the relationship between exposure and effects was not performed and was beyond the scope of the workgroup, the comparison of the effects levels from several studies were compared to typical body burdens in the US population (both selected individual congeners or total PCBs as understood from NHANES III). The evaluation is supported by the fact that multiple endpoints suggest a monotonic relationship between PCB exposure and adverse effect whether the biomarker is cord blood or placental tissue. This suggests there is no margin of safety between body burden of PCBs in the US population and body burdens that are associated with adverse effects on multiple outcomes as a consequence of in utero exposure.

There is good evidence that dietary fats (e.g., omega-3 fatty acids) in fish have beneficial impacts on both adults and the developing fetus. But a comparison of the ratio of PCB levels to omega-3 fatty acids suggests that, with the exception of smaller bluefish, striped bass and bluefish offer a significantly higher amount of PCBs per gram of omega-3 fatty acids than other typical dietary omega-3 fatty acid sources. Hence, it would not appear that strong consideration of the health benefits of fish is valuable when thinking about PCB exposure from striped bass and larger bluefish.

The Advisory Subworkgroup compiled consumption advisory data on all of the Atlantic coastal states for bluefish and striped bass. The current health advisories produced by the states for consumption of striped and bluefish are similar. Beyond the basic similarity, however, there are significant differences in the physical locations of advisories, how the human populations are defined, toxicity assessment sources used, and parameter choice in defining human exposures to chemical residues in fish (e.g., meal size, exposure duration, etc.). The similarities and differences in these variables and the rational behind them are discussed in the advisory chapter.

Recommendations

The Workgroup concluded that across the Atlantic coastal states, there appears to be significant variety and divergence in consumption advice given for bluefish and striped bass. However, there are also many similarities and areas where consensus can be built. Despite differences in how advisories are derived under various risk assessment methodologies, the majority of states are not that different on how they view PCB toxicity and exposure assessment. For this reason, it seems feasible for many of the Atlantic coast states to adjust their advice to be more consistent.

For striped bass, consistent advisories should apply only to those migratory fish that move from jurisdiction to jurisdiction. Given their biology and the fishing regulations, those fish are typically large migratory females. Populations that do not migrate (e.g., striped bass from South Carolina to Florida) or those fish in spawning locations may be evaluated by local jurisdictions to determine the need, if any, for advisories. The concentrations of PCBs in these migratory fish, however, support a meal per month consumption limit using standard risk based methods. The toxicological benchmarks on which these estimates are based, however, do not take into account the new epidemiological studies showing neurodevelopmental effects children exposed in utero. For that reason, a majority of states feel a no-consumption advisory for recreationally caught striped bass is warranted for the sensitive population. Hence, the workgroup recommends no more than a one meal per month baseline advisory for everyone, with a recommendation for no consumption for the sensitive population.

While there is significantly less data for bluefish, and the state data is more variable, it is clear larger bluefish do have PCB concentrations at levels that require fish consumption advisories.

As there is a size dependence of PCB concentration in bluefish and generally no size restrictions on possession bluefish consumption advice can be split into two categories based on size. However, the importance of the differing fisheries varies based on location, with smaller fish being less common in northern states. Hence, the size distinction and advice relevant for those smaller fish should be a jurisdictional decision. The data for bluefish larger than 20” are roughly twice the striped bass concentrations and warrant a meal every other month advisory for everyone. As with striped bass, however, the newer literature on neurodevelopmental effects causes a majority of states to support a no consumption advisory for the sensitive population.

It is recognized that states have considerable experience relative to their fisheries, their populations, and their evaluation of toxicological data. Hence the workgroup proposes the following advice as a consideration as a starting point for further discussion.

Table 1: Proposed Advice for Striped Bass and Bluefish along Atlantic Coast States		
	women who may get pregnant and young women and girls.	men, boys, adult women who will not get pregnant
Striped Bass		
Coastal Marine Waters from Maine to North Carolina	1 meal per month to No Consumption	1 meal per month
Coastal Marine Waters from South Carolina to Florida	No Need for Consistent Advice	
Large Bluefish (where size distinction is a local decision)		
Coastal Marine Waters from Maine to North Carolina	1 meal every other month to No Consumption	1 meal every other month
Coastal Marine Waters from South Carolina to Florida		Not possible to develop advice without more data
Small Bluefish (where size distinction is a local decision)		
Coastal Marine Waters from Maine to Florida	Advice to vary by state based on data and local conditions	

An issue of further discussion among states if and when they develop consistent advice would be whether or not to put young boys in the sensitive population.

The states involved in drafting this report will strive for consensus on how to implement the recommendations in this report. It is hoped that a more consistent advisory can be developed, or at least the existing advisories can be brought closer together. At the conclusion of these discussions, there will be a coordinated risk communication effort to educate the fish consuming public about new and existing advisories for striped bass and bluefish.

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Chapter 1: Introduction

I. Objectives of the Workgroup

Throughout the eastern coastal states, there are a wide variety of consumption advisories for recreationally striped bass and bluefish due to PCB contamination. The reasons for the differences in advisories vary greatly; they may be political, they may vary due to differences in analytical methodology or toxicological basis, or they may vary in biological and management aspects. The differences in consumption advisories can be confusing for the public who may receive conflicting messages, i.e., if two states issue different advisories on the same water body as in Long Island Sound. The Eastern Coastal Striped Bass and Bluefish Consumption Advisory Workgroup was formed to explore the feasibility of developing a joint advisory for recreationally caught migratory marine striped bass and bluefish. This workgroup did not address populations of landlocked striped bass, non-migratory populations of striped bass, or commercially available striped bass (farm raised or wild).

Developing consensus on a joint advisory is not the sole purpose of this workgroup. By having most of the eastern coastal states participating in this process, we hoped to bring together the expertise and informational resources that exist in each state on the topic of PCBs in fish. It was anticipated that by pulling all of the information and data together in one place, we could bring states closer together on that topic, even if consensus could not be reached. The final report will then document the information gathering process and become a standard resource on the issue of PCBs and striped bass and bluefish consumption advisories.

The three main objectives for this workgroup are:

1). To analyze the feasibility of a joint consumption advisory based on PCB contaminant data for all of the Atlantic coastal states for striped bass and bluefish. If a joint consumption advisory is not feasible, then provide the rational for this conclusion.

2) To compile and describe existing striped bass and bluefish PCB data, including the PCB concentrations in fish tissue from various eastern coastal states and the methodology used to analyze the tissue. To analyze the feasibility of a common database and analytical methodology for PCB concentrations in striped bass and bluefish.

3) To compile and describe the biological and management aspects of striped bass and bluefish that impact decisions on developing coastal wide consumption advice. Review parameters used in issuing state fish consumption advisories and the toxicological bases used to develop this advice.

II. Methodology

In the fall of 2004, a conference call to discuss potential changes to existing fish advisories among individuals who develop recreational fish consumption advisories in states from New Jersey to Maine led to a discussion as to whether or not it made sense to have consistent advice for migratory coastal fish. From this initial dialog a project was formed to prepare a document to assess the feasibility of developing a common coastal advisory for striped bass and bluefish due to PCBs along the Atlantic coast. "Common" could be the entire Atlantic coast, or subregions, i.e. New England, Mid-Coast, Southern, depending on the outcome of this effort. Additionally, it was recognized that while the objective is to work towards a common advisory, there may be states that participate in this process that do not adopt any advisory or final recommendations.

Since most of the individuals who would be involved in this effort meet periodically at the EPA sponsored Fish Forum, our milestone for completing the project was to compile the majority of the work via the internet and conference calls with a final meeting at the Fall 2005 Fish Forum in Baltimore, MD. While the effort extended well beyond that timeframe, the Fish Forum provided an excellent opportunity to present and discuss preliminary findings.

We canvassed state and federal agencies involved with striped bass and bluefish, PCB analysis, and consumption advisories to gauge the level of interest. Biologists, toxicologists, and fisheries managers all participated in the effort. Input was received from all Atlantic coastal states. Participating regulatory agencies included both state representatives (fisheries managers, chemists, and toxicologists), as well as the Food and Drug Administration, the Environmental Protection Agency, National Oceanographic and Atmospheric Administration, and the Atlantic States Marine Fisheries Commission. Participants were assigned to the subworkgroup(s) that best matched their expertise and/or interest. Each subworkgroup conducted a series of conference calls and email exchanges to develop the findings for the chapters in this report.

We encouraged open participation throughout the proceedings. Anyone could listen and participate in a subworkgroup conference call without actually being a member of a subworkgroup. Conference calls were conducted within the various subworkgroups (open to anyone who would like to participate) to contribute written material for draft chapters.

Draft chapters were then posted on the website for review (http://www.maine.gov/dhhs/eohp/fish/PCBSTBhome.shtml).
The five subworkgroups and their members were:

A. Data Subworkgroup

Key Objective: Compile and describe existing data on PCBs in striped bass and bluefish along the Atlantic Coast. Possibly assess feasibility of developing a centralized database accessible by all coastal states. Possibly evaluate the feasibility of developing a common methodology for analyzing and reporting PCB data in striped bass and bluefish. Additionally, this group was charged with evaluating the length/PCB relationship for striped bass and bluefish.

Gary Buchanan (lead), New Jersey Department of Environmental Protection
Eric Frohmberg, Maine Center for Disease Control
Rick Greene, Delaware Department of Natural Resources and Environmental Control
Ron Sloan New York Department of Environmental Conservation
Larry Skinner, New York Department of Environmental Conservation
Jack Schwartz, Massachusetts Division of Marine Fisheries
Sharee Rusnak, Connecticut Department of Public Health
Ashok Deshpande, National Oceanographic and Atmospheric Administration.

B. Biology Subworkgroup

Key Objective: Summarize information available about movement and populations of striped bass and bluefish up and down the coast. Provide technical resources for other workgroups - i.e., are there distinct population patterns that can explain observed variability in PCB levels?

Eric Frohmberg (lead), Maine Center for Disease Control
George Henderson, Florida Fish and Wildlife Conservation Commission
Rich McBride, Florida Fish and Wildlife Conservation Commission
Byron Young, New York Department of Environmental Conservation
Victor Crecco, Connecticut Department of Environmental Protection, Marine Fisheries Division
Paul Caruso, Massachusetts Division of Marine Fisheries.

C. Health Effects Subworkgroup

Key Objective: Summarize information on different estimates of toxicity used by the states and federal programs in developing advisories and more generally review new literature on the toxicology of PCBs. Possibly assess and review EPA's development of a benchmark dose for PCBs. Possibly evaluate the feasibility of developing a toxicity value based on the current literature. Additionally, this group was charged with weighing the benefits and risks

Deborah Rice (lead), Maine Center for Disease Control
Gary Ginsberg, Connecticut Department of Public Health
Elaine Krueger, Massachusetts Department of Public Health
Alan Stern, New Jersey Department of Environmental Protection
Bob Vanderslice, Rhode Island Department of Health
Joe Sekerke, Florida Department of Health.
Eric Frohmberg, Maine Center for Disease Control

D. Advisory Subworkgroup

Key Objective: Summarize current advisories and fish tissue action levels for striped bass and bluefish along the Atlantic Coast.

Joe Beaman (lead), Maryland Department of the Environment
Eric Frohmberg, Maine Center for Disease Control
Tony Forti, New York Department of Health
Sharee Rusnak, Connecticut Department of Public Health.

E. Organizational Subworkgroup

Key Objective: Bring all the information gathered from the other subworkgroups into one document that makes recommendations on the feasibility of a coastal advisory for striped bass and bluefish based on PCBs.

Eric Frohmberg (lead)
Deb Rice, Maine Center for Disease Control
Andy Smith, Maine Center for Disease Control
Gary Buchanan, New Jersey Department of Environmental Protection
Bruce Ruppel, New Jersey Department of Environmental Protection
Luanne Williams, North Carolina Department of Health and Human Services
Jack Schwartz, Massachusetts Division of Marine Fisheries
Brian Toal, Connecticut Department of Public Health
Joe Beaman, Maryland Department of the Environment
Ed Horn, New York Department of Health
Tony Forti, New York Department of Health
Margaret Round, Massachusetts Department of Health
Timothy McAuley, Massachusetts Department of Health

Comments were incorporated into draft chapters, which were then evaluated jointly by the organizational subworkgroup, individual subworkgroups and members at large. The report was then organized by separate chapters representing the findings from each subworkgroup.

Chapter 2: PCBs in Striped Bass and Bluefish

I. Introduction

The data subworkgroup was tasked with the key objective to compile and describe existing striped bass and bluefish PCB data along the Atlantic coast and, where possible, assess the feasibility of a common database and analytical methodology. This section describes the available PCB data for these species. The majority of recent data have been collected by state agencies and there are limited data from other sources. Appropriate state agencies from all of the Atlantic Coastal states from Maine to Florida were contacted for recent PCB data and information for both species. Data within the past five years were requested, however in some cases the only available data were more than five years old. Table 2-1 summarizes the available data based on the responses from these states. A literature search was also conducted to see what data might be available for both species. In addition, federal agencies were contacted (e.g., NOAA, EPA, FDA) to determine if recent data were available. More recent data are being generated by some states, but have not been incorporated into this document.

This project has focused on total PCBs as a measure of this class of contaminants in these two popular recreational species. States vary in their analytical techniques and method of measurement. For example, some states analyze PCB Aroclors while others measure varying numbers of individual congeners. Brief descriptions of the analytical methods employed are also presented in this chapter.

Generally, more recent and robust data are available for striped bass as compared to bluefish (11 versus 8 states; 1873 versus 424 data points, respectively; Table 2-1). Additional details are provided in the sections below for each state. There are limited other data available, with the most prominent being the NOAA bluefish PCB study conducted in the mid-1980's. No other large-scale coastwide study of PCBs in adult bluefish or striped bass was identified. NOAA is currently conducting a study to identify subpopulations of snapper bluefish along the East Coast using PCB congener distributions (Deshpande 2006).

At the present time, PCBs are the principal compounds causing issuance of health advisories to restrict consumption of striped bass and bluefish due to excessive residue levels in edible flesh. Due to the widespread impacts of PCBs, substantial attention is given to their remediation and to the issuance of fish consumption advisories. PCBs include coplanar PCBs which have dioxin-like toxicity and may drive a site specific fish consumption advisory. However, this document addresses total PCBs and does not consider dioxin-like PCBs.

Organochlorine pesticides, such as DDT and chlordane, are commonly evaluated but now represent less of an environmental problem since they have been long banned and are on the decline in the environment. There are other xenobiotics on the horizon, such as the polyhalogenated diphenylethers, including PBDEs, the chlorinated dioxins and dibenzofurans and other manufactured organics but relatively little is known of them compared to the available data coastwide on PCBs. Attention to these other chemicals, including heavy metals (e.g., mercury) and PAHs, must wait until additional resources are available to assess their impacts on a coastwide basis.

Table 2-1: Summary of available state PCB data for striped bass and bluefish from along the Atlantic Coast of the United States.

State	Fish samples[1]		Generally targeted fish lengths (mm)[2]		Collection years[3]
	Striped bass	Bluefish	Striped bass	Bluefish	
Maine	Yes (71)	Yes (10)	508 to 660; and ≥1016	As available	Striped bass: 2002, 2004, 2006 Bluefish: 2002, 2004
New Hampshire	No	No	--	--	
Massachusetts	Yes (76)	No	>711	--	1997, 1998
Rhode Island	Yes (34)	No	>711	--	1996
Connecticut	No	Yes (60)	--	>457	1997
Connecticut + New York	Yes (103)	Yes (136)	≥610	≥305	2006
New York	Yes (1249)	Yes (98)	≥457	<305 305-559 ≥559	Striped bass: 1994-2006 Bluefish: 1993, 1998, 1999
New Jersey	Yes (83)	Yes (71)	>457	>305	Striped bass: 1998-1999, 2002, 2004 Bluefish: 1997-1999, 2004
Pennsylvania	No	No	--	--	
Delaware	Yes (20)	Yes (30)	>711	As available	Striped bass: 2002, 2007 Bluefish: 2004, 2005
Maryland	Yes (81)	Yes (8)	>457	>203	Striped bass: 2001-2005 Bluefish: 2002

Virginia	Yes (89)	Yes (6)	>457	As available	Striped bass: 2002-2004 Bluefish: 2003, 2004
North Carolina	Yes (30)	Yes (5)	>457	As available	Striped bass: 1996 Bluefish: 1989
South Carolina	No	No	--	--	
Georgia	Yes (37)	No	>559	--	2004, 2005
Florida	No	No	--	--	
Total No. States	11	8			
Total No. Samples	1873	424			

[1] Yes indicates PCB data were submitted for the species. The numbers of samples are provided in parenthesis; some samples are composites of several fish. No indicates no data were provided or available.
[2] For striped bass, target sizes are generally legal sizes. Legal sizes have varied by year. In some cases, fish outside the target sizes were taken when target sized fish were unavailable. For length conversion, 25.4 mm = 1 inch.
[3] Collection years for which data are included in this report. Some states have data that were obtained prior to the years given and may be used for temporal or spatial analysis.

II. State Data

A. Overview

The chemical residue data gathered for striped bass and bluefish by states along the Atlantic coast contains variability that is affected by proximity to major PCB sources and may be affected by size-PCB relationships. Since striped bass are migratory fish that spawn within tributaries of the Atlantic, and some tributaries, bays and harbors contain PCB sources, the individual states' PCB data for striped bass have been organized by populations that represent coastal stocks (Table 2-2), and bays, harbors, and tributary waters (both spawning stocks and non-spawning stocks, where information exists) (Table 2-3). Where elevated PCB concentrations exist, they will be addressed in the state specific data discussions of this chapter. Trends in PCB concentrations, where known, are addressed in individual discussions (Section II. B. and Section IV). In contrast, bluefish are primarily coastal fisheries with limited incursions into coastal tributaries. Also, the volume of chemical residue information for bluefish is more limited. A definite size-PCB relationship exists for bluefish (see Section II.B.), therefore, PCB data for bluefish are segregated by length of fish, i.e., Table 2-4 contains bluefish less than 20 inches (508 mm) in total length, and bluefish over 508 mm are included in Table 2-5.

PCBs in striped bass were determined for fish that were generally greater than minimum legal lengths permitted for harvest of the fish. The lengths permitted for harvest vary among states (see Chapter 3), but generally targeted sizes are noted in Table 2-1. Since 1999, coastal striped bass, almost regardless of location of collection, contain relatively uniform PCB concentrations (Table 2-2 and Figure 2-1). However, the variability of data for striped bass in nearshore and tributary sites is evident in Figures 2-2 and 2-3. New York Harbor and the Hudson River at Troy stand out as locations near sources of PCBs.

In most states, bluefish lack size restrictions on fish that may be taken. Therefore, unless specific sizes are targeted for sampling, any available size may be sampled. When the length-PCB relationship is taken into consideration, there is relative uniformity of analytical results for PCBs for coastal stocks of adult bluefish with the exception of New York Harbor (Table 2-5, Figure 2-5). However, the data for adult bluefish in New York Harbor was last obtained in 1994 and needs to be updated. The greatest relative PCB variation for the species occurs in young-of-year bluefish with elevated concentrations likely due to their association with contaminated nearshore environments, e.g., the Hudson River and New York Harbor. Data obtained for the period 1998 to 2006 indicate reduced or low exposures to PCBs throughout the range of these young fish (Table 2-4, Figure 2-4).

During this assessment and review, the reader must be cognizant of the differing analytical methods used for quantifying PCBs (Table 2-6 and Section V.). Over time, the methods employed have had differing levels of sensitivity and have quantified PCBs in different manners. The methods have reported Aroclors (mixtures of PCBs varying in degree of chlorination) or differing numbers of specific PCB congeners (up to all 209 possible congeners). Total PCBs as reported here are the sum of the available data for PCB Aroclors or congeners. Total PCBs based on congener data may not be inclusive of all PCBs that were present in the sample, thus an underestimate of total PCB concentrations may be reported in some cases.

Table 2-2: PCBs in coastal Atlantic Coast striped bass

State/ Area	Year	Ave. Length (mm)	Ave. Weight (g)	Ave. Lipid (%)	Ave. PCB (ng/g)	Median PCB (ng/g)	Min. PCB (ng/g)	Max. PCB (ng/g)	Std. Dev. (ng/g)	N[1]	Individual (I) or Composite (C); Source; other notes
Maine	2002	610	nd[2]	3.0	172	nr[3]	30	722	130	30	I
	2004	592	2019	1.6	176	nr	54	444	79	25	
	2006	600	2319	2.2	133	nr	54	432	90	16	
Massachusetts	1997	840	6514	2.0	291	nr	47	1400	199	76	I; Schwartz et al., 1998
Rhode Island	1996	788	nr	nr	190	112	nd[4]	620	195	34	I; Sloan et al., 2005; NYSDEC files
Connecticut/ New York (Long Island Sound)	1994	688	3811	4.5	1175	nr	240	5750	nr	303	I; Sloan et al., 1995
	1999-2000	526	1507	2.9	164	nr	22	787	155	22	I; McReynolds et al., 2004
	2006	787	5181	1.5	253	206	19	1445	193	103	I; Incomplete data set; provisional data from on-going 2-year study
New York/New Jersey (Bight)	1999-2000	560	1920	2.8	372	nr	107	853	197	17	I; McReynolds et al., 2004
New Jersey	1998-1999	830	6363	3.3	417	362	86	1092	247	22	I; Horwitz et al., 2006
	2004	763	4310	1.8	221	152	84	1270	256	20	

1 Number of samples.
2 nd = not determined (for ME).
3 nr = not reported.
4 nd = not detected (for RI). All seven PCB Aroclors were less than 52 ppb.

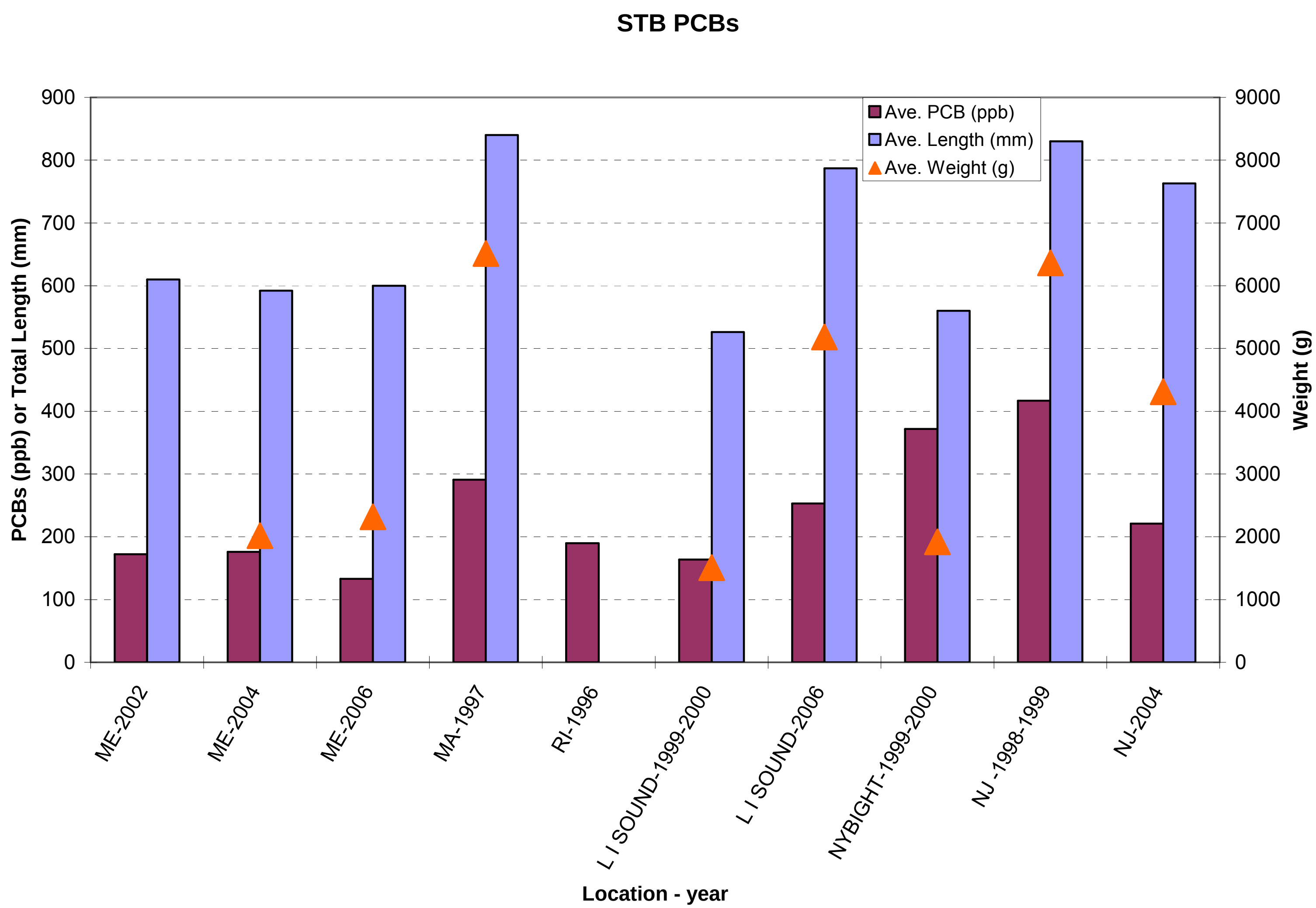


Figure 2-1: Average PCBs, total lengths and weights of Atlantic Coast striped bass; 1996-2006.

Table 2-3: PCBs in striped bass from bays, harbors and riverine populations along the Atlantic Coast.											
State/Area	Year	Ave. Length (mm)	Ave. Weight (g)	Ave. Lipid (%)	Ave. PCB (ng/g)	Median PCB (ng/g)	Min. PCB (ng/g)	Max. PCB (ng/g)	Std. Dev. (ng/g)	N[1]	Individual (I) or Composite (C); reference
Bays and harbors											
New York (Harbor)	1998	652	3194	3.3	420	nr[2]	<20	2110	nr	85	I; Skinner 2001
	1999-2000	547	1909	3.7	1141	nr	99	22149	nr	74	I; McReynolds et al., 2004
New Jersey (Passaic R. + Raritan R. & Bay)	1998-1999	690	3267	2.3	431	404	139	819	248	5	I; Raritan Bay only
	2002-2004	563	1767	1.8	526	485	133	1465	448	7	I; Horwitz et al., 2005; Horwitz et al., 2006
New Jersey (Delaware Bay)	1998-1999	796	5755	4.4	679	583	199	1280	383	10	I; Horwitz et al., 2006
	2004	791	5020	0.3	209	190	159	313	60	5	
Delaware (Delaware Estuary)	2002	652	2737	1.8	261	211	112	761	196	10	I
	2007	828	6661	2.7	249	239	109	451	103	10	
Maryland (Chesapeake Bay, spring)	2002	591	2587	6.4	422	372	237	1095	215	16	I
	2003	589	2048	5.0	343	nc[3]	201	523	nc	4	3C5, 1C6; 21 fish
	2005	849	6480	8.1	470	--	457	480	--	2	1C3, 1C4; 7 fish
Maryland (Chesapeake Bay, fall)	2001	533	1380	1.8	133	nc	48	271	nc	10	2C4, 6C5, 2C6; 50 fish
	2002	585	1783	1.2	242	--	--	--	--	1	C of 3 fish
	2003	527	1487	1.1	180	nc	27	302	nc	6	2C4, 4C5; 28 fish
	2005	508	1088	0.64	26	nc	16	44	nc	3	C of 5 each; 15 fish

State/Area	Year	Ave. Length (mm)	Ave. Weight (g)	Ave. Lipid (%)	Ave. PCB (ng/g)	Median PCB (ng/g)	Min. PCB (ng/g)	Max. PCB (ng/g)	Std. Dev. (ng/g)	N[1]	Individual (I) or Composite (C); reference
Virginia (Chesapeake Bay, spring)	2003	608	3365	12.3	192	158	50	414	111	18	I
Virginia (Chesapeake Bay, fall)	2003	512	1598	5.5	99	74	11	218	69	10	I
North Carolina (Albemarle Sound)	1996	nr	nr	nr	315	nr	nr	nr	nr	29	Sloan et al., 2005
	1999	nr	nr	nr	<190					1	I
Riverine migratory spawning populations[4]											
New York (Hudson R. - Poughkeepsie to New York City)	2002	671	3397	3.3	1545 (850)	671 (666)	173	52980 (4014)	6054 (654)	75 (74)	I; in 2002, the outlier fish is excluded in parenthetic values
	2003	619	2758	4.2	950	672	10	5590	1013	36	
	2004	620	2876	3.2	479	383	108	4980	630	60	
	2005	614	2643	3.3	653	497	82	5340	659	160	
	2006	640	2848	3.1	535	425	70	2820	447	120	
New York (Hudson R. - Troy, spring)	2002	780	5704	4.1	1406	714	97	5923	1534	21	I; outlier fish in 2004 and 2005 are excluded in parenthetic values
	2003	658	3492	2.5	1402	1080	309	6530	1392	20	
	2004	694 (713)	3912 (4196)	3.4 (3.3)	10500 (2070)	1385 (1370)	329	115960 (5900)	26360 (1370)	20 (17)	
	2005	706 (713)	4243 (4341)	3.1 (3.1)	3909 (1049)	743 (716)	133	86850 (4220)	15700 (1108)	30 (29)	
	2006	773	5536	4.0	1129	563	110	7100	1638	20	

State/Area	Year	Ave. Length (mm)	Ave. Weight (g)	Ave. Lipid (%)	Ave. PCB (ng/g)	Median PCB (ng/g)	Min. PCB (ng/g)	Max. PCB (ng/g)	Std. Dev. (ng/g)	N[1]	Individual (I) or Composite (C); reference
New Jersey (Delaware R.)	1998-1999	647	3219	2.2	627	640	166	1631	385	14	I
Maryland (Choptank R.)	2003	646	3066	5.4	363	280	108	875	238	10	C of 5 each; 50 fish
Maryland Patuxent R.)	2005	773	4440	4.7	458	nc	285	737	244	3	C of 4 each; 12 fish
Maryland (Potomac R.)	2002	626	2774	4.1	408	397	79	1031	253	14	I
	2003	560	2038	3.7	427	nc	200	620	nc	4	2C4, 2C5; 18 fish
Virginia (James R.)	2002	607	2978	5.4	215	173	117	494	122	8	3 C, 5 I; 21 fish
	2003	672	3475	8.0	322	330	174	452	132	4	C; 10 fish
	2004	565	2041	7.2	394	313	93	1483	282	46	I
Riverine resident spawning population[4]											
Georgia (Savannah R., spring)	2004	435	1161	nr2	<100	<100	<100	<100	0	17	I (15) + 2 C; 25 fish
	2005	864	9160	nr	<100	<100	<100	<100	0	10	I
Riverine non-spawning populations[4]											
New York (Hudson River - Troy, fall)	2002	672	3320	3.3	2857	2430	902	7365	1718	20	I
	2003	630	2841	2.7	2699	2500	410	4510	1167	15	
	2004	532	1581	1.9	1964	1890	1090	2710	565	12	
	2005	632	3271	8.5	4507	3940	1050	19820	3867	21	
	2006	637	3224	4.4	3210	2220	998	7980	2256	15	

State/Area	Year	Ave. Length (mm)	Ave. Weight (g)	Ave. Lipid (%)	Ave. PCB (ng/g)	Median PCB (ng/g)	Min. PCB (ng/g)	Max. PCB (ng/g)	Std. Dev. (ng/g)	N[1]	Individual (I) or Composite (C); reference
Maryland (Elk River)	2004	460	1009	1.1	158	--	--	--	--	1	I
Maryland (Potomac R.)	2001	484	944	1.8	130	nc	42	320	nc	4	2C5, 2C6: 22 fish
	2003	521	1408	0.65	83	nc	48	147	nc	3	C of 5; 15 fish
Virginia (Tribs of Chesapeake Bay)	2003	449	1155	5.4	33	29	7.5	61	27	3	1C2, 1C4, 1I; 7 fish
Georgia (Savannah R., fall)	2004	688	3492	nr	<30	<30	<30	<30	0	10	I

[1] Number of samples.
[2] nr = not reported.
[3] nc = not calculated
[4] Spawning populations occur in spring. Non-spawning populations are generally sampled in fall.

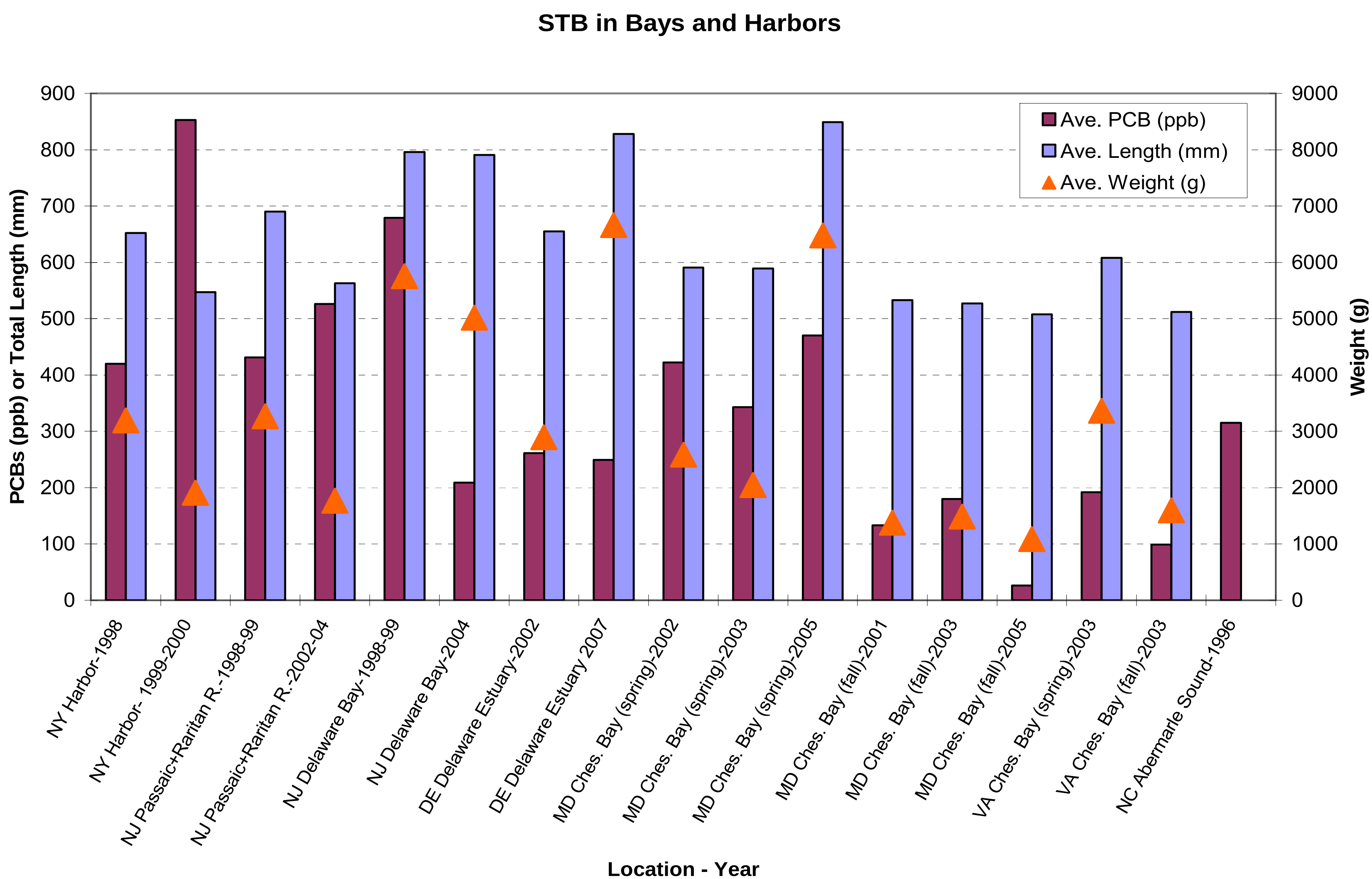


Figure 2-2: Average PCBs, total lengths and weights of striped bass in bays and harbors along the Atlantic Coast.

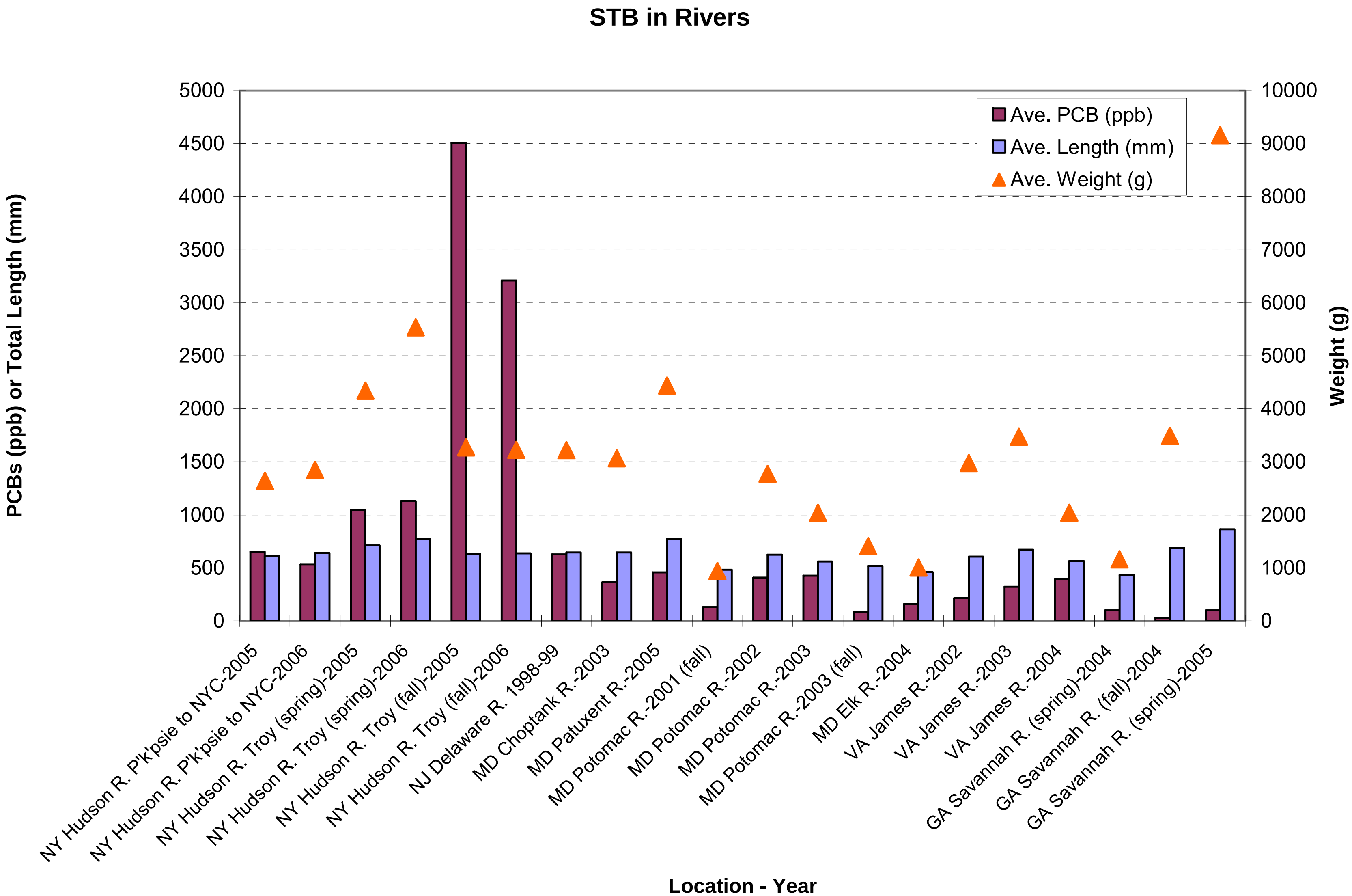


Figure 2-3: Average PCBs, total lengths and weights of striped bass in rivers tributary to the Atlantic Ocean.

Table 2-4: PCBs in Atlantic Coast bluefish less than 508 mm (20 in.).											
State/Area	Year	Ave. Length (mm)	Ave. Weight (g)	Ave. Lipid (%)	Ave. PCB (ng/g)	Median PCB (ng/g)	Min. PCB (ng/g)	Max. PCB (ng/g)	Std. Dev. (ng/g)	N[1]	Individual (I) or Composite (C); references or notes
Connecticut/ New York (Long Island Sound)	2006	411	663	0.83	69	54	18	237	50	25	I; incomplete data set; provisional data from on-going 2-year study
New York/ New Jersey (Bight)	1993	452[2]	1073	9.6	930	nr[3]	590	1490	nc[4]	7	I; Skinner et al., 1996
New York Harbor	1993	349[2]	719	7.4	990	nr	220	3060	nc	27	I; Skinner et al., 1996
	1998	488[2]	1135	6.3	358	nr	159	730	nr	22	I; Skinner 2001
New York (Hudson R.)	1999	168	38	1.2	904	nr	360	1740	nr	18	I; Sloan et al., 2002
New Jersey (Ocean + Raritan R. and Bay)	1998	289	315	3.3	277	308	199	353	70	5	I
	2004	406	704	5.6	367	305	182	587	162	8	I + C of 5 fish; Horwitz et al., 2006
New Jersey (Delaware Bay)	1999	486	949	0.7	330	330	253	407	109	2	I
	2004	350	464	4.8	289	268	112	488	189	3	C of 5 fish

Delaware (Bay + Indian R. Inlet)	2004	314	308	0.9	42	36	16	86	19	15	I
Maryland (Chesapeake Bay)	2002	297	250	2.7	119	82	6.6	310	126	5	I
Maryland (Potomac R.)	2002	285	240	3.0	57	nr	15	80	37	3	I

State/Area	Year	Ave. Length (mm)	Ave. Weight (g)	Ave. Lipid (%)	Ave. PCB (ng/g)	Median PCB (ng/g)	Min. PCB (ng/g)	Max. PCB (ng/g)	Std. Dev. (ng/g)	N[1]	Individual (I) or Composite (C); references or notes
Virginia	2003	294	241	3.9	27	30.6	7.0	42.8	18.2	3	C (2-4/composite)
	2004	264	220	6.6	14	14	5.3	22.5	8.6	3	C (2-3/composite)
North Carolina	1989	314	375	nr	<13	<13	<13	<13	0	5	C (5/composite); whole

1 Number of samples.
2 Size range sampled extended to 559 mm (22 in.).
3 nr = not reported.
4 nc = not calculated. Data reported for individual areas and size categories.

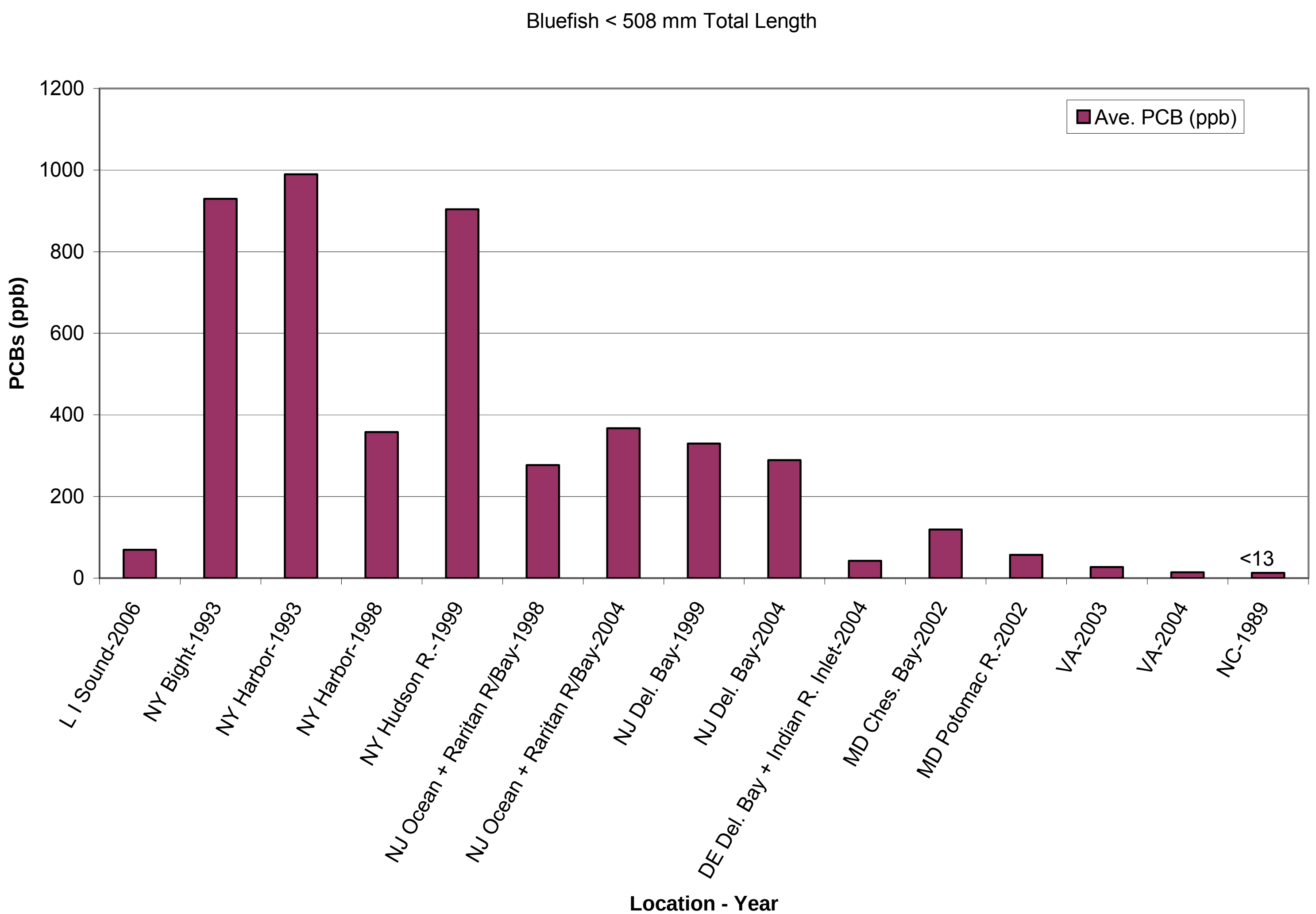


Figure 2-4: Average PCBs in bluefish less than 508 mm (20 in.) along the Atlantic Coast.

Table 2-5: PCBs in Atlantic Coast bluefish greater than 508 mm (20 in).											
State/Area	Year	Ave. Length (mm)	Ave. Weight (g)	Ave. Lipid (%)	Ave. PCB (ng/g)	Median PCB (ng/g)	Min. PCB (ng/g)	Max. PCB (ng/g)	Std. Dev. (ng/g)	N[1]	Individual (I) or Composite (C); references or notes
Maine	2002	788	nr[2]	5.3	658	619	119	1053	402	5	I; Kennebec River
	2004	781	nr	1.2	161	143	77	301	83.9	5	I; Old Orchard Beach
Connecticut	1997	655	2761	6.7	832	503	96	5577	nr	60	I; Rusnak, 2005
Connecticut/New York (Long Island Sound)	2006	684	2716	3.8	483	nr	51	3170	440	111	I; Incomplete data set; provisional data from on-going 2-year study
New York/ New Jersey (Bight)	1993	648[3]	2508	13.6	760	nr	200	1420	510	5	I; Skinner et al., 1996
New York Harbor	1993	757[3]	2997	9.9	2670	nr	580	8800	nc[4]	19	I; Skinner et al., 1996
New Jersey (Ocean + Raritan R. and Bay)	1997-1999	756	3973	7.7	587	500	204	1330	306	31	I; Horwitz et al., 2006
	2004	735	3467	5.6	473	306	69	1820	440	19	

New Jersey (Delaware Bay)	1999	724	3341	4.8	949	917	913	1017	59	3	I
Delaware	2004	750	nr		297					1	I
	2005	722	3137	1.3	574	309	114	2040	532	14	

[1] Number of samples.
[2] nr = not reported.
[3] Size range is 559 mm or greater.
[4] nc = not calculated. Data reported for individual areas of harbor.

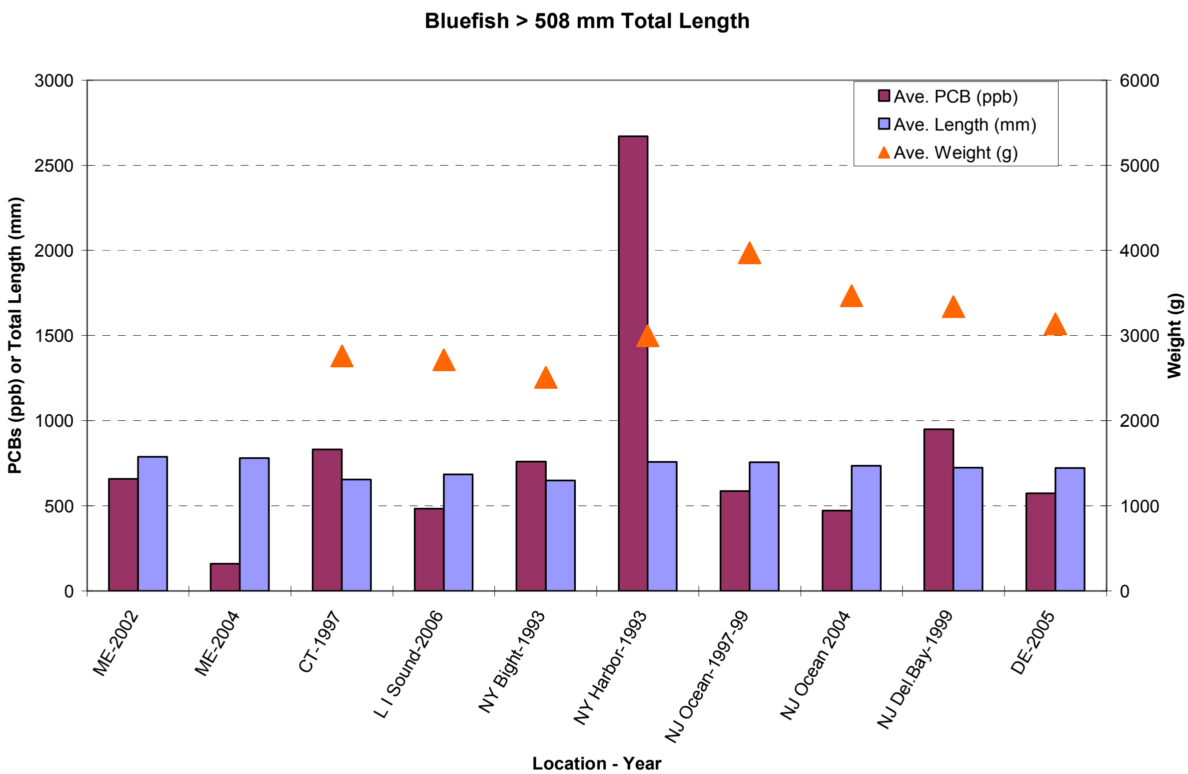


Figure 2-5: Average PCBs, total length and weight of bluefish greater than 508 mm (20 in.) from along the Atlantic Coast.

B. Length-PCB Relationships in Striped Bass and Bluefish

Length-contaminant relationships have been frequently reported for fish taken from freshwaters but less often for fish taken from the marine environment. The relationship, where it exists, is normally a function of the duration of exposure where exposures are relatively constant. The correlation normally improves when the age of the fish has been determined. In striped bass and bluefish from along the Atlantic Coast, two different situations appear to exist.

Striped bass taken from Long Island Sound during 2006 showed no length-PCB relationship (n = 103) nor is there any apparent relationship for this species in New York Harbor in 1998 (Figure 2-6). This observation is consistent with the lack of a length-PCB relationship observed for striped bass in 1994 for the entire marine district of New York, and for the Hudson River during most years between 1977 and 1994 (Sloan et al., 1995). The lack of a size-PCB correlation in striped bass has continued within the Hudson River through 2006. When significant correlations do exist they were weak, and as a consequence, in New York waters any significant correlations between length of striped bass and PCB concentration are considered spurious (Sloan et al., 2005). This applies to Connecticut waters of Long Island Sound as well. However, sufficient evidence is lacking for determining the presence or absence of a length-PCB relationship for striped bass populations elsewhere along the Atlantic Coast.

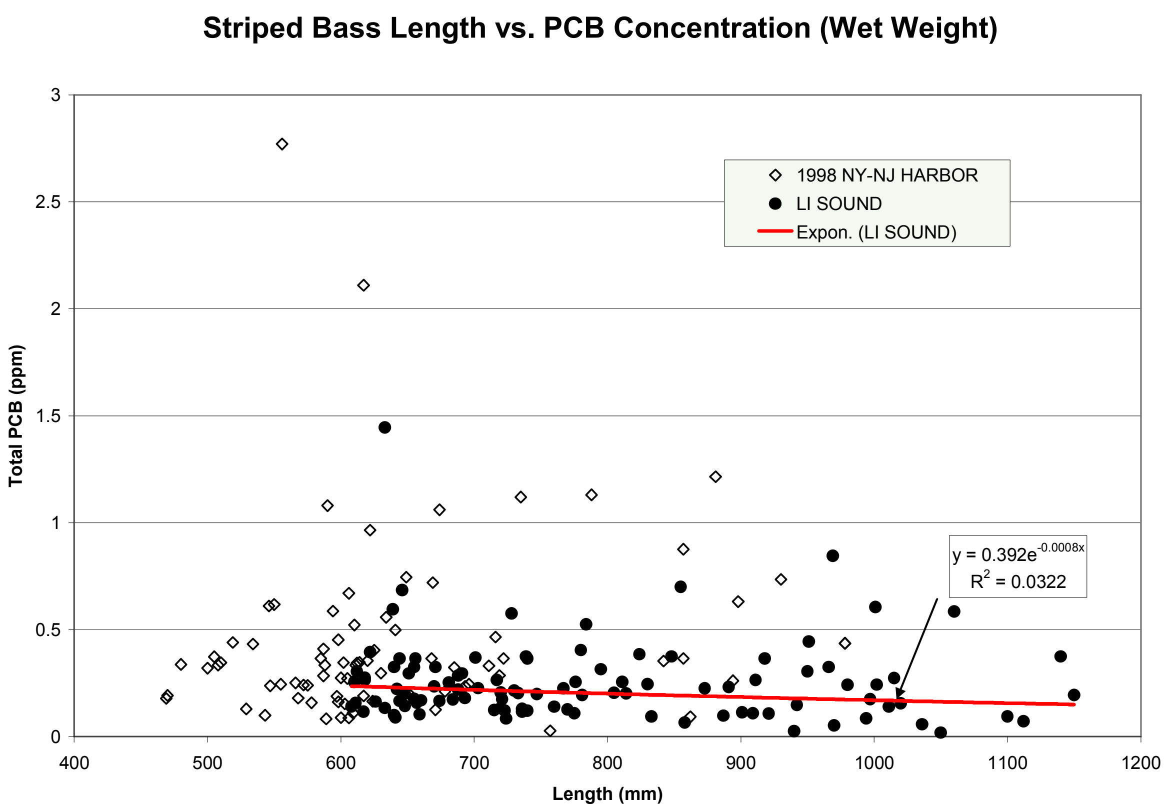
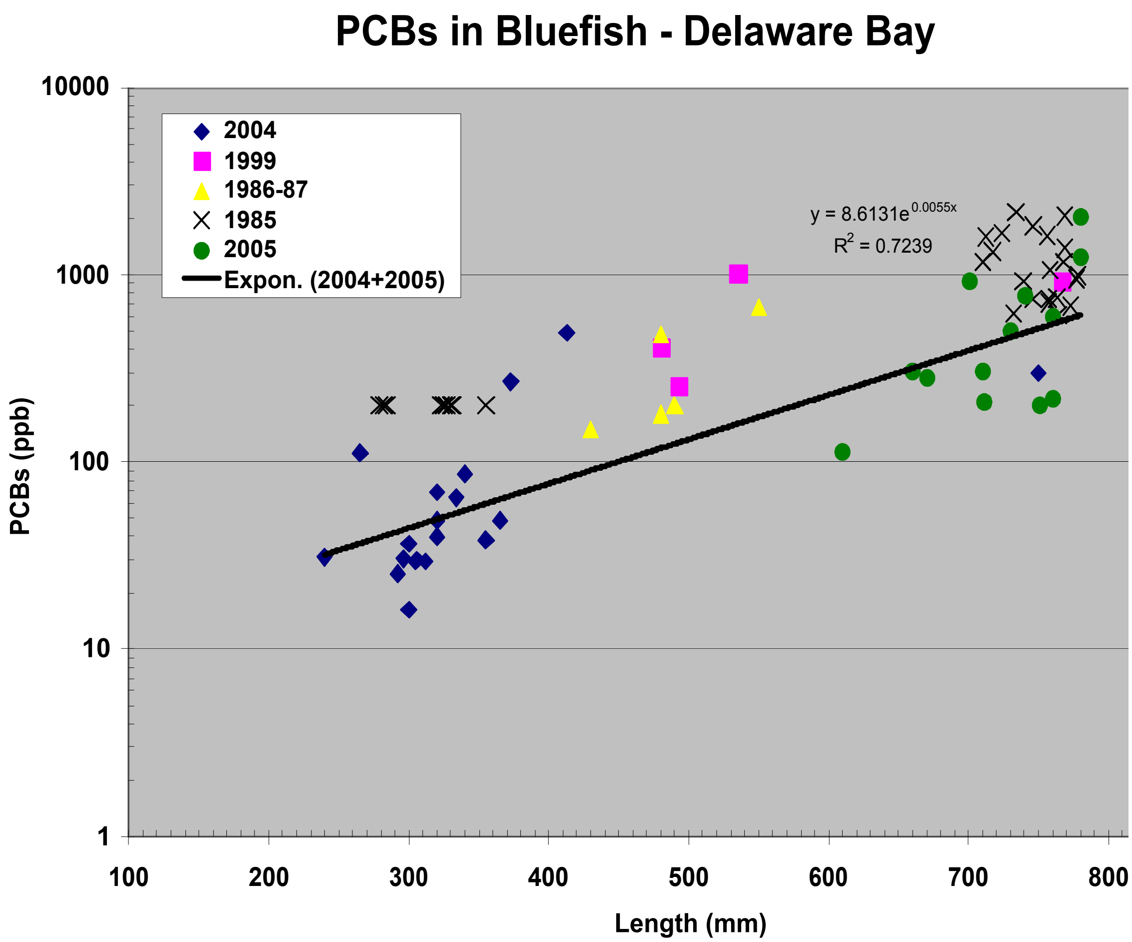


Figure 2-6: The lack of a length-PCB relationship for striped bass taken from Long Island Sound in 2006. Total PCB in standard filets on a wet weight basis.

A series of collections of bluefish from Delaware Bay from 1985 through 2005 were analyzed for PCBs. When the data are combined it produces what appears to be a significant correlation between length and PCB concentration (Figure 2-7). However, there is an expectation that PCB levels have declined within the 20 year period examined and as observed within Figure 2-7. Therefore, data for 2004 and 2005 only were examined. A distinct difference in PCB concentrations is evident in bluefish less than 450 mm collected in 2004 (n = 17) when compared to bluefish greater than 600 mm and collected in 2005 (n = 11). Long Island Sound bluefish collections in 2006 (n = 136) further refines and strengthens the significant (p<0.001) length-PCB relationship (Figure 2-8). These observations support the strong size-PCB concentration relationship in bluefish along the entire Atlantic Coast reported in a federal study conducted in 1984-1985 (NOAA/FDA/EPA, 1986). Duration of PCB exposure, i.e., smaller younger fish contain lower PCB concentrations than larger older fish, is believed to be the primary factor which would explain the observed relationship.

Figure 2-7: Length-PCB relationship in Delaware Bay bluefish.



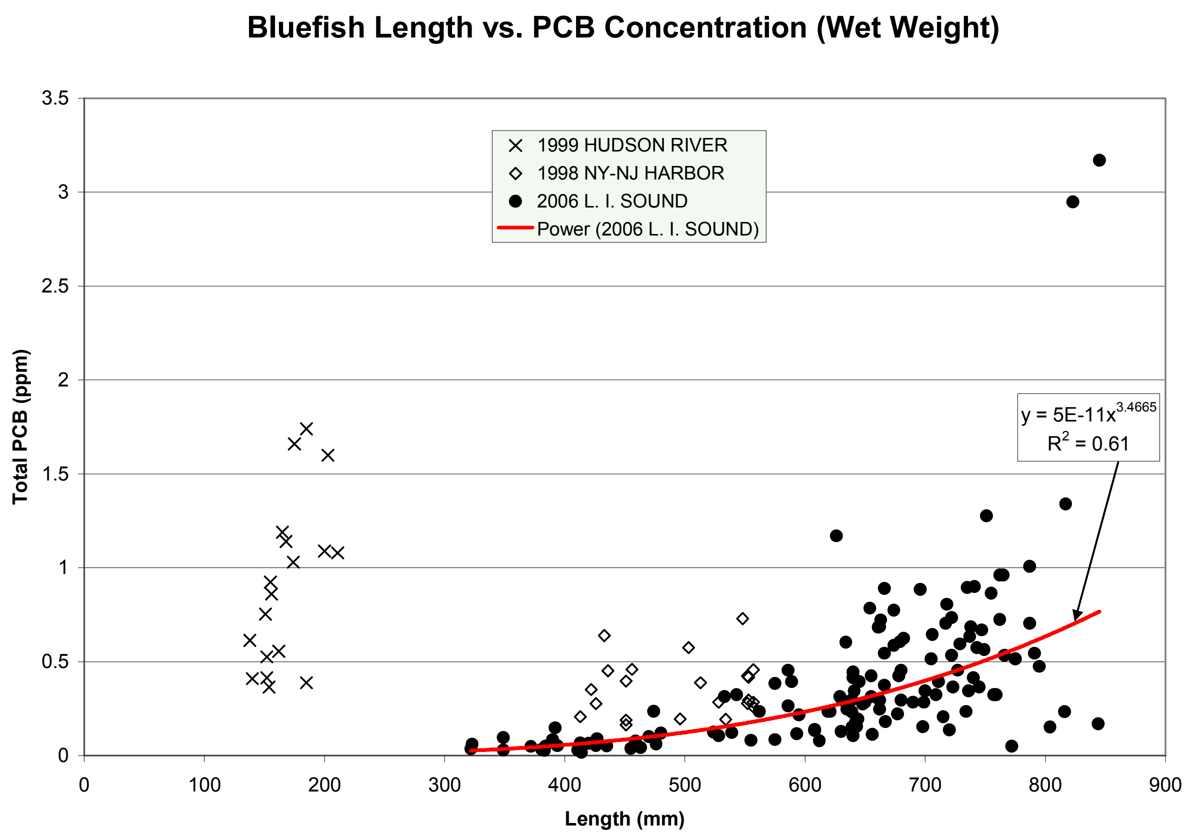


Figure 2-8: Length-PCB relationship for Long Island Sound bluefish.

For New York, it is interesting to note substantially elevated PCB concentrations in young-of-year bluefish (snappers) taken in 1999 from the lower Hudson River (Figure 2-8), a river which contains known sources of PCBs and consequently produces for fish greater exposures to PCBs.

C. State Specific Information

Each state had varying resources to examine PCBs in striped bass and bluefish, and employed differing collection, sample preparation and analytical techniques. Data use and interpretation must be tempered by these observed differences. Important information useful in evaluating the differences are enumerated for each state hereafter and include collection year, location of collection, number of samples, size, sex and age of fish (where available), collection season, sample portion analyzed, analytical methodology, and quantitation methods. Sample portions, analytical methods and PCB quantitation employed are summarized in Table 2-6. States also vary in how they define a legal fish (e.g., minimum size limits), so states are targeting different sized fish (see Table 2-1 for targeted lengths of fish). All of these factors may increase the level of uncertainty in data interpretation and analysis. All data included in this report are reported as total PCBs on a wet weight basis in units of ng/g (ppb).

1. Maine

Maine collected legal sized striped bass (508 to 660 mm and over 1016 mm) in June of 2002, 2004 and 2006 while bluefish (all sizes are legal) were collected in June 2002 and 2004. All data were analyzed as individual fish, filet, skin off. Fish collected in 2002 were analyzed by the Texas A and M GERG Lab. Fish collected in 2004 were analyzed by Pace Analytical Services, Inc. Fish collected in 2006 were analyzed by AXYS Analytical Services, Ltd. All fish were analyzed for 209 congeners, and a subset of fish was also analyzed via the homologue method in 2002. Total PCBs are the sum of detectable PCB congeners; congeners at less than detection limits were treated as zero.

Striped Bass: Striped bass were sampled in the tidal portions of seven selected rivers (Penobscot, Kennebec, Androscoggin, Royal, Scarborough, Saco and York Rivers) draining central and southern Maine and a portion of New Hampshire. All rivers were not sampled in each year. Historic discharges of PCBs are known for the Kennebec and Androscoggin Rivers. In addition, a small spawning population of striped bass is believed to occur in the Kennebec River (Flagg and Squires 1999). Five fish were collected and analyzed from each location in 2002 and 2004 while three fish per location were taken and analyzed in 2006. Weights were not recorded in 2002.

The populations sampled are believed to represent coastal stocks rather than specific stocks for each specific location. Significant differences in PCB concentrations between locations were seldom evident. Therefore, the data for all locations are combined by year in Table 2-2.

Average PCB concentrations were 172 ppb in 2002, 176 ppb in 2004, and 133 ppb in 2006. Minimum PCB values were about 55 ppb or less while maximum PCB levels ranged from 722 ppb in 2002 to 432 ppb in 2006. Lipids ranged from 1.6 to 3.0 percent.

Bluefish: Adult bluefish were sampled from the tidal portion of the Kennebec River and off Old Orchard Beach (in southern Maine). The data are summarized separately in Table 2-5 due to the significant difference in PCB concentrations on a wet weight basis.

Five bluefish with an average length of 788 mm taken from the Kennebec River in 2002 contained 658 ppb PCB, (range 119 ppb to 1053 ppb), and 5.3 percent lipid content. Five bluefish taken off Old Orchard Beach in 2004 had an average PCB concentration of 161 ppb (range 77 ppb to 301 ppb), and an average lipid content of 1.2 percent. If the PCB data are normalized to lipid content, the differences in PCB levels cease to exist. The differing PCB levels observed are a function of lipid content.

2. New Hampshire

Recent PCB data were not available for either striped bass or bluefish from New Hampshire waters. Data generated by Maine and Massachusetts are believed to adequately represent PCB conditions in striped bass and bluefish within New Hampshire waters.

Table 2-6: Fish sample portions analyzed and analytical methods for PCBs employed.

State	Sample portion		Analytical method	PCB quantification[1]
	Striped bass	Bluefish		
Maine	Filet - skin off	Filet - skin off	EPA Method 1668A	209 congeners
New Hampshire	None	None		
Massachusetts	Standard filet[2]	None	Schwartz et al., 1998	19 congeners
Rhode Island	Standard filet	None	EPA Method 8080	7 Aroclors
Connecticut	None	Scaled filet	FDA PAM 211.13f modified[3]	Aroclors 1254 and 1260
Connecticut + New York	Standard filet	Standard filet	MSCL NY4[4]	6 Aroclors
New York	Standard filet	Standard filet	MSCL NY4[4]	6 Aroclors
New Jersey	Filet - skin off with belly flap	Filet - skin off with belly flap	EPA Method 8082, see [5]; coplanars by EPA Method 1668	110 congeners through 2002; 125 congeners in 2004
Pennsylvania	None	None		

Delaware	Filet - skin on	Filet - skin on	In 1992 -99: EPA Methods 8290 and 680 In 2002 - 2007: EPA Method 1668A	1992 - 1999: 47 to 79 congeners + 10 homologs 2002 + 2007: 209 congeners
Maryland	Standard filet	None	USEPA (1981)	97 peaks representing 134 congeners
Virginia	Edible filet	Edible filet	Draft EPA Method 1668 (USEPA 1997)	~ 100 congeners
North Carolina	Filet	Whole fish	Not available	Aroclors
South Carolina	None	None		
Georgia	Edible filet	None	EPA Method 8082	9 Aroclors
Florida	None	None		

[1] Total PCBs are quantified as the sum of detectable PCB Aroclor, homolog or congener concentrations.
[2] Standard filet is a filet with skin and belly flap on; scales are removed.
[3] See method in Appendix 2-1.
[4] Mississippi State Chemical Laboratory New York Method 4; see Appendix 2-2.
[5] New Jersey samples quantified per methods of Swackhamer (1987).

3. Massachusetts

Striped Bass: State surveys measured PCB concentration in skin-on filets of striped bass collected in 1997 (Schwartz et al., 1998) and 1998 over a wide geographic area of state coastal waters. Nineteen PCB congener peaks were identified and summed as total PCBs based on a 1:1 mixture of Aroclor 1254 and 1260, which matched the PCB pattern observed in the striped bass samples. PCB concentrations are provided as parts per billion (ng/g) wet weight. Field data were recorded for the dates, locations and numbers of fish collected along with total length, weight, sex, and age.

Seventy-six individual striped bass were analyzed. Mean total length was 33 inches (840 mm) with a range of 28 to 41 inches (711 to 1041 mm). The mean total PCB concentration was 291 ppb (std. dev. = 199; 95% confidence interval = 46 ppb), with a range of 47 to 1400 ppb (Table 2-2).

Bluefish: There were no recent bluefish data available.

4. Rhode Island

Data for striped bass and bluefish being generated by Connecticut and New York for Long Island Sound in 2006 may be applicable to Rhode Island due to sharing of a common border. The stocks are not believed to be different. Similarly, data for striped bass provided by Massachusetts are applicable also.

Striped Bass: The available PCB data on striped bass from Rhode Island waters consists of 34 samples collected in 1996 (Table 2-2). These data were submitted to NY State to allow the commercial sale of striped bass in New York State (Sloan et al., 2005). PCB concentrations averaged 190 ppb in fish averaging 788 mm in length. The data appear spuriously low, given the relatively higher concentrations found in striped bass from adjoining waters such as eastern Long Island Sound and in Massachusetts at the time of collection. Striped bass, even though migratory, tend to reflect localized source conditions (Sloan et al. 1995, 2005, Skinner et al. 1996) but Rhode Island exposures should be comparable.

Bluefish: There are no additional bluefish data available.

5. Connecticut

Striped Bass: See 6. Connecticut and New York.

Bluefish: Connecticut's most recent data (Rusnak, 2005) consists of bluefish caught and analyzed in 1997. A total of 60 bluefish were collected in fall 1997 in Long Island Sound. The locations are georeferenced. The Connecticut Department of Public Health Laboratory analyzed scaled individual filets for Aroclors 1254 and 1260. The detection limit was 100 ppb. The average length was 656 mm (431-885 mm), the average weight was 2,761 grams (780-6,940 g) and the average percent lipid was 6.7% (1.2-22.7%). The average PCB concentration was 832 ppb, and the median concentration was 503 ppb. The minimum and maximum concentrations were 96 ppb and 5,577 ppb, respectively (Table 2-5).

Also, see “6. Connecticut and New York” for further information on PCBs in bluefish.

6. Connecticut and New York

Connecticut and New York are conducting a 2-year bi-state assessment of PCB concentrations in striped bass and bluefish taken from Long Island Sound. Sampling was being conducted in 2006 and 2007. Preliminary results are reported for 2006 samples. The data reported here will change based on data being generated for 2007 collections and, if needed, any finding of quality assurance reviews. However, the range in PCB values reported are not expected to change significantly, thus, the data are used here to aid the general characterization of PCBs in coastal stocks of fish. In addition, the eastern portion of the study area borders on Rhode Island, thus, the information may be applicable for their coastal stocks as well.

The study design separates Long Island Sound into four areas (western, north central, south central, and eastern areas). The segregation into areas is based on observed spatial differences in PCB concentrations in striped bass during past sampling efforts (Sloan et al., 1988, 1995) and an effort to minimize any potential bias in sampling. Sampling in each area is conducted during two seasons, i.e., in spring-early summer and in late summer-fall. During the two years of the study a total of twenty striped bass larger than 610 mm are to be taken from each sampling area during each season (160 fish total). All PCB analyses are conducted on standard filets of individual specimens.

For bluefish, sampling reflects the size-PCB relationships demonstrated by the 1985 federal study of PCBs in coastal bluefish (NOAA/FDA/EPA, 1987). Two size groups with differing sample numbers are required over the two-year period, i.e., five fish per area per season for bluefish 305 to 508 mm in total length, and 20 bluefish per area and season for fish greater than 508 mm. The total potential bluefish sample sizes are 40 smaller bluefish and 160 large bluefish. All PCB analyses are conducted on standard filets of individual specimens.

Striped bass: As stated previously (Section II. B.), there were no significant length-PCB relationships for striped bass from Long Island Sound. Further, in 2006, there were no spatial differences in PCB concentrations in striped bass from the Sound. For the 103 fish analyzed (Table 2-2), the average PCB concentration was 253 ppb with a minimum of 19 ppb and a maximum of 1445 ppb. The range in length of fish sampled was 608 to 1150 mm, average of 787 mm. Lipid content averaged 1.5 percent.

Bluefish: As stated in Section II B., a length-PCB relationship exists for bluefish taken from Long Island Sound. The 25 smaller bluefish (305 to 508 mm) had an average PCB concentration of 69 ppb with a minimum of 18 ppb and maximum of 237 ppb (Table 2-4). The 111 bluefish greater than 508 mm had an average PCB concentration of 483 ppb, with a minimum of 51 ppb and a maximum of 3170 ppb. There were no spatial differences in PCB levels. The size range sampled was 322 to 845 mm (Table 2-5).

7. New York

The most extensive PCB data collected on striped bass consists of the data collected since the 1970's for the Hudson River (Spagnoli and Skinner, 1977; Horn et al., 1979,; Sloan et al., 2005). New York has measured the concentrations of PCBs in various species of fish as part of a monitoring program examining the large scale PCB discharges in the upper Hudson River. The following provides some general information excerpted from Sloan et al. (2005) and supplemented by data from collections in 2004 through 2006. Sloan et al. (2005) found that generally upstream Hudson River fish had greater PCB concentrations than downstream fish. They ranked the locations from highest to lowest in PCB concentrations for striped bass, which also were in downstream order, as: Albany/Troy > Catskill > Poughkeepsie ≈ Tappan Zee ≈ George Washington Bridge.

Striped Bass: In the lower Hudson River (Poughkeepsie to New York City), data from 2002 (Sloan et al., 2005) indicate that striped bass averaged 849 ppb PCBs based on a sample of 67 males and 7 females (data from 1 female with a PCB concentrations of 52,980 ppb was not used, average PCBs with this sample would be 2,240 ppb). Fish averaged 3.2% lipids, 671 mm in length and 3,397 g in weight. Female fish averaged 460 ppb PCBs and male fish averaged 890 ppb PCBs. There were no female fish collected in 2003, but the male fish average PCB concentration was 855 ppb for this stretch of the Hudson River. In the three years since 2003, and without considering differences in PCBs based on sex of the fish, average PCB concentrations have ranged from 479 ppb to 653 ppb. Lipid concentrations were about three percent each year. Although minimum PCB levels have generally been 100 ppb or less, the maximum values have ranged up to 5340 ppb (Table 2-3). These high levels of PCBs are often outliers and may have a substantial impact on the mean despite the relatively large sample sizes.

In the upper Hudson River estuary by Troy, NY (RM 153) during spring 2002, 41 striped bass averaged 2,110 ppb PCBs (range of 100-7,360 ppb). These fish averaged 727 mm in length, 4,541 g in weight and 3.7 % lipid (0.6-12.3%). In 2003, 35 striped bass averaged 1,960 ppb PCBs (range 310 – 6,530 ppb) for fish averaging 2.6% lipid. The 2003 fish were smaller than the 2002 fish and averaged 646 mm in length and 3,213 g in weight. For 2004 and 2005, the mean PCB concentrations in striped bass from Troy showed great variability primarily due to extreme outlier concentrations (up to 115,960 ppb). Exclusion of three outliers for 2004 reduced the mean PCB value to 2066 ppb in 17 samples from 10,500 ppb in 20 samples. For 2005 samples exclusion of one outlier reduced the mean PCB from 3909 ppb in 30 samples to 1049 ppb in 29 samples. These alternative mean values are more consistent with historic data but are indicative of the potential data assessment issues when fish are taken in closer proximity to PCB sources. For 2006 samples, the mean PCB concentration was 1129 ppb (range from 110 ppb to 7100 ppb) for 20 striped bass (Table 2-3).

In the mid- to late 1990s, there were requests from several Atlantic Coast states to review their striped bass PCB data in order to allow commercial sales in New York State markets. Hence, there was an opportunity to further compare PCB results from other states to Hudson River conditions (Figure 2-9). Even though the 1998 Hudson River comparison year reflected average concentrations, on a wet weight basis, as being less than 2 ppm for all striped bass below Catskill, the results from the other states were usually substantially lower compared to the Hudson River samples regardless of location. The other Atlantic states, upon review of the data by New York State, were eventually allowed to sell striped bass in New York commercial markets since they met the US Food and Drug Administration tolerance of 2.0 ppm. These states included Massachusetts, Rhode Island, Delaware, Maryland, Virginia, and North Carolina.

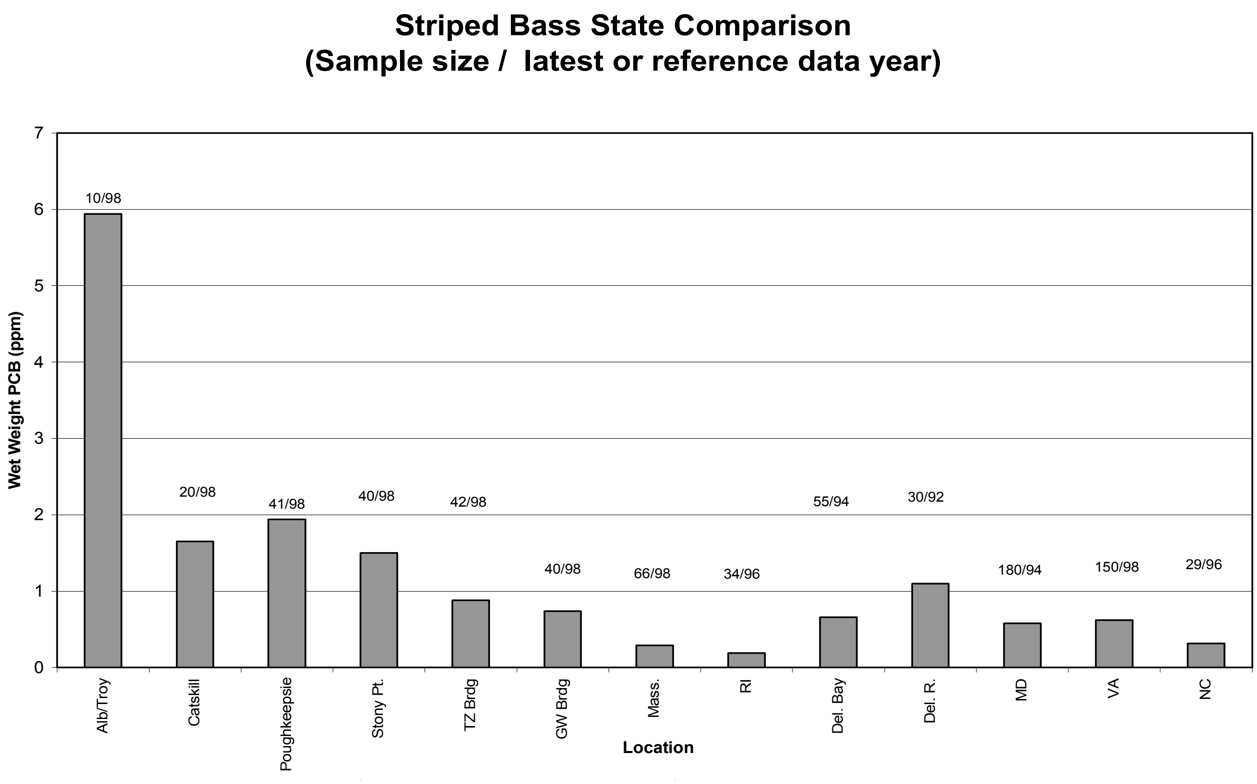


Figure 2-9: Average PCB concentrations in striped bass from other states (data submitted to NY to allow commercial sales in NY markets) compared to striped bass at several Hudson River locations.

Data on striped bass were collected in New York-New Jersey Harbor in 1999-2000 as well as the New York Bight (Atlantic Ocean waters between Long Island and New Jersey) (McReynolds et al., 2004). PCB concentrations averaged 1,141 ppb in 74 samples from several locations in the NY-NJ Harbor (range 99 ppb to 22,149 ppb). Fish averaged 547 mm in length, 1909 g in weight and lipids averaged 3.7%. PCBs in striped bass averaged 411 ppb in 17 samples from the NY Bight. These fish averaged 556 mm in length, 1896 g in weight and 2.8% lipids (Table 2-3).

New York also collected PCB data on striped bass in Long Island Sound which borders Connecticut. Data from 1994 (Sloan et al., 1995) indicated striped bass average PCB concentrations of 1,175 ppb (range 240 ppb to 5750 ppb) for 303 samples collected during the spring, summer and fall. Fish averaged 688 mm in length and 3811 g in weight, and lipids averaged 4.5% (Table 2-2).

Bluefish: Recent bluefish data from NY waters are more limited. Skinner (2001) collected 22 bluefish samples from the New York Harbor in 1998 (Table 2-4). Fish averaged 488 mm in length, 1135 grams in weight and 6.3% lipids. Average PCB concentrations were 358 ppb (159 ppb to 730 ppb). Fish collected in the NY Bight in 1993 averaged 664 ppb PCBs (range 385 ppb to 1132 ppb for 14 samples) (Skinner et al. 1996). Fish averaged 561 mm in length, 2522 g in weight and 6.8% lipids (Table 2-5). Eighteen samples of bluefish were collected from the Hudson River in 1999 (Sloan et al. 2002). The fish were much smaller when compared to all other collections and averaged 168 mm in length, 38 g in weight and only 1.2% lipids. These Hudson River fish averaged 904 ppb PCBs (range 360 ppb to 1,740 ppb) (Table 2-4).

8. New Jersey

In 1976, NJDEP instituted a comprehensive program to survey possible contamination of fish and shellfish in New Jersey waters. The initial result of these studies showed elevated levels of PCB contamination in certain estuarine species of fish (i.e., striped bass, bluefish, and American eel). In general, the data showed that saltwater and migratory species tended to have higher concentrations than freshwater species. Other important recreational and commercial fish (e.g., summer and winter flounder, weakfish, smallmouth and largemouth bass, perch, carp, etc.), however, did not exhibit elevated levels of PCBs. These results prompted NJDEP to issue the first NJ fish consumption advisories for PCBs in several recreational marine/estuarine species in 1982 including striped bass and bluefish. Subsequent monitoring activities were then targeted at these species.

NJDEP's Division of Science, Research & Technology (DSRT) conducted an estuarine/marine survey from 1997-1999 in conjunction with the Academy of Natural Science of Philadelphia (ANSP) (Ashley & Horwitz, 2000). These combined data are discussed below. PCB analyses included congener specific analysis for 110 congeners and co-eluters using GC/ECD. All congener concentrations were added to estimate a total PCB concentration. Data for 2002 collections of striped bass from the Passaic River were included in Horwitz et al. (2005).

More recently, in 2004, DSRT and ANSP conducted a study of PCB, pesticide and mercury concentrations in selected fish species, including striped bass and bluefish, collected from NJ's estuarine and marine waters (Horwitz et al., 2006). A total of 125 PCB congeners (includes coeluting PCBs) were determined.

Striped Bass: Coastal stocks of striped bass were sampled in 1998-99 and 2004. PCB values averaged 417 ppb in 1998-99 but declined to 221 ppb in 2004. Minimum values in both periods were about 85 ppb while maximum concentrations were 1092 ppb and 1270 ppb in 1998-99 and 2004, respectively. Lipid levels declined as well from 3.3 % to 1.8 % (Table 2-2).

Striped bass from Delaware Bay showed a change in PCB levels from 679 ppb in 1998-99 to 209 ppb in 2004 but this decline is coincident with a major decline in lipid content from 4.4 % to 0.3 % in the respective years. Fish were of similar lengths (average about 790 mm) each year. Minimum and maximum PCB values were not substantially different, i.e., minimums were 150 to 200 ppb and maximums were 1465 ppb and 1280 ppb in the respective years (Table 2-3). Raritan Bay was sampled in 1998-99 when striped bass averaging 690 mm contained 431 ppb PCB (minimum 139 ppb, maximum 819 ppb). Lipid content averaged 2.3 %. For sampling results from the Passaic River (2002) and the Raritan system (2004), striped bass averaged 563 mm and exhibited average PCB concentrations of 526 ppb (minimum 133 ppb, maximum 1465 ppb). Average lipid content had declined to 1.8 % (Table 2-3).

Bluefish: This species was collected from six locations in 1997-99. Five bluefish less than 508 mm from the ocean or the Raritan system contained an average of 277 ppb PCB (minimum 199 ppb, maximum 353 ppb) while two fish from Delaware Bay had 300 ppb PCB (average of 253 and 407 ppb). In 2004, eight samples from the ocean and Raritan system contained an average of 367 ppb whereas Delaware Bay composite samples averaged 289 ppb PCB. Substantial increases in lipid content were evident between the two sampling periods (Table 2-4).

For large bluefish (>508 mm), Delaware Bay was sampled in 1999 when three fish averaged 949 ppb PCB (minimum 913 ppb, maximum 1017 ppb). Lipid content was 4.8 percent. Bluefish taken from 1997 through 1999 from the Atlantic Ocean and the Raritan system (n = 31) contained 587 ppb PCB with maximum PCBs of 1330, minimum of 204 ppb. In 2004, average PCBs declined to 473 ppb while the maximum PCB increased to 1820 ppb (minimum 69 ppb) (n=19). Lipid content was 7.7 % and 5.6 % in 1997-99 and 2004, respectively (Table 2-5).

Overall, on a regional basis, bluefish averaged 300 ppb PCBs along the coast, 289 ppb in Delaware Bay, and 778 ppb in the Raritan-Passaic complex.

9. Pennsylvania

While not a "coastal state", Pennsylvania was included due to it's bordering the Delaware Estuary and the presence of a striped bass fishery in Pennsylvania waters of the Delaware River. However, no PCB data were available for the state. PCB data for striped bass generated by Delaware and New Jersey for the Delaware River estuary may be considered representative of striped bass in Pennsylvania waters of the estuary.

Striped Bass: No data were available for striped bass.

Bluefish: No data were available for bluefish.

10. Delaware

Striped Bass: The State of Delaware collects striped bass from the Delaware Estuary from two locations: the open waters of the Delaware Bay and up estuary in the tidal Delaware River. Land use/land cover adjacent to the Delaware Bay location is largely salt marsh and agriculture, whereas land use/land cover adjacent to the tidal river are urban (Philadelphia, Camden, Wilmington), with significant industrial use directly along the waterfront. Results from monitoring are used to determine if there are significant differences in contaminant levels between the two sampling locations and to track changes over time. This paired sampling approach was used in 1992, 1997, 2002, and in 2007. Typically, five individual adult striped bass are collected from the Delaware Bay in late February prior to the species' migration up river to spawn. Five additional striped bass are then collected in early to mid-May in the tidal River near the Cherry Island Flats, an important spawning area for striped bass. Similarly sized fish are collected at both locations to facilitate comparison of tissue contaminant levels between the two sites. Further, males are targeted in a deliberate effort to preserve the female spawning stock.

All striped bass samples collected by Delaware have been analyzed for PCBs using congener-specific methods. Samples collected in 1992 and 1997 were analyzed for a subset of congeners based on their mammalian toxicity, abundance in parent Aroclors, and detection in other well-conducted studies. The congener testing for the 1992 and 1997 samples were supplemented with homolog testing to ensure that total PCB mass in the fish was being fully characterized. The 2002 and 2007 samples were analyzed for all 209 possible congeners using EPA Method 1668A with a separate DB1 carbon column to get greater chromatographic separation of particular congeners. Total PCBs for the 2002 and 2007 samples were simply calculated as the sum of all 209 congeners, including any coeluting congeners. Congeners below detection were treated as zero.

For the most recent samples (2007), total PCBs in the Delaware Bay samples (n = 5) ranged from 182 ppb to 451 ppb wet weight with a mean of 266 ppb. For this same year, total PCB ranged from 109 ppb to 378 ppb for Delaware River striped bass samples, with a mean of 232 ppb (n = 5) (data is combined in Table 2-3). For all ten samples, the average length, weight and lipid content were 828 mm, 6661 g, and 2.7 percent, respectively.

Bluefish: Bluefish have not been a major focus for Delaware's fish tissue monitoring program. Consequently, historical data are sparse. However, with the issuance of a fish advisory for bluefish caught in the Delaware Estuary in 2004 as part of a joint action with the State of New Jersey, Delaware has expanded bluefish testing in Delaware coastal waters. During 2004, Delaware collected a total of 16 bluefish samples from its coastal waters. In 2005, Delaware collected 14 additional bluefish samples. All samples were individual fish. Skin-on filets were retained for chemical analysis. Results for the 2004 fish are available and are reported below.

Ten of the samples collected in 2004 were collected from the Delaware Bay; five of the samples were collected from the Indian River Inlet (connects the Atlantic Ocean and the Indian River Bay in southern Delaware); and a single sample was collected in the Atlantic Ocean ~ 31.6 miles east southeast of the Indian River Inlet. The 10 samples from the Delaware Bay and the 5 samples from the Indian River Inlet were "snapper blues". The average length for the Delaware Bay samples was 306 mm, with a range from 292 mm to 334 mm. The average length for the Inlet samples was slightly larger at 340 mm, with a range from 320 mm to 365 mm. In contrast, the single bluefish caught offshore during 2004 was much larger at 750 mm. The 2005 bluefish were also large, with an average length of 722 mm and a length range between 610 mm and 780 mm.

The total PCB concentration in the 10 bluefish samples collected in 2004 from Delaware Bay ranged from 16.2 to 68.8 ppb wet weight with a mean of 36.2 ppb. The mean for the five bluefish samples collected in 2004 from the Indian River Inlet was 52.4 ppb with a range from 38.4 to 86.4 ppb. For both data sets, little of the variability in total PCB was explained by variability in fish length or lipid content. The data for these two locations are combined in Table 2-4. Finally, the total PCB concentration in the single large bluefish collected offshore in 2004 was 297 ppb (Table 2-5).

The 2005 adult bluefish (n = 14 fish) contained 574 ppb PCB with a minimum PCB of 114 ppb and maximum of 2040 ppb. Lipids averaged 1.3 % (Table 2-5).

11. Maryland

Striped Bass: Data were available for striped bass for the years 2001 to 2005. Striped bass samples were collected from Chesapeake Bay (42 PCB samples), the Potomac River (25 samples), the Choptank River (10 samples), the Patuxent River (3 samples) and Elk River (1 sample) using both individual fish (35 specimens) and composites of four to six fish (46 samples). Samples were analyzed for 134 PCB congeners using GC/ECD at the University of Maryland Chesapeake Biological Laboratory using skin-on filets. The 272 striped bass collected ranged in size from 457 mm to 900 mm with an average size of 580 mm and an average wet weight of 2,158 g (range: 746 – 7,428 g). Lipids averaged 3.3 % and ranged from 0.09 to 12.8 %. PCB concentrations averaged 262 ppb (wet wt) and ranged from 16 ppb to 1,095 ppb. The data for individual locations are provided in Table 2-3.

Bluefish: In 2002, "snapper" bluefish were taken from Chesapeake Bay (5 specimens) and the Potomac River (3 individuals). Lengths of the eight fish ranged from 255 mm to 320 mm and weights ranged from 155 g to 295 g. Lipids ranged from 0.89 to 5.2 percent with averages of 2.7 and 3.0 percent for Chesapeake Bay and the Potomac River, respectively. PCB concentrations differed by location with an average of 119 ppb in bluefish from Chesapeake Bay and 57 ppb in fish from the Potomac River. PCB concentrations ranged from 7 ppb to 310 ppb (Table 2-4). Adult bluefish were not sampled.

12. Virginia

Virginia collected striped bass samples in 2002, 2003 and 2004, and bluefish samples in 2003 and 2004. The minimum legal size of striped bass in different Virginia waters ranges from 18 (457 mm) to 28 (711 mm) inches, although the Chesapeake Bay and coastal spring trophy-size striped bass recreational fisheries minimum legal size is 32 inches (813 mm). With a few exceptions, most striped bass were above the legal size of 18 inches (457 mm). A limited number of striped bass samples were above the legal size of 28 inches (711 mm). Only one striped bass caught in 2002 and two caught in 2003 were above the bay and coastal spring trophy-size striped bass recreational fisheries minimum legal size (32 inches). There is no apparent minimum size restriction for bluefish in Virginia waters. The lengths of the individual fish in the composite samples are not reported, however approximate lengths were estimated by dividing the sum of minimum and maximum length by 2.

PCBs in striped bass and bluefish were analyzed by the congener method. No detection limit is reported for the PCB congeners. Analytical results for PCBs in the fish filets are expressed on wet-weight basis.

Striped Bass: The striped bass samples were collected from the James River and Chesapeake Bay (Table 2-3). They were analyzed for PCBs in individual edible fish filets and in composites of filets of 2-5 individual striped bass. Eight striped bass samples (5 composites + 3 individuals; total of 21 fish) were collected from three different locations in the James River in April, May, and July 2002. The lengths of the individual striped bass used for 2002 composite analyses ranged from 419 to 940 mm. The average total PCB concentration was 215 ppb, with a standard deviation of 122 ppb. The average lipid content was 5.4% (2.5% minimum and 8.8% maximum).

A total of 35 samples of striped bass were analyzed in 2003 (Table 2-3), 28 were from Chesapeake Bay, three samples (2 composites and one individual fish) from tributaries to Chesapeake Bay, and four composite samples from the James River. Eighteen fish were caught in March 2003, ten in November 2003, and one each from tributaries in June, July and August from different areas of the Virginia portion of the Chesapeake Bay. The lengths of the individual fish from the Chesapeake in 2003 in spring collections ranged from 473 to 920 mm, with an average length of 608 mm. The average total PCB concentration was 192 ppb, with a standard deviation of 111 ppb. The average lipid content was 12.3 % with the minimum 3.6% and maximum 29.5%. Fall 2003 collections of striped bass averaged 512 mm in length, 5.5 % lipid and 99 ppb PCB (standard deviation 69 ppb). Lipid content appears to have a significant influence on PCB concentrations.

The striped bass samples for the four composite analyses (total of 10 fish) were collected from one location in the James River in March and May 2003. The lengths of the individual striped bass used for 2003 analyses ranged from 555 to 745 mm. The average total PCB concentration was 322 ppb, with a standard deviation of 132 ppb. The median concentration was 330 ppb, minimum 174 ppb, and maximum 452 ppb. The average lipid content was 8.0 %, and the minimum 7.1%, and maximum 9.4%.

A total of 46 samples of individual striped bass were collected in 2004. All of the samples came from the James River or a tributary to that river. PCB concentrations averaged 394 ppb with a minimum of 93 ppb and a maximum of 1483 ppb. Lipids averaged 7.2% for fish averaging approximately 565 mm in total length and 2041 g in weight.

Bluefish: Only composite samples of edible bluefish filets were analyzed for PCBs. The bluefish were collected in June/July 2003 and July/August of 2004 from tidewater estuaries located in eastern Virginia. One bluefish filet composite of 4 bluefish was analyzed for June 2003 and two composites (two fish per composite) were analyzed for July 2003. The 2003 average PCB concentration was 26.8 ppb, with a standard deviation of 18.2 ppb. The median concentration was 30.6 ppb, minimum 7.0 ppb, and maximum 42.8 ppb. The average lipid content was 3.9 %, with a standard deviation of 0.5. The median lipid content was 3.7%, minimum 3.5%, and maximum 4.5%. For 2004, PCB concentrations averaged 14.0 ppb with a standard deviation of 8.6 in three composite samples (2-3 fish per composite). The range of PCB concentrations was 5.3 ppb to 22 ppb. Lipids averaged 6.6% for these bluefish that averaged 264 mm in total length and 220 g in weight (Table 2-4).

13. North Carolina

North Carolina's most recent data consists of bluefish caught and analyzed in 1989 and striped bass caught and analyzed in 1999 (Williams, 2005).

Striped Bass: It appears that one individual striped bass was collected in October 1999 in Albemarle Sound at Laurel Point. The filet was analyzed by the North Carolina Chemistry Lab at the Division of Water Quality for total PCBs as Aroclors. Length and weight were not recorded, but the average PCB concentration was <190 ppb. Striped bass collected in 1996 averaged 315 ppb PCBs based on 29 samples submitted to NY State for consideration in the sale of striped bass (Sloan et al., 2005) (Table 2-3).

Bluefish: A total of 5 composites of 5 individual whole bluefish were collected in May 1989 at Stumpy Point Bay near Stumpy Point, near Pamlico Sound. Whole fish were analyzed by the North Carolina Chemistry Lab at the Division of Water Quality for total PCBs as Aroclors. The bluefish were small fish, with an average length was 314 mm and an average weight of 375 g. The average PCB concentration was <13 ppb (Table 2-4).

14. South Carolina

Recent PCB data were not available for either striped bass or bluefish from South Carolina waters.

15. Georgia

Striped Bass: The state of Georgia has collected striped bass from several locations in the Savannah River in spring and fall of 2004 and in spring 2005. A total of 45 fish were collected, most were analyzed individually, with two five-fish composites. Length ranged from 320 to 998 mm and weight ranged from 407 to 14,515 grams. Sex was not determined in 2004, all 2005 fish were female. Sampling locations ranged from Route 301 down to the coast, a distance of approximately 65 air miles (and many more river miles due to numerous meanders). PCBs were not detected in any fish; detection limits were 30 ppb for fall 2004 samples, and 100 ppb for the spring 2004 and 2005 samples (Table 2-3).

Bluefish: No data were available for bluefish.

16. Florida

Recent PCB data were not available for either striped bass or bluefish from Florida waters. Striped bass and bluefish are minor incidental fisheries in these waters.

III. Data from Other Sources

A. The 1984-1986 Federal Survey of PCBs in Atlantic Coast Bluefish

From 1984 to 1986, NOAA, with FDA and EPA, analyzed bluefish from the Atlantic Coast (NOAA/FDA/EPA, 1986, 1987). Fish were collapsed into small (<300 mm fork length), medium (301-500 mm) and large (>501 mm) categories. 924 five-fish composites and 500 individual fish were analyzed for PCBs in the study area; in addition, eleven 25-fish composites of snappers were analyzed for the New York Bight. Five geographic regions were sampled, New England, (RI, MA), New York Bight (CT, NY, NJ), Maryland-Virginia, North Carolina and Florida (Figure 2-10). Florida fish were sampled, but not analyzed for PCBs. Skin-on filets were analyzed. Aroclor analysis was performed with a limit of detection (LOD) of 100 ppb and a limit of quantitation (LOQ) of 300 ppb. Aroclors that were detected at concentrations greater than the LOD but less than the LOQ were assigned an estimated concentration of 200 ppb. Such results were assigned the qualifier of "T" for Trace.

Figure 2-10: Sampling locations for the 1985 NOAA Bluefish Survey

The New England region was sampled in both June and August of 1985. The data on the fish collected as five fish composites are reported in Table 2-7.

Table 2-7: Data from 1985 NOAA study: New England: 5 Fish Composites						
Date	Size (mm)	No. 5 Fish Composites	% Lipid	Median PCB in ppb	Mean PCB in ppb	Maximum PCB in ppb
June 1985	<300	1	2.1	<200		
	300-500	6	2.0	<200	260	540
	>500	65	3.5	1190	1230	2930
August 1985	<300	0	No data			
	300-500	6	1.4	<200	340	710
	>500	65	10.4	1370	4800	40,640
October 1985	<300	0	No data			
	300-500	4	7.4	890	940	1380
	>500	65	13.2	1020	1020	2440

The data for individual fish collected in New England during June and October of 1985 are reported in Table 2-8.

Table 2-8: Data from 1985 NOAA study: New England: Individual Fish						
Date	Size (mm)	Sample Size	% Lipid	Median PCB in ppb	Mean PCB in ppb	Maximum PCB in ppb
June 1985	<300	9	1.9	<200	290	650
	300-500	37	2.8	<200	380	1200
	>500	54	3.4	940	1040	3480
October 1985	<300	15	4.9	<200	350	1170
	300-500	21	4.4	560	560	1250
	>500	64	10.6	1100	1200	3210

The New York Bight region was sampled in May/June, August and October/November of 1985. The data on fish collected as five fish composites are reported in Table 2-9.

Table 2-9: Data from 1985 NOAA study: New York Bight: 5 Fish Composites						
Date	Size (mm)	No. 5 Fish Composites	% Lipid	Median PCB in ppb	Mean PCB in ppb	Maximum PCB in ppb
May/June 1985	<300	6	1.9	<200	250	500
	300-500	6	1.6	<200	330	610
	>500	65	4.5	980	1060	2910
August 1985	<300	0	No data			
	300-500	6	1.1	<200	250	510
	>500	65	4.0	770	950	6140
October/ November 1985	<300	6	2.0	<200		
	300-500	4	4.9	<200		
	>500	64	15.1	1860	1990	4380

The New York Bight region was sampled for individual fish in May/June, and October/November of 1985. The data on individual fish are reported in Table 2-10.

Table 2-10: Data from 1985 NOAA study: New York Bight: Individual Fish						
Date	Size (mm)	Sample Size	% Lipid	Median PCB in ppb	Mean PCB in ppb	Maximum PCB in ppb
May/June 1985	<300	15	1.5	<200	250	630
	300-500	30	1.7	<200	400	1070
	>500	58	4.6	1330	1330	23020
		57*	4.6	950	950	4380
October 1985	<300	15	2.5	<200	240	620
	300-500	30	2.6	<200	210	610
	>500	56	11.4	1460	1760	5810

* Excludes outlier maximum value.

The New York Bight region was sampled for snapper bluefish in October 1985 and January 1986. The data for the 25-fish composites are reported in Table 2-11.

Table 2-11: Data from 1985 NOAA study: New York Bight: 25 Fish Composites						
Date	Size (mm)	No. 25 Fish Composites	% Lipid	Median PCB in ppb	Mean PCB in ppb	Maximum PCB in ppb
October 1985	<300	10	0.8	<200	<200	540
January 1986	<300	1	1.9	<200		

The region off Maryland and Virginia was sampled in May and September/October 1985. The data associated with those samplings are reported in Table 2-12. There were no individual fish analyzed from Maryland and Virginia; only 5-fish composite data are reported.

Table 2-12: Data from 1985 NOAA study: Maryland/Virginia: 5 Fish Composites						
Date	Size (mm)	No. 5 Fish Composites	% Lipid	Median PCB in ppb	Mean PCB in ppb	Maximum PCB in ppb
June 1985	<300	7	1.2	<200		
	300-500	10	0.8	<200		
	>500	0	No data			
September/ October 1985	<300	6	4.0	<200		
	300-500	6	5.2	<200		
	>500	0	No data			

North Carolina was sampled in January/February, March and in April of 1985. The data are presented in Table 2-13. Of the large bluefish captured in January /February, one highly contaminated fish (45,420 ppb) has a strong influence on the mean. Excluding that one fish drops the average concentration from 2210 to 1530 ppb.

Table 2-13: Data from 1985 NOAA study: North Carolina: 5 Fish Composites						
Date	Size (mm)	No. 5 Fish Composites	% Lipid	Median PCB in ppb	Mean PCB in ppb	Maximum PCB in ppb
January/ February 1985	<300	6	2.3	<200	260	550
	300-500	6	5.0	780	700	1250
	>500	65	16.8	1350	2210	45420
		64*	16.5	1370	1530	8290
March 1985	<300	0	No data			
	300-500	6	0.3	<200		
	>500	65	12.1	1530	1570	3140
April 1985	<300	6	0.8	<200	250	520
	300-500	6	0.9	<200		
	>500	0	No data			

* Excludes outlier maximum value.

Individual fish from North Carolina were sampled in January/February 1985. The data are presented in Table 2-14.

Table 2-14: Data from 1985 NOAA study: North Carolina: Individual Fish						
Date	Size (mm)	Sample Size	% Lipid	Median PCB in ppb	Mean PCB in ppb	Maximum PCB in ppb
January/ February 1985	<300	14	2.3	<200	290	950
	300-500	30	3.2	<200	400	1200
	>500	55	15.1	1430	1760	4530

IV. Temporal trends

Some states have sufficient data collected over time to make positive statements about temporal trends in PCB concentrations within striped bass and bluefish. The two species are addressed separately hereafter.

A. Striped bass

In the last 30 years, PCB concentrations have declined dramatically in the Hudson River but the greatest proportion of the decline occurred immediately following the cessation of direct discharges to the Hudson River. Results for the river reach from Poughkeepsie (river mile [RM] 76) downstream to the George Washington Bridge (RM 12), are presented in Figure 2-11 and show the general decline in PCB concentrations over time. Since the Hudson River is a major source of PCBs to coastal waters of the region, declines experienced in the river would be expected to be reflected in declines for the region, e.g., the New York Bight and Long Island Sound.

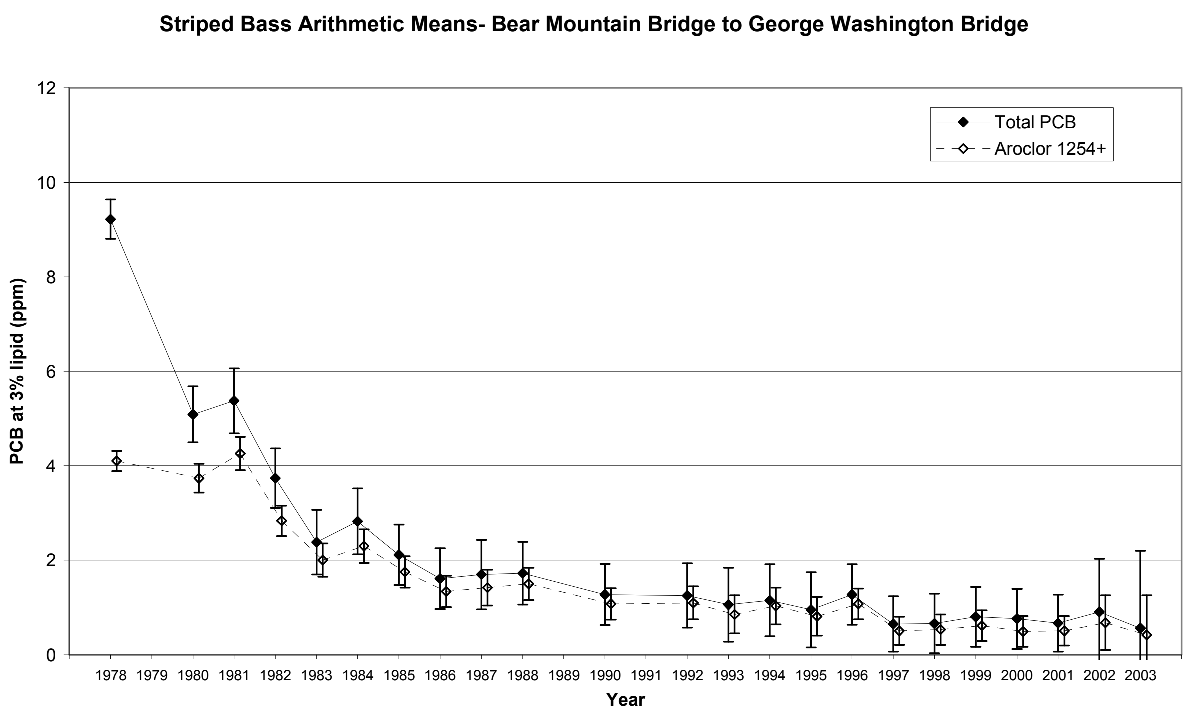


Figure 2-11: Trend in arithmetic PCB concentrations at 3% lipid for striped bass collected from Poughkeepsie to George Washington Bridge in the lower Hudson River (River Miles 76-12).

Figure 2-12 depicts temporal changes in average PCB concentrations in striped bass from New Jersey waters of the Raritan and Passaic Rivers and the Atlantic Ocean, including the New York Bight. PCB declines between 1982 and 2004 are approximately 85 percent for the Raritan and Passaic, and, for the period 1985 to 2004, nearly 90 percent for the Atlantic Ocean.

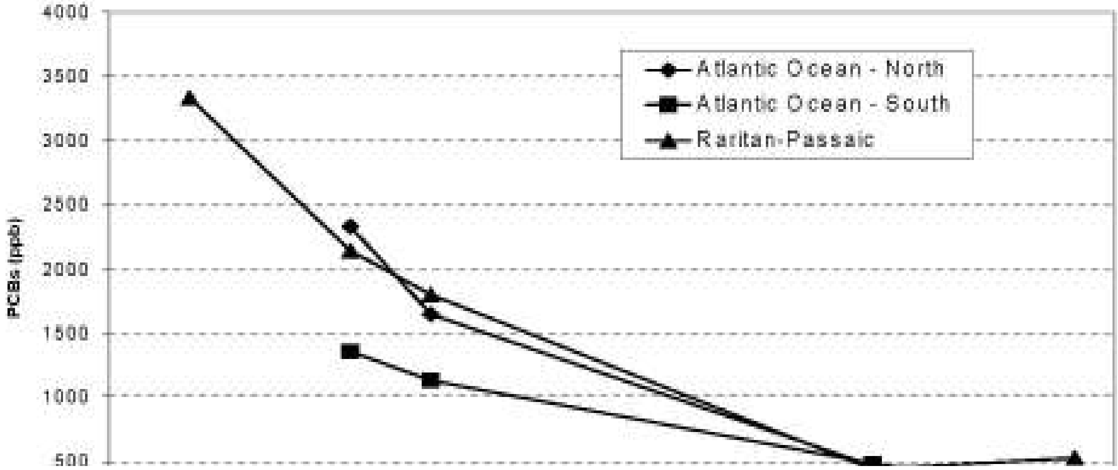


Figure 2-12: Average PCB concentrations in striped bass from New Jersey coastal waters.

PCB concentrations in Long Island Sound fish taken in 2006 (preliminary data) appear to have declined by approximately 78 percent from 1994 levels (Table 2-2), and 89 percent from concentrations observed in 1985 (calculated from Sloan et al., 1988) (Figure 2-13). Fish from western Long Island Sound have historically been influenced by PCB sources in the Hudson River and New York City (Horn et al., 1979; Sloan and Hattala, 1991; Sloan et al., 1988, 1995, 2002) but in 2006 there were no apparent spatial differences in PCB concentrations in striped bass within the Sound. The declines in PCB concentrations suggest remedial efforts to reduce PCB exposures within the environment are producing success, however, additional efforts to control sources of PCBs are still warranted.

Figure 2-14 shows the concentration of total PCB in striped bass from the Delaware Estuary over the period 1989 through 2007. This graph includes the paired samples collected by Delaware in 1992, 1997, 2002 and 2007 as well as other samples collected in 1988, 1989, 1991, 1997 and 2004 by the USFWS, the NJDEP, or DE DNREC. First note the significant declines in total PCB concentration over the period, with a leveling off in recent years. Second, the total PCB concentration in the tidal Delaware River is always nominally greater than the concentration in the Delaware Bay fish collected in the same year. Statistical analysis indicates that the difference in PCB concentration between the two locations is unrelated to fish length or lipid content. The difference is attributed to higher exposure levels of PCBs in the tidal Delaware River in comparison to the Bay. This interpretation is supported by data showing significantly higher concentrations of PCBs in the water column and sediments of the tidal River in comparison to the Bay (DRBC, 2003; EPA, 2003) as well as higher concentrations of PCBs, in general, in all fish from the tidal Delaware River in comparison to fish from the Delaware Bay (DRBC, 2002).

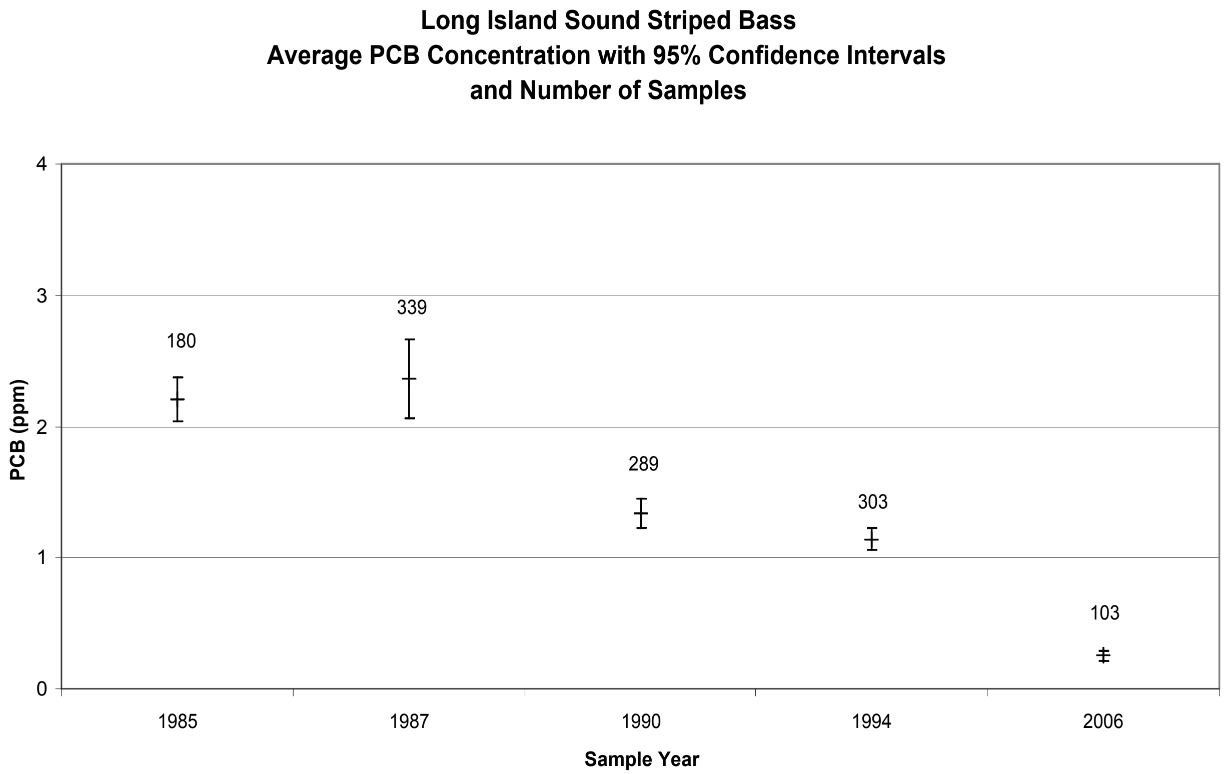


Figure 2-13: Temporal changes in PCB concentrations in Long Island Sound striped bass.

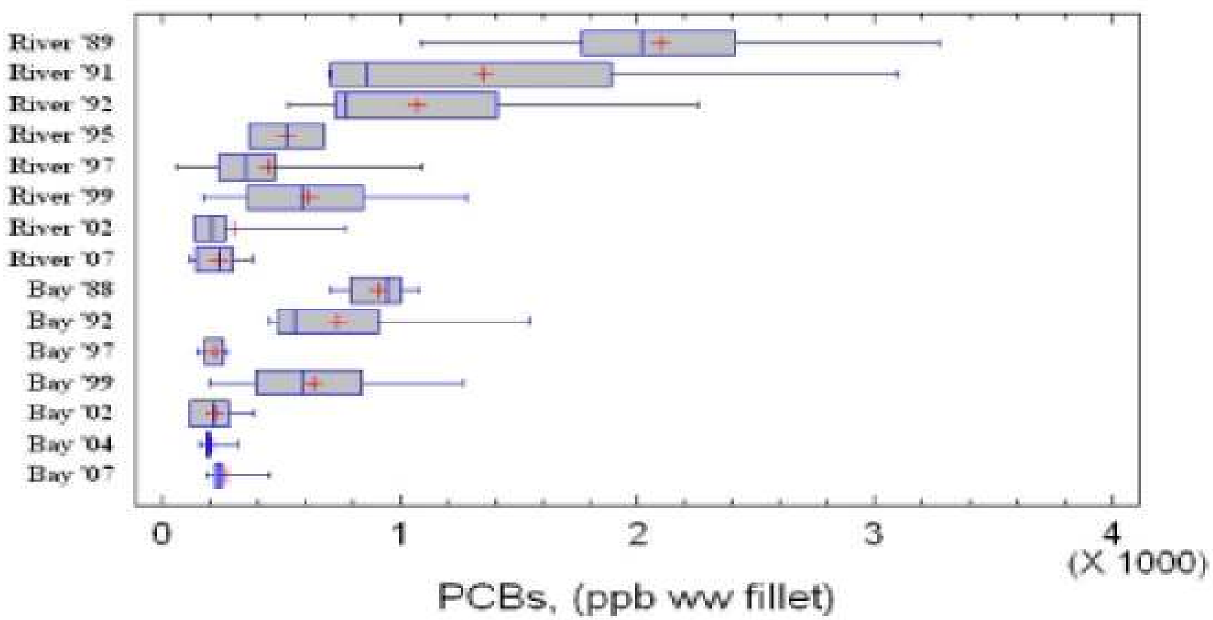


Figure 2-14: Temporal trends in Total PCBs in striped bass from the Delaware estuary.

B. Bluefish

The 1985 NOAA/FDA/EPA (1986, 1987) study of PCBs in coastal bluefish had two sampling areas that are pertinent to Long Island Sound, i.e., New England and the New York Bight. Indeed, a portion of the samples for the New York Bight were taken from the Sound. Sampling was segregated by size and into two seasons. Comparisons of the data by size groups has shown there is little difference among the data by size between seasons and areas, therefore, the data were combined by size group for comparison with the 2006 Long Island Sound provisional data. The size groups within the federal study closely approximate the size groups for the 2006 Sound study thus are considered equivalent for the purposes here. Only PCB data for individual samples have been included; composite sample data are excluded. Calculated changes in PCB concentrations between 1985 and 2006 are presented below.

NOAA/FDA/EPA (1986)			Long Island Sound 2006		Change
Size group (mm)	n	Mean PCB (ppb)	n	Mean PCB (ppb)	(%)
300 - 500	109	412	25	69	−83
> 500	232	1330	111	483	−63

Specifically for Long Island Sound collections in the NOAA/FDA/EPA (1987) study, only fish greater than 500 mm had comparable data. For 326 fish in 78 analyses (16 individuals + 62 composites of 5 fish), the weighted average PCB concentration was 1933 ppb (minimum of 20 ppb and maximum of 6140 ppb). A decline of 75 percent would be suggested by 2006 collections. The apparent temporal changes in PCB levels in bluefish are in the same order of magnitude as those observed for striped bass.

Temporal trends for bluefish in New Jersey coastal waters have been examined since 1982. Figure 2-15 includes bluefish data for 1993 from NOAA (Deshpande et al., 2000) and New York (Skinner et al., 1996) for the New York Bight (i.e., Atlantic Ocean-North location). PCBs in bluefish from the Atlantic Ocean have declined by approximately 70 percent between 1985 and 2004.

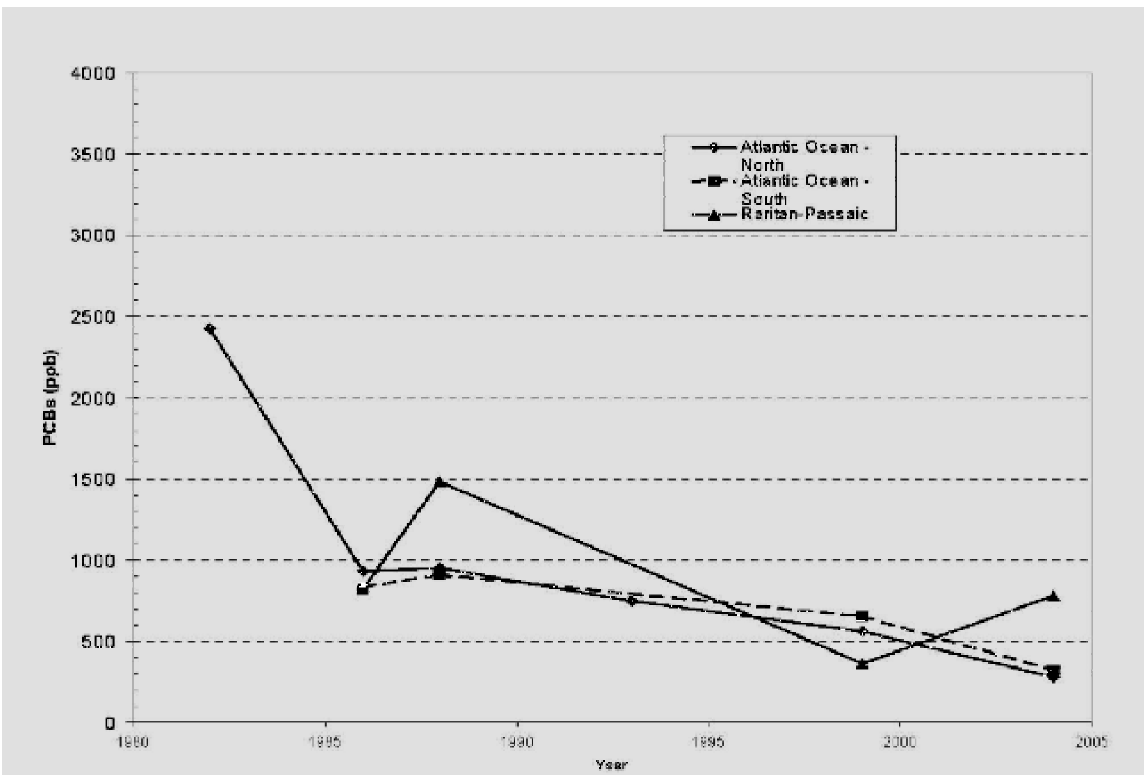


Figure 2-15: Temporal changes in average PCBs in bluefish from New Jersey coastal waters.

As with Long Island Sound, Delaware Bay was sampled by the NOAA/FDA/EPA (1986, 1987) study and by Delaware and New Jersey in 2004 and 2005. The federal data are for composites of 5 fish while the state data are for individual and composite fish samples. Apparent declines in PCB concentrations are evident, viz.:

	NOAA/FDA/EPA (1986)		Delaware Bay 2004-2005		%
Size group (mm)	n	Mean PCB (ppb)	n	Mean PCB (ppb)	Change
300 - 500	9	200*	18	83	−58
> 500	21	1179	14	574	−51

* All values were indicated as "Trace" meaning PCBs were detected above the 100 ppb detection limit but did not exceed the quantitation limit of 300 ppb. The NOAA/FDA/EPA (1986, 1987) study assigned a value of 200 ppb to "Trace" levels of PCBs.

V. Analytical Methods for PCBs in Fish

Available laboratory methods provide the capability to identify and quantify PCBs in a wide variety of environmental matrices, including fish. Traditionally, analyzing fish tissue for PCBs is accomplished using a laboratory instrument called a gas chromatograph (GC). Total PCBs can be quantified as the sum of Aroclors (industrial mixtures produced by the Monsanto Co.), sum of homologs (PCB groups based on their number of chlorine atoms), or the sum of separate PCB congeners, of which 209 possible configurations exist. Choosing the method for quantifying PCBs depends, among other factors, on the program(s) for which the data are to be applied. While all methods measure PCBs, they can differ in how results are expressed (Aroclors vs homologs vs congeners), level of sensitivity (i.e., detection limits) and quality control/quality assurance, and level of specificity. Regardless of which method is used, the laboratory procedures for fish tissue analysis by GC involve the following general steps:

1. The samples are subjected to an extraction procedure to draw the PCBs out of the tissue matrix. This is accomplished using organic solvents such as methylene chloride and hexane.

2. The sample extract is cleaned up to isolate the PCBs in a solvent and to remove interfering substances.

3. A small subsample of the solvent extract is injected into the GC. The GC is equipped with either an electron capture detector (ECD) or mass spectrometer (MS) which separates PCB congeners or homologs based on chemical-physical properties. Once separated, each compound or homolog can be quantified by comparing the sample responses to the responses of the known calibration standards.

A. EPA Method 8080

The EPA laboratory method that has been traditionally used for determining PCBs in environmental samples, including fish tissue, is Method 8080. Method 8080 was replaced with Method 8081 following the introduction of an upgraded capillary column. Both of these methods rely upon GC/ECD instrumentation, both express PCB results in terms of Aroclor content, and both attempt to identify various organochlorine pesticides in the extract along with PCB Aroclors. For a particular Aroclor mixture to be considered detected using this method, five chromatographic peaks must be present that match five predetermined peaks of standards (although more may be present). If all five of the predetermined peaks are not seen, the particular Aroclor is reported as non-detected. If the Aroclor is determined to be present, then the concentration is calculated by adding the five peak areas and comparing that total area to the cumulative peak area of the standards.

B. EPA Method 8082 (see: http://www.epa.gov/epaoswer/hazwaste/test/pdfs/8082.pdf)

Just as Method 8080 was replaced by Method 8081, Method 8081 was also replaced, this time by two separate methods, Method 8081A and Method 8082. Method 8081A is used exclusively for organochlorine pesticides, and Method 8082 is used exclusively for PCBs. Method 8082 is a GC/ECD method that can be used to determine PCB Aroclors or 19 specific PCB congeners (IUPAC 1, 5, 18, 31, 44, 52, 66, 87, 101, 110, 138, 141, 151, 153, 170, 180, 183, 187, and 206). The EPA further indicates that Method 8082 may be appropriate for additional congeners. Several commercial laboratories have successfully modified Method 8082 to include an expanded list of PCB congeners.

C. FDA Pesticide Analytical Manual (see: http://www.cfsan.fda.gov/~frf/pami1.html)

The Pesticide Analytical Manual, Volume 1, was developed to measure numerous chemical compounds, including PCBs, in a wide array of food commodities. For PCBs in fish tissue, the method follows the same procedure outlined above (solvent extraction, extract clean-up, GC/ECD determination). PCBs are quantified on the basis of one or more Aroclors (section 504-10). The Aroclor reference standard is selected to match the PCB sample pattern. A single Aroclor or, more often, a mixture of Aroclors that produce the most similar pattern to the sample pattern is used for quantitation. When the sample PCBs match with a single Aroclor reference standard, all peaks matching the Aroclor pattern are quantified by area or height and summed. However, fish tissue samples often display patterns that are different from the Aroclor reference. For these samples PCBs are quantified by comparing the area of each peak in the sample to peaks at the same retention time, relative to pp'-DDE, in a calibrated lot of Aroclor reference standard, and applying a weight percent factor associated with the peak in the reference standard (Table 504-c). Narrow bore capillary GC columns are used to quantify PCBs.

D. EPA Method 680

With regard to PCB homolog testing, the primary method available is Method 680. This is a GC/MS (gas chromatography/mass spectrometry) method that uses the average of two characteristic chromatographic peaks from each chlorobiphenyl group to quantify the amount of PCB present at each homolog group. Results are reported for each PCB homolog group, which are then summed to produce total PCB. The PQL (practical quantitation limit) for each homolog group is in the low (e.g., 1 to 10) µg/kg (ppb) range for solid matrices.

E. EPA Method 1668/1668A (see: http://www.epa.gov/Region3/1668a.pdf)

Recently, more refined and advanced methods in PCB analysis have become available. The EPA has proposed Method 1668 (EPA, 1997) and 1668A (EPA, 1999), both of which are Isotope Dilution High-Resolution Gas Chromatography/ High-Resolution Mass Spectrometry (HRGC/HRMS) methods. These two methods were proposed as a part of new sludge rules proposed by the U.S. EPA in December of 1999. Method 1668 focuses exclusively on 12 non-ortho and mono-ortho substituted PCB congeners demonstrating dioxin-like toxicity. Method 1668A, where "A" denotes revision A of Method 1668, includes the 13 congeners in the original method, plus the remaining 196 possible congeners. In all, approximately 125 specific PCB congeners can be adequately resolved (separated) through Method 1668A. The remaining congeners co-elute in pairs, and are determined as several mixtures of congeners. EPA is recommending the use of Method 1668A in various regulatory and non-regulatory programs where high quality, congener-specific PCB data are needed or desired (EPA, 2000).

Despite the advantages associated with congener specific methods, there are noteworthy disadvantages. The main disadvantages are cost and the lack of labs qualified to perform such work. Furthermore, congener information generates exceedingly large and complex data sets, which translates into longer turnaround times for review and follow-up action. Finally, the fact that Methods 1668 and 1668A are still in the process of being validated represents a disadvantage, especially for regulatory programs unwilling or unable to specify such testing methods in permits or in monitoring programs. PCB analysis based on Aroclors does not provide information on individual congeners, but provides compliance with other federal and state environmental programs that regulate PCBs in fish, water, and sediment. Methods using GC/ECD do not provide the extreme low level of sensitivity achievable with GC/MS/HRMS. GC/ECD analysis using packed or wide bore columns will not achieve the higher resolution achievable with narrow bore columns, but reduces the overall cost of analysis.

VI. Summary and Conclusions

The information compiled in this chapter indicates that data robustness by state varies considerably. Limited data are available for bluefish coastwide with only eight states reporting results; no data for bluefish are reported for states south of North Carolina. Moderate levels of striped bass data are available for eleven coastal states and an extensive data base is available for New York waters. The complete data set included in this report contains a total of 1873 PCB data points for striped bass and 424 PCB data points for bluefish. The range of reported mean striped bass PCB levels was 10,500 ppb (NY, Hudson River at Troy) down to the detection limit of 30 ppb (Savannah River, GA). The range of reported mean bluefish PCB levels was 2670 ppb (NY, New York Harbor, 1993) to < 13 ppb (NC). Tables 2-2 through 2-5 plus Figures 2-1 through 2-5 provide geographic summaries of the average PCB concentrations in striped bass and bluefish for regional and specific locations along the Atlantic coast.

Data interpretation must be tempered by differences in collection year, number of samples, size, sex and age of fish, collection season, analytical methodology, quantitation methods, as well as data variability (see Tables 2-2 through 2-6 and Figures 2-1 through 2-5 which provide much of this information). States also vary in how they define a legal fish (e.g., minimum size limits), so states may be targeting different sized fish (Table 2-1). All of these factors contribute to uncertainty in data interpretation and analysis. As a result, the data subworkgroup has recognized that differences in sampling objectives and methods among states complicate regional or coastwide data comparisons.

Despite the data variables described above, qualitatively it can be noted that, in some instances, similarities in data sets appear. For example, among the eleven coastal striped bass data sets the mean concentrations for ten data sets are within the same order of magnitude, despite being reported by six states over a span of ten years. The mean concentrations for eight of these data sets fall within the range of 100 ppb to 300 ppb (Table 2-2). A quantitative statistical comparison has not been attempted, and coastal striped bass data sets from jurisdictions south of New Jersey were unavailable for comparison. The continued presence of PCBs in these commonly consumed species, the associated human health concerns with PCB ingestion, and the relative paucity of recent contaminant data for these fish from some locations, particularly for bluefish, argues for a coordinated coastwide study for both species similar to that conducted for bluefish in the mid 1980s.

Total PCB concentrations were determined using either GC/ECD or GC/MS/HRMS techniques, and quantified on the basis of either Aroclors or individual congeners. All PCB measurements were reported on a wet weight basis. Procedurally, the use of standardized reference materials by all laboratories would be advantageous for assuring data quality.

The Data subworkgroup compared PCB results from the 1980's to recent data for bluefish and striped bass. Results show clear declines in average PCB concentrations over time for these two species (see Figures 2-11 through 2-15). The magnitude of the declines in PCB concentrations are similar for the two species and are generally 70 percent or greater between 1985 and the most recent year. Together these declines indicate the ban on PCB production, followed by control of PCB sources, is having a positive impact on the quality of the fish.

In general, the areas generating the highest PCB concentrations are associated with developed urban, industrial conditions such as the Hudson River, the NY/NJ Harbor areas, and, to a lesser extent, the lower Delaware River system. Given the often small samples sizes involved, the disparity in years, analytical conditions, and exposure regimes encountered, any further apparent regional differences should not be emphasized or construed until a more rigorous coast-wide sampling/analytical regime is formulated and implemented.

For striped bass, there were no apparent length-PCB relationships for fish from Long Island Sound and the Hudson River. Young fish less than 457 mm were not analyzed for PCB. Sufficient data for other waters for assessing a length-PCB relationships is lacking.

Bluefish demonstrated strong positive length-PCB relationships throughout much of the range in which they are found. The presence of the length-PCB relationship is consistent with observations in the 1980's. Any evaluation of data for PCBs in bluefish must consider this factor.

Although some PCB data for striped bass and bluefish may be included in larger databases, most of the information resides within each state. It was generally agreed that a common database for PCB data has merit. The database should include state, federal, and academic PCB data sources for these two species.

VII. Recommendations for Future Data Development

Assess the feasibility of conducting a comprehensive coastwide sampling and analysis program to measure PCBs in striped bass and bluefish. This study should include archiving of fish tissue for potential future analysis (e.g., to compare future tissue concentrations of emerging contaminants to archived samples). NOAA conducted a similar PCB study in the mid-1980s for bluefish. Federal agencies, such as NOAA, EPA and FDA should be contacted to determine feasibility and funding.

Develop a searchable common repository for striped bass and bluefish PCB data, to include data from coastal states with fisheries. Invite participation from federal agencies and academic institutions that produce PCB data for these species.

Acknowledge that multiple methods exist for the determination and quantitation of PCBs. Encourage states to include standardized reference materials along with PCB sample analyses, as well as use of a standardized approach for determining total extractable organics (TEO, “lipids”). The objective is to ensure the data generated is accurate and reliable for each chosen analytical method.

Data on other contaminants in striped bass and bluefish should be considered and assessed. While PCBs have been dominant in the development of health advisories in the past, increased attention on mercury and certain classes of organic compounds may alter future health advice.

Lipophilic contaminant data (e.g., PCBs) should be normalized to TEO content and evaluated to provide consideration of any bias due to various lipid extraction methods.

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Appendix 2-1: Procedure for Determination of PCBs in Fish Tissue
Connecticut Department of Health Services

This substitute procedure for FDA PAM 211.13f was developed circa 1986 as an experimentally proven technique for precise and consistent determination of PCB content in various species of fish and other tissue samples. Excellent lipid yields result from efficient solvent extraction of the large interstitial tissue spaces produced by sublimation of water through lyophilization. Eight hour Soxhlet reflux with hot solvent reduces or eliminates the inherent variation in recovery that results from blending samples with petroleum ether according to the FDA procedure (PAM Section 211.13f).

Procedural Steps:

1. Switch on refrigeration unit of the Virtis Consul 1.5 Freeze Drier; allow 1.5 hours for temperature equilibration to − 40 deg. Cent.

2. Remove frozen fillets from freezer and allow to thaw for about 1 hour; slice fish fillets with scalpel into small (2" square) pieces and place into ordinary beaker.

3. Homogenize pieces into a “soup-like broth” using a Virtishear Tissue Homogenizer.

4. Transfer 30-50 grams of the homogenate to a thick walled beaker capable of withstanding high vacuum.

5. Place beaker on vacuum shelf; insert a clean product temperature probe into sample and seal chamber with acrylic cover plate.

6. Wait for product to cool to 5 - 10 deg. Cent. below its eutectic temperature (−28 to −34 deg. Cent.); this generally requires about 4 to 5 hours.

7. Switch condenser on; turn refrigerator off.

8. When condenser temperature reaches −40 deg. Cent., switch vacuum pump on.

9. When chamber vacuum is reduced to 100 microns, switch on shelf heat; operate shelf heat at 1 deg. Cent.

10. Allow sample to freeze dry for 24 hours; as process continues peak vacuum occurs at approximately 5 microns with condenser temperature dropping to −60 to −65 deg. Cent.; process is complete when tissue exhibits a fluffy, flaky texture.

11. When freeze drying is complete, break vacuum by opening vacuum release valve; switch off vacuum pump, shelf heat and condenser temp.; open acrylic cover and remove prepared sample.

12. Transfer sample to a Whatman 43 x 123 mm glass microfibre thimble (Cat. # 2814 432); place sample in standard Soxhlet apparatus and reflux with 300 mL of hexane for a minimum of 8 hours (overnight).

13. Add boiling chips to a clean Kuderna Danish concentrator tube and obtain tare weight.

14. Allow Soxhlet apparatus to cool and transfer hexane extract quantitatively to a 300 mL chromatographic column containing approximately 4" of sodium sulfate.

15. Collect extract in 500 mL K-D flask to which is attached the tared concentrator tube prepared in step 13.

16. Slowly concentrate extract down to approximately 2 mL on a Buchi Rotovap.

17. Remove K-D assembly from Rotovap and rinse down sides of flask with 2 mL portions of hexane.

18. Concentrate extract to dryness using a gentle stream of dry nitrogen applied through a Pasteur pipette.

19. Obtain weight and determine percent lipid.

20. Prepare a 300 mL chromatographic column containing a layer of approximately 4: of Florisil (bottom) on top of which is placed 2" of sodium sulfate; wet the column with approximately 100 mL of hexane; allow the hexane to elute while tapping the sides of the column to dislodge trapped air; allow solvent to drain to a level of approximately 0.5 cm above the top of the sulfate layer.

21. Dissolve the lipid obtained in step 19 with 2 - 3 mL of hexane and quantitatively transfer lipid to the column prepared in step 20.

22. Elute column with 200 mL of hexane into a 500 K-D flask; this cleaned up fraction contains the PCBs to be analyzed.

23. Concentrate the extract down to an adjusted final volume of 10 mL using a combination of Rotovap and nitrogen blowdown methods specified in steps 16 - 18; DO

NOT EVAPORATE TO DRYNESS AS NOTED IN STEP 18 HOWEVER; reduce volume instead to slightly less than 0.5 mL and dilute to mark.

24. Analyze the sample by gas chromatography using packed or capillary columns with electron capture detection.

Appendix 2-2: MSCL Method NY-4 (for New York Dept. of Environmental Conservation)

Analysis for Organochlorine Pesticides and PCBs in Animal Tissue

Five-gram fish samples or two-gram egg samples are weighed into 250 ml beaker then thorough mixed with 150 grams (5 g samples) or 75 grams (2 g samples) of anhydrous sodium sulfate (SOP1.255). The samples are stored in a dessicator overnight. The samples are then soxhlet extracted (SOP 1.259) with 600 ml hexane (SOP 1.255) for seven hours. The extract is concentrated by rotary evaporation (SOP 1.129); transferred to a tarred test tube through a Pasteur pipette containing sodium sulfate, and further concentrated to dryness for lipid determination (SOP 1.264).

The weighed lipid sample is dissolved in 4 ml of methylene chloride and the fat removed by injecting 2 ml on a Waters high pressure GPC (Gel Permeation Chromatography) (EPA Method 3640A). The fraction is concentrated by Turbovap and then exchanged into hexane.

The sample is transferred to a 300 ml glass chromatographic column (Kontes # 420280-0242) containing 20 g Florisil (SOP 1.255) topped with 1 cm sodium sulfate and the sample tube rinsed three times with about 2 ml petroleum ether. The column is eluted with 200 ml 6 % diethyl ether (SOP 1.255)/94 % petroleum ether (Fraction I) followed by 200 ml 15 % diethyl ether/85 % petroleum ether (Fraction II). If Endosulfan II and/or Endosulfan Sulfate analysis is required, then 200 ml 50 % diethyl ether/50 % petroleum ether (Fraction III) is required. The diethyl ether used in this analysis contains 2 % ethanol (SOP 1.255). Fractions II and III are concentrated to an appropriate volume for quantification of residues by megabore column electron capture gas chromatography (SOP 1.265) (DB-608 and DB-5 dual columns). Dieldrin and Endrin are in Fraction II, and some delta-BHC. Fraction I is concentrated to 5 ml and transferred to a silicic acid (SOP 1.255) chromatographic column (custom columns 1 cm OD x 40 cm with a 100 ml reservoir on top, Ace Glass) for additional cleanup required for separation of PCBs from other organochlorines. Five grams of hot silicic acid is put into the column, which already has a glass wool plug and about 3-mm sodium sulfate in the bottom. The silicic acid is topped with 10-mm sodium sulfate and prewashed with 10 ml hexane. Three fractions are eluted from the silicic acid column. The sample in 5 ml solvent is added to the column and rinsed into the column with 3, 1, 1-ml hexane. Then the sample is eluted with 20 ml petroleum ether (Fraction SAI). Fraction SAII is 150 ml petroleum ether. Fraction SAIII is 20 ml of a mixed solvent consisting of 1 part acetonitrile, 19 parts hexane and 80 parts methylene chloride (SOP 1.255). Each is concentrated to appropriate volume for quantification of residues by megabore column, electron capture gas chromatography. HCB and Mirex are in SAI. PCBs are found in SAII. The rest of the compounds are in SAIII.

GC determinations were run on a Varian 3600 GC with a Varian Star Data System ver 5 and a Varian 8200 Autosampler. All GCs were equipped with dual DB-608 (0.83 μ film thickness, J & W Scientific # 125-1730) and DB-5 (1.5 μ film thickness, J & W Scientific # 125-0532) 30 m megabore columns. All compounds were calculated using a three point standard curve forced through the origin using external standards (SOP 1.267).

PCBs were determined by shooting SAII fractions on a Varian 3400 GC with a Varian Star Data System ver 5 and a Varian 8200 Autosampler. This GC is equipped with a 60 m DB-5 0.25 ID capillary column. Another Varian 3400 GC equipped with a 60 m DB-XLB 0.25 ID capillary column is also used as a second system for PCBs.
The compounds were calculated in the following manner. All the Aroclor standards are at 0.5 ng/μl with one μl shot.

Starting with Aroclor 1260, 4 peaks that are unique to this mixture are located. The areas of the standards are summed and the same peaks located in the sample and also summed. Aroclor 1260 is calculated by the following formula to obtain PPM 1260.

(Area sample)(weight of standard shot in ng)
(Area 1260 standard)(basis shot in mg)

Aroclor 1254 is calculated by locating the major peaks in the mixture that are normally found in samples. The areas of these peaks are summed. Because some of this area comes from Aroclor 1260 and not all from Aroclor 1254, the contribution from Aroclor 1260 has to be subtracted from the total area. Aroclor 1254 is calculated by using the formula:

{(Area sample)-[((PPM 1260)(basis)(area from 1260))/ng 1260 std]}(wt 1254 std in ng)
(Area 1254 standard)(basis shot in mg)

Results are in PPM.

Aroclor 1248 and Aroclor 1242 are calculated in a similar fashion, subtracting the contribution from 1254 in the 1248, and the 1248 in the 1242.

Total PCBs are calculated by adding the sum of Aroclor 1242, 1248, 1254 and 1260.

Basis = (weight of the sample mg/final volume of sample μl)(μl of sample shot)

Chapter 3: Biology of Striped Bass and Bluefish

I. Introduction

The following chapter identifies biology and management aspects of striped bass and bluefish that impact any decisions on developing coastal wide advice. The biology of these species, in particular the spatial and temporal distributions of these fish and their dietary habits, is discussed first. The extent of the recreational fishery in the various states and their associated regulations is then detailed.

II. Biology of Striped Bass and Bluefish

One way in which to evaluate the need for consistent advisories along the Atlantic coast is by evaluating the biology of these two species. The following describes the biology associated with the migration patterns, temporal distribution and some spawning habits of striped bass and bluefish. Generally speaking, striped bass are well studied, but more complicated in terms of migration patterns and biology. There is not nearly as much tagging information for bluefish, but again, their migration and spawning patterns appear to be simpler.

A. Summary of the Spatial and Temporal Distribution of Atlantic Coast Striped Bass

Anadromous populations of Atlantic coast striped bass, Morone saxatilis, range from the St. Lawrence River, Canada to the Roanoke River, North Carolina (ASMFC 1990). Anadromous striped bass spawn in discrete coastal rivers and estuaries in the spring and then either return to the ocean or remain in coastal estuaries. In USA waters, discrete and self-sustaining spawning stocks of striped bass have been documented in the Hudson River, Delaware River, Chesapeake Bay and Roanoke River (Rago et al 1989) and an emerging stock is thought to exist in the Kennebec River estuary (Flagg and Squiers 1999) There are smaller resident populations found in some southern waters (e.g., the Savannah River (Gaddis, 2006).

The temporal and spatial extent of striped bass migration differs by age, sex and river of origin across a latitudinal gradient. The onset of spawning migration in the Hudson River usually begins during early April and extends through mid-June (Hoff et al 1988). Recent tagging of the Hudson River spawning stock (ASMFC 2004) shows that, after spawning, larger and older (ages 7+) female striped bass undergo extensive migration northward to coastal and offshore waters from New York to Maine from July through November. During this period, few tag recoveries of adult female stripers have been reported south of New Jersey. However, during winter months (December-February), larger female stripers apparently undergo extensive migration southward to coastal

Virginia and North Carolina and apparently remain there until spawning season (March-April). Nearly all tag recoveries reported from mature female Hudson stripers have occurred during winter off of Virginia and North Carolina. Whether or not mature male striped bass (ages 3+) undergo extensive migration into New England waters is not nearly as clear as for mature female bass based on tag-recapture studies. Juvenile striped bass from the Hudson River stock tend to migrate by late August into Long Island Sound, along the south shore of Long Island and along the New Jersey coast (Boreman and Klauda 1988, Vecchio 1992). The temporal-spatial distribution of sub-adult (mostly ages 1-4) and male striped bass from the Hudson stock is somewhat unclear. Recent tagging studies in the Hudson River and off Long Island (ASMFC 2004) indicate that smaller and younger (ages 2-4) stripers remain mostly in estuaries adjoining the tri-state area (Connecticut, New York and New Jersey). Only about 1-3% of recaptures from sub-adult Hudson stripers have been taken south of New Jersey.

Figure 3-1 identifies the dominant locations of breeding striped bass, migrating populations and adults wintering offshore.

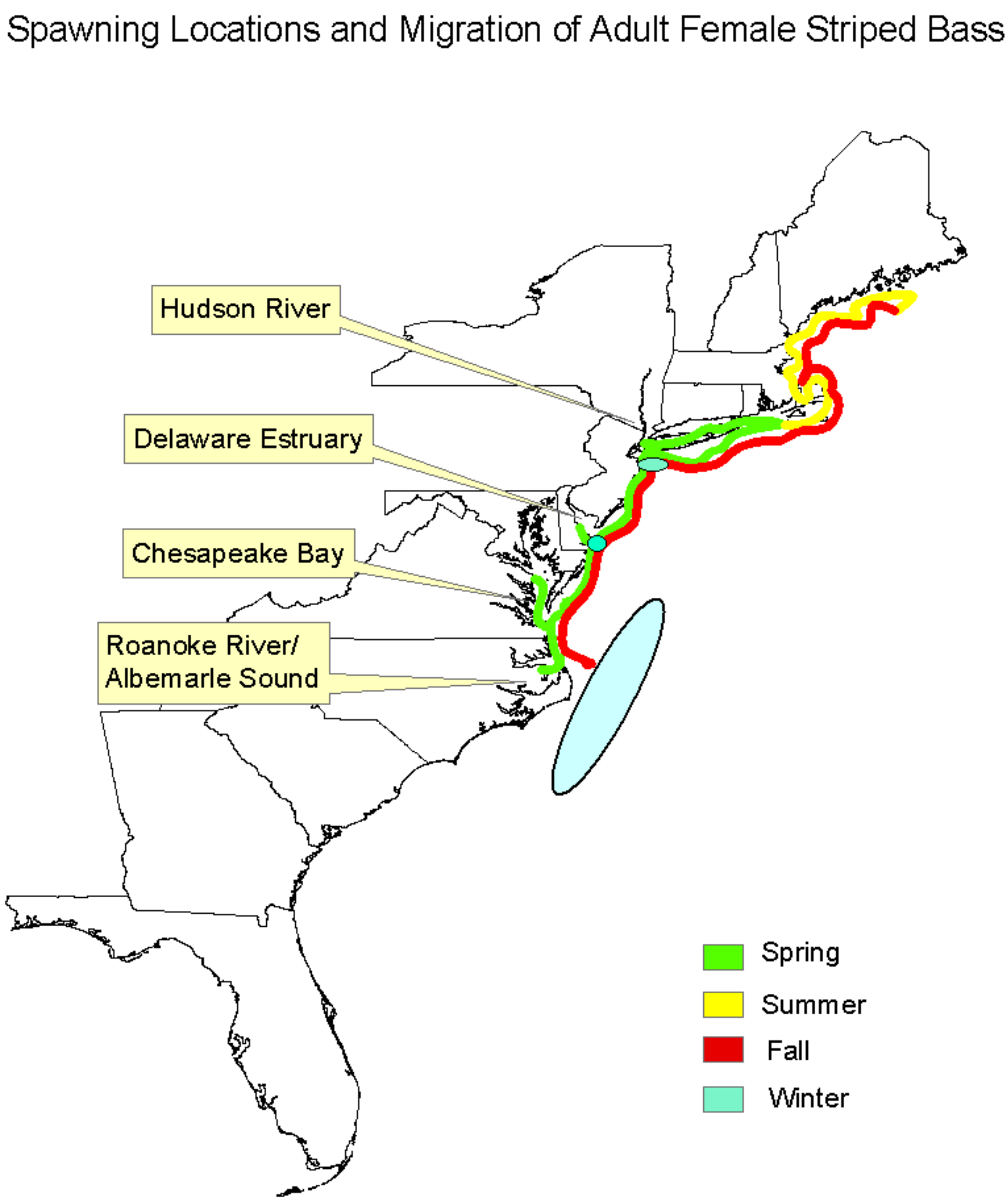

Figure 3-1: Locations of Breeding Striped Bass, Migrating Populations and Adults Wintering Offshore

The Chesapeake Bay stock of striped bass is widely regarded as the largest of the four major spawning stocks (Goodyear et al 1985, Kohlenstein 1980, Fabrizio 1987). Spawning migration in the Chesapeake usually begins during early April and extends through mid-June (Kohlenstein 1980). Recent tag-recovery studies in the Rappahannock River and upper Chesapeake Bay (ASMFC 2004) show that, after spawning, larger and older (ages 7+) female striped bass move more extensively along the Atlantic coast than stripers from the Hudson River stock. Tag recoveries of Chesapeake stripers from July through November have occurred as far south as Virginia to as far north as Nova Scotia, Canada. As winter approaches, mature female stripers undergo an extensive southward migration. Like the Hudson River stock, nearly all tag recoveries from mature female stripers from the Bay stock have taken place during winter (December and February) off Virginia and North Carolina. Kohlenstein (1980) tagged mature (ages 3+) male stripers in the Choptank River, Maryland from 1977-1979, and noted that few mature male stripers were recovered outside of Chesapeake Bay. Based on these findings, Kohlenstein (1980) concluded that most mature male stripers from the Chesapeake stock are not migratory. Juvenile male and sub-adult (ages 1-4) female striped bass are known to remain within the Bay (Goodyear et al 1985) for several years. But as sexual maturity approaches, female striped bass gradually (ages 4-8) emigrate from the Bay and join the coastal migratory stock. These migratory female stripers return during April and May to spawn in the Chesapeake. Juvenile striped bass are known to remain in Chesapeake Bay and use it as a nursery area for several years.

The Delaware River stock of striped bass had been in recruitment failure until about 1990 primarily due to long-term and severe hypoxic conditions near the city of Philadelphia (ASMFC 1990). Following extensive pollution abatement during the mid-1980's, striped bass abundance in the Delaware, as measured by juvenile seine surveys, rose steadily thereafter to peak abundance in 2003 and 2004 (Tom Baum NJ BMF pers. comm.). Like the Chesapeake Bay and Hudson stocks, spawning migration in the Delaware River begins during early April and extends through mid-June (ASMFC 1990). Recent tagging studies in the Delaware River (ASMFC 2004) show that larger and older (ages 7+) female striped bass undergo extensive migration northward into New England from July to November that spatially overlap the migratory range of Chesapeake striped bass. Like the Hudson River and Chesapeake stocks, nearly all tag recoveries from mature female stripers from the Delaware River have taken place during winter (December and February) off Virginia and North Carolina. The spatial and temporal distribution of male and sub-adult female (ages 1-6) stripers from the Delaware River to the coast is not well understood.

The overall abundance of the Roanoke River stock of striped bass is believed to be the smallest of the four anadromous stocks. Early tagging studies of spawning stripers in the Roanoke River (Merriman 1941) revealed very limited mixing with the coastal migratory stock. Recent tagging studies in the Roanoke River from 1990 to 2006 have indicated that several larger and older (ages 7+) stripers have been recovered within estuaries from Delaware through New England (Goodwin and Winslow 2007). Sub-adult (ages 1 to 5) and juvenile striped bass from the Roanoke are known to use Albemarle Sound as a nursery area (Olsen and Rulifson 1992).

There are also non-migratory populations of striped bass found in southern waters (Gaddis, 2006). While there is some tag data that suggests migration from one freshwater system to another via freshets, it is thought that most striped bass remain resident in a particular freshwater environment. Unlike anadromous stocks, these will spawn in tidal portions of the streams, but then migrate upstream to find cooler water over the summer months, typically at springs and dams. As cooler temperatures develop, the fish migrate back downstream and feed on menhaden and shrimp. Examples of this include the Santee Cooper River system in South Carolina and the Savannah River system in Georgia.

B. Dietary Habits of Striped Bass

As striped bass are a large, migratory predator, the dietary habits are diverse and dependent on age/size/life stage and location. Life stage impacts dietary habits in that young fish will have available foods that differ from adult fish (both in terms of size but also location as young fish and adult fish occupy different areas at different times). Additionally, for young fish prey distribution is relatively consistent along the Atlantic coast in brackish estuaries (where striped bass spend their first year of life) but will vary within river or estuarine systems based on location and salinity (Walter et al. 2003). Location impacts diet in that various prey species are available in southern waters (for example spot) that are not available in northern waters.

C. Dependence on Age/size/life stage

Walter et al. (2003) summarized dietary studies of young of year striped bass. Generally speaking these studies were conducted in estuarine nursery areas. There was little regional variation along the Atlantic coast, but there was variability between different studies within the same watershed. Across region variability was attributed to the fact that dietary availability in tidal freshwater rivers and brackish estuaries are generally similar across their Atlantic coast. Within a particular river, however, the available prey will vary based on spatial location and salinity regime (Markel and Grant 1970, Boynton, et al. 1981; Robichaud-Leblanc et al. 1997 all aci Walter et al. 2003). Walter's review suggests fish 30-70 mm fed primarily upon cladocerans, copepods and insects, while around 50 mm the fish would switch towards decapod crustaceans and mysid shrimp and at around 70-90 mm there was a shift towards greater piscivory. This change in diet is attributable to both changes in size and changes in habitat as the fish move from natal tidal fresh water into higher salinity estuaries.

For age one and older fish Atlantic menhaden are an important prey species (32% of the overall diet in the studies reviewed by Walter et al. (2003)). Other important dietary items include decapod crustaceans, weakfishes (in southern waters), amphipods, and sand shrimp.

D. Geographic Variation

As fish migrate from one location to another, one would expect differences in prey based on availability alone. The literature suggests that is the case with migratory striped bass. For example, drums and croakers that are common in southern waters are replaced by hakes and Atlantic tomcod in Northern waters (Waubaum aci Walter 2003). Similarly, American sand lance replaces bay anchovy as striped bass move north.

i. Northern Waters

Walter (2003) identifies waters roughly north of Toms River, NJ as "Upper Atlantic" and suggests amphipods and sand shrimp are important parts of the diet in spring and summer, while herrings make up a portion of the remainder of the diet – in particular as blueback herring spawn in tributary rivers in the spring and are available to pre and post spawning striped bass. Atlantic menhaden appear in the diets in summer. Autumn striped bass in the Upper Atlantic include amphipods, menhaden, bay anchovies and hakes/whiting.

Nelson et al. (2003) evaluated stomach contents of 3006 striped bass off the Massachusetts coast. Generally speaking, fish and crustaceans dominated the diet (~90-95% both by weight and number). Important dietary items included menhaden, shad, etc., sand eels, searobin, sand shrimp, American Lobster, and rock, lady and green crabs.

ii. Mid-Atlantic Waters

Walter (2003) names an area south of roughly Toms River, NJ to roughly the Va/NC border as the "Chesapeake-Delaware Region". In this area Atlantic Menhaden was the dominant fish in the diet of most age classes. Smaller fish (150-600mm) consumed more blue crabs, mysid shrimp and anchovies in spring and summer and more gizzard shad and white perch in winter. Other important fish included the sciaenid fishes (spot, Atlantic croaker and weakfish) and blueback herring and alewives.

Walter and Austin (2003) evaluated the stomach contents of 1225 large (>458 mm TL) striped bass in the Chesapeake Bay. The dominant dietary prey species was Menhaden followed by anchovies, spot, gizzard shad, blue crab, Atlantic croaker and summer flounder.

iii. South

In the North Carolina region, Walter et al. (2003) noted that menhaden was the predominant prey across all seasons. River herrings and drums/croakers made up much of the rest of the diet.

Rudershausen et al. (2005) collected 1399 striped bass from Albemarle Sound in 2002 and 2003 to characterize diet, prey size and type selectivity. Important dietary components included river herrings, Atlantic menhaden, bay anchovy, silversides, and yellow perch in age-1 striped bass, with a shift towards Atlantic menhaden for older striped bass. The authors noted variations in prey selectivity based on both time (year to year variation) and collection method (purse seine vs. beach seine).

III. Bluefish life history

Bluefish (Pomatomus saltatrix) is a coastal pelagic species with a worldwide subtropical distribution (Juanes et al., 1996; Goodbred and Graves, 1996). Bluefish spawn offshore (Kendall and Walford, 1979; Kendall and Naplin, 1981), the larvae develop into juveniles in continental shelf waters (Marks and Conover, 1993; Hare and Cowen, 1994), and juveniles reside in estuarine and near shore shelf habitats (Able and Fahay, 1998; Able et al., 2003). Bluefish are seasonally highly migratory along the U.S. Atlantic coast and are generally found north of the Carolinas in quantity only in warmer months (Beaumariage, 1969; Lund and Maltezos, 1970). Recent plotting of NMFS trawl survey data over time reveals that more adult bluefish are being caught in deep water sampling strata of the northeast states and the Mid-Atlantic Bight until late winter months when they retreat to the North Carolina area (Gary Shepard NMFS - personal communication). Fahay et al. (1999) summarized bluefish life history for the U.S. Atlantic coast, from Maine to Florida. They review stage-specific (i.e., egg, larva, juvenile, and adult) habitat use and geographic distribution, and they include reviews of bluefish reproduction, food habits, predators, migratory patterns, and stock structure.

Bluefish spawn offshore from approximately Massachusetts to Florida (Norcross and Richardson, 1974; Kendall and Walford, 1979; Kendall and Naplin, 1981; Collins and Stender, 1987). Lassiter (1962) postulated that discrete intra-annual cohorts were produced. He referred to these as the spring-spawned cohort and the summer-spawned cohort. Since then, a fall-spawned cohort has been recognized (Collins and Stender, 1987). Thus the bluefish spawning grounds are expansive and the spawning season is prolonged.

Figure 3-2 graphically represents the general locations and movements of bluefish as they relate to season.

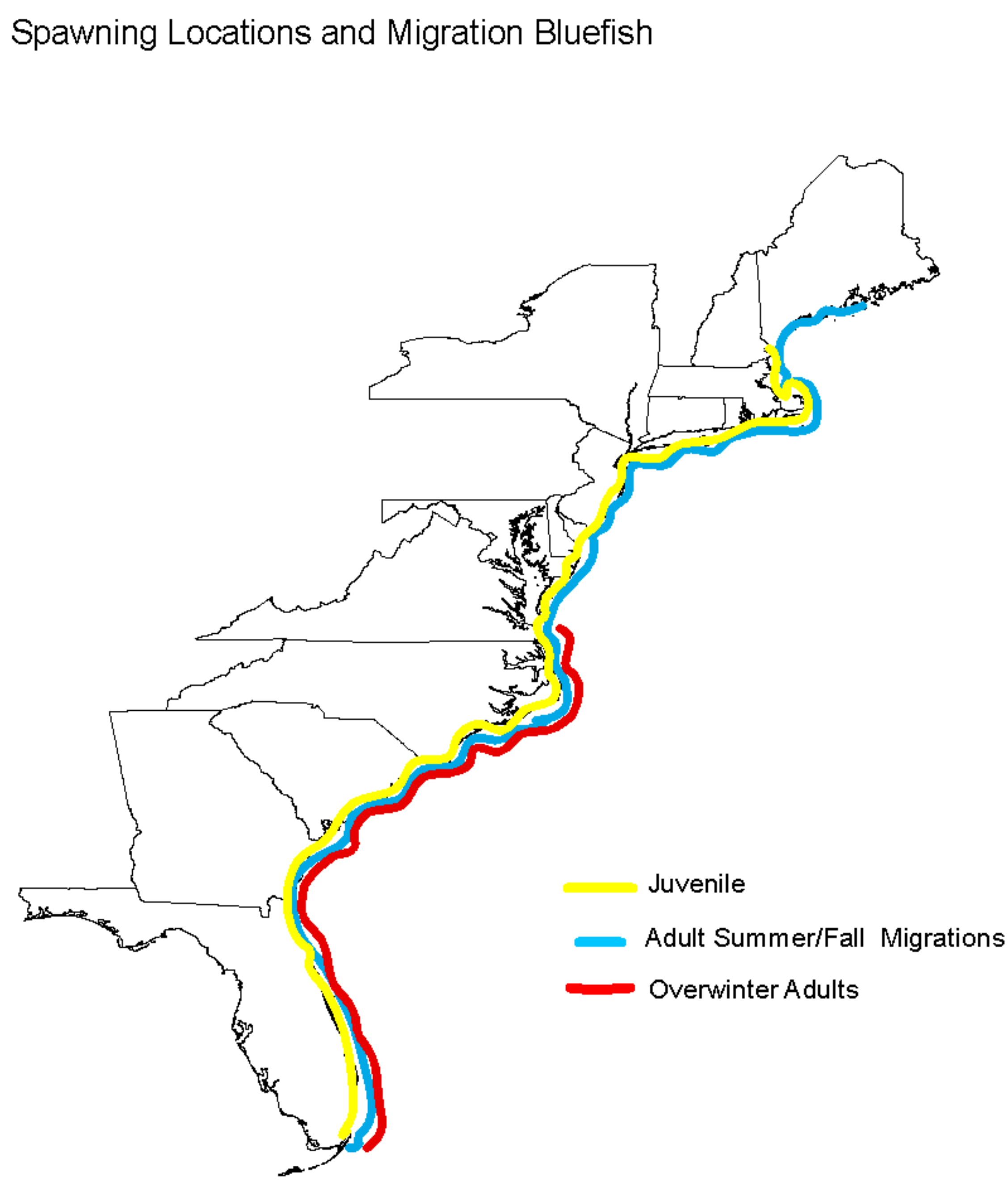

Figure 3-2: Locations and Movements of Bluefish as they Relate to Season.

Sex ratios differed significantly from 1:1 as reported by Lassiter (1962), who observed approximately two females to every male, but the sex ratios observed by Chiarella and Conover (1990) did not differ significantly from 1:1.

Bluefish are distributed as geographically isolated populations in warm and warm-temperate waters around the world. Goodbred and Graves (1996) found genetically distinct populations among samples from six different ocean areas, but populations in closer proximity were more similar genetically. For example, no complete mtDNA nucleotide sequences were shared between areas, but divergences ranged from a low of 0.26% between the western and eastern North Atlantic Oceans and a high of 1.75% between Brazilian and western Australian samples. There is also notable (mtDNA) genetic variation within geographically isolated populations, but Graves et al. (1992) concluded that the western North Atlantic stock shared a common gene pool. Davidson (2002) examined both mtDNA and nuclear DNA and concurred with Graves et al.'s, (1992) finding of a unit stock in the western North Atlantic. Davidson (2002) also found that bluefish from the western North Atlantic and the Gulf of Mexico share a common gene pool.

Bluefish in the western North Atlantic have been managed as a single stock (NEFSC, 1997; Fahay et al., 1999). A unit stock hypothesis has been supported by genetic data (see above). In light of this, latitudinal variation in meristic differences (e.g, number of stripes, fin rays, etc.), as observed by Lund (1961), would appear to represent a variation due to environment rather than genetics.

General movement trends are for adult Western North Atlantic bluefish to migrate from the Hatteras area in the spring inshore and to the north as the season progresses. Adult bluefish usually reach the New Jersey shore area in mid April, reaching the south coast of Cape Cod early to mid-May and Maine shores by early to mid June. Bluefish remain in Maine/New Hampshire inshore waters until late summer, in Massachusetts waters until mid to late October and off New Jersey until early to mid-December.

Juveniles recruit to Mid-Atlantic Bight and Northern states estuaries from early June to late August. Fall migration of juveniles generally follows the coastline north to south, with fish leaving northern estuaries in mid to late September and New Jersey area estuaries in late October. It is generally assumed that age one and two bluefish do not commonly migrate to the northern extent of their range, being uncommon north of Cape Cod. There is some additional evidence to suggest that bluefish found off the Florida Coast are not part of the Mid Atlantic Bight migratory stock.

While juvenile bluefish spend much of their time inshore in estuaries, adult bluefish usually spend only the late spring, summer and fall months in close proximity to shore and are only infrequent visitors to enclosed inshore waters. Also, unlike striped bass which are highly associated with coastal near shore waters, some bluefish can be found well offshore during most months of the year. Whether these offshore fish are a discrete component of the entire stock or merely an extension of the entire stock is unknown.

IV. Dietary Habits of Bluefish

Bluefish dietary habits reflect their opportunistic predaceous behavior. Generally speaking there is a relationship between size of prey and size of bluefish (larger bluefish eat larger prey), and there are distinct changes in consumption based on age and location (as fish move inshore or offshore). While cannibalism has been noted, it does not appear to be a significant portion of the diet.

A. Juvenile Bluefish

Juanes et al. (1996) summarizes the early life histories of bluefish globally. They discuss the variation in diet associated with changes in size (as they grow) and location (as they move from oceanic to coastal habitats). Generally speaking, they summarize the diet of early life stage bluefish as locally abundant fishes – such as silversides or anchovies.

Juanes et al. (1993) evaluated the stomach contents of young bluefish in the Hudson River. A size dependence was noted (smaller bluefish feeding on smaller prey). There was not a strong relationship between size and species predation, with the exception of Atlantic Tomcod that was preyed upon more frequently among larger bluefish. The general conclusion was that the young bluefish were opportunistic, with commonly consumed fish including striped bass, blueback herring, and American shad. Crustaceans were a very small portion of the diet.

Buckel et al. (1999) examined gut contents of 989 YOY bluefish collected in 1994 and 1995. For both years, the dominant fish prey for spring spawned bluefish in all locations was bay anchovy. Other important prey included long-finned squid, striped anchovy, butterfish and round herring. Bay anchovy was also important for summer spawned bluefish, but long finned squid were not. The difference was made up from other invertebrates, such as copepods, amphipods, mysids, and crab larvae.

B. Adult Bluefish

Buckel et al. (1999) also examined gut contents of 275 adult bluefish collected in 1994 and 1995. Adult bluefish collected in the Georges Bank region had fed on butterfish, squid, round herring and Atlantic herring. Adults captured from Cape Hatteras to Montauk Point, NY had fed on bay anchovy, butterfish, round herring, and squid. There also was noticed year to year variation, where in 1995 both adults and young of year bluefish fed on channeled whelk, where they did not in 1994. Table 3-1 displays some of those data demonstrating variation by species consumed from location to location.

Table 3-1: Temporal and Geographic Variation in Bluefish Diet				
Percent by weight of selected bluefish diet in various locations (Buckel et al. 1999)				
	1994		1995	
	Georges Bank (n=50)	Hatteras-Montauk (n=65)	Georges Bank (n=44)	Hatteras-Montauk (n=116)
Bay Anchovy		21.4		34.9
Butterfish	18.6	26.5	16.3	9.0
Long Finned Squid	23.7	5.2	18.1	10.9
Channeled Whelk				13.0

Bowman et al. (2000) evaluated stomach contents of 568 bluefish collected during the NEFSC bottom trawl survey crusies from 1977 to 1980. Sampling locations include offshore south of Cape Hatteras, Middle Atlantic, Southern New England, Georges Bank, Gulf of Maine and Scotian Shelf, inshore south of Cape Hatteras and inshore north of Cape Hatteras. Overall, of the bluefish analyzed, approximately 60% by weight of the stomach contents consisted of some type of fish, vs. 40% squid. That said, those data varied significantly by location (see Table 3-2)

Table 3-2: Geographic Variations in Bluefish Diet					
Percent by weight of bluefish diet in various locations (Bowman et al. 2000)					
	Mid Atlantic	S. New England	Georges Bank	Inshore N of Cape Hatteras	South of Cape Hatteras
Fish	98.1	4.6	33.9	75.5	94.1
Squid	1.3	95.3	65.8	22.2	3.5

Richards (1976) also evaluated stomach contents of adult bluefish in Long Island Sound. Species consumed include long-finned squid, alewife, menhaden, bay anchovies, silver hake, butterfish, bluefish and round herring.

V. Recreational Striped Bass and Bluefish Regulations

A final way in which to evaluate a fishery in relation to fish consumption advisories is to look at the fishing regulations. There is no state along the East coast that forbids the catching of striped bass or bluefish. The limits on how many fish an angler can keep are based on fish population, not safe consumption levels. The following summarizes the recreational fishing regulations for striped bass and bluefish for the states along the Atlantic coast. Exceptions to the regulations and sources consulted are found in Appendix A to this chapter.

Fishing regulations for bluefish are jointly managed by Atlantic States Marine Fisheries Council and the Mid Atlantic Fisheries Management Council (ASMFC). They determine yearly Total Allowable Landings, and the recreational fishery gets 83% of that. That said, even though the landings are partitioned in this manner, since the recreational fishery has not approached their Total Allowable Landings, any unused landings have been shifted back to the commercial fishery. Coastwide regulations are adjusted yearly to reach the recreational harvest limit. States can set more conservative regulations if they want (most have stayed at 10 bluefish despite an allowable increase to 15 individual fish).

Striped bass are managed by ASMFC along with states under an ASMFC Fishery Management Plan (FMP). Each state sets recreational regulations within this federal framework. In general, most states elect to adopt regulations consistent with periodically updated framework (usually tied to stock assessment updates) but can elect to use conservation equivalency to have different but equivalent regulations. Coastal and producer states are usually under different regulatory guidelines. These regulations are specifically set for population management purposes and not for advisory purposes.

Table 3-3: Recreational Fishing Regulations for Striped Bass				
State	Minimum Length Inches (Total Length)	Possession Limit (Fish/Angler/Day)	Season	Other
Maine	20-26” or >40”	1	All Year	
New Hampshire	28”	2 (only 1 >40”)	All Year	
Massachusetts	28”	2		
Rhode Island	28”	2	All Year	
Connecticut	28”	2	All Year	
New York	28	2	Apr 15-Dec 15	Party/Charter Boats
	28”	1-28-40” 1 >40”	Apr 15-Dec 15	All other anglers
New Jersey	28”	2 fish > 28”	Atlantic Ocean, all year	
Delaware	15” Non-Tidal 28” Tidal	2	All Year	
Maryland (Coastal Bays and Atlantic Ocean	28”	2	All Year	
Virginia(Coastal Bays and Atlantic Ocean	28”	2	Jan 1-Mar 31	Ches. Bay Spring Season: May 16-June15, Min size: 18", Max size: 28". Possession limit 2 Fish/Angler
			May 16-Dec 31	Ches. Bay Fall Season: Oct 4-Dec 31. Min Size: 18", Max Size: 28". Possession limit 2 Fish/Angler
North Carolina (Atlantic Ocean)	28”	2	All Year	
South Carolina	None	10	All Year	Rod and Reel Only, may not be sold
Georgia	22”	2	All year	Fork Length
Florida	No Regulations			

Table 3-4: Recreational Fishing Regulations for Bluefish				
State	Minimum Length Inches (Total Length)	Possession Limit (Fish/Angler /Day)	Season	Other
Maine	None	3	All Year	
New Hampshire	None	10	All Year	No Selling: Oct 1-Jun 30 Hook and Line Only
Massachusetts	None	10	All Year	
Rhode Island	None	10	All Year	
Connecticut	None	10	All Year	
New York	None for 1st 10 fish, then 12" for next 5 fish	15	All Year	
New Jersey	None	15	All Year	
Delaware	None	10	All Year	
Maryland	8"	10	All Year	
Virginia	None	10	All Year	
North Carolina	Only 5 fish >24"	15	All Year	
South Carolina	None	15	All Year	
Georgia	12" Fork Length	15	Mar 16-Nov 30	
Florida	12" Fork Length	10	All year	

VI. Extent of the Recreational Fisheries

The need for and location of advisories is in part based on the availability of fish. The availability of fish can be evaluated through the Marine Recreational Fisheries Statistics Survey through the National Marine Fisheries Service (a branch of the National Oceanic and Atmospheric Administration (NOAA). The MRFSS is a telephone and intercept (interview) survey of marine recreational anglers to identify catch, effort and participation statistics characterizing the marine recreational fishery. The MRFSS does not collect data on freshwater systems so it likely underestimates catch in states with freshwater striped bass fisheries (for example, Connecticut, New York, New Jersey, Delaware, Maryland and Virginia). It also provides biological, social and economic data. The following summarizes the 2006 data (the most recent data available at the time of query) (NMFS 2007).

Figures 3-3 through 3-7 summarize bluefish and striped bass recreational harvest data from the Marine Recreational Fisheries Statistics Survey (MRFSS) for 2006. The data include all fishing modes (shore fishing, charter boats, private and rental boats) and all fishing areas (inland, state and federal waters). The data are summarized by number of fish harvested per Atlantic Coast State. In this case, "harvested" represent "fish that are brought back to the dock in a form that can be identified by trained interviewers" (also known as "Type A" fish). These graphs also include Type B1, which are fish that are caught and identified by anglers, and may be released, filleted on-board or used for bait. Type B1 harvest has been included in this summary because it is important to capture those fish that may be filleted on board and later consumed. However, please keep in mind that the following data also include fish that may be discarded dead or used for bait and would thus not be consumed. This is considered to be a very small portion of this category, however. Fish released alive are not included in the data presented below. Figure 3-1 depicts the number of striped bass and bluefish caught recreationally in 2006 per U.S. East coast state. Massachusetts, New York, New Jersey, North Carolina, and Eastern Florida have the most significant bluefish recreational fisheries; all land more than 600,000 bluefish per year. Rhode Island, Connecticut, Maryland and Virginia land between 200,000 and 500,000 bluefish per year. Maine, New Hampshire, Delaware, South Carolina and Georgia harvest less than 200,000 bluefish per year. In fact Maine, New Hampshire and Georgia have very little fishery, harvesting 6,408, 10,372, and 3,294 bluefish, respectively.

In Massachusetts, New York, New Jersey, Maryland and Virginia striped bass harvests were greater than 200,000 annually. Maine, New Hampshire, Rhode Island, Connecticut, Delaware, North Carolina, and South Carolina harvested less than 150,000 striped bass. Anglers in South Carolina harvested only 1,704 striped bass in 2006, while in Georgia they reportedly harvested none. The MRFSS provided no striped bass harvest data for Eastern Florida.

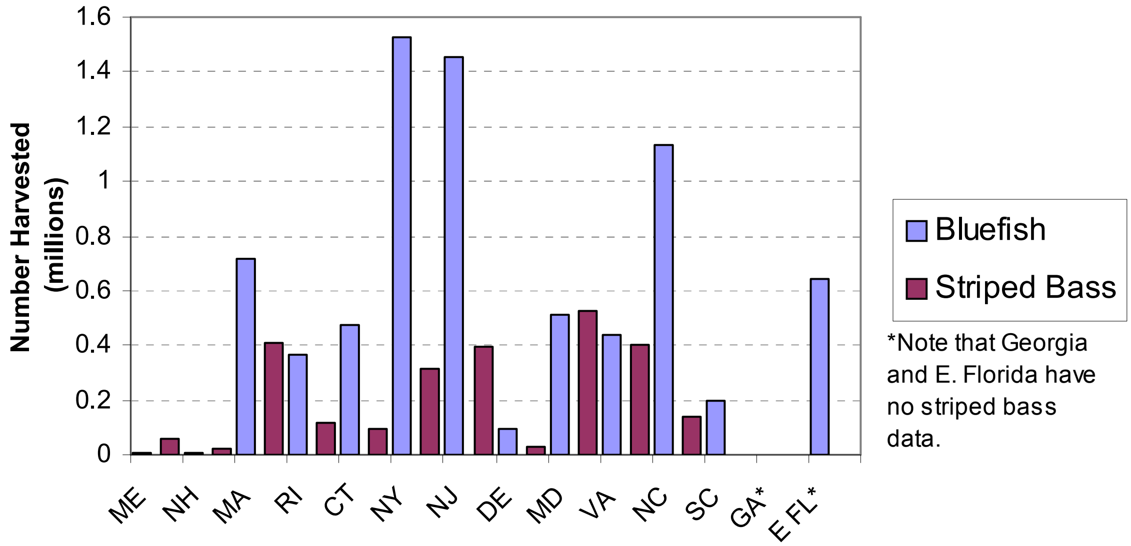

Figure 3-3: Number of Type A and B1 Bluefish and Striped Bass Harvested Recreationally along the U.S. East Coast, 2006

Figure 3-4 shows the total number of fish caught recreationally per U.S. East coast state. Eastern Florida harvested the most recreational fish with 27 million. This is approximately 13 million fish more than the next state, Virginia, which harvested over 13 million recreational fish. States that harvested between 5 and 12 million fish annually include Massachusetts, New York, New Jersey, Maryland, Virginia, North Carolina and South Carolina. Again, although Eastern Florida harvested the most recreational fish of all the eastern U.S. states, this does not include striped bass, as there is no striped bass fishery in this state. Maine, New Hampshire, Rhode Island, Connecticut, Delaware, and Georgia harvested less than 3 million recreational fish each. In fact, Maine and New Hampshire had the smallest recreational fisheries, harvesting less than 600,000 fish annually. For each U.S. East coast state striped bass and bluefish are a minority of the overall recreational fishery.

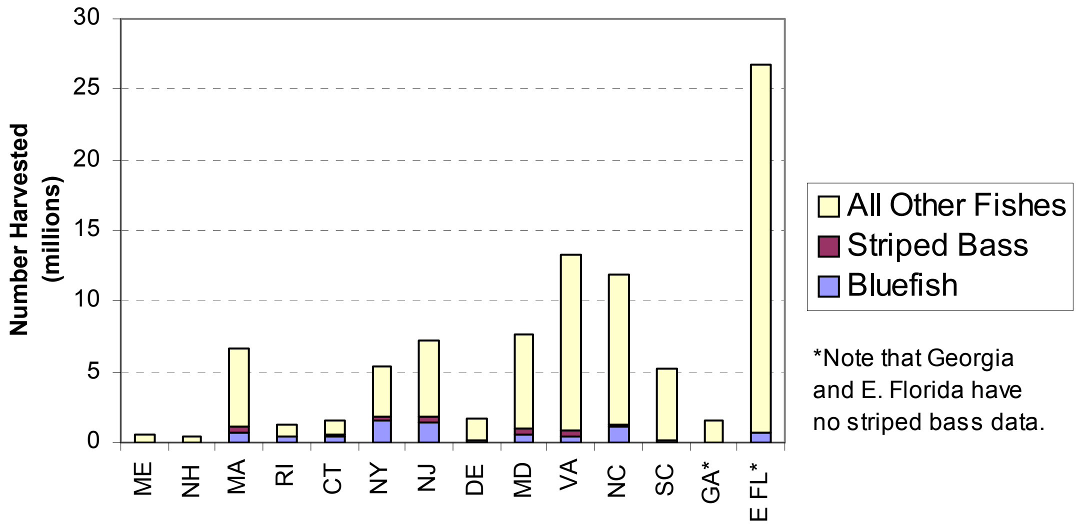

Figure 3-4: Number of Type A and B1 Bluefish, Striped Bass and All Other Fishes Harvested Recreationally along the U.S. East Coast, 2006

Figure 3-5 shows striped bass, bluefish and all other fisheries harvests as a percentage of the total fish harvested recreationally within that state for 2006. This chart demonstrates that bluefish and striped bass collectively make up less than 40% of the total recreational harvest for each state along the U.S. East coast. Rhode Island, Connecticut, New York and New Jersey's bluefish and striped bass harvests make up 25 to 40% of that states total recreational harvest, while Maine, Massachusetts, Maryland, and North Carolina's bluefish and striped bass harvest is between 10 and 20% of the total recreational fish from each state. All other states land less than 10% of their total harvest from bluefish and striped bass. Virginia and North Carolina land more than 10 million recreational fish annually, which are some of the states with the highest harvests, yet less than 10% of these harvests come from bluefish and striped bass. Conversely, although Rhode Island and Connecticut land fewer than 1 million fish annually, bluefish and striped bass make up a relatively high percentage of the recreational harvest, 32.9 and 37.5% respectively. Bluefish are also a small percentage of Eastern Florida's large total recreational harvests (2.4%). Again striped bass data are not available for Eastern Florida. In Georgia, bluefish and striped bass make up only 0.2% of the total recreational harvest, but again, reportedly, no striped bass were caught in Georgia in 2006.

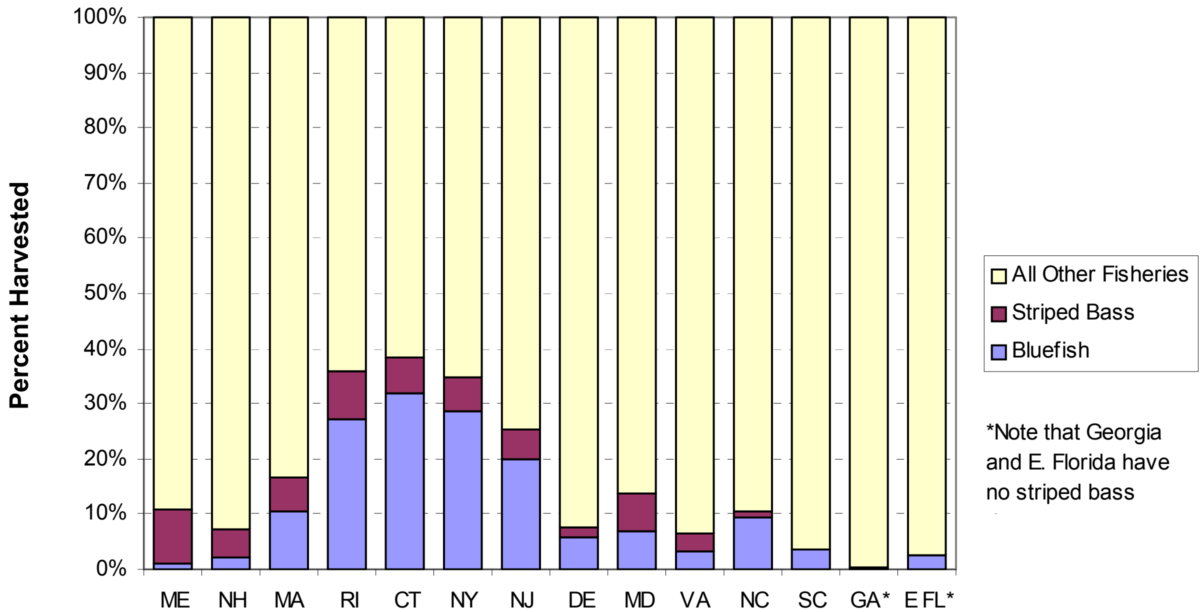

Figure 3-5: Percent of Type A and B1 Bluefish, Striped Bass and All Other Fishes Harvested Recreationally along the U.S. East Coast, 2006

Figures 3-6 and 3-7 represent the recreational harvest of bluefish and striped bass along the US east coast in weight (in pounds and as a percentage, respectively). Type A and B1 data are included here and signify fish brought back to the dock and identified by trained interviewers, as well as fish that were released, filleted on-board or used for bait and thus identified on-board by the anglers. It was suggested that weight data should be considered because the weights of bluefish and striped bass vary along the U.S. East coast depending on local fishing regulations and the local fish population. Also, looking at harvest by weight may reduce the effect that baitfish have on this data, as it is thought that whole keepers and filleted fish will weigh more than bait fish.

The relationship between harvest of bluefish and striped bass in weight compared to the harvest in number. The harvest in weight exaggerates the difference in harvest between bluefish and striped bass since the average weight of striped bass landed is greater than bluefish.

Figure 3-6 demonstrates that the total recreational fisheries in Massachusetts, New York and New Jersey are similar to their striped bass and bluefish harvests-very plentiful by weight. North Carolina and Eastern Florida similarly have high harvests of all species combined, about 25 million pounds apiece, but striped bass and bluefish harvests make up a small portion of the overall recreational harvest. Maine, New Hampshire, Rhode Island, Connecticut, Delaware, South Carolina, and Georgia's anglers all land less than 6 million pounds of recreational fish each year.

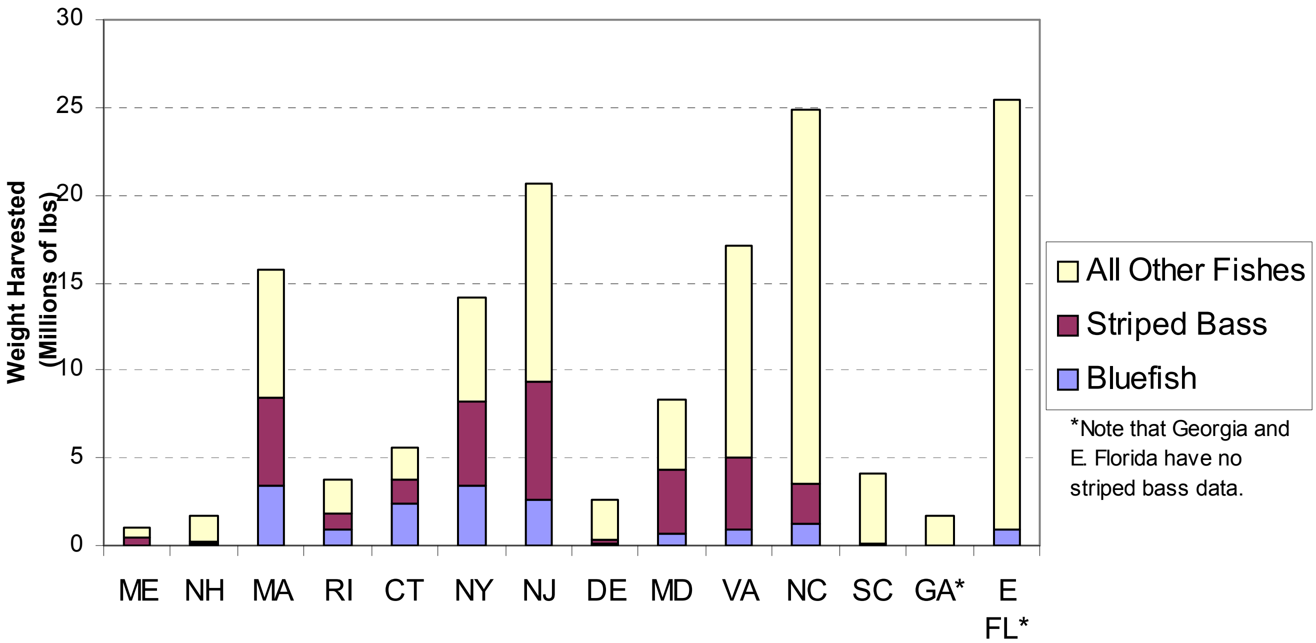

Figure 3-6: Weight of Type A and B1 Bluefish, Striped Bass and All Other Fishes Harvested Recreationally along the U.S. East Coast, 2006

Figure 3-7 tells an interesting story, especially when compared with Figures 3-4 and 3-5, and shows that some states that harvest relatively few bluefish and striped bass as compared with other U.S. East coast states have a relatively high proportion of bluefish and striped bass amongst their recreational harvest. Over 40% of the total recreational fishery by weight consists of bluefish and striped bass harvest in Massachusetts, Rhode Island, Connecticut, New York New Jersey, Maryland and North Carolina. . Conversely, a very small proportion of Eastern Florida's angler's harvest is attributable to bluefish although, again, Eastern Florida has no established striped bass fishery. Less than 40% of the recreational fishery consists of bluefish and striped bass in Maine, New Hampshire, Delaware, and Virginia.

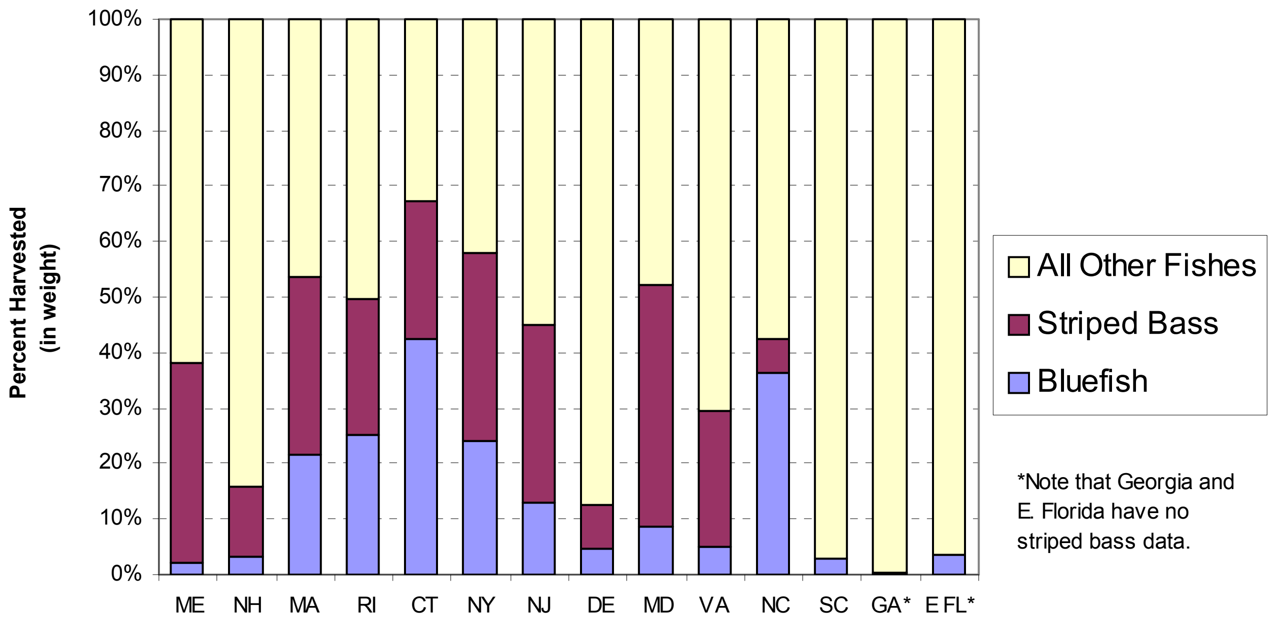

Figure 3-7: Percentages by Weight of Type A and B1 Bluefish, Striped Bass and All Other Fishes Harvested Recreationally Along the U.S. East Coast, 2006

Figures 3-5 and 3-7 are consistent in that they both show Massachusetts, Rhode Island Connecticut New York and Maryland as having the greatest percentage of bluefish and striped bass harvest compared to other fishes. However when we take into account the weight of fish harvested rather than simply the number, we see the bluefish and striped bass make up a larger percentage of harvest for each state. This is especially true for striped bass.

VII. Conclusions

Striped bass are found from Florida north to Maine, but their importance as a fishery in Florida, Georgia and South Carolina is very limited. The major spawning locations for striped bass include the Hudson River, the Delaware Estuary, the Chesapeake Bay, and Albermarle Sound/Roanoke River. Adult striped bass migrate north over the summer, then overwinter off the coast of Virginia/North Carolina.

While the dates of arrival of striped bass from location to location are generally adequate, it is felt it is not accurate enough to identify breeding stock based on time of arrival for various locations (to influence sampling programs).

Bluefish are found from Florida to Maine, but they are not important fisheries in Georgia and South Carolina. Bluefish along the Atlantic Coast are considered one population. Both bluefish and striped bass are opportunistic feeders. Their diets will be dominated by available resources at any particular location and time.

VIII. Recommendations for Future Work

As any particular state will be impacted by different populations of striped bass, any PCB sampling program should be tailored to the biology of the striped bass inhabiting the waters. For example:

Northern New England states, should vary their sampling times to capture different migratory stocks entering the waters. While the times of arrival are not consistent enough to allocate particular breeding populations to arrival times, it is the case that different populations will arrive at different times. An angler will be sampling randomly from these populations over the season and a sampling program should capture this.

States that are impacted by both migratory fish and fish that have a breeding population will need to tailor their sampling regime to capture both local fish as well as migratory fish.

Finally, southern states with resident non-migratory populations of striped bass will be measuring local sources of contamination and hence have a simpler sampling scheme.

An alternative possibility for sampling would be to sample the large migratory female striped bass that winter offshore of North Carolina. This population would represent a mix of the various stocks as would be seen migrating up and down the coast. Additional populations of overwintering striped bass include the mouth of the Hudson River and the mouth of the Chesapeake Bay. A similar strategy could be applied for bluefish, where the larger overwintering adults could be sampled off the coast of Virginia.

Depending on the location of the sampling program, it may also be worthwhile to sex the fish collected, as the female striped bass are the sex that are migrating up and down the coast while males tend to be resident.

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Appendix 3-1: Exceptions to Striped Bass and Bluefish Recreational Fishing Regulations

Maine:

Striped Bass. On the Kennebec, Sheepscot, Androscoggin rivers and related bays and tributaries, the open season is July 1 through November 30. There is a catch and release season from May 1 through June 30, but with single hooked artificial lures only.

New Hampshire. No additional regulations beyond Table 3-3 and 3-4.

Massachusetts. No additional regulations beyond Table 3-3 and 3-4.

Rhode Island. No additional regulations beyond Table 3-3 and 3-4.

Connecticut. No additional regulations beyond Table 3-3 and 3-4.

New York. Striped Bass. 1 striped bass per angler per day may be taken north of the George Washington Bridge. Striped bass must be 18" total length and can be caught from Mar 16-Nov 30.

New Jersey:

Striped Bass. On the Delaware River and tributaries, Trenton to Salem River and tributaries the open season is all of March and June 1 through December 31. The Atlantic Ocean from 0-3 miles from shore has no closed season, but beyond 3 miles the fishery is closed. All other marine waters are open from March through December.

Delaware:

During April and May the striped bass recreational season is closed on the spawning grounds of the Nanticoke River, C & D Canal and Delaware River and their tributaries north of the southern most jetty at the C & D canal.

Maryland:

Striped bass has a catch and release season from March 1 through May 3 on a section of the Susquehanna flats. The spring trophy season is from April 16 through May 15 and allows fishermen to catch 1 striped bass per day that is at least 28" in length on the main stem of Chesapeake Bay. From May 16 through December 15 fishermen may take 2 striped bass between 18 and 28" per day or they may take 1 between 18 and 28" and 1 larger than 28" per day. The May portion of this season must be fished on the main stem of the Chesapeake bay, while the June through December 15 portion may be fished anywhere on Maryland's Chesapeake Bay and its tributaries. There is also a Potomac River and Maryland tributaries season from April 16 through December 31. From April 16 through May 15 of this season, fishermen can take 1 28" or greater striped bass per day in one section of the Potomac. Then from May 16 through the end of the calendar year fishermen can take 2 striped bass from 18 to 28" long per day or 1 striped bass from 18 to 28" long plus 1 that is greater than 28" per day on another section of that river and its tributaries. See http://www.dnr.state.md.us/fisheries/fishingreport/frmapindex.asp for further details about the geographic limitations of each striped bass fishing season.

Virginia:

Virginia has two striped bass trophy seasons. The first applies to the coastal area from May 1 through May 15 and the second applies to the Chesapeake Bay and its tributaries from May 1 through June 15. During these trophy seasons fishermen may take 1 striped bass at least 32" long. There is a Chesapeake Bay spring season lasting from May 16 through June 15 when fishermen can take 2 striped bass between 18 and 28" on the main stem of Chesapeake Bay and Virginia's Chesapeake Bay tributary rivers. However this does not include the tributaries that empty into the Potomac River. One of the fish kept may be larger than 32" but a catch report is required. No striped bass greater than 32" may be taken in the Spawning reaches from May 1 through June 15. There is also a Chesapeake Bay fall season, also on the waters described for the spring season, which runs from October 4 through December 31. At this time, length and possession limits are the same as the spring season, but one fish of the 2 fish possession limit may be larger than 28 inches.

North Carolina:

In the Albemarle Sound Management Area between January 1 and April 30, fishermen may take 3 striped bass per person per day that are at least 18" in total length. There is also a fall season where fishermen must follow the same possession and size limits as the spring. In coastal areas other than the Atlantic Ocean from 0-3 miles offshore2 fish per day per person may be kept. The fall season is from Oct 1 – Dec 31 and spring season from Jan 1 – Apr 30.. In the Roanoke River striped bass greater than 18" may be caught, but no fish between 22 and 27" may be possessed at any time And only 1 fish greater than 27" may be in the daily creel. the season is from March 1 through April 30

South Carolina:

In the Wando, Cooper Rivers, and the Santee River downstream to the AIW, there is a 21" striped bass minimum. There is a 5 fish per person per day limit in these rivers, but a 10 fish per person per day limit in other South Carolina waters. There is a 2 striped bass per day limit in the Savannah River.

Georgia:You may only keep two fish that are 22 inches or longer, **except** the minimum length is 22 inches on the North Newport River, Medway River including Mount Hope Creek, Little Ogeechee River, Ogeechee River; Oconee River downstream of GA Hwy 22 in Milledgeville; Ocmulgee River downstream of GA Hwy 96 bridge between Houston and Twiggs counties; Altamaha River, Saint Mary's River, Satilla River, and the tributaries to these river sections; and from saltwater. The minimum length is 27 inches on the Savannah River and its tributaries downstream of J. Strom Thurmond Dam (2 fish limit).

Florida:

No regulations.

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Chapter 4 Health Effects of PCBs

I. Introduction

This chapter focuses on epidemiological evidence for neurotoxicity as a result of developmental exposure to PCBs, rather than on experimental studies. Neurotoxicity has been identified in a number of longitudinal prospective cohort studies as a consequence of environmental exposure to PCBs. These studies allow an estimation of the maternal body burden of PCBs in humans that may result in adverse effects, and are therefore potentially suitable for developing a fish consumption advisory.

This being said, a number of other types of studies and endpoints are addressed, including the carcinogenic effects of PCBs and associated risk implications. This chapter is provides background on the derivation of existing toxicity values for PCB risk assessment and updates these regulatory reviews with a new analysis of the epidemiology evidence for low dose PCB effects on neurodevelopment. This is discussed in the context of traditional risk assessment approaches towards setting fish consumption advice and also with respect to whether the general population PCB body burden is approaching a risk level of concern. Finally, a brief discussion of the relative sources of PCBs and Omega-3 fatty acids in the diet are presented, as it relates to the health benefits of fish consumption.

II. Current Toxicity Values Available for Use in Setting Advisories

The toxicological basis for east coast state fish consumption advisories based on PCB concentrations in fish varies among the states. Toxicological bases include application of EPA's cancer slope factor for PCBs, EPA's reference dose (RfD) for Aroclor 1254 or 1016, the Great Lakes Health Protective Value (HPV) from the Great Lakes Protocol. While not a toxicity value upon which risk based decision criteria are based, some states have used FDA's tolerance level to help make decisions on fish advisories. Each of these approaches is briefly described.

A. FDA Tolerance Level and the Exposure Level used to Derive Tolerance

The FDA tolerance (2 ppm) is a tolerance level designed for commercial fisheries. While the exposures to chemicals vary significantly from commercial fisheries to recreational fisheries, some states consider FDA's tolerance value when setting advisories (New York and Massachusetts). So, while the risk benefit analysis used in developing the tolerance level reduces confidence for its use in the derivation of fish advisories for recreationally caught bluefish and striped bass, it's basis will be discussed in brief. More detail will be given to the "exposure level" on which the tolerance is based.

i. Basis of the FDA Tolerance Level

FDA provided the risk assessment component used in the risk-benefit analysis that lead to the reduction of the 5 ppm temporary tolerance to the 2 ppm final tolerance in a 1982 publication (Cordle, et al., 1982). The publication describes an acceptable PCB exposure dose of 1 ug/kg/day or 0.001 mg/kg/day for pregnant women, infants and young children based upon clinical and epidemiological evidence of PCB-induced health effects from exposure to contaminated cooking oil in Japan. The FDA publication also provided an exposure assessment for the U.S. population that suggested that the major PCB-containing fish species had concentrations between 0.25-1.7 ppm. Based upon the amounts of these species eaten by fish consumers in a 1978-79 survey of nearly 26,000 individuals, FDA estimated a 50% consumption rate of 8.25 g/day and a 90th percentile rate of 23 g/day. This yielded daily exposure estimates at a 2 ppm Tolerance Level that ranged between 0.08 to 0.21 ug/kg/day for a 70 kg adult. Since these exposure levels were below the target exposure dose of 1 ug/kg/day a 2 ppm tolerance level was judged by FDA to be health protective (Toal and Ginsberg 1999).

That said, use of the tolerance for developing advisories for recreational fish is hampered by the following difficulties:

- It is based upon national average levels of fish consumption, which do not reflect the amounts of fish consumption possible in sport or subsistence fisher families or in other high end fish consumers. Further, the consumption survey data are from the 1970's which may underestimate current levels of fish consumption. Additionally, the exposure assumptions are national in scope and do not reflect regional difference which would be important for recreational advisories.

- Perhaps most importantly, it is based upon the premise of a single bright-line cutoff for fish consumption, not recognizing that risks vary depending upon the fish concentration and frequency of meal consumption.

ii. FDA Exposure Level upon which the Tolerance is based

The 0.001 mg/kg/day exposure level was derived from the Yusho incident in which humans were poisoned by cooking oil contaminated by PCBs (and, as discussed further, PCDFs). FDA also utilized a 10 fold safety factor, thus setting the acceptable exposure level 10 fold below that experienced in the Yusho incident (0.0001 mg/kg/day or 1 ug/kg/day)[1]. It should be noted that the Japanese group exposed to the contaminated cooking oil experienced overt health effects including chloracne, neurological disorders (visual disturbances, numbness and weakness in limbs) and disturbances in liver function. This population also had an increased cancer risk and offspring had skin pigmentation abnormalities and multiple neurobehavioral effects that persisted for years. When extrapolating from such marked effects in humans, a 10 fold safety factor does not

[1] The exposure level is equivalent in concept to the toxicity values (Reference Dose, Acceptable Daily Intake, etc.) discussed further (note the consistent units of mg PCB per kg body weight per day).

provide assurance that some degree of toxicity would not be experienced in the general population or that effects wouldn't occur in sensitive individuals (Toal and Ginsberg 1999). A key FDA assumption was that exposure in the U.S. population would be significant for only 1000 days (2.7 years) from the time of their analysis (1982) due to the expectation that PCB fish concentrations would drop below levels of concern in that time.

However, the larger issue with the Yusho dataset is that it is not considered to be valid for PCB risk assessment (ATSDR, 1998). A major limitation is that the incident involved a mixed exposure to PCBs and polychlorinated dibenzofurans (PCDFs). Since the role of PCDFs and PCBs cannot easily be separated in this case, the Yusho incident is not optimal for dose-response assessment of PCB effects in humans (ATSDR 1998) (Toal and Ginsberg 1999).

Therefore, the risk assessment that was used in the development of the FDA 2 ppm PCB tolerance level is limited in the following ways (Toal and Ginsberg 1999):

- It is quite dated, not taking into consideration more recent monkey studies showing low dose effects on immune function, reproduction, and fetal development (Tryphonas 1989; Arnold 1995). The FDA acceptable exposure level used in the development of the tolerance level also does not take into consideration the recent epidemiologic investigations reporting associations between developmental exposure to PCBs and adverse neurodevelopmental and other outcomes.

- The FDA tolerance level relies primarily upon the Yusho incident to develop an acceptable exposure level. This incident showed marked health effects but its relevance to setting acceptable exposure levels for PCBs is decreased by several factors, the most important being the likely contribution of PCDFs to the toxicity seen. FDA discussed some of the other data available at the time (early rat and monkey studies) which suggested that health effects might be possible below the 1 ug/kg/day acceptable exposure level. However, FDA did not strongly consider these findings because of several uncertainties and since monkeys appeared to be more sensitive than rodents or humans.

- FDA developed an acceptable exposure level under the assumption that exposure would not be chronic, but limited to 2.7 years on the basis that PCB levels in foods were expected to decline. However, PCBs are very persistent and they continue to enter the environment from a variety of old industrial sites (ATSDR 1998). For the purpose of risk assessment it is prudent to consider current exposures from fish consumption to be chronic rather than set allowable exposures on the high end because in the future, PCB exposures may decline, thus offsetting some of the chronic risks.

B. Toxicity Values from USEPA and ATSDR

The toxicity values derived for Aroclors and mixtures of PCBS are summarized in Table 4-1. These values are briefly described in Sections 4 and 5.

Table 4-1. Summary of PCBs Toxicity Values

	Toxicity Values			
PCB Mixture	Description	Value	Critical Effect	Species
Aroclor 1016	USEPA Chronic oral reference dose[1]	7×10^{-5} mg/kg/day	Birthweight	Rhesus Monkey
Aroclor 1254	USEPA Chronic oral reference dose[1]	2×10^{-5} mg/kg/day	Immune/Dermal	
Aroclor 1254	Chronic ATSDR Minimum Risk Level[2]	2×10^{-5} mg/kg/day	Immune/Dermal	
Bioaccumulative, higher chorination	US EPA Oral Slope Factor[1]	2.0/mg/kg/day	Female liver tumors	Rat
More water soluble and volatile PCBs	US EPA Oral Slope Factor[1]	0.4/mg/kg/day	Female liver tumors	
Low chlorination PCBs	US EPA Oral Slope Factor[1]	7×10^{-2} /mg/kg/day	Female liver tumors	
PCBs in Fish	Great Lakes Health Protection Value[3]	5×10^{-5} mg/kg/day	Immune/Menstrual /Endocrine	Monkey and Human

[1]US EPA 1996, 1997 Reference doses are found under the Aroclor entries, cancer slope factors are found under the polychlorinated biphenyl entry
[2]ATSDR 2000.
[3]GLSFATF (1993).

i Non-Cancer

USEPA has developed reference doses (RfDs) of 2×10^{-5} mg/kg/day for Aroclor 1254 and 7×10^{-5} mg/kg/day for Aroclor 1016 . The US EPA has not derived reference doses for other mixtures because of insufficient data. US EPA derived an Aroclor 1254 RfD of 2×10^{-5} mg/kg/day based upon a Lowest Observed Adverse Effect Level (LOAEL) in adult female Rhesus monkeys of 0.005 mg/kg/day for both an immune system endpoint (decreased antibody response in vitro) and a dermal response (swollen Meibomian gland in eye, altered nails). A uncertainty factor of 300 was applied to this LOAEL (3 fold for inter-species extrapolation, 10 fold for intraspecies uncertainty, 3 fold to extrapolate from a LOAEL to a NOAEL (No Observed Adverse Effect Level), 3 fold to adjust from subchronic - 55 month - exposure to chronic RfD) to yield an RfD of 2 x 10^{-5} mg/kg/day. Similar effects were also observed at this lowest dose in the offspring of these monkeys. Assuming that similar uncertainty factors are applied to the developmental LOAEL as used above, the developmental RfD would be the same as the chronic RfD of 2 x 10^{-5} mg/kg/day (US EPA 2003), although EPA does not in fact develop developmental RfDs.

The oral RfD for Aroclor 1016 is 7 x 10^{-5} mg/kg/day based upon a developmental LOAEL in monkeys whose mothers were exposed to this Aroclor for 7 months prior to delivery. The LOAEL for reduced birth weight (80% of control) was 0.028 mg/kg/day with the NOAEL determined to be 0.007 mg/kg/day. An overall uncertainty factor of 100 to account for interspecies extrapolation (10-fold), 3 fold for intraspecies uncertianty (3-fold), and to adjust subchronic to chronic (3-fold)) was applied to the NOAEL to yield a RfD of 7 x 10^{-5} mg/kg/day (US EPA 2003).

In its Toxicological Profile, ATSDR developed a chronic oral Minimum Risk Level (MRL) of 2 x 10^{-5} mg/kg/day for Aroclor 1254 based upon the same study and endpoints in monkeys as that used by USEPA in its Aroclor 1254 RfD. ATSDR used the same overall uncertainty factor (300 fold) but it was constructed differently. (10 fold for adjusting from a LOAEL to NOAEL, 3 fold for interspecies uncertainty, 10 fold for intraspecies uncertainty) (ATSDR 2000).

US EPA recommends the use of 2 x 10^{-5} mg/kg/day as the dose to use when calculating number of fish meals per month or week (US EPA 2000). Additionally, it is worth noting that the effects of concern (decreased antibody response in vitro and swollen Meibomian gland in eye, altered nails) apply to all individuals, as does the ATSDR, FDA and Great Lakes risk-based targets. Finally, it is worth noting that these estimates of toxicity are based on commercial mixtures (Aroclors) that were dosed to animals, not the biodegraded suite of congeners found in fish. However, the supporting epidemiological database discussed below involved human exposure to PCBs in fish and so the dose response from these studies is directly relevant to risk assessment in support of fish consumption advisories.

ii Cancer

USEPA has developed a range of oral cancer slope factors which corresponds to the range of PCB mixtures tested in a 1996 bioassay series. Relying principally upon findings of liver tumors in female rats receiving lifetime dietary exposure, the summarized data show similar potency in the higher chlorinated Aroclor mixtures (1254 and 1260), somewhat lower potency with Aroclor 1242, and lower potency again for Aroclor 1016. Based upon this pattern of decreasing potency with decreasing chlorination, and based upon the environmental fate of PCBs (higher chlorination mixtures tend to have greater environmental persistence and bioaccumulation in fish and other foods), the cancer slope factor for PCBs found in the food chain was set at 2.0/mg/kg/day, the slope factor for more water soluble and volatile (lower chlorination) PCBS was set at 0.4/mg/kg/day, and the slope factor for the lowest chlorination mixtures was set at 7 x 10^{-5} mg/kg/day (US EPA 2003). This information is summarized in Table 4-1.

C. Calculation of Consumption Rates using USEPA's Risk Based Method

USEPA has developed guidance for use by states in developing fish consumption advisories for recreational fish (USEPA 2000). It is recognized that states often modify these procedures to reflect conditions specific to their state, but for illustrative purposes, the guidance will be followed to demonstrate the results of a risk based approach for developing consumption advisories for striped bass and bluefish.

i. Derivation of a risk based decision criteria for Noncancer Toxicological Endpoints

Most non-cancer effects are thought to have a threshold dose, i.e., a dose below which no deleterious effect is expected to occur[2]. At doses above zero, but below the threshold, the risk of a non-cancer health effect is assumed to be zero. At doses above the threshold, the risk of a non-cancer effect typically increases with dose. USEPA establishes RfDs as posted on its IRIS database, which begin with the no effect level from animal or human studies and then incorporate uncertainty factors that take into account a variety of extrapolations (e.g., cross-species, inter-individual). The resulting RfD is intended to be well below any known effect levels and also below the human threshold dose even for subtle effects in sensitive individuals. Fish Consumption Advisories can be set at a contaminant intake dose less than or equal to the RfD resulting in an insignificant risk of deleterious effect from lifetime exposure at the advisory level. The RfD is considered an upper estimate of that dose level for the human population.

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[2] The reference dose is defined as an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure fo the human population (including sensitive subgroups such as children, the sick and the elderly) that is likely to be without an appreciable risk of deleterious effects during a lifetime (US EPA, 2002, 2004b; ATSDR, 1996).

The equation (USEPA 2000) for determining risk based decision criteria for noncancer toxicological endpoints is:

$$RBDC = \frac{(RfD \times BW)}{FC}$$

Where,

RBDC = Risk based decision criteria (mg/kg)
RfD = Reference Dose (mg/kg/day)
BW = Body Weight (kg)
FC = Fish Consumption Rate (kg/day)

The Reference Dose (RfD) is 2×10^{-5} mg/kg/day.

The body weight (BW) of the exposed individual is required because the RfD is expressed on a "per kilogram body weight" basis. The average body weight for adult males and females combined is assumed to be 70 kilograms (kg). (USEPA 2000)

A fish consumption rate (FC) of one eight ounce (227 grams) meal per week is used to derive risk based decision criterias (EPA 2000). One fish meal per week is equivalent to an average daily fish consumption rate of 0.0324 kg/day. It is recognized that an 8 ounce meal is an upper estimate of fish consumption.

ii. Derivation of Risk based decision criteria based on cancer effects

For many carcinogens, a single interaction between it and a cellular molecule can theoretically cause changes in the cell that can eventually lead to cancer. This mechanism does not have a threshold dose because any dose level, no matter how small, may pose a small but finite probability of initiating a cancer effect. Risk is assumed to be zero only at zero dose. Theoretically, it is not possible to keep doses below a threshold dose. Thus, guidelines for carcinogenic contaminants in an environmental medium (e.g., water or soil) are typically based on a level of excess risk from exposure to the contaminant in that environmental medium. Fish consumption advisories based on cancer effects are set at a level believed to represent a minimal risk of cancer from a lifetime of exposure. USEPA (2000) recommends defining the lifetime of exposure as 70 years. Carcinogens are assumed to act in a non-threshold manner - in that any amount of exposure to a carcinogen can cause an increase in risk.

The equation for determining risk based decision criteria for cancer effects is:

$$RBDC = \frac{(RSD \times BW)}{FC}$$

Where,

RBDC = Risk based decision criteria (mg/kg)
BW = Body Weight (kg)
FC = Fish Consumption Rate (kg/day)
RSD = Risk Specific Dose[3] (mg/kg-day)

and,

$$RSD = \frac{ARL}{CSF}$$

Where,

ARL = Acceptable Risk Level (unitless)
CSF = Cancer Slope Factor $(\text{mg/kg-day})^{-1}$

Body weight and fish consumption rate are previously defined. The acceptable risk level is for this exercise is defined as 1 in 100,000 (USEPA 2005). It is recognized that the acceptable risk level is a policy decision that can range from 1 in 1,000,000 to 1 in 10,000 or greater. It is also recognized that this value varies from state to state.
The cancer slope factor (CSF) is discussed above, and for these example calculations, a CSF of 2 /mg/kg/day.

iii. Calculation of Risk Based Decision Criteria

Using these equations and calculations, one can determine the concentration at which one would (using the US EPA recommended risk assessment method) issue advice for different consumption rates. As discussed in Chapter 4 there are data specific to striped bass and bluefish on contaminant loss due to cooking and preparation methods. USEPA (2000) recommends that states should use their knowledge of local fish preparation methods when determining whether or not to include cooking loss as part of their calculation. For this exercise, the results are presented both assuming no loss of PCBs due to cooking trimming and 50% loss due to cooking and trimming. A value of 50% is consistent with the value used in the Great Lakes Protocol and is not inconsistent with the data presented in Chapter 4

[3] The Risk Specific Dose is defined as the dose associated with a specific risk level (e.g., 1 in a million or 1 in a 100,000).

	Non Cancer Risk based decision criteria (without cooking loss)	Non Cancer Risk based decision criteria (with cooking loss)	Cancer Risk based decision criteria (without cooking loss)	Cancer Risk based decision criteria (with cooking loss).
One meal / week	43.2 ug/kg	86.4 ug/kg	10.8 ug/kg	21.6 ug/kg
One meal / month	173 ug/kg	346 ug/kg	43.2 ug/kg	86.4 ug/kg

One important modification of this method that is used by Delaware and Maine recognizes that PCBs contain certain congeners that act toxicologically like dioxins (referred to as coplanar PCBs or dioxin-like PCBs). In this method, dioxin like PCBs are subtracted from total PCBs and, using a TEF scheme (WHO 2005), combined with dioxin measurements to develop risk based decision criteria. Limitations of this method are whether or not dioxins and furans are included in the analysis, and the choice of toxicological benchmark to be used for the comparison (EPA's reassessment (not final) or ATSDR's and WHO's non-cancer estimates).

D. The Great Lakes Protocol

Health departments and natural resource departments from the eight Great Lake States convened a task force in the early 1990's to develop a consistent framework for risk-based fish consumption advisories for the Great Lakes. This resulted in the 1993 "Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory", a document that in addition to describing a general framework, also provided a risk assessment focus on PCBs in fish (GLSFATF 1993). The task force reviewed the toxicology and epidemiology literature for PCBs and rather than settling upon a key endpoint or study, they used a composite weight-of-evidence approach spanning a number of endpoints in monkeys (immunological, endocrine) and humans (developmental) for non-cancer effects. The task force also reviewed the basis for PCBs health benchmarks developed by ATSDR, EPA/IRIS, the National Wildlife Federation, the World Health Organization, the Tennessee Valley Authority, and the Ohio River Valley Sanitation Commission. The result of their composite analysis was the development of a risk based decision criteria termed a Health Protection Value (HPV) of 5×10^{-5} mg/kg/day. Their document shows that the animal and human data provide good support for this value and it is within the range of values derived by other bodies for PCBs (Toal and Ginsberg 1999).

Fish consumption advice for PCBs was then described based upon this HPV and other key assumptions: average meal size for 70 kg of one-half pound (227 grams); 50% reduction in fish fillet PCBs content (skin on, scales off fillet) through trimming and cooking losses of fatty portions of the fish. The goal of the advisory program was to limit PCBs exposure from fish to the HPV (5×10^{-5} mg/kg/day * 70 kg = 0.0035 mg/day), with less frequent meals needed to limit exposure to 0.0035 mg/day as PCBs fish concentrations rise (Toal and Ginsberg 1999).

The protocol assumed a 50% loss of PCBs from fish due to trimming and cooking calculations of PCB advisory levels. The 50% PCBs loss was derived from studies in six different species showing a range of trimming losses of organochlorine contaminants between 43 to 64%. A number of studies examining the effects of various cooking methods on organochlorine fish content were also reviewed. On the basis that most anglers trim their catch and that PCB-based advisories stress trimming to reduce exposure, the protocol adopted a 50% reduction in PCBs from the amount available in the raw fillet (Toal and Ginsberg 1999).

The risk-based PCBs fish concentration cutoffs for different meal frequencies developed in the protocol generated broad consumption categories as shown below. These categories were lumped fish across a range of concentrations into generalized categories (e.g., one meal per week or month) to facilitate risk communication and compliance.

Great Lakes Protocol	
	PCB Level in Fish
One meal / week	60 to 200 ug/kg
One meal / month	210 to 1,000 ug/kg
No Consumption	> 1,900 ug/kg

The health risks and associated meal frequencies described above may be somewhat higher in young children due to their higher intake rate per fish meal per body weight. This factor may warrant the advisory to maintain a focus on young children given that the postnatal risks associated with PCBs have not been well explored but exposure may be greatest during that period.

III. Epidemiological Studies of Neuropsychological Effects of PCBs in Children

It became clear from episodes of human poisoning in Japan and Taiwan that the fetus was more sensitive to the effects of PCBs than the adult (see Schantz et al., 2003 for review). In the poisoning episodes, babies were born with hyperpigmented skin, orbital edema, gingival hyperplasia, natal teeth, abnormal calcification of the skull, and hypersecretion of the Meibomian glands. Severely affected children were mentally retarded and had other neurological impairments. Follow-up studies of the Taiwan cohort identified lowered IQ, sensory abnormalities, and emotional problems.

These episodes of human poisoning prompted exploration of the consequences of environmental exposure to PCBs. Several longitudinal prospective studies assessed the effects of PCB exposure on developmental neuropsychological function in children as a consequence of prenatal and/or postnatal exposure to PCBs (see Schantz et al., 2003 and Rice, 2006, for reviews). Neuropsychological deficits that persisted to the latest ages measured were documented as a consequence of pre- or post-natal PCB exposure. These studies are all high-quality studies, with good covariate control.

Current toxicity values are based on data from studies that are one to two decades old, and rely on animal studies or initial results from the first epidemiological study. The more recent data from several epidemiological studies would provide a more appropriate basis of a noncancer RfD for PCBs than would the animal studies currently used.

A. Michigan Study

A study was initiated in the 1980s in which women who did or did not eat Lake Michigan fish were recruited, and their offspring assessed at various ages from infancy to 11 years, with about 250-325 children assessed at various ages (Table 4-2). The analytical methodology used in this study for detection of PCBs was less sensitive and precise than methods currently available. PCB analysis was performed by packed-column gas chromatography, adapting the Webb-McCall method. Aroclors 1016 and 1260 were used as reference standards. The concentrations of specific congeners could not be determined by this method, and this method would result in measurement error because the pattern of congeners in human tissue does not match commercial mixtures; this could potentially lead to exposure misclassification. PCB concentrations were measured in cord and maternal blood and breast milk. Duration of breast feeding and fish consumption were also ascertained. Over two-thirds of the cord blood samples and 22% of the maternal blood samples were below the analytical detection limit attained in the study. For some analyses of endpoints at four and 11 years, a composite of maternal and cord blood and milk PCB levels was used as the measure of prenatal exposure to address this problem.

Table 4-2. Summary of Identified Associations Between PCB Exposure and Adverse Neuropsychological Effects					
	Michigan	Oswego	The Netherlands	Germany	Faroe Islands
Study Population	eaters and non-eaters of Lake Michgan fish	eaters and non-eaters of Lake Ontario fish	general population, half breast-fed, half not	general population	fish- and whale-consuming population
Number of subjects	325	309	418	171	450 with PCB levels
PCB analysis	packed-column GC, Aroclors 1016 and 1260 as references	cord blood: 68 congeners or congener pairs	cord and maternal blood: 118, 158, 153, 180 breast milk in breast-feeding mothers: 118, 138, 153, 180; 17 dioxins and furans; 6 dioxin-like and 20 ortho-substituted PCB congeners	cord and maternal blood, breast milk: 138, 153, 180	cord tissue: 138, 153, 180
Infant neurological status	NBAS: abnormal responses (based on fish consumption)	NBAS: abnormal responses	Precchtl neurological exam: abnormal responses	Np	np
Fagan test of recognition memory	impaired: lower preference for novel stimulus	impaired: lower preference for novel stimulus	Np	no effect	np
Bayley Scales of Infant Development	no effect	Np	PDI: lower score MDI: no effect	MDI: lower score PDI: no effect	np
Cognitive effects 3–4 years	McCarthy: lower IQ	McCarthy: lower IQ	K-ABC: lower IQ	K-ABC: lower IQ	np

Cognitive effects 4–7 years	np	McCarthy: no effect on IQ	McCarthy: lower IQ in less-advantaged children	K-ABC: non-significant negative effect on IQ	Bender Gestalt: no effect WISC-R (3 subtests): no effect
Cognitive effects in later childhood	WISC-R, 11 years: decreased full-scale and verbal IQ	WISC-III, 9 years: decreased full-scale and verbal IQ	Tower of London, 9 years: poorer performance Rey Complex Figure Test: no effect	Np	np
Attention/response inibition/processing speed	vigilance task: increased errors of commission freedom from distractibility WISC-R: impaired Wisconsin Card Sort: increased perseverative errors mental rotation task: slower reaction time	vigilance task: increased errors of commission DRL: fewer reinforcements, shorter time between responses WISC-III freedom from distractibility: impaired	vigilance task: increased errors simple reaction time: impaired	Np	vigilance task: no effect after control for mercury

Language	Woodcock Reading Mastery Test word comprehension: impaired WISC-R reading comprehension, verbal comprehension: impaired	np	Reynell Language Development Scale: impaired performance	Np	Boston Naming Test: no effect after control for mercury California Verbal Learning Test: no effect
Memory	WISC-R vocabulary and information scores: impaired	np	Auditory Verbal Learning Task: no effect	Np	np
Social Behavior	np	np	CBCL: increased abnormal scores	Np	np
Activity	rating scale: decreased activity	np	rating scale: increased activity play behavior: sexually dimorphic differences	Np	np

np = not performed
NBAS: Neonatal Behavioral Assessment Battery; McCarthy: McCarthy Scales of Children's Abilities; PDI: Psychomotor Development Index; MDI: Mental Development Index; K-ABC: Kaufman Assessment Battery for Children; WISC-R: Wechsler Intelligence Scale for Children – Revised; CBCL: Child Behavior Checklist

Covariates included SES, maternal IQ, HOME score, maternal education, parity, maternal drinking and smoking during pregnancy, and other measures of the child's environment. Concentrations of lead, PBBs, DDT, and seven pesticides were measured at 4 years. Of the pesticides, only DDT was detected. Body burden of methylmercury was not measured.

Prenatal PCB exposure was associated with lower birth weight, smaller head circumference, and shorter gestational age (Fein et al., 1984). Decreased weight persisted at least until four years of age (Jacobson et al., 1990b). Maternal fish consumption was associated with motoric immaturity, poorer lability of states, abnormal reflexes, and a greater degree of startle on the Neonatal Behavioral Assessment Scale (NBAS) during infancy (Jacobson et al., 1984). Neither fish consumption nor cord serum PCB concentration was associated with performance on the Bayley Scales at 5 and 7 months (Jacobson and Jacobson, 1986), but a deficit on the Fagan Test of Recognition Memory was associated with cord PCB levels (Jacobson et al., 1985). At four years of age, breast milk and cord PCB levels were associated with poorer performance on the McCarthy Scales for verbal and numeric memory (Jacobson et al., 1990a). Prenatal exposure was also related to poorer short-term memory and increased reaction time on a visual discrimination task (Jacobson et al., 1992). A decreased number correct responses and increased errors of commission were observed at four years of age on the Sternberg Memory paradigm, a computerized test of working memory that allows responding to digits not on a sample list (Jacobson and Jacobson, 2003a). The child's concurrent PCB blood concentration was associated with reduced activity at four years (Jacobson et al., 1990b).

The Michigan cohort was assessed for a final time at 11 years of age. Prenatal exposure was associated with decreased full-scale and verbal IQ on the WISC-R, particularly with memory and attention subscales (Jacobson and Jacobson, 1996). Prenatal PCB exposure was also associated with poorer word comprehension and overall reading comprehension. The most highly exposed children (children whose prenatal PCB exposure equivalent was estimated to be at least 1.25 ug/g milk fat, 4.7 ng/g cord serum, or 9.7 ng/g maternal serum) were more than three times more likely to score one standard deviation below the mean for full-scale IQ and twice as likely to be at least two years behind in reading. The most highly exposed children averaged 6.2 points lower in IQ than children less exposed. Prenatal PCB exposure was also associated with increased perseverative errors on the Wisconsin Card Sort test, deficits in attention on the Digit Cancellation task, slower reaction time on a mental rotation task, and increased errors of commission on a vigilance test at 11 years (Jacobson and Jacobson, 2003b). These results are indicative of problems with executive function.

In a re-examination of the effects at 4 and 11 years (Jacobson and Jacobson, 2002), investigators reported a decrease in IQ at four and 11 years in infants breast-fed fewer than 6 weeks, but not those breast-fed more than 6 weeks (Jacobson and Jacobson, 1992). These results could be accounted for statistically by quality of parental intellectual input, with adverse effects strongest in children of less verbally competent mothers (Jacobson and Jacobson, 2002a; Jacobson et al., 1999). The findings in these studies are consistent with studies in lead-exposed children, in which adverse effects were greater in less advantaged children (Bellinger, 2000). It appears that high-quality parental care may ameliorate, or at least attenuate, the effects of neurotoxic agents. Effects were observed on nine of 21 outcome measures in infants breast-fed fewer than six weeks, and on two different measures in infants breast-fed more than six weeks (Jacobson and Jacobson, 2003b). These latter effects (reaction time on a mental rotation task and errors on the Seashore Rhythm test) may be chance findings, or may reflect an influence of postnatal exposure.

B. Oswego Study

The Oswego longitudinal prospective study included women recruited from 1991-1994 who did or did not consume Lake Ontario fish. A total of 309 offspring were assessed during infancy and childhood. Sixty-eight congeners or congener pairs were measured in cord blood, with no analysis of maternal blood (Stewart et al., 1999). Breast milk was analyzed from a subset of women at varying times during the first six months following delivery, thereby essentially obviating the possibility of assessing any effects of postnatal exposure via breast milk.

Covariables included maternal and paternal education and physical characteristics (age, height, weight, etc.); maternal IQ and performance on relevant tasks assessed in the children; HOME score; pregnancy and birth weight; head circumference; illicit and licit drug use, smoking, alcohol consumption, and caffeine intake during pregnancy; and several other health and demographic variables of the family. Cord blood concentrations of DDE, mirex, and hexachlorobenzene were also measured, as well as maternal hair mercury and blood lead concentration of the child. These contaminants were not directly related to performance on any measure.

Fish consumption was predictive of the concentration of the most highly chlorinated PCB congeners (Cl 7-9), but not the lower chlorinated homologs (Cl 1-3 or 4-6). Overall PCB levels in fish-eaters and non-fish-eaters were not different (P. Stewart, personal communication). Maternal intake of Lake Ontario fish or highly chlorinated PCBs predicted poorer performance on the NBAS at 6 and 12 months (Lonky et al., 1996; Stewart et al., 2000), similar to results in the Michigan study. Decreased fixation time for the novel stimulus on the Fagan Test of Recognition Memory was associated with highly chlorinated PCBs at 6 but not 12 months (Darville et al., 2000); this test was also affected in the Michigan study. IQ was assessed on the McCarthy Scales at 38 and 54 months of age (Stewart et al., 2003b). Effects were observed at 38 but not 54 months after covariate control; an interaction between PCBs and mercury was observed at 38 months.

Performance on a vigilance task was assessed in the Oswego study at 4.5 years of age (Stewart et al., 2003a). As in the Michigan study, increased errors of commission (failure of response inhibition) were related to in utero PCB exposure. In addition, an interaction was found between the size of the corpus collosum (a major brain fiber tract subserving interhemispheric communication) and increased PCB body burden on errors of commission; children with smaller corpus collosums were more impaired by increased

PCB exposure. Children in this cohort were reassessed on a vigilance task at 8.0 and 9.5 years of age, to explore the behavioral mechanism responsible for the poor performance associated with PCB exposure (Stewart et al., 2005). Manipulation of schedule parameters indicated that failure of response inhibition rather than impairment of sustained attention was responsible for the performance deficit. Children were also tested on another measure of failure if response inhibition/ increased impulsivity at nine years of age: the Differential Reinforcement of Low rate (DRL) Stewart et al. 2006). This test proved sensitive to developmental PDB and lead exposure in animals. Failure of response inhibition was independently associated with lead, PCBs, and methylmercury in the Oswego cohort. As in the Michigan cohort, the results of these latter tasks are indicative of deficits in executive function that persisted to later ages.

IQ on the WISC-III was assessed at nine years of age as a function of placental tissue PCB concentrations (Stewart et al., 2008). In contrast to the previous papers in which PCBs were not detected in a large segment of the sample, PCBs were detected in 100% of the samples. This was the result of improved analytical methodology and well as the fact that there is a higher lipid content and therefore higher levels of PCBs in placental tissue compared to cord blood. The authors performed linear regressions for full-scale IQ, performance IQ, verbal IQ, and freedom from distractibility as a function of the total of the 75 congener peaks, as well as congeners 118, 138, 153, and 180. Full-scale IQ was inversely associated with total PCBs, and marginally with 153 and 180. Verbal IQ was significantly inversely associated with total PCBs, 153, and 180, as was freedon from distractibility. Performance IQ was not related to PCB exposure.

C. Dutch Study

A study in the Netherlands was designed to assess the relative contribution of PCB and dioxin exposure in utero versus through breast milk on neuropsychological functions. Exposure was through the general food supply. A total of 418 mother-infant pairs were recruited from two cities, Rotterdam and Gröningen, in 1990–1992, with half the women in each city planning to breast-feed for at least 6 weeks and half not planning to breast feed.

The Dutch investigators measured, in both maternal and cord blood, the four congeners that typically are found at the highest concentrations in human tissue (congeners 118, 138, 153, and 180) (Koopman-Esseboom et al., 1996) (Table 4-2). They also measured 17 dioxins and furans, 6 coplanar or mono-ortho coplanar (dioxin-like) PCB congeners, and 20 ortho-substituted congeners in breast milk shortly after birth from the half of the mothers who breast-fed their infants. PCBs and other lipid-soluble chemicals are at higher concentrations in milk than blood, so that sampling of breast milk allowed analysis of more congeners with greater accuracy. The dioxins, furans, and dioxin-like congeners were used to calculate dioxin TEQs separately, or as a total TEQ. This provided the opportunity to determine the association between performance and concentrations of dioxins, dioxin-like- and non-dioxin-like PCBs in breast-fed infants, as well as the sum of the four congeners in maternal and cord blood and breast milk in the full cohort. Covariates included gestational length, birth weight, parity, parental IQ, HOME score, and alcohol use and smoking during pregnancy. Other contaminants were not measured.

Table 4-3. PCB congeners, dioxins, and furans analyzed in the Dutch study (from Schantz et al., 2003)				
Exposure variable, IUPAC no.	Chorine substitution pattern	Number of subjects	Mean tissue level	Mean TEQ
ΣPCBs in maternal plasma				
118 138 153 180	2,3´,4,4´,5 2,2´,3,4,4´,5´ 2,2´,4,4´,5,5´ 2,2´,3,4,4´,5,5´	415 415 415 415 ΣPCBs = 2.21 ng/g	0.16 ng/g 0.60 ng/g 0.91 ng/g 0.54 ng/g	
ΣPCBs in cord blood				
118 138 153 180	2,3´,4,4´,5 2,2´,3,4,4´,5´ 2,2´,4,4´,5,5´ 2,2´,3,4,4´,5,5´	373 382 382 382	0.04 ng/g 0.13 ng/g 0.18 ng/g 0.10 ng/g ΣPCBs = 0.45 ng/g	
ΣPCBs in breast milk ng/g fat				
118 138 153 180	2,3´,4,4´,5 2,2´,3,4,4´,5´ 2,2´,4,4´,5,5´ 2,2´,3,4,4´,5,5´	195 195 195 195	35.5 ng/g 129.9 ng/g 186.3 ng/g 76.8 ng/g ΣPCBs = 428.5	3.6 0.8
Nondioxin-like PCBs measured in breast milk ng/g fat				
28 52 66 70 99 101 128 137	2,4,4´ 2,2´,5,5´ 2,3´,4,4´ 2,3´,4´,5 2,2´,4,4´,5 2,2´,4,5,5´ 2,2´,3,3´,4,4´ 2,2´,3,4,4´,5	195 195 195 195 195 195 195 195	12.1 ng/g 2.6 ng/g 11.6 ng/g 18.5 ng/g 19.7 ng/g 1.5 ng/g 4.0 ng/g 16.8 ng/g	

138 141 151 153 177 183 187 194 195 202	2,2´,3,4,4´,5´ 2,2´,3,4,5,5´ 2,2´,3,5,5´,6 2,2´,4,4´,5,5´ 2,2´,3,3´,4´,5,6 2,2´,3,4,4´,5´,6 2,2´,3,4´,5,5´,6 2,2´,3,3´,4,4´,5,5´ 2,2´,3,3´,4,4´,5,6 2,2´,3,3´,5,5´,6,6´	195 195 195 195 195 195 195 195 195 195	129.9 ng/g 1.1 ng/g 0.9 ng/g 186.3 ng/g 6.3 ng/g 12.2 ng/g 20.0 ng/g 8.6 ng/g 2.9 ng/g 0.9 ng/g ΣPCBs = 455.9 ng/g	
Mono-ortho PCBs in breast milk ng/g fat				
105 118 156	2,3,3´,4,4´ 2,3´,4,4´,5 2,3,3´,4,4´,5	195 195 195	9.4 ng/g 35.5 ng/g 21.0 ng/g ΣPCBs = 65.9 ng/g	0.9 3.6 10.5 Σ TEQ = 15.0
Di-ortho PCBs in breast milk ng/g fat				
170 180	2,2´,3,3´,4,4´,5 2,2´,3,4,4´,5,5´	195 195	37.1 ng/g 76.8 ng/g ΣPCBs = 113.9 ng/g	3.7 0.8 ΣTEQ = 4.5
Planar PCBs in breast milk ng/g fat				
77 126 169	3,3´,4,4´ 3,3´,4,4´,5 3,3´,4,4´,5,5´	194 194 194	0.0193 ng/g 0.152 ng/g 0.0843 ng/g ΣPCBs = 0.2556 ng/g	0.01 15.2 0.8 ΣTEQ = 16.0
Dioxins in breast milk				
48 54 66 67 70 73 75	2,3,7,8 1,2,3,7,8 1,2,3,4,7,8 1,2,3,6,7,8 1,2,3,7,8,9 1,2,3,4,6,7,8 1,2,3,4,6,7,8,9	176 176 176 176 176 176 176	0.004 ng/g 0.0106 ng/g 0.0087 ng/g 0.0474 ng/g 0.0067 ng/g 0.0632 ng/g 0.7996 ng/g Σ Dioxins = 0.9402 ng/g	4.0 5.3 0.9 4.7 0.7 0.6 0.8 Σ TEQ = 17.0

Furans in breast milk				
83 94 114 118 121 130 124 131 134 135	2,3,7,8 1,2,3,7,8 2,3,4,7,8 1,2,3,4,7,8 1,2,3,6,7,8 2,3,4,6,7,8 1,2,3,7,8,9 1,2,3,4,6,7,8 1,2,3,4,7,8,9 1,2,3,4,6,7,8,9	176 176 176 176 176 176 176 176 176 176	0.0008 ng/g 0.0003 ng/g 0.0227 ng/g 0.0066 ng/g 0.0057 ng/g 0.0036 ng/g 0.0003 ng/g 0.0079 ng/g 0.0002 ng/g 0.0022 ng/g Σ Furans 0.0505 ng/g	0.08 0.01 11.3 0.7 0.6 0.4 0.03 0.08 0.0 0.0 Σ TEQ = 13.2 Total dioxin Σ TEQ = 65.7

Infants were assessed on the Prechtl neurological exam between 10 and 21 days after birth (Huisman et al., 1995a), which measures postural tone and reflexes. PCBs in maternal milk and total TEQ were related to poorer performance, whereas PCB levels in maternal or cord blood were unrelated (Table 4-3). Maternal blood PCB concentration was negatively associated with performance on the Bayley psychomotor development index (PDI) at three months. In contrast, postnatal TEQ, but not measures of prenatal exposure, was associated with poorer performance on the Bayley PDI at seven months, negating the positive effects of breastfeeding at higher exposures (Koopman-Esseboom et al., 1996). No effects of PCB exposure were observed on the Bayley Scales at 18 months, and no effects on the Bayley mental development index (MDI) were observed at 3 or 7 months. Maternal or cord blood PCB concentrations predicted poorer neurological status at 18 months of age (Huisman et al., 1995b).

Table 4-4. Neurobehavioral, Neuropsychological, and Neuroendocrine effects of the Dutch study to 3.5 years of age (from Schantz et al., 2003)

Test	Age (months)	Outcome	Exposure BF = breast fed FF = formula fed	ΣPCB in cord blood	ΣPCB in maternal blood	ΣPCB in milk	Total dioxin/ PCB TEQs	References
Birth size and growth								Patandin et al. (1998)
Birth weight	0	↓	BF + FF	$p = 0.03$ (179)	$p = 0.057$ (203)			
Length	0.3	—	BF + FF	NS	NS			
Head circumference	3	—	BF + FF	NS	NS			
Prechtl's	0.5	↓	BF	NS	NS	$p < 0.01$	$p < 0.01$	Huisman et

neurological exam						(194)	(168)	al. (1995a)
Bayley Scales of Infant Development								Koopman-Esseboom et al. (1996)
MDI	3	—	BF + FF	NS	NS	NS	NS	
PDI	3	↓	BF + FF	NS	p = 0.02 (198)	NS	NS	
MDI	7	—	BF + FF	NS	NS	NS	NS	
PDI	7	↓	BF + FF	NS	NS	NS	p = 0.05 (182)	
MDI	18	—	BF + FF	NS	NS	NS	NS	
PDI	18	—	BF + FF	NS	NS	NS	NS	
Neurological optimality	18	↓	BF + FF	p = 0.003 (373)	NS	NS	NS	Huisman et al. (1995b)
Fluency of motility	18	—	BF + FF	NS	NS	NS	NS	Huisman et al. (1995b)
Touwen/Hempel neurological exam	42	—	BF + FF	NS	NS	NS	NS	Lanting et al. (1998)
K-ABC								
Overall cognitive	42	↓	BF + FF	NS	p = 0.005 (373)	NS	NS	Patandin et al. (1999b)
Sequential		↓	BF + FF	NS	p = 0.02 (373)	NS	NS	
Simultaneous		↓	BF + FF	p = 0.02 (384)	p = 0.02 (384)	NS	NS	
Reynell language		—	BF + FF	NS	NS	NS	NS	
K-ABC								
Overall cognitive	42	—	BF	NS	NS	NS	NS	
Sequential		—	BF	NS	NS	NS	NS	
Simultaneous		—	BF	NS	NS	NS	NS	
Reynell language		—	BF	NS	NS	NS	NS	
K-ABC								
Overall cognitive	42	↓	FF	NS	p = 0.0006 (178)	NS	NS	
Sequential		↓	FF	NS	p = 0.002 (178)	NS	NS	
Simultaneous		↓	FF	p = 0.02	p = 0.007 (186)	NS	NS	
Reynell language		↓	FF	p = 0.01	p = 0.03 (90)	NS	NS	

Assessment of a number of functional domains was performed at 3.5 years. Children were tested on the Dutch version of the Kaufman Assessment Battery for Children (K-ABC) and the Reynall Language Development Scales (RDLS) (Patandin et al., 1999b).

Increased PCB concentration in maternal or cord blood predicted poorer performance on the K-ABC in the formula-fed group only, but not the breast-fed group, despite the fact that PCB levels were higher in breast-feeding mothers and in the children at 3.5 years (Patandin et al., 1997). This may be due to the fact that the children from the breast-fed group were from a more socially advantaged environment (Vreugdenhil et al., 2002a). Similarly, adverse effects of in utero exposure were observed in formula-fed infants but not breast-fed infants on the RLDS. Effects were not related to postnatal exposure or the various measures of TEQ.

Effects on some measures were also found to be related to the concurrent body burden of the child at 3.5 years but not to prenatal exposure as measured by maternal or cord blood PCB concentrations. Significant associations were observed for increased reaction time on a vigilance task, more hyperactive behavior on a parents' questionnaire, and poorer attention in the breast-fed group (Patandin et al., 1999c). The fact that these effects were observed in the breast-fed group may reflect the higher body burdens of breast-fed children. Errors of commission on the vigilance task were associated with PCB concentrations in cord blood. TEQ was not associated with any measure.

Problem behavior was assessed at 3.5 years using the Child Behavior Check List (CBCL) (Patandin et al., 1999a). Effects were found on the internalizing, withdrawn/depressed scales, and aggressive scales associated with maternal or cord plasma PCB concentrations and/or breast milk TEQ.

The Dutch study found negative effects of PCBs at 6.5 years of age on the McCarthy Scales in less- but not more-advantaged children (Vreugdenhil et al., 2002a). Poorer performance was associated with prenatal exposure as measured by the sum of the four congeners in maternal or cord blood, but not with TEQ or postnatal exposure. Analyses revealed that it was because formula-fed infants were from less advantaged homes, and not the formula-versus-breast-fed dichotomy per se, that accounted for the difference in performance on the McCarthy scales.

Sexually dimorphic play behavior was examined at 7.5 years using the Pre-School Activity Inventory to test the hypothesis that PCBs and dioxins exert effects on behavior via endocrine disruption (Vreugdenhil et al., 2002b). Prenatal PCB concentrations were associated with less masculinized play behavior in boys and more masculinized behavior in girls, whereas higher prenatal dioxin levels were associated with more feminized play behavior in both boys and girls.

An interesting strategy for the determination of pre- versus postnatal effects was adopted by the Dutch investigators in an assessment of performance on several tasks at 9.0 years of age (Vreugdenhil et al., 2004). The half of the cohort from Rotterdam were assessed on the Tower of London, a task that requires planning a number of moves to reach a goal, and measures executive function. Children were also tested on simple reaction time, visuospatial recognition, and auditory memory tasks. Maternal serum PCB concentrations were associated with poorer performance on the Tower of London, and longer and more variable reaction times on the reaction time task (Table 4-5). In additional analyses, the cohort was divided into six groups: formula-fed, low or high prenatal exposure as assessed by maternal blood levels; breast-fed for less than 16 weeks, low or high prenatal exposure; and breast-fed for more than 16 weeks, low or high prenatal exposure. On the Tower of London, there was evidence of prenatal effects (formula-fed high vs. low) as well as a postnatal effect (breast-fed low vs. formula-fed low). There was a marginal effect of breast-fed long vs. breast-fed short, and other comparisons were as would be expected (breast-fed short or long vs. formula-fed). On a simple reaction-time task, only prenatal exposure was predictive of performance.

Table 4-5. Summary of the effects of prenatal and postnatal exposure at 9 years in the Dutch study

Variable	ΣPCBhigh versus ΣPCBlow			BFshort versus FF			BFlong versus FF			BFlong versus BFshort			Adjusted R2
	B	SE B	p	B	SE B	p	B	SE B	p	B	SE B	p	
Simple reaction time test													
reaction time	26.58	12.76	.041	18.88	13.79	.175	20.42	14.03	.150	1.53	15.70	.922	.04
standard deviation	22.04	6.77	.002	2.48	7.31	.735	-6.95	7.44	.354	-9.44	8.33	.261	.23
Tower of London	-1.85	.67	.007	-.39	.72	.593	-1.81	.73	.015	-1.42	.82	.089	.23

Results for multiple simultaneous regression analysis: FF = formula fed; BFshort = 6-16 weeks of breast-feeding; BFlong = > 17 weeks of breast-feeding

The Dutch investigators also examined the effects of PCBs on thyroid hormone status of mother and infants, as well as immune status and function. Decreased thyroid hormones and deficits in immune function were observed in this cohort (see Schantz et al., 2003, for review). No information is available about the relative sensitivity of these effects compared to neurotoxicity. However, the effects on cognitive and other behavioral endpoints clearly constitute adverse effects, whereas the consequences of the changes in other organ systems are less clear.

D. German Study

The German study consisted of 171 mother-infant pairs recruited in Düsseldorf in 1993. As in the Dutch study, exposure to PCBs was through the general food supply. The study measured three congeners (153, 138, and 180) in cord plasma and breast milk, and recorded weeks of breastfeeding. Covariates included maternal IQ, parental education, HOME score, smoking and alcohol consumption during pregnancy, mother's body mass index, Apgar score, parity, and health status. Lead concentration was measured in cord blood.

Unlike results for the Michigan and Oswego studies, no effect was observed on the Fagan Test of Recognition Memory at 7 months, perhaps because of poor experimental control (Winneke et al., 1998). PCB levels in breast milk were associated with poorer performance on the Bayley MDI at 7 months. Negative associations were also observed for breast milk PCB levels and the Bayley at 30 months and the K-ABC at 42 months after covariate control (Walkowiak et al., 2001). HOME score was positively associated with mental and motor development on the Bayley Scales at 30 months and on the K-ABC at 42 months, whereas increasing milk PCB concentrations were associated with poorer performance, when each variable was adjusted for the other (Walkowiak et al., 2001). An effect of postnatal exposure was also observed on the K-ABC, as measured both by the child's blood PCB level at 42 months and the breast milk PCB concentration times the weeks of breast feeding, after control for prenatal exposure. Potential effects of postnatal exposure were apparently not assessed before 42 months.

Based on 70 children (fewer than half the original cohort) effects of neither milk PCB levels (prenatal exposure) nor the child's concurrent blood PCB concentration (postnatal exposure) were significantly associated with the K-ABC at 72 months of age, although the trend was negative for both for the mental processing scale (Winneke et al., 2002). Effects of the HOME score were still a predictor of positive outcome at 72 months on the K-ABC in this relatively advantaged population (Winneke et al., 2002).

E. Faroe Islands Study

The Faroe Islands study was designed to assess the effects of in utero methylmercury exposure, with mothers recruited in 1986–1987 (Grandjean et al., 1997). Five PCB congeners (118, 138, 153, 170, and 180) were measured in cord tissue in half the cohort only, but only 138, 153, and 180 were used as exposure markers. Covariates included maternal IQ, maternal and paternal education, paternal employment, maternal smoking and alcohol consumption during pregnancy, the child's familiarity with computers and computer games, and other environmental and demographic factors. Methylmercury was measured in maternal hair and umbilical cord blood, and in the child at 1 and 7 years. Concentrations of p,p′-DDE were measured in cord tissue in half the cohort.

Performance was assessed on a number of domain-specific tests at 7 years of age in 917 children. Behavior was not measured before 7 years. Tests included finger tap, a continuous performance (vigilance) task, three subtests of the WISC-R (Digit Spans, Similarities, and Block Designs), the Bender Visual Motor Test, the California Verbal Learning Test, and the Boston Naming Test.

Only limited effects of PCBs were observed prior to control for methylmercury exposure (Grandjean et al., 2001) despite high PCB concentrations in this population (Longnecker et al., 2003). A negative association was found between cord tissue PCB levels and performance on the Boston Naming Test, a test of language development, before adjustment for methylmercury. This is consistent with the effects on language in the Dutch and Michigan studies. Effects were also found on reaction time on a continuous performance (vigilance) task. Effects on vigilance task performance were also observed in the Michigan, Dutch, and Oswego studies, but on commission errors (impulse control) rather than reaction time (attention). No effects of PCBs were found on any endpoint in the Faroe Islands study after controlling for methylmercury exposure, although there was some indication of effects on several endpoints in children in the highest tertile with respect to methylmercury. The reason for the lack of results in this study are unknown. A lean tissue (cord tissue) was used for PCB analysis, which might result in less accurate analysis and thereby exposure misclassification. The correlation between cord blood and cord tissue PCB concentrations, based on 50 samples, was 0.90 after log transformation. In the Dutch and German studies, media with higher concentrations of PCBs (maternal blood or milk) were better predictors of performance than cord blood. Cord blood PCB concentrations did not predict performance on any measure in the German study, and on only a few measures in the Dutch study. In the Oswego study, only cord blood concentrations were available, but 68 congeners rather than three were used as measures of exposure. In addition, the more highly-chlorinated congeners best predicted performance, and often total PCBs did not. Finally, the Faroe Islands study only assessed the effects of PCBs at 7 years of age, on endpoints designed to be sensitive to the neurotoxic effects of methylmercury. However, these endpoints assessed some of the domains affected by PCBs in other studies.

F. Summary of Epidemiology Studies

These studies are all high quality studies. All have good covariate control for typical (non-chemical) potential confounders. With respect to exposure to chemicals other than PCBs, the studies differed in the completeness of assessment. The Oswego study analyzed a number of chemicals that are found in Lake Ontario fish, including mercury, DDE, mirex, and hexachlorobenzene. Additionally, lead concentrations were determined in the children. The Michigan study was also designed to compare the offspring of fish-eaters versus non-fish-eaters. The study has been criticized for not determining exposure to methylmercury (NRC, 2000), which may have been correlated with PCB levels. The Oswego study was designed in many ways as a replication of the Michigan study, and effects were similar even after controlling for methylmercury. Neither the Dutch nor German study were designed to assess the effects of exposure to PCBs through fish; exposure was assumed to be through the general food supply. In fact, the Dutch investigators estimated that fish contributed 11% and dairy products contributed 43% of the PCB-TEQ body burden in preschool children (Patandin et al., 1999d). There is no reason to believe that PCBs and methylmercury body burdens would be highly correlated in either the Dutch or German study. The Faroe Islands study analyzed PCBs and DDE in cord tissue in addition to methylmercury. Lead was apparently not measured in either the Dutch or Faroe Islands studies, but would not be expected to be correlated with PCBs.

There is reasonable congruence among the various studies with respect to the pattern of neurotoxic effects, perhaps with the exception of the Faroe Islands study (Table 4-1). All the studies that examined neurological function during infancy identified effects of prenatal PCB exposure. Effects on IQ were identified in early childhood in all studies. Deficits in IQ and other cognitive endpoints were still apparent at 11 years in the Michigan study and at 9 years in the Oswego study. In the Dutch study, IQ deficits only persisted in less advantaged children. The Michigan study also found that children of less intellectually competent mothers exhibited deficits at 4 and 11 years, whereas more advantaged children did not. In the German study, the effects on IQ were attenuated or not present later in childhood. This was also true in the Faroe Islands study on the three subtests of full-scale IQ that were assessed. The Faroe Islands study did not find effects on attention and language, identified in the Michigan study. The Michigan, Dutch, and Oswego studies also assessed behavioral domains in addition to IQ. All three found adverse effects on a number of endpoints at the oldest ages tested, which are indicative of deficits in executive function. This suggests that developmental PCB exposure has permanent effects on the ability to plan and exercise impulse control. It also suggests that standard clinical measures of IQ are not as sensitive in detecting deficits produced by PCB exposure as more domain-specific tasks. It further indicates that although the effects on IQ may attenuate or disappear at later ages, deficits in important cognitive domains persist. A number of other behavioral domains were also found to be affected in the Dutch study.

Even though the discussion in this document focuses on the findings in epidemiological studies, it is important to understand that there is a substantial experimental literature documenting adverse effects of PCB exposure, including neuropsychological deficits on multiple tasks in rodents (e.g. Schantz et al., 1997; Widholm et al., 2004, 2001; Roegge et al., 2000) and monkeys (Rice, 2000). In fact, similar effects on the DRL task of impulsivity were observed in rats (Sable et al., 2006), monkeys (Rice, 1998), and children (Stewart et al., 2006). In addition, identified mechanisms of neurotoxicity include effects on neurotransmitter systems, calcium homeostasis, second messenger systems, and effects on specific brain receptors (e.g. Kodavanti et al., 1996, 1993, 1998; Seegal et al., 1991; Pessah et al., 2006; Wong et al., 1997; Coccini et al., 2007). The experimental literature provides reassurance regarding the causality of the associations observed in epidemiological studies. In particular, studies in monkeys documented developmental neurotoxicity at peak blood levels for a short time during infancy of about 2 ppb wet weight (Rice, 1997) with behavioral testing years after blood concentrations were at background.

G. Consequences to society of ubiquitous PCB exposure

The effect sizes observed in the epidemiological studies of the neuropsychological consequences of exposure to PCBs are small. Nonetheless, these deficits may have important consequences on a population level (Bellinger 2007). Perhaps the most straightforward endpoint to discuss with regard to effects at the population level is IQ. IQ is normalized such that the distribution conforms to a "bell-shaped" curve. Even a small shift in the overall distribution has a relatively large effect on the tails of the distribution. For example, shifting the IQ distribution by 5 points results in a doubling of the number of individuals in the mentally-retarded range (below 70) and a decrease of gifted individuals (above 130) by a factor of 2.5 The Oswego study found that for each 1 ng/g (wet weight) increase in total PCBs, the full-scale IQ decreased by 3 point and the verbal IQ decreased by 4 points. This translated roughly to a 6-7 point decline in full-scale IQ and a 9 point decrease in verbal IQ across the PCB ranges in the study. An effect of this magnitude has important implications for the population.

In addition, there is a high correlation between IQ and lifetime earnings. The National Longitudinal Survey of youth (NLSY) provides a robust database for calculation of the predictive power of IQ measured ruing youth on earning capacity in adulthood. This survey is a stratified random sample of 12,686 individuals recruited at ages 12-22 in 1970, with annual follow-up interviews. More recently, it was estimated that each IQ point is worth $14,500 over a lifetime of earning (Grosse et al., 2002). Estimates have also been made concerning other societal benefits of a small increase in IQ using the NLSY data. A 3% increase in IQ (3 points) would result in a 12% reduction in low-birth-weight births, a 15% reduction in out-of-wedlock births, an 18% reduction in welfare recipiency, a 28% reduction in the high-school drop-out rate, a 25% reduction in the poverty rate, and a 25% reduction in the number of males interviewed in jail (Weiss, 2000).

The effect of PCBs on IQ has apparently not been monetized. However, the cost of IQ loss associated with lead and methylmercury exposure has been estimated. The monetary cost associated with the ubiquitous exposure of fetuses and children to lead in industrialized societies has been calculated by Schwartz (1994a) in an estimation of the benefits of a 1 ug/dl reduction in the population mean blood lead concentration. Note that a 1 ug/dl reduction in blood lead concentrations would result in a shift in the population of <1 IQ point based on meta-analyses (Schwartz, 1994b; WHO, 1994). The largest single cost was lost earnings as a result of decreased intellectual capability: $5.06 billion in 1994 dollars. The total cost, including increased medical care, compensatory education, and neonatal mortality and morbidity, was $6.94 billion 1994 dollars. In a later similar analysis using the NLSY database (Salkever, 1995) to monetize the effect of decreased cognitive ability on earning capacity, the estimated gain in earnings was $7.5 billion U.S. per year for a decrease in blood lead levels of 1 ug/dl in the U.S. population. In similar analyses, the economic cost of prenatal exposure to methylmercury was estimated to be $9 billion annually associated with loss of IQ (Trasande et al., 2005) and $298 million for the associated increase in mental retardation (Trasande et al., 2006).

In addition to effects on IQ observed in several studies, several studies also found deficits on impulse control associated with in utero PCB exposure. In particular, the Oswego study found impaired performance on a DRL task and a vigilance task at three ages. These tasks are also affected in ADHD (Paule et al., 2000; Avila et al., 2004; Fischer et al., 2005) and lead exposure is also associated with increased impulsivity. Increased impulsivity is associated with criminality as well as other antisocial behaviors such as problem gambling and out-of-wedlock birth (Farrington et al., 1989; Barnes et al., 2005; Askénazy et al., 2003; Vitaro et al., 2001; Luengo et al., 1994; White et al., 1994; Vitacco et al., 2002; Babinski et al., 1999; Farrington et al., 1989, 1995). Developmental lead exposure is also associated with increased delinquency and criminality later in life (Needleman et al., 1996, 2002; Dietrich et al., 2001; Nevin et al., 2000), which may be at least in part a consequence of effects on IQ and/or impulsivity.

Deficits in IQ and increased impulsivity are only two of the endpoints associated with in utero PCB exposure. Others include deficits in memory, attention, school performance, and social competence. All of these adverse effects may negatively affect the ability of an individual to function successfully, and therefore have potentially important consequences for society.

IV. Evidence for Relative Neurotoxicity of Individual Congeners

The issue of which congeners are producing toxicity is an important one for public health. Unfortunately, not enough information is available from either human or animal studies to determine the congeners or congener classes responsible for the observed neurotoxic effects.

The relative toxicity of dioxin-like versus non-dioxin-like congeners with respect to neurotoxicity is unknown. The Oswego study did not analyze the planar congeners (77, 126, and 169), although dioxin-like congeners 118, 105, 170, and 180 were measured. In the Oswego study, the more highly chlorinated PCBs best predicted performance in the analyses using cord blood, but that may be because these congeners are more reliably analyzed than lower-chlorinated congeners because of lack of interference from other chemicals. In the study of IQ at 9 years, using more sensitive methodology, comparison of the predictive value of the four most prevalent congeners revealed associations for the more highly-chlorinated congeners 153 and 180, but not 118 and 138.

The epidemiological study that is the most informative with respect to the relative toxicity of individual congeners is the Dutch study, which measured the dioxin-like congeners 77, 126, 169, 105, 118, 110, 67, 77, and 180 in breast milk only, and 118 and 180 in cord and maternal blood. They also measured a number of dioxins and furans, and combined the TEFs in various ways to assess the effects of different TEQs. Congener 126 is the most active with respect to Ah receptor activation, which does not seem to be an important mechanism for neurotoxicity. For cognitive effects, maternal blood PCB levels were the best predictors of performance measures on the Bayley Scales during infancy (Koopman-Esseboom et al., 1996), and the K-ABC at 3.5 years of age (Patandin et al., 1999b). The sum of PCBs in cord blood was predictive of five outcomes, whereas maternal blood PCB levels were predictive of nine outcomes. This may well be due to the higher levels in maternal compared to cord blood, allowing more accurate measurement of PCB concentrations. PCB levels in milk and milk TEQ were both predictive of only one measure in early assessments: neurological status during infancy (Huisman et al., 1995a; Koopman-Esseboom et al., 1996). Similarly, planar, mono-ortho, or dioxin TEQ were not predictive of free play behavior, performance on a vigilance task, or activity according to a parents' questionnaire at 3.5 years (Patandin et al., 1999d). Total TEQ, dioxin-TEQ, and planar PCB TEQ were each predictive of a more adverse score on the internalizing scale of the CBCL, whereas the sum of the four congeners measured in maternal or cord blood were not (Patandin et al., 1999a). All measures were predictive of adverse scores on the withdrawal/depressed scale. In a subsequent study on play behavior, all four measures were predictive of differential behavior in boys and girls: dioxin TEQ in milk predicted more feminized play behavior in both sexes, whereas the sum of the four PCB congeners in cord or maternal blood predicted less masculinized behavior in boys and the sum of the four PCB congeners in milk predicted more masculinized behavior in girls (Vreugdenhil et al., 2002). In summary, cognitive effects, including deficits on IQ, were best predicted by maternal PCB concentrations as measured by the four congeners analyzed in maternal blood. TEQ was predictive of outcome on non-cognitive endpoints at 3.5 years of age, and on the masculine/feminine dimension of play behavior at 6.5 years.

Both the German and Faroe Islands studies used only three congeners as markers of exposure, precluding the possibility of exploring congeners that may be more associated with effects.

The behavioral effects of in utero and/or lactational exposure to individual congeners has been studied for only a few congeners in animal studies, and some have only been assessed in a single study (review by Rice, 2004). In a series of studies in rats with dioxin (TCDD) and five PCB congeners with or without dioxin-like properties (28, 118, 153, 77, 95), Schantz and colleagues (Schantz et al., 1996, 1997, 1995) found all to be neurotoxic, but with different patterns of impairment on the two tasks examined. There was no pattern in terms of the relative potencies of dioxin-like versus non-dioxin-like congeners in that series of studies, with most PCB congeners having LOAEL/NOAELs within an order of magnitude of each other. Congener 126 had a LOAEL four orders of magnitude lower than the other congeners tested by Schantz and colleagues, with PCB-treated rats making fewer errors than controls. Rice and colleagues (Bushnell and Rice, 1999; Crofton and Rice, 1999; Geller et al., 2000; Rice and Hayward, 1999; Rice, 1999), on the other hand, reported minimal neurotoxicity following developmental exposure to congener 126 on a variety of tests of cognition and sensory function, at the same doses used by Schantz and colleagues and a longer exposure time. Effects were observed in other organ systems (weight gain, anogenital distance, blood biochemistry, thyroid hormones) in the cohort. Effects of postnatal exposure to congeners 156 and 52 have been assessed in the mouse. However, the results are difficult to interpret since littermates were treated as independent observations in the statistical analysis, a serious violation of experimental design.

The question of whether some congeners are more toxic than others, and which those may be, remains largely unaddressed in either epidemiological or whole animal studies.

V. Comparison of body burden at which effects are observed in epidemiological studies and those in the US population

There is no information published to date on the shape of the relationship between in utero or postnatal exposure to PCBs and performance on any measure. It is unknown whether the relationship is best fit by a linear model, which would suggest that there is no threshold within the range of body burdens studied, or whether it is sublinear (shallower slope at lower body burdens), suggesting that there is a threshold of body burden below which there does not appear to be an adverse effect. Further, if there is a threshold it is critical to know where it lies on the population dose response curve to understand whether background body burden or incremental exposures above background (e.g., from fish meals) can create a neurodevelopmental risk. However, the epidemiological studies reviewed above restricted the statistical analyses to a determination of whether there was an association between exposure and performance on one or more measures. In contrast to the literature on PCBs, the shape of the exposure-effect relationship, and whether there may be a threshold, has been studied for the neurotoxicants lead and methylmercury, both by individual investigators (Davidson et al., 2001; Canfield et al., 2003; Bellinger and Needleman, 2003) and government agencies (NRC, 2000; Budtz-Jørgensen et al., 1999, 2000; Schwartz 1994). For those neurotoxicants, there is evidence that the relationship may be supralinear: i.e., a relatively steeper slope, and therefore greater relative effect, at lower body burdens than at higher. The shape of the dose-effect relationship for PCBs, however, is unclear.

Comparison of exposures among epidemiological studies, or comparison to body burdens in the US population, is not straightforward for several reasons. The Michigan study used older, less sensitive analytical methodology that did not determine concentrations of individual congeners. Newer studies analyzed different congeners and different numbers of congeners. In addition, PCBs were assayed in different tissues (cord blood, maternal blood, breast milk, cord or placental tissue), with some studies measuring concentrations in more than one tissue.

In spite of these limitations, some information may be gleaned from the presentation of data from some of the epidemiological studies and endpoints. Further, information on levels of individual congeners in these studies may be compared to those in a representative sample of women of child-bearing age or children the US population, as assessed in the third national report of body burdens of environmental chemicals designed to be representative of the US population, the NHANES survey (CDC, 2005). Fortunately, the best study with respect to comparability of body burdens to those in the US population is also the study with the best information concerning the shape of the exposure-effect relationship, including identification of an effect level. That study is the Oswego study.

A. Oswego Study

The dose-response relationship between PCBs body burden and neurodevelopment was evaluated categorically in most of the Oswego publications. A total of 293 mother-infant pairs were assessed at the beginning of the study. In some of the later publications, sample sizes diminished, as fewer subjects participated at 8 and 9.5 years of age (174-184 subjects total). In all but the latest publication, PCBs exposures were further divided based upon degree of chlorination: low (1 to 3 chlorine atoms), moderate (4-6 chlorines) or high (7-9 chlorines), in addition to total PCB levels. Study participants were assigned to one of four categories based upon umbilical cord blood PCB concentrations, as described below. In the most recent paper in this series, PCB effects on IQ were assessed at9 years of age, with linear regression used to determine the relationship between performance and placental tissue levels of total PCBs, as well as congeners 118, 138, 153, and 180. In addition, the sample was divided by quintile and by each 1 ng/g increment in total PCB levels, and the data from the four outcomes were presented graphically.

As discussed above, there was a strong correlation between Lake Ontario fish consumption and highly chlorinated (Cl 7-9; congeners 170-206) PCB congeners in the early papers (Stewart et al., 1999). Lightly and moderately chlorinated PCBs were not associated with Lake Ontario fish consumption and so may have been from background dietary sources (commercial fish, dairy, meat, etc) or other sources (e.g., PCBs in caulking, light fixtures, built environment). Even for Lake Ontario fish consumers, non-Lake Ontario sources were predominant, as the highly-chlorinated fraction was still a minority of the body burden. A caveat to this statement is the possibility that highly-chlorinated PCBs from fish may be metabolized to more lowly-chlorinated congeners and then retained. However, this does not appear likely since PCB metabolism involves a primary arene oxidation step at unsubstituted sites on the ring structure, forming hydroxides with the same chlorine content (ATSDR Tox Profile, 2006). Thus, it appears that the major source of lower-chlorinated PCBs in the Oswego population was not Lake Ontario fish but other, undefined background sources. However, in terms of highly-chlorinated congeners, lake fish consumption appears to be the major source in this population.

Out of 293 women enrolled in the study, the majority (173) had no detectable highly-chlorinated PCBs in cord blood, and the remainder of the population was divided into tertiles of 40 subjects each. For total PCBs, there were fewer subjects with non-detectable levels in cord blood, so the population was divided in standard (evenly sized) quartiles. Statistical associations between PCBs exposure and poorer performance on the neonatal test battery (NBAS) were found only for the highly-chlorinated congeners (Stewart, et al., 2000). Highly-chlorinated PCBs were therefore the focus of follow-up testing at later ages in most assessments, to the exclusion of less chlorinated congeners. The associations between total PCBs and neurodevelopmental outcomes were determined during infancy (Darville, et al., 2000) and in Stewart, et al, (2006) but not in the intervening studies (Stewart, et al., 2003, 2005). Total PCBs in cord blood were associated with diminished performance on the Fagan test of recognition memory at 6 and 12 months (Darville, et al., 2000) and with a significant alteration in performance on a differential reinforcement of low rates (DRL) schedule at 9.5 years (Stewart, et al., 2006). Regarding the latter finding, the statistical association existed for both total PCBs and highly-chlorinated PCBs, but was strongest for total PCBs (Stewart, et al., 2006).

No association was found between lower-chlorinated PCBs in the one study in which this was assessed (Stewart, et al., 2000). This may result from analytical interference with measurement of lower-chlorinated congeners in a lean medium such as cord blood, in which lipid and PCB levels are low. Such analytical difficulty may result in exposure misclassification and obscure the contribution of fish to lower-chlorinated PCBs or the association of lower-chlorinated PCBs with health outcomes (Stewart, et al., 2003). .

In the assessment of IQ at 9 years, associations were seen with total PCBs and congeners 153 and 180, but not with 118 and 138. These results are consistent with previous analyses from this study, in which associations were found with the more highly but not lower chlorinated congeners.

The relationship between total PCBs and infant intelligence on the Fagan test is depicted below in Figure 4-1 (Darvill, et al., 2000).

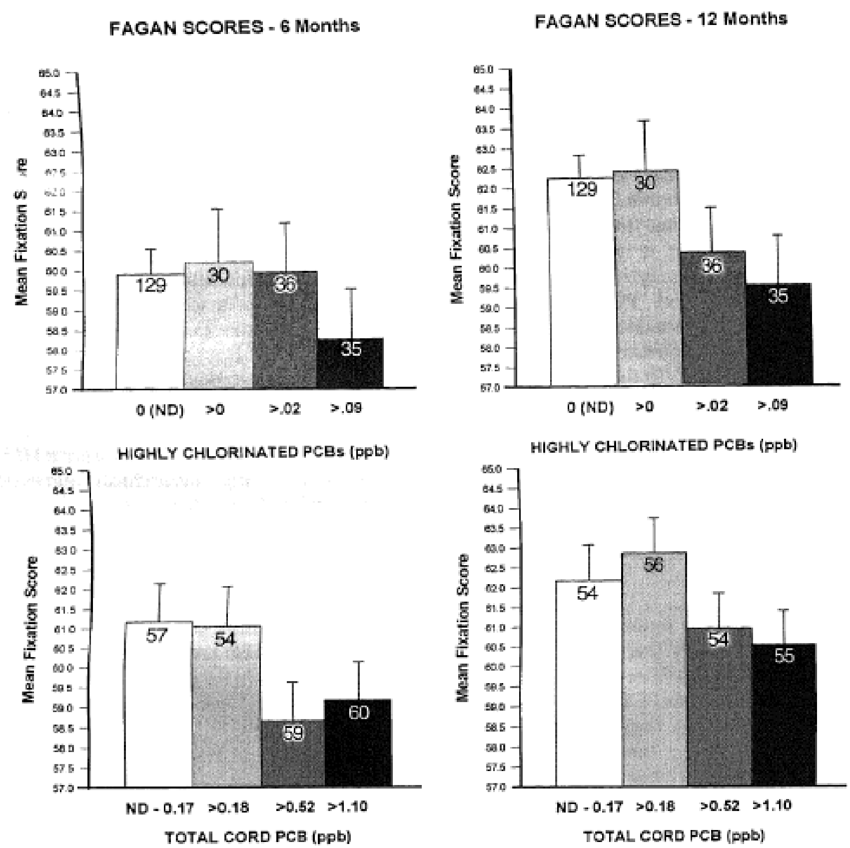


Figure 4-1 Mean FTII fixation scores (adjusted for covariates) at 6- and 12-month assessments by cord-blood levels (ppb, wet-weight) of highly chlorinated PCB congener homologues (top) and total PCBs (bottom). From Stewart et al. (1999)

The histogram plots show an effect in the middle tertile of non-zero group for highly-chlorinated congeners at 12 months of age and at the 3rd quartile of the total PCBs at both 6 and 12 months. The lowest exposure level was not associated with an adverse outcome, making it possible to identify an effect level. For highly-chlorinated PCBs, this corresponds to exposures at >0.02 ppb. For total PCBs, the third quartile corresponds to cord blood levels of 0.52 – 1.10 ppb. These results in cord blood are expressed per wet weight and so are difficult to compare with the NHANES results, which are also expressed per wet weight but are measured in circulating (venous) blood. Lipid levels are lower in cord blood than venous blood and so one would expect PCB results on a wet weight basis to be lower in cord blood. Expressing the results on a lipid-adjusted basis is the standard means of normalizing between tissues that may have different lipid contents. This requires information on lipid-adjusted levels from the Oswego study. Perhaps a larger concern with comparability between the Oswego study and the NHANES data is that the total PCBs biomarker in the Oswego study includes 68 congeners or congener pairs (Stewart et al., 1999), whereas the NHANES list of PCB analytes is only 33 congeners. Therefore, summing across the NHANES congeners is unlikely to yield a total PCB level that is comparable to that which was derived in the Oswego studies.

These comparability issues also exist with the second report from the Oswego study in which a statistical association was found with total PCBs (Stewart, et al., 2006). A scatterplot and regression coefficients were presented, but there was no analysis of the exposure-effect relationship. The scatter plot (below) represents a statistically-significant negative regression coefficent for total PCB relationship with IRT score:

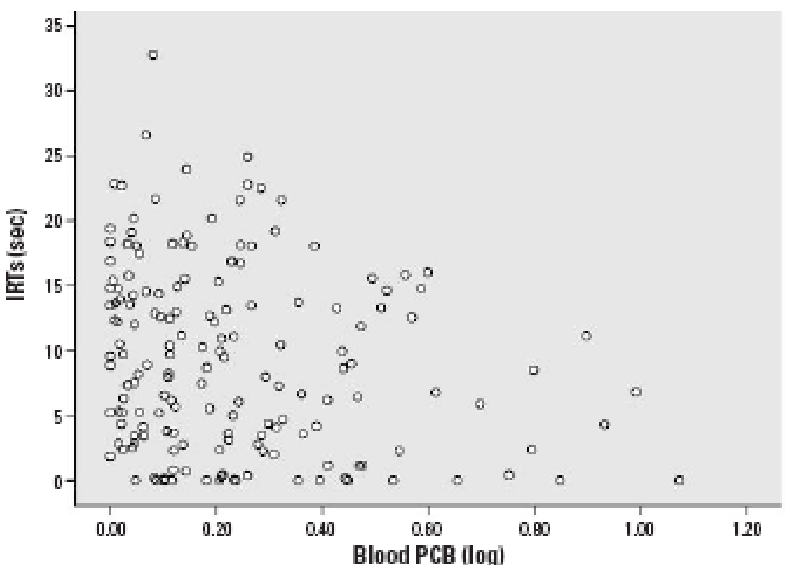
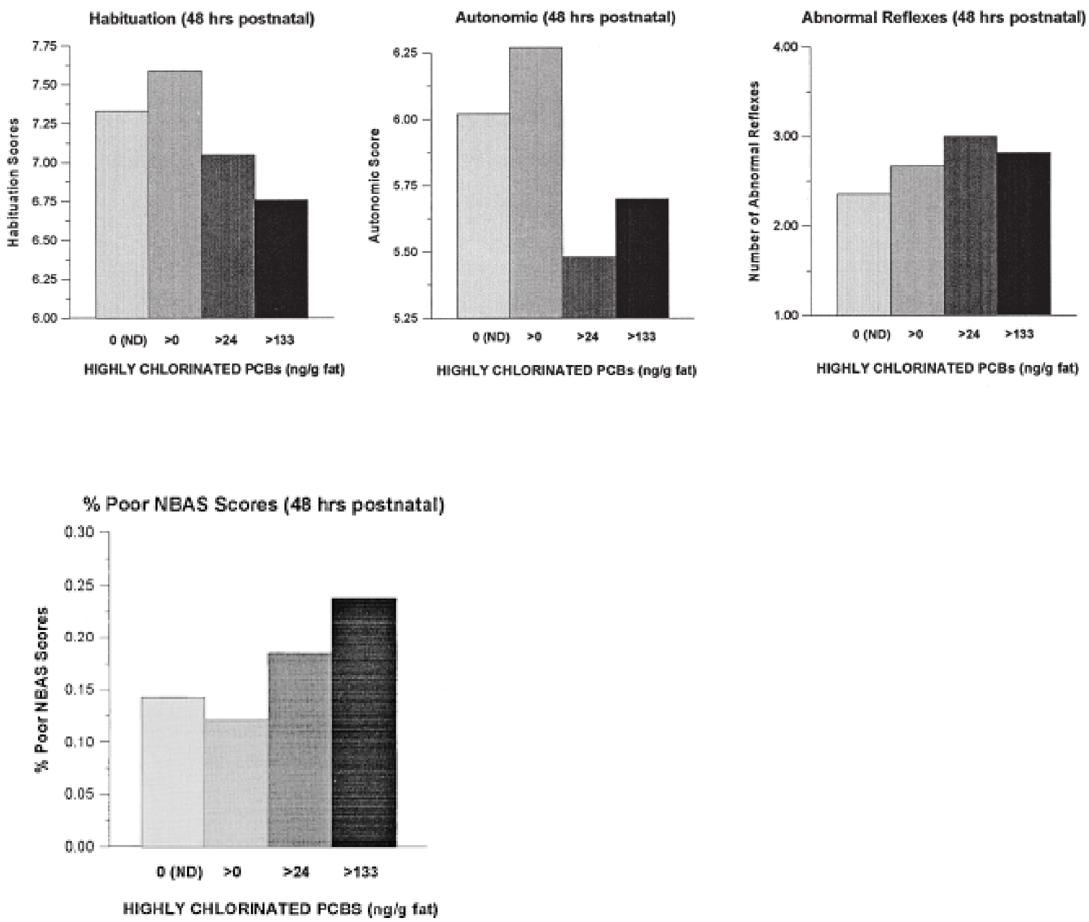


Figure 4-2: Scatterplot of the covariate-controlled relationshiop between total cord blood PCBs (log x+1) and the IRT of each subject. A significant negative relationshiop (β=-0.215, p=0.008) is observed. From Stewart, et al., 2006

From this presentation it is impossible to determine whether there was a threshold for an effect, although perhaps not until the mid-range PCB concentrations (log x +1= 0.4 or 0.25 ppb and higher) did the scatter points appear consistently different than the response at the lowest PCB concentrations. This suggests that a concentration of >0.25 ppb is associated with an adverse developmental effect; if this were the case, it would be a lower effect level than that for the Fagan test at 6 months and 1 year of age (Darville, et al., 2000). However, picking a point of departure for effects in the above plot is speculative since the exposure-effect relationship, including the possibility of a threshold, is not clear. Further, there are relatively few measurements at higher blood PCB levels, such that the distribution of responses in this region is not well characterized. The lack of exposure-effect analysis in this study and the overall issues of comparability of this total PCB biomarker with the NHANES data is unfortunate given that, in several side-by-side evaluations in the Oswego series, it appears that the total PCBs has at least as strong a relationship to neurocognitive outcome as the highly-chlorinated congeners.

Several of the Oswego study publications show statistically significant relationships between highly-chlorinated PCBs and a variety of neurodevelopmental outcomes. The correlation between highly-chlorinated PCBs in cord blood and neonatal NBAS performance is shown in the following figures from Stewart, et al. (2000). Reproduced here are the individual domain test results and a summary figure of the composite results for reflexes, autonomic responses, and habituation measures. The statistics for these endpoints included tests for significance of the regression coefficients across the tertiles, whereas pair-wise tests of significance were not performed. Visual comparison of the histograms suggests a consistent effect in the mid and upper tertiles, with little if any consistent effect at the lowest tertile. The regression coefficients for the various endpoints were generally significant, indicating an overall relationship with PCB concentration.



Figures 4-3: From Stewart et al. 2003

This exposure-effect relationship is consistent with the analyses of the Fagan test at 6 and 12 months of age (presented above; Darvill, et al., 2000) and errors of commission on the 2003 continuous performance test at the 4.5 years of age (Stewart et al., 2003a). Children with detectable PCBs in cord blood had a pattern of increased errors across the blocks with the results for the moderately and highly exposed groups being statistically significantly different from the non-detect group . Errors in the lowest exposed tertile were also increased, although not significantly.

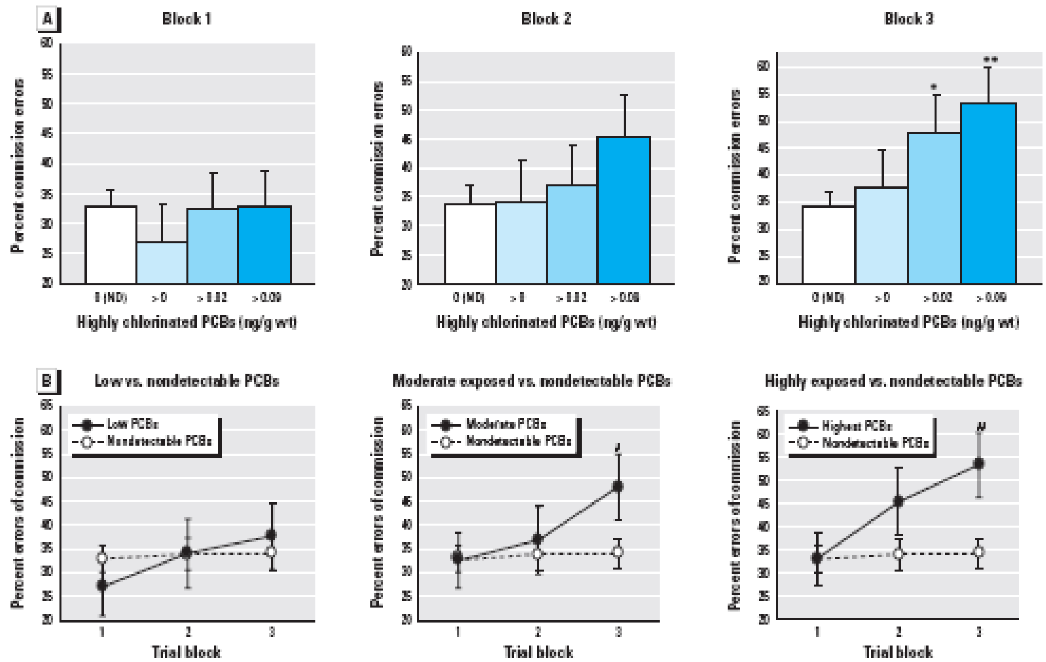


Figure 4-4: (A) Dose-response relationships between PCBs and commission errors across the three 4-min testing blocks. *p=0.052' *p=0.008. (B) Within-group changes in commission errors across the three testing blocks. Left, children with nondetectable PCB levels versus those with low exposure; middle, nondetects versus moderate exposure; right, nondetects versus high exposure. *p=0.036; *p=0.002. Error bars represent SE From Stewart et al., 2003.

Testing of associations between highly-chlorinated PCBs and neuropsychological function was continued in this cohort at 8 and 9.5 years of age (Stewart, et al., 2005). The rate of commission errors was increased once again by PCB exposure, with evidence for a monotonic exposure-effect relationship for all exposed groups (see Figure 4-5). However, statistical significance was only obtained in the highest tertile.

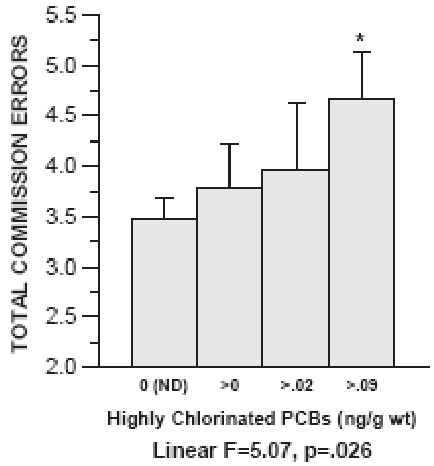


Figure 4-5: Dose-response relationship between cord blood PCB levels and total commission errors on the NES2 CPT at 8 years of age. A significant linear term is shown (p=0.026). *Highest exposure group differed from the least exposure group (p=0.022). From Stewart et al. 2005

Children in this cohort were also tested on the McCarthy Scales at 3.5 years of age (Stewart, et al., 2003a). Histograms suggest that impairment on the General Cognitive Index was present beginning at the lowest exposure tertile.

For the examination of IQ at 9 years, the relationship between outcomes and PCB placental tissue concentrations was examined by dividing the cohort into 0.50 ppb wet weight intervals (Figure 4-6), as well as by quintile (Figure 4-7). When the data are divided into quintiles, it appears that the first quintile to be negatively affected is the fourth, or between the 60^{th} and 80^{th} percentile of the study cohort. When data are plotted as a function of true exposure intervals, effects may be present at 2.0 to 2.5 ppb for full scale IQ and verbal comprehension index, between 1.5 and 2.0 ppb for freedon from distractability, and as low as 1.0 to 1.5 for verbal IQ; these judgements are made in comparison to the results at or below 1.0 ppb.

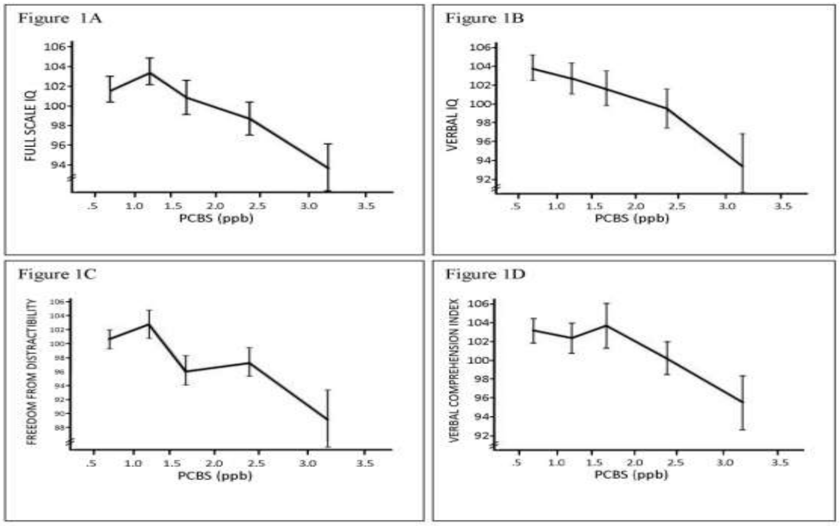


Figure 1A-D: Dose-response functions for PCB-IQ effect expressed in true exposure intervals (nd-0.99, 1.00-1.49, 1.5-1.99, 2.0-2.49, 2.5+ ppb) against adjusted IQ means. Adjusted group means and sems are plotted against the median PCB concentration within each interval. Linear F tests (Braver & Sheets, 1993) showed significant linear dose-response relationships between PCBs and Full Scale IQ, Verbal IQ and Freedom from Distractibility (all $p<.05$).

Figure 4-6: Outcomes and PCB placental tissue concentrations at 10 ppb intervals (from Stewart et al. 2005.

Figure 2:

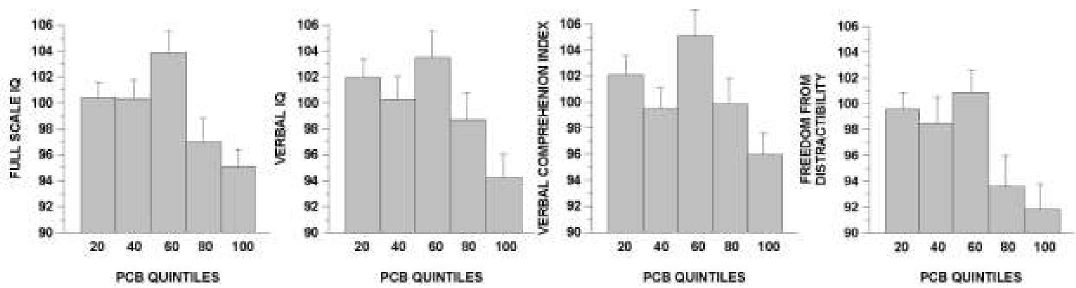


Figure 2: Dose-response functions for PCB-IQ effect expressed ordinally, in exposure quintiles (31-32 subjects per group). Linear F tests (Braver & Sheets, 1993) showed significant linear dose-response relationships between PCBs and Full Scale IQ, Verbal IQ and Freedom from Distractibility (all $p<.05$).

Figure 4-7: Outcomes and PCB placental tissue concentrations by tertiles (from Stewart et al. 2005.

Although other interpretations of the exposure-effect relationships in the Oswego series of publications are possible, the following tentative conclusions are drawn from the available data.

1. The Oswego study is currently the most relevant for evaluating risks from fish ingestion at lower body burdens.

2. Total PCBs and highly-chlorinated PCBs in cord blood, and total PCBs and PCB congeners 153 and 180 in placental tissue provide a reasonable basis for evaluating exposure-effect relationships for neurodevelopmental effects from fish ingestion.

3. A threshold for the neurodevelopmental effects of PCBs may or may not exist, depending upon the endpoint. The middle tertile of the highly-chlorinated congener grouping is a consistent effect level across most endpoints from the Oswego study for outcomes associated with cord blood PCBs. For IQ at 9 years, the fourth quintile is affected for all four outcomes. Given the greater sensitivity of the PCB analysis for the placental tissue and the correlation with IQ at 9 years,

these data were used to compare to body burdens in the general US population in the NHANES dataset.

The concentrations of the four major PCB congeners in placental tissue in the Oswego study are in Table 4-6. Wet weight values were lipid-adjusted based on lipid concentrations in 76 samples (mean lipid, 0,68%, SD=0.15%) as reported in Stewart, et al. (2008).

Table 4-6. Distribution of 4 major PCB congeners in placental samples in the Oswego Study

			Percentile Distribution			
	5	**25**	**50**	**75**	**90**	**95**
PCB 118	**3.16**	**9.01**	**13.08**	**18.84**	**26.32**	**33.64**
PCB 138	**4.70**	**10.00**	**17.35**	**19.59**	**30.03**	**40.59**
PCB 153	**7.87**	**13.13**	**18.38**	**25.59**	**37.15**	**54.24**
PCB 180	**3.22**	**6.25**	**8.53**	**12.84**	**18.85**	**25.10**
Sum of Major Peaks	**22.26**	**40.66**	**55.78**	**74.45**	**110.42**	**152.49**

Metric = ng/g lipid adjusted

Table 4-7 presents the full and verbal IQ as a function of each of the four most prevalent congeners, as well as the total of those four, as a function of true increments. For 153, there appears to be a monotonic decrease for both full and verbal IQ, which is also the case for 138 and verbal IQ. The results for the other congeners and outcomes appear to be more variable, but for all except full-scale IQ and 138, the general trend is for poorer performance associated with increased levels of PCBs.

Table 4-7. Relationship between PCB four congeners and full-scale and verbal IQ
Standard Concentration Intervals (ng/g wet weight).

	0-.049	.05-.099	.10-.149	.15-.199	.20 +
PCB 118 IQ	103.3	102.1	101.3	99.6	100.9
PCB118 VQ	106.4	102.2	102.5	99.6	97.9
PCB118 (n)	(28)	(58)	(43)	(18)	(9)
Med ng/g lipid	4.6	10.3	17.4	25.0	31.2
Max ng/g lipid	7.21	14.55	21.91	28.38	58.82
PCB 138 IQ	98.6	103.0	100.2	101.3	100.0
PCB138 VQ	104.2	100.8	103.3	102.4	97.5
PCB138 (n)	(19)	(56)	(49)	(15)	(17)
Med ng/g lipid	5.4	10.9	17.1	25.0	39.6
Max ng/g lipid	7.21	14.55	21.91	29.11	73.52
PCB 153 IQ	101.9	99.4	100.6	99.8	96.4
PCB153 VQ	103.5	101.1	100.3	100.4	93.8
PCB153 (n)	(6)	(42)	(50)	(28)	(30)
Med ng/g lipid	4.9	11.6	17.6	25.1	36.8
Max ng/g lipid	6.6	14.6	21.9	28.4	80.9
PCB 180 IQ	102.4	104.5	101.2	99.8	93.01
PCB180 VQ	104.0	105.2	100.8	101.9	88.8
PCB180 (n)	(55)	(69)	(22)	(5)	(5)
Med ng/g lipid	5.3	10.1	16.9	24.9	35.3
Max ng/g lipid	7.2	14.6	21.9	26.9	44.1
4 Peaks IQ	101.2	102.8	101.4	103.8	94.9
4 Peaks VQ	104.3	102.8	103.1	103.7	90.9
4 Peaks (n)	(17)	(71)	(39)	(15)	(14)
Med ng/g lipid	22.6	45.6	70.6	100.0	152.9

Note:

1. IQ = **Full Scale IQ;** VQ = **Verbal IQ**
2. **"4 Peaks" = sum of PCB 118,138, 153 and 180**
3. **Lipid-adjusted median and peak values were supplied directly by Dr. Paul Stewart**
4. **These concentration intervals were created to be the same across congeners,**

irrespective of their actual distributions. The n's within each category vary from one congener to the next, since the distributions and ranges of each congener differ. The sum of all 4 major congeners represents approximately 25% of Total PCB, which was derived from 75 peaks. Since the effect of Total PCB is larger in Stewart et al (2008) than for these individual peaks, it is likely other PCB congeners are involved. More detailed congener-IQ associations are a subject of a future publication.

The data from the Oswego study for these four congeners can be compared to levels from NHANES. The levels for women ages16-49 (as was done for methylmercury) are in Table 4-8 and in Table 4-9 for women 16-39. Since the body burden of PCBs increases over the lifetime, inclusion of older women who contribute a small proportion of babies results in an overestimation of blood levels in women of child-bearing potential. In the Oswego study, only one mother was over 40 years of age. The blood levels of the 4 congeners including women to 49 years of age were 39 to 75 % higher at the 95th percentile compared to women 16-39. Note that values are only provided when (approximately) all the data points relevant for any particular percentile are above the LOD for that congener.

Table 4-8. Concentrations of 4 the most prevalent PCB congeners in women 16-49, NHANES

	1%	5%	10%	25% Q1	50% Median	75% Q3	90%	95%	99%	100% Max
PCB118 N=644 BDL: 52%*	<LOD	<LOD	<LOD	<LOD	<LOD	11.2	19.5	25.3	48.9	78.8
PCB138 N=641 BDL: 24%*	<LOD	<LOD	<LOD	<LOD	14.8	26.9	43.6	62.3	110	226
PCB153 N=644 18%*	<LOD	<LOD	<LOD	<LOD	19.8	36.7	64.2	81.3	152	268
PCB180 N=643 BDL: 36%*	<LOD	<LOD	<LOD	<LOD	<LOD	22.2	39.5	51.3	87.9	205
Metric = Lipid Adj (ng/g)										

Table 4-9. Concentrations of the 4 most prevalent PCB congeners for women 16-39, NHANES										
	1%	5%	10%	25% Q1	50% Median	75% Q3	90%	95%	99%	100% Max
PCB118 N=516 BDL: 60%	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	14.3	18.7	48.9	78.8
PCB138 N =513 BDL: 28%	<LOD	<LOD	<LOD	<LOD	11.1	19.7	30.4	41.1	88.7	187
PCB153 N=516 BDL: 22%	<LOD	<LOD	<LOD	<LOD	14.6	26.6	39.6	52.9	99.9	168
PCB180 N=515 BDL: 45%	<LOD	<LOD	<LOD	<LOD	<LOD	15.6	24	29.5	65.2	90.6
Metric = Lipid Adj (ng/g) BDL = below detection limit										

For congener 118, levels at the 90th percentile are about twice as high in the Oswego study compared to US women 16-39. For congener 138, the 90th percentile is the same as that of US women. For congener 153, the 50th percentile is slightly higher in the Oswego cohort, whereas the 90th percentiles are comparable In contrast, the 90th percentile for 180 is lower for Oswego, and the 50th percentile is similar.

PCB levels at which effects occurin the Oswego study in relation to each of these four congeners, and a comparison to levels in the US population, may be approximated from Table 4-7. This approximation does not rely on statistical comparison, but rather a systematic impairment of performance as PCB body burden increases. The comparison of PCB levels in the Oswego study to those in NHANES is hampered by the fact that for a substantial percentage of the population of US women, levels are below the limit of detection for the methodology used, even for these four most prevalent congeners.

For congener 118, there is a monotonic decrease in verbal IQ, with an effect for children at least above 7.21 ng/g (the maximum value of children in the lowest quintile), which is below the 90th percentile of NHANES. For 138, there is a decrease in verbal IQ for children above 29 ng/g lipid (the highest value in the fourth quintile), also below the 90th percentile for NHANES. Both full and verbal IQ decrease above 6.6 ng/g for 153. The 50th percentile of NHANES is 14.6 ng/g. For congener 180, full and verbal IQ decrease above 7.2 ng/g (the highest value in the first quintile), below the 75th percentile of US women. It is unknown which congeners are actually responsible for the decrement in IQ, although in the Oswego study 153 and 180 were associated with IQ and the other two congeners were not under linear regression analysis. It must also be kept in mind that associations were stronger when the full set of 75 congeners were included. Nonetheless, it appears that effect were observed in the Oswego study at body burdens that overlap those in US women of child-bearing age.

A caveat exists in that we are comparing PCB levels in cord blood or placental tissue (Oswego studies) against venous blood from the general population in the NHANES dataset. However, comparison on a lipid-adjusted basis should correct for this difference and make the results directly comparable. In fact, there is good correspondence between levels of individual PCB congeners in maternal and cord blood on a lipid-adjusted basis (Jaraczewska et al. 2006). In spite of this, there may be other differences between the biomonitored media in the Oswego vs NHANES studies that could bias the comparison in one direction or the other.

B. Dutch Study

As discussed above, the main exposure marker in the Dutch study was the sum of congeners 118, 138, 153, and 180 in maternal blood. Although effects were observed on multiple endpoints between the neonatal period and nine years of age, most published papers do not provide information concerning the shape of the exposure-effect function. The relationship between PCB levels in maternal serum and IQ at 42 months as assessed on the Kaufman-ABC was represented graphically, however (Patandin, 1999b).

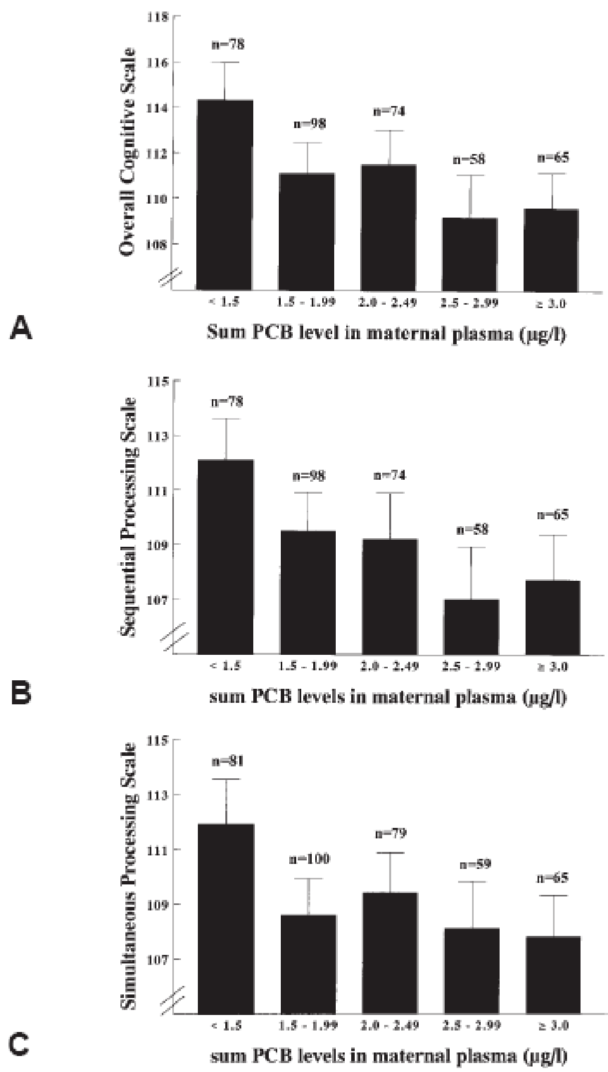


Figure 4-8: Five cutoff points are given for ∑PCB concentrations measured in maternal plasma based on range and distribution of ∑PCB concentrations. Bars represent dose response relationship of mean score and SEM on overall cognitive scale of Dutch version of Kaufman Assessment Battery for Children and Maternal ∑PCB concentrations adjusted for covariables (maternal age, parity, sex, parental education and verbal IQ, HOME score, maternal alcohol use and cigarette smoking during pregnancy, feeding type in infancy, breast-feeding period, and study center). A: Score on overall cognitive scale in highest exposed group (∑PCB maternal ≥ 3 µg/L) is 4 points lower compared with that in lowest exposed group (∑PCB maternal < 1.5 µg/L). In B and C similar dose-response relationships are given for sequential and simultaneous processing scale of K-ABC, which also present 4-point deficit between highest exposed and lowest exposed group. From Patandin 1999b

Children in all four of the higher quintiles performed more poorly than those in the first quintile. This suggests an effect level for total PCBs at least as low as the 2nd quintile (1.5 to 1.99 ug/L), although statistical significance was not reported. A more refined analysis of the population is needed to understand whether lower-exposed individuals also exhibit a demonstrable response. However, the Pantandin et al. (1999b) data are useful for comparison of an apparent PCBs effect level in the Dutch population to US body burdens. The following table presents the PCB levels in NHANES for the sum of the 4 PCB congeners tabulated in the Dutch study:

Table 4-10. Total PCBs (Congener #118, 138, 153 and 180) in US Population (data tabulated from NHANES/CDC SAS files for study year 2001/2002 downloaded from CDC website)

Group Measured	50th %	75th %	90th %	95th %	99th%
16-49 yr old women	0.33	0.61	1.05	1.37	2.58
16-39 yr old women	0.19	0.42	0.69	1.00	1.60
(ug/L plasma)					

Cognitive Effect Level in Dutch study ≅ 1.5-1.99 ug/L

The demonstrated effect level in the Dutch study for this endpoint may be beyond the 99th percentile of the background US distribution based on women 16-39 years old, and below the 99th percentile for women 16-49. Given that dose-response analysis was not done in the Dutch study below this exposure level, we do not know if effects were present at lower levels.

C. Otitis Media in an Inuit Population

The immune system appears to be a sensitive measure of PCB toxicity as assessed in both animal and human studies. Associations have been observed in human studies between PCB body burden and increased susceptibility to infectious disease (Weisglas-Kuperus, et al., 2000; Karmus, et al., 2001, Dallaire, et al., 2006), reduced antibody response to vaccination in children (Heilmann, et al., 2006), and increased occurrence of Non-Hodgkin's Lymphoma (De Roos, et al., 2005). A study of young Inuit children (0-5 yrs old) provided evidence of an immunotoxic effect as measured by an increased incidence of acute otitis media related to PCB body burden (Dallaire, et al., 2006). PCB prenatal exposure was measured by congener 153 lipid-adjusted results in cord blood. The results below suggest a monotonic exposure-effect relationship.

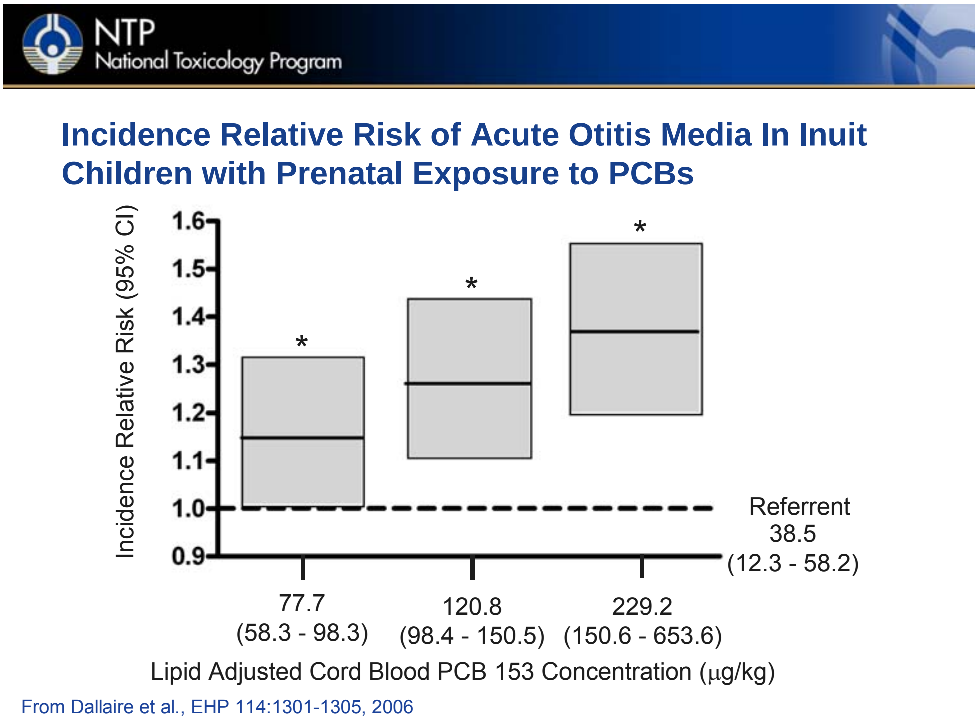


Figure 4-9: Figure from NTP presentation at the Upstream Indicators Conference,

The low exposure group mean PCB153 concentration was 77.7 ng/g, which as depicted below is between the 95th and 99th percentile of the NHANES data for the US women between 16 and 39 years of age.

Table 4-11: PCB 153 (ng/g lipid) in US Population (from CDC, 2005)					
Group Measured	50th %	75th %	90th %	95th %	99th
Women 16-49	20	37	64	81	
Women 16-39[1]	14.6	26.6	39.6	52.9	99.9

[1]Data for this group calculated by Mass DOH, January 2007 and re-confirmed by CTDPH from CDC SAS data files.

Otitis Media effect level ≅ 77.7 ng/g

D. Body Burden Summary and Conclusions

The findings of associations between PCB body burden and adverse neurodevelopmental and immunotoxic effects in the studies described above suggest that such effects are occurring at levels of exposure present in the U.S. population. The following table shows the baseline population body burden for women of childbearing age in which an apparent effect level was seen in the three examples described above.

Table 4-12: Summary Table: Health Outcomes and Associated Body Burdens

Study	Endpoint	Biomarker	% of NHANES Distribution at Apparent Effect Level
Oswego	IQ at 9 years	congeners 118, 138, 153, 180 in placental tissue, lipid adjusted	below 50th to 90th, depending on outcome
Dutch	Several neurodevelopmental endpoints	PCBs 118, 138, 153, 180 in venous blood, wet wt	beyond the 99th
Inuit	Otitis media	PCB 153 Lipid-adjusted cord blood vs venous blood	95th to 99th

The body burdens at which effects were observed in these studies compared to those in NHANES are reasonably consistent. The PCB body burdens in the Dutch and Inuit studies were mostly higher than those in the U.S., and a body burden at which effects were not observed was not identified. Exposures were lower in the Oswego study, allowing the lower end of the dose-response relationship to be examined and a range of effect levels identified. Better definition of the Dutch and Inuit exposure-effect relationships, if that had been possible, may have revealed effects at lower body burdens that were relevant to a larger percentage of the U.S. population.

It is also important to recognize that the epidemiological methods used in these studies to assess exposure-effect relationships are crude, and the current analysis is limited to statistical comparisons of grouped data or visual comparisons of histograms. More sophisticated analysis of the raw data would presumably provide a better-defined exposure-effect relationship, including perhaps indication of a threshold. Based on the present analyses, it seems reasonable to conclude that results are consistent with an effect level for a variety of outcomes at concentrations that are within the exposure of the U.S.

population (16-39 year old women). Although the uncertainties in the underlying analysis merit further attention, the current conclusion that a substantial fractions of the US population has body burdens of concern for adverse effects of PCB exposure appears to be reasonable.

Hazard analyses based on the Oswego (or other epidemiological) studies would ideally be based on benchmark dose (BMD) analysis of the relationship between body burden (maternal and/or cord blood) and effect on various endpoints. To derive an RfD, a pharmacokinetic model of some sort would have to be used to convert from body burden to maternal intake.

VI. Options for the development of a Striped Bass and Bluefish Advisory

The epidemiological studies have documented robust behavioral deficits resulting from in utero exposure to PCBs. Based on the Oswego study, deleterious effects appear possible at body burdens typical of women in the general U.S. population.

PCBs have a long half-life in the human body, decades for some congeners. Therefore exposure across the lifespan, including during childhood, determines transgeneration exposure. This is also the case for dioxins; it was because of this reality that the National Academy of Sciences Institute of Medicine recommended that exposure be minimized, beginning in early childhood (IOM, 2003). Current levels of exposure may already be within the range associated with adverse developmental outcomes. Consequently it is recommended that any advisory for striped bass and bluefish not result in an appreciable increase in the body burden of PCBs for females.

This recommendation is a departure from the standard risk-based approaches involving an RfD or CSF to determine limits of exposure and in some ways can be more complex. Setting a fish consumption limit based upon background body burden may involve one of three approaches (or a combination of the 3) as follows.

The recommendation could be based on an estimation of the potential contribution to body burden of US women from consumption of a particular fish species. This requires knowledge of the fish PCB concentration (mean, median, percentiles), the fish ingestion rate (this variable can be backfit to derive the target daily dose), and a toxicokinetic tool (e.g., PBTK model) to convert daily dose in mg/kg/day to body burden. This tool would be similar to the biokinetic slope factor used in lead risk assessment modeling. The population distribution of toxicant body burden would be derived from actual biomonitoring data or from modeling approaches. The incremental increase in body burden due to PCBs in striped bass would then be estimated using dosimetry modeling approaches. The acceptable increment in body burden due to striped bass would be a risk management decision. While this analytical option may be the most robust, it requires data and techniques not currently available for PCBs (e.g., biokinetic model). Further, using this approach for PCBs is more complicated than for lead due to the large number of congeners that would need to be considered in modeling PCB body burden. These congeners will each have their own biokinetics and toxicological properties.

Rather than base decisions on body burden, it may be more direct to consider background daily dose of PCBs in the U.S. diet and to have as a goal that the fish species in question contribute no more than a certain percentage to total daily PCB dose. This approach necessitates knowledge of PCB levels in commonly eaten foods and distributional inputs for the level of consumption of these foods. These dietary calculations have been conducted for dioxins. While at least some data regarding PCBs in food exists, we don't believe that calculations of cumulative dietary exposure are available.

The third approach also uses background exposure rates in foods as a point of comparison, except that this approach is less comprehensive than #2 above. In this case, the acceptability of a given fish ingestion rate would be judged against other PCB-containing foods that are commonly eaten and for which there are no special precautions. There would be no accumulation of exposure dose, just direct comparisons of dose from striped bass or bluefish to dose from other specific food items. This approach may be the simplest in that data on PCB levels in dairy, meat, poultry, etc. can be obtained, consumption rates can be found in tables, and the daily PCB dose from these items can be compared to what may be available from striped bass. It would then be assumed that a consumption rate of striped bass which contributed no more daily dose than what is available in these other commonly eaten food items, would also not substantially increase body burden. Issues would arise as to which PCB fish concentration to use as the basis of calculations (mean, median, upper percentile), as well as the consumption rate that should be used for the comparison foods. Some initial data for assisting in this regard were presented below (Table 4-14 – Typical PCB levels in some Animal Based Protein Sources).

VII. Health Benefits of Eating Fish

Fish are nutrient rich foods that are readily available to most Americans. They are a good source of high-quality protein (an important nutrient) and are rich in many micronutrients, such as unsaturated fatty acids, vitamins, and minerals. In addition, they are generally lower in saturated fatty acids (risk factors for heart diseases) than other protein foods (meat, poultry, and eggs). Consequently, many organizations concerned about the relationships between diet and health recommend that most Americans should increase their consumption of fish (see specific recommendations below, and Table 4-13). This recommendation stems from a weight-of-evidence that shows or suggests that many health benefits are associated with fish consumption.

Evidence suggests that the benefits from fish consumption stem, at least in part, from the nature of the dietary fats in fish. Dietary fats are generally grouped into three major categories: saturated fats (which are solids at room temperature) such as beef fat and lard; mono-unsaturated oils such as olive oil; and polyunsaturated oils such as fish, corn, and canola, which contain polyunsaturated fatty acids (PUFAs). Two types of PUFAs exist, omega-6 fatty acids and omega-3 fatty acids; these are essential fatty acids. They are important for normal growth and adequate supplies cannot be made by the body, thus, they must be obtained from the diet. Omega-6 fatty acids are found in vegetable oils and most plant seeds. Two of the most important omega-3-fatty acids are eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are found mainly in fatty fish. Another important omega-3-fatty acid is alpha-linolenic acid (ALA), which is found mainly in plants. Although humans can metabolically convert ALA to EPA or DHA ALA is not a primary source of EPA or DHA because the conversion rate is inefficient and cannot provide recommended daily intakes of EPA or DHA. Fish are the major dietary source of EPA and DHA.. The table below provides a summary of the cellular importance of these fatty acids (taken from IOM, 2007).

Omega-3 Fatty Acid	Function
EPA (eicosapentaenoic acid)	A precursor molecule in the human synthesis of one family of eicosanoids (signaling molecules), including prostaglandins, thromboxane, leukotrienes, hydroxy fatty acids, and lipoxins. These compounds serve as modulators of cardiovascular, pulmonary, immune, reproductive, and secretory functions at the cellular level.
DHA (docosahexaenoic acid)	A component of all membrane structural lipids in neural tissues, retina, and spermatozoa. The developing brain accumulates large amounts of DHA late in fetal life. This accumulation continues post-natally through at least the first two years of life

Historically, dietary fats have been considered risk factors for cardiovascular disease. However, early studies of Eskimo populations with seafood diets (primarily fish, sea birds, seal, and whale) showed that they had low rates of coronary heart disease even though their diet was very high in fats (Bang et al. 1971). Researcher hypothesized that the omega-3 fatty acids in the seafood could, in part, be responsible for the cardiovascular benefits. Since then, results from a wide-variety of studies, including mode-of-action, animal and human studies, have provided additional evidence to show or suggest that increased intakes of 3-omega acids such as EPA and DHA are likely responsible, at least in part, for the beneficial effects of fish consumption on cardiovascular health. Moreover, researchers have also provided evidence that fish consumption may have beneficial effects on other health endpoints.

Recently, a report by a Committee of the Institute of Medicine of the National Academies (IOM, 2007) summarized the evidence on the causal relationship between fish consumption and health benefits. The Committee focused on two major sets of benefits – Benefits to the Prevention of Adult Chronic Disease and Benefits to Women, Infants, and Young Children. Below is a summary of the Committees' major findings.

A. Benefits for the Prevention of Adult Disease

Evidence suggests that increased seafood consumption is associated with a decreased risk of cardiovascular deaths (e.g., sudden deaths or death from coronary heart disease) and cardiovascular events in the general population. However, it is uncertain whether this association is mediated through an increase in EPA and DHA consumption and/or a decrease in saturated fat consumption and/or other correlates of seafood consumption.

Evidence on the hypothesis that consumption of fish oil supplements for individuals with a history of myocardial infarctions (a sudden insufficiency of arterial or venous blood supply involving the middle layer of the heart; usually as a result of a closed, or closing, coronary artery) will protect them from further coronary events is mixed.

The effect of increased seafood consumption on the lipid profile of the general population is unclear. However, experimental studies of EPA/DHA supplementation at levels >1 g/day showed decreased triglyceride levels; the effect on other components of the lipid profile is less clear.

Evidence for a benefit associated with seafood consumption or fish oil supplements on blood pressure, stroke, cancer, asthma, type 2 diabetes, or Alzheimer’s disease is inconclusive. Observational studies have suggested a protective role of EPA/DHA for each of these diseases, but supportive evidence from randomized clinical trials is either nonexistent or inconclusive.

A recent report Mozaffarian and Rimm (2006), not summarized in the IOM (2007) Report, provides additional evidence on the cardiovascular benefits of fish consumption. Results of a meta-analysis of the best available human studies (randomized trials and large prospective studies) suggested that modest consumption of fish (e.g., 1-2 servings/wk), especially species with higher levels of EPA and DHA, reduced risk of coronary death by 36% (95% confidence interval, 20%-50%; $P < 0.001$) and total mortality by 17% (95% confidence interval, 0%-32%; $P = 0.046$).

B. Benefits to Women, Infants, and Young Children

Results from a variety of studies show an association between increased intake of seafood or fish oil supplements and increased duration of gestation. This increased gestation length generally results in increased birth weight, which itself is positively associated with improvements in cognitive ability.

Observational studies provide evidence that the infants and children of mothers who consume seafood or EPA/DHA supplements during pregnancy and/or lactation may have improved developmental outcomes (i.e., cognitive benefits and improved visual acuity).

There is no convincing evidence that attention deficit hyperactivity disorder (ADHD) other behavioral disorders, or asthma can be prevented or treated in children with seafood or EPA/DHA consumption.

A recent study (Hibbeln et al., 2007) published after the IOM (2007) Report provides additional evidence that consumption of fish has beneficial effects on neurodevelopment during childhood. In the study, about 12,000 pregnant women completed a food frequency questionnaire assessing seafood consumption at 32 weeks' gestation. Multivariable logistic regression models, which controlled for 28 potential confounders involving social disadvantage, perinatal, and dietary items, were used to compare developmental, behavioral, and cognitive outcomes in children (age 6 months to 8 years) of women consuming no seafood, low amounts of seafood (1-340 g/week), or large amounts of seafood >340 g/week during pregnancy. After adjustment for confounding factors, no or low (< 340 g/week) maternal seafood intake during pregnancy was associated with increased risk that the mother's children would be in the lowest quartile for verbal intelligence quotient. No or low maternal seafood intake was also associated with increased risk of suboptimum outcomes for prosocial behavior, fine motor, communication, and social development scores. For each outcome measure, the lower the intake of seafood during pregnancy, the higher the risk of suboptimum developmental outcome. For each outcome measure, the odds ratios for no intake vs high intake was between 1.25 and 1.5 and the 95% lower confidence limit exceeded 1.

Given these and other data on the benefits of fish consumption (IOM, 2007), several groups have recommended that Americans consume more seafood (Table 4-13). Moreover, the IOM Committee (IOM, 2007) found that average quantities of seafood and EPA and DHA consumed by the general US population are below levels suggested by many authoritative groups. Consequently, they provided two recommendations that directly addressed fish and seafood consumption.

Recommendation 1: Dietary advice to the general population from federal agencies should emphasize that seafood is a component of a healthy diet, particularly as it can displace other protein sources higher in saturated fat.

Recommendation 2: Although advice from federal agencies should also support inclusion of seafood in the diets of pregnant females or those who may become pregnant any consumption advice should stay within federal advisories for specific seafood types and state advisories for locally-caught fish.

The IOM Committee (2007) emphasis on health benefits of seafood, as opposed to health benefits of dietary supplements containing omega-3 fatty acid, stems, in part, from two observations. (1) The IOM (2007) Committee noted that the health benefits of seafood consumption may not be limited to intakes of omega-3-fatty acids, such as EPA/DHA. Other nutrients present in seafood (e.g., selenium) may provide specific health benefits or facilitate the action of EPA/DHA. (2) The Committee also noted that Americans generally consume too much saturated fat and cholesterol and too little "good fats" such as the omega-3 fatty acids EPA and DHA in fish. Thus, the substitution of seafood for other food sources may decrease exposure to nutrients (e.g., saturated fats) that are risk factors for human diseases. This benefit might not occur with the use of dietary supplements. The American Heart Association (AHA 2003 a, b) has made a similar conclusion and suggests “a dietary (i.e., food based) approach to increasing omega-3 fatty acid intake is preferable” to supplement based approach.

The IOM Committee (2007) also noted the potential for adverse health effects associated with excessive consumption of dietary supplements containing omega-3 fatty acids. Potential effects include increased bleeding time, reduced glycemic control among diabetics, and increased levels of low-density lipoprotein (LDL) cholesterol. The IOM Committee (2007) noted that the FDA, after reviewing the literature on increased bleed time and fish oil, recommended limiting omega-3 fatty acid intake from supplements to reduce the risk of health effects. In addition, organic contaminants such as PCBs are lipophilic and may concentration in fish oil (Shim et al., 2003). Consequently, manufacturers of fish oil products have recognized the need to provide uncontaminated fish oil (e.g., Melanson et al. 2005). Nonetheless, the only US organizations in Table 4-13 that recommends fish oil supplements is the American Heart Association (AHA, 2003a,b), but only for people with documented chronic heart disease or in need of triglyceride lowering, and only after consultation with the physician or under the supervision of a physician.

TABLE 4-13: Recommendations of American Organizations for Seafood and EPA/DHA Consumption (taken from IOM, 2007).					
Organization	Audience	Purpose of Recommendation	Recommendations		
			Type of Fish/Seafood	Serving size	# of Servings
American Heart Association	Healthy adults (without documented coronary heart disease)	Reduce cardiovascular disease by dietary and lifestyle facts among the general population	All fish, particularly fatty fish (salmon, albacore tuna, mackerel, lake trout, herring, and sardines)	3 ounces cooked (or 4 ounces raw)	Two per week
	People with documented heart disease	Secondary prevention	EPA+DHA per day, preferably from fatty fish; supplements can be considered with physician consultation	1 gram EPA+DHA	Once per day
	People with elevated triglycerides	Lower triglycerides	EPA+DHA per day as a capsule with physician consultation	2-4 grams EPA+DHA	Once per day
Dietary Guidelines Advisory Committee	Unspecified	Provide sound and current dietary guidelines to consumers	Fish, especially salmon, trout, white (albacore or bluefin) tuna, mackerel, or other fish that are high in EPA and DHA	4 ounces	Two per week
My Pyramid	Americans	Help Americans make healthy food choices, given their sex, age, and activity level	Fish rich in omega-3 fatty acids, such as salmon, trout, and herring	Not specified	More often
National Cholesterol Education Program, National Heart, Lung, & Blood Institute	People with high LDL-cholesterol/those adopting therapeutic lifestyle changes (TLC)	Healthy lifestyle recommendation for a healthy heart	Fish, type unspecified	≤ 5 ounces	One per day
American Diabetes Association	Unspecified	Lower risk of diabetes, and protect your heart and blood vessels	Fish	Not specified	2-3 per week

C. Risk of Fish Consumption

Unfortunately, fish and shellfish commonly contain chemical contaminants. These contaminants include inorganic compounds (e.g., methylmercury, other metals) and organic compounds (e.g., dioxins, dioxin-like compounds, and PCBs). Excessive intakes of these contaminants are associated with adverse effects in animals and people, and thus, exposure to these contaminants from fish or other sources pose potential health risks (e.g., cancer, neurotoxicity, cardiovascular disease, impaired neurodevelopmental) to consumers. Consequently, the potential health risks associated with the consumption of fish containing contaminants needs to be considered by consumers who eat fish for its benefits (e.g., AHA, 2003a,b; FSA, 2004; IOM, 2007; Mozaffarian and Rimm, 2006).

The level of risk from exposures to chemicals, including chemicals in fish, depends on many factors, including exposure factors (degree, frequency, and length of exposure) and an individuals' personal characteristics (i.e., age, sex, diet, family traits, lifestyle, genetic background, presence of other chemicals in their body (e.g., alcohol, prescription drugs), and state of health). In turn, contaminant levels in fish depend on many variables, including the chemical properties of the contaminant and the characteristics of the seafood (e.g., fish type (species), size, age, its diet, and geographic source or harvest location). Omega-3 fatty acids in fish may also depend on these factors. Thus, any assessment of the risks and benefits of fish consumption should identify important characteristics of the exposed population and provide estimates of the contaminant and omega-3-fatty acids levels in fish. Unfortunately, such data are limited and published assessments on the risk and benefits of fish consumption have compensated for these limitations by discussing the risk-benefits in general terms (IOM, 2007) or restricting their risk-benefit analysis to certain contaminants (e.g., methylmercury, dioxin and dioxin-like PCBs) or species (e.g., salmon) (e.g., Mozaffarian and Rimm, 2006).

Both the IOM (2007) Committee and Mozaffarian and Rimm (2006) focused much of their attention on the risks and benefits associated with the consumption of commercially available seafood contaminated with methylmercury or dioxin and dioxin-like-compounds, which includes only some of the PCBs (i.e., dioxin-like PCBs). The IOM (2007) Committee and Mozaffarian and Rimm (2006) concluded that health benefits of consuming commercially available seafood outweigh the health risks from the studied contaminants for most people under most conditions. Both groups urged caution and careful consideration of risk for sensitive subgroups (i.e., pregnant women and women of childbearing age) or for people who eat greater than average amounts of fish.

More important, both the IOM (2007) Committee and Mozaffarian and Rimm (2006) emphasized that consumers should realize that local or regional contamination problems can lead to contaminant levels in fish that greatly exceed levels typically found in commercially available seafood. This is more likely for organic contaminants (e.g., dioxins and PCBs) and for fish with high fat levels. For example, the IOM (2007) Committee specifically recognized that compounds such as dioxins and PCBs accumulate in fat tissue and are found predominantly in fatty fish and fish that live in fresh or coastal waters, including striped bass, bluefish, American eel, lake trout, and farmed Atlantic salmon.

These changes in contaminant levels alter the risk-benefit ratios even if fish consumption rates are unchanged. In such cases, both the IOM (2007) Committee and Mozaffarian and Rimm (2006) recognized that their risk-benefit analysis were not appropriate for such situations. Moreover, the IOM (2007) recognized that guidance for consumers of such fish, such as subsistence and recreational fishers, would require further separate, specific analyses of risks and benefits beyond the scope of the committee's charge. Consequently, both the IOM (2007) Committee and Mozaffarian and Rimm (2006) advised consumers to consult state advisories before consuming fish that are contaminated by regional and local sources of persistent organic contaminants.

D. PCB Concentrations in Protein Sources (Fish, Meat)

Dietary advisories and consumer decisions about what ;protein source to eat should be based, in part, on knowledge about the concentrations of chemical contaminants and nutrients (good and bad) in the protein source (IOM, 2007). The literature on total PCB levels in commercial food is very sparse, and here we focus on data on protein sources (fish, meat). . The FDA's Total Diet Study (FDA 2008) is national in scope, but limited in sample size. Total PCB concentrations are expressed as Aroclor equivalents, rather than as the sum of results from congener-specific measurements. Sample collections are generally conducted four times each year, once in each of four geographic regions of the country (West, North Central, South, and Northeast). Food samples are purchased from supermarkets, grocery stores and fast food restaurants in three cities in the region and are shipped to a central laboratory. The foods are then prepared table-ready and the three samples are combined to form a single analytical composite for each food. Several other studies describing PCB levels in commonly consumed commercial fish are summarized below. Total PCB concentrations in these studies are expressed as the sum of congener-specific concentrations (Hites et al. 2004) or as Arclor equivalents (McBride et al. 2005) and represent uncooked homogenized fillets. Several other studies citing PCB levels in commercially important fish have been identified, but are not included in this analysis as they do not appear to adequately represent US population exposure. (e.g., PCBs in spanish sardines).

Table 4-14 – Measured PCB Levels in Some Animal Protein				
Product	Sample Size	Results		
		Concentration (ppb)		Detection Frequency
		Mean	Maximum	
US National Data (FDA, 2008)*				
Baked Beef Chuck Roast	44	0.23	10	2.3%
Pan cooked Beef steak loin	40	0.50	20	2.5%
Pan cooked Pork Chop	44	0.45	20	2.3%
Baked Pork Roast	44	0.23	10	2.3%
Pan cooked lamb chop	44	0.23	10	2.3%
Fried Chicken (breast, leg, thigh)	40	0.23	9	2.5%
Canned Tuna in Oil	40	1.0	40	2.5%
Fried Eggs	40	1.2	39	5%
Homemade Meatloaf	44	0.45	20	2.3%
Pan cooked veal cutlet	40	0.25	10	2.5%
Roasted Chicken Breast	44	1.4	30	4.5%
Baked Salmon Steaks or Filets	24	24	55	93%
Washington State Data (McBride et al., 2005)**				
Salmon	17	31.5	88.4	76%
Canned tuna	40	12.6	18.9	0%
Flounder	19	9.6	10.7	5%
Cod	33	9.8	18.5	0%
Pollock	23	9.9	18.5	0%
Halibut	29	14.6	27.4	62%
Red Snapper	27	14.7	27	74%
Catfish	24	15.1	45.4	8%
International Data (Hites et al., 2004)				
Salmon	246	D.L. to ~ 50		NR

* For Non-Detects (ND), zero used to compute mean.
** For Non-Detects (ND), ½ of the Level of Detection was used to calculate mean and maximum.
NR: Not Reported

Table 4-15 compares the levels of PCBs (derived from Table 2-2 in chapter 2 in recreationally caught migratory striped bass in eastern coastal waters. This table does not include data on riverine or estuarine striped bass.

Table 4-15: Average PCB levels in Migratory Striped Bass along Eastern Coastal States			
Location	Date	Average Concentration (ppb)	Sample Size (I=individual)
Maine	2002-2006	160	71 (I)
Massachusetts	1997	291	76 (I)
Rhode Island	1996	190	34 (I)
New York (LI Sound)	1994	1175	303 (I)
New York (LI Sound)	1999-2000	164	22 (I)
New York (LI Sound)	2006	253	103 (I)
New York (NY Bight)	1999-2000	372	17 (I)
New Jersey	2004	221	20 (I)
New Jersey	1998-1999	417	22 (I)

Tables 4-16 and 4-17 compare the levels of PCBs (derived from Table 2-4 and 2-5 in chapter 2) in recreationally caught bluefish in eastern coastal waters. Since several states break up the consumption advisories based on size the bluefish data will be broken into two relatively arbitrary size classifications for comparison. "Large" bluefish will be defined as over 20" and "small" bluefish will be defined as under 20" (508 mm). It is recognized that every state may have their own criteria for defining large and small and that this comparison is strictly illustrative.

Table 4-16: Average PCB levels in Bluefish > 508 mm (20") along Eastern Coastal States				
Location	Date	Average Concentration (ppb)	Average Length (mm)	Sample Size (I=individual)
Maine	2002-2004	410	785	10(I)
NY (Long Island Sound)	2006	483	684	111 (I)
New York/New Jersey (Bight)	1993	760	648	5 (I)
Connecticut	1997	832	655	60 (I)
New Jersey	2004	473	735	19 (I)
New Jersey	1997-1999	587	756	31 (I)
New Jersey (De Bay)	1999	949	727	3 (I)
Delaware	2004	297	750	1 (I)
Delaware	2005	574	722	14 (I)

Table 4-17: Average PCB levels in Bluefish < 508 mm (20”) along Eastern Coastal States				
Location	Date	Average Concentration (ppb)	Average Length (mm)	Sample Size (I=individual, C=composites)
Connecticut/New York (LI Sound)	2006	69	411	50 (I)
NY Bight (NY/NJ)	1993	930	452	7(I)
NY Harbor	1993	990	349	27 (I)
New York Harbor	1998	358	488	22(I)
NY – Hudson R	1999	904	168	18 (I)
New Jersey (Ocean and Raritan R and Bay)	1998	277	289	5 (I)
New Jersey (Ocean and Raritan R and Bay)	2004	367	406	8 (I+C)
New Jersey (Delaware Bay)	1999	330	486	2 (I)
New Jersey (Delaware Bay)	2004	289	350	3 (C)
Delaware (Bay + Indian River Inlet)	2004	42	314	15 (I)
Maryland (Chesapeake Bay)	2002	119	297	5 (I)
Maryland (Potomac River)	2002	57	285	3 (I)
Virginia	2003	27	294	3 (C)
Virginia	2004	14	264	3 (C)
North Carolina	1998	<13	314	5 (C)

Meat is not a major source of omega-3-fatty acids (IOM, 2007). Thus, the focus is on omega-3-fatty acid concentrations in different species of fish, which are a significant dietary source of omega-3 fatty acids readily available to Americans. Table 4-18 provides average omega-3 fatty acid levels (combination of DHA and EPA) in various fish species and the reported PCB levels in the same fish species presented in Tables 4-15 to 4-17. While it is recognized that concentrations of PCBs in these fish vary based on location, year of sampling and analysis method, the average of the data by state reported since 1999/2000 is displayed.

Table 4-18: Comparison of PCB levels to Omega-3 Fatty Acid Levels		
Product	Average PCB Level (ppb)	Omega-3 Fatty Acids (EPA + DHA) g/100 g[1]
Canned Tuna[2]	29	0.79
Salmon (mix of farmed and wild) [3]	30	1.4
Flounder	9.6	0.2
Cod	9.8	0.2
Pollock	9.9	0.4
Halibut	14.6	0.4
Red Snapper	14.7	0.2
Catfish	15.1	0.3
Striped Bass	234	0.7
"Large" Bluefish	447	0.7
"Small" Bluefish	123	0.7

[1] Average of all species specific data from Mahaffey 2004 and Santerre 1999
[2] Average of light and white tuna
[3] Estimated from FDA 2005, McBride 2005 and Hites 2004

It is important to recognize several limitations of the data contained in Table 4-18. Good data on PCBs in commercial fish species is often very limited. The influence of size, year and location of the collection of fish influences PCB content and may not be adequately captured in the data presented in Table 4-14. Additionally, data on omega-3 fatty acid content in fish is also very limited and the factors which influence PCB concentration may also covary with omega-3 content.

Those qualifications noted, assuming a meal size of 4 ounces (0.113 kg as per dietary recommended meal sizes) one can calculate the PCB and the EPA/DHA doses at the American Heart Association recommended 2 meal per week consumption rate. Then, one can compare the exposures of micrograms of PCBs per gram of omega-3 fatty acids. While this exercise does not adequately capture variability of both omega-3 fatty acid content and PCB concentrations, it does allow one to compare relative dietary sources of omega-3 fatty acids and their associated PCB intake. In this comparison, a lower number minimizes the PCB intake per gram of Omega-3 fatty acids. Figure 4-10 shows that relationship.

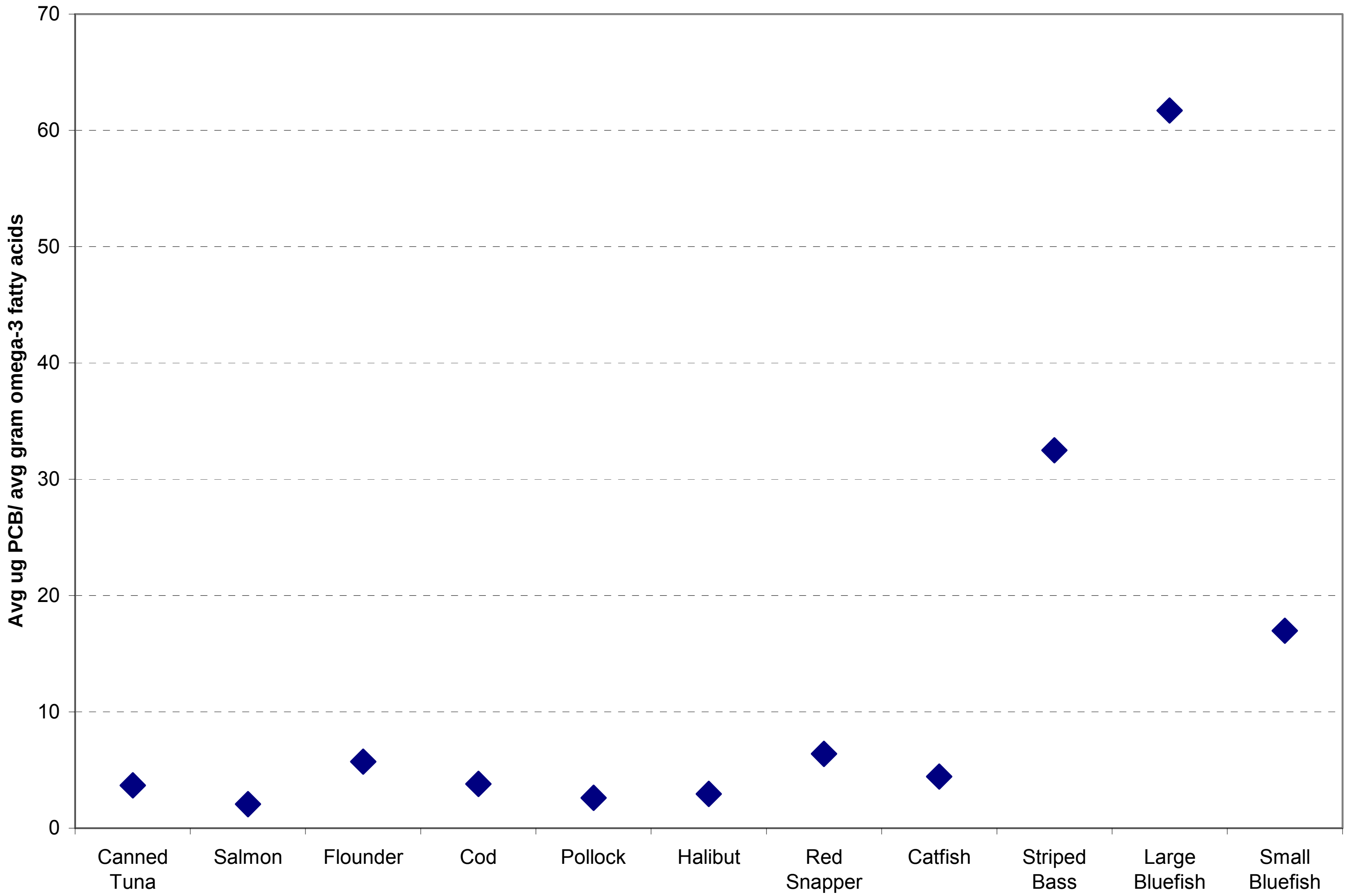


Figure 4-10: Ratio of PCBs to Omega-3 Fatty Acids for Various Fish Species

So while striped bass and bluefish can be considered moderate sources of omega-3 fatty acids (compared to salmon on the high end and cod/pollock on the low end), they would also appear to be a dominant source of PCBs. Or to rephrase, for PCBs in striped Bass and bluefish, for which we have a reasonable data set, omega-3 fatty acid levels would have to be roughly an order of magnitude higher than the current estimates to make them consistent with other dietary omega-3 fatty acid sources. A valuable research objective would be to include EPA and DHA levels with any future PCB analysis for both striped bass, variable sized bluefish, and commercially consumed fish.

The IOM (2007) Committee concluded that it "it would be difficult for federal agencies to develop a list of "good fish" and "bad fish" that would not become obsolete in a short time" because the contaminant levels in commercially available seafood change constantly with changes in seafood sources, harvest location, and cultivation practices. However, such is not the case when local and state public health agencies issue fish advisories based on relatively stable contaminant levels in a particular species or group of species from a particular area or water body. The IOM Committee (2006) also concluded that any analysis of the risks and benefits from fish consumption must contain information on the nutrient and contaminant levels in the consumed fish and on the characteristics of the consumers (e.g., age, sex, health and reproductive status). For example, when developing advice for consumers, mercury (if not other contaminants such as dioxins) should also be evaluated.

VII. Summary and Conclusions

The current toxicological bases for developing advisories based on PCBs consist of FDA's tolerance for commercial fish, EPA's Reference Dose, ATSDR's Minimum Risk Level, or the Great Lakes Health Protection Value. All these values are outdated and do not take into account the effects observed in the several longitudinal prospective epidemiological studies published in the last 20 years.

That said, using standard risk based methods as described by EPA's guidance for developing fish consumption advisories for sportcaught fish, one can develop "risk based decision criteria" to compare PCB levels in striped bass and bluefish to various consumption rates. These decision criteria vary based on whether a 0% or 50% cooking loss is assumed, or whether cancer as an endpoint is considered (at a 1/100,000 risk level). One meal per week consumption rates range from 11 to 87 ug/kg and one meal per month consumption rates range from 43 to 346 ug/kg.

There are several well-designed epidemiological studies evaluating neuropsychological effects in children exposed to PCBs. The effects seen in these studies are supported by animal data and mechanistic studies. Characterization of the shape of the relationship between exposure and effect has not been performed and was beyond the scope of this workgroup. However, comparison of the effect levels from one study (Oswego) can be compared to typical body burdens in the US population to estimate whether PCB body burdens are at levels similar to those at which effects were observed. Although the analysis is sub-optimal (estimating effect levels from published histograms), the evaluation is supported by the fact that multiple endpoints suggest a monotonic relationship between PCB exposure and adverse effect sin the Oswego study. If the second tertile is chosen as an effect level, the levels at which effects are observed in the Oswego study are well within the range of PCB levels found in the general US population of women of child-bearing age. . This suggests that there is no margin of safety between body burdens of PCBs in the US population and body burdens that are associated with adverse effects on multiple outcomes as a consequence of in utero exposure.

There is evidence that dietary fats in fish have beneficial impacts on both adults and the developing fetus. A comparison of the ratio of PCB levels to omega-3 fatty acid levels suggests that, with the exception of smaller bluefish, striped bass and bluefish offer a significantly higher amount of PCBs per gram of omega-3 fatty acids than other typical dietary omega-3 fatty acid sources. Given these results, it would not appear that strong consideration of the health benefits of fish is valuable when thinking about PCB exposure from striped bass and larger bluefish.

VIII. Recommendations for Future Research.

There are a number of areas for which additional information or analysis would inform the risk assessment process. Some of these analyses could potentially be performed with data currently collected, others may require further data-gathering efforts.

Perhaps the most important need with respect to the health effects of PCBs is characterization of the relationship between exposure and effect, and determination of a defined effect level. This would be done most accurately and rigorously by benchmark dose (BMD) analysis, as has been performed for methylmercury (NRC, 2000). BMD analysis could be performed for existing studies, with an emphasis on results for the Oswego study. Such an analysis would provide information on whether there was an apparent threshold within the range of body burdens in the U.S. population, and/or provide a point of departure for derivation of a toxicity value such as an RfD.

An estimation of the relationship between body burden and intake would also provide important information for risk assessment. PCBs are a mixture, and there is some information on half-lives in blood or other compartments (e.g., adipose tissue) for at least some congeners. In addition, Longnecker et al. (2003) have converted concentrations of 153 in various tissues to concentration in blood. These and other data could be incorporated into a pharmacokinetic (PK) model.

More information is needed on both the levels of PCBs in various foods and consumption patterns of foods containing PCBs in the U.S. population. Concentrations in food should be based on modern analytical techniques, not based on Aroclor analysis and high detection limits. Information on subpopulations such as women of child-bearing age and children would also be valuable. If such data were relatively complete and reliable, it would allow estimation of the contribution of consumption of striped bass or bluefish to body burden, including the blood compartment, for various groups.

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Chapter 5: Current Advisories for Striped Bass and Bluefish

I. Introduction

Currently the health advisories produced by the states for consumption of striped bass and bluefish along the eastern United States are similar (Figure 1). Beyond that basic similarity, however, there are significant differences in the physical locations of advisories, how the human populations are defined, toxicity sources used, and the parameters that are used in defining human exposures to chemical residues in fish (e.g., meal size, exposure duration, etc.). The following chapter identifies the health advice currently given by each state for striped bass and bluefish and identifies the parameters used by each state to develop the fish consumption advisories.

The parameters that are identified below under each state's description include the acceptable cancer risk level, the source used for non-cancer toxicity, and assumptions used to assess contaminant exposures, i.e., body weight, meal size, exposure duration and contaminant loss during cooking and trimming. For those states that do not have advice for striped bass and bluefish, those tables represent their standard procedures for developing advice for PCBs. EPA has developed guidance to assist states in the development of fish consumption advisories and addresses each of these parameters (EPA 1999).

Acceptable Risk Level (ARL): The choice of acceptable risk level (for carcinogens) is a policy decision that varies by state. EPA typically uses acceptable risk levels between 1/10,000 and 1/1,000,000. The ARL adopted by each state is provided below although some states have chosen to not explicitly evaluate cancer as a health endpoint for fish consumption advisories. These states either assume or check to ensure that the risk levels associated with non-cancer based advisories fall within or below a range of acceptable risk.

States also vary in their choice of non-cancer toxicity values as described below. EPA recommends EPA derived reference doses (RfD) presented in the IRIS database. The bases for non-cancer impacts are described in the toxicology chapter.

Body weight and meal size are dependent on whether or not children and pregnant women are explicitly evaluated for developing advice. EPA's guidance discusses these parameters in detail, but their default value for body weight is 72 kgs for adult males and females (the "general population"), 64 kgs for women of reproductive age, and 14 kgs for children under 6 years of age. EPA also assumes an 8 ounce meal of cooked fish filet for the average 72 kg consumer and a 3 ounce meal for children under 4 years of age. EPA additionally provides scaling values to modify these numbers for other populations. The states have used similar values for adults but often have not addressed differing exposure scenarios for children (see below).

The exposure duration is the time period over which an individual is exposed to one or more contaminants. In the case of an individual fisher, the exposure duration is equivalent to the time interval over which he or she catches and consumes fish. Typically however, fish consumption is not constant for purposes of risk estimation, especially for short-term or seasonal recreational fishers. Often, average and maximum residence time in an area where exposure is likely to occur is used in the adult population risk assessment as a surrogate for actual exposure duration. For childrens' risk assessments, especially with respect to developmental toxins such as mercury and PCBs, the exposure duration is equal to the maximum age in the range considered for the childs' risk assessment, whether it be 6, 10, or even 15 years. While exposure duration assumptions may not always be sufficiently conservative, these assumptions may be balanced by overly conservative assumptions in other aspects of the assessment. Risk assessors and managers need to judge if the overall margin of safety afforded by the use of uncertainty factors and conservative assumptions provides satisfactory protection for fish consumer populations of concern.

Another issue that deserves greater discussion is how the sensitive population is defined from state to state. While the health effects chapter discusses the developmental effects of PCBs, how the sensitive population is actually defined varies significantly from state to state. While this is both a technical issue (for which the toxicology may not be sufficiently developed to give a clear answer) it is also a risk communication issue (where clarity and simplicity is critical).

Additionally, due to the relatively large volume of literature that is specific to cooking loss of PCBs in striped bass and bluefish, that particular issue is discussed in greater depth in this chapter.

Finally, as discussed in the biology chapter, striped bass in particular are a migratory species with discrete spawning locations along the Atlantic coast. These particular spawning locations may or may not be localized hotspots of PCB contamination. As such, they may deserve more or less restrictive advice than the migratory population of striped bass (in which both the more and less contaminated spawning stocks mix forming a more homogenous population which anglers can "sample").

The health risk assessment information presented in this chapter outlines the current methods used by states to derive fish advisories based on PCB contamination. However, several other factors besides health risk assessment may be considered when deriving fish advisories and their formats, e.g.:

- Because of the health benefits of fish consumption, advisories should balance protection from contaminants without discouraging people from eating fish.
- Advisories should make special consideration for high-risk populations (e.g., the fetus and young children are of greater concern because chemicals may have a greater effect on developing organs).
- Advisories should be easy to understand and use.
- Advisories should be consistent within a state (and among adjoining states, as feasible).

- Fish contamination uncertainties (due to variations in contaminant levels by location, species, fish ages/sizes, timing of fish collections, and by laboratory) should also be considered.

Thus, because of the many additional factors to be considered, the states may derive fish advisories that do not strictly follow the characterization of potential risk as derived by health risk assessment. Moreover, fish advisories may vary between the states even when their advisory derivations employ the same fish data and health risk assessment approach.

II. State Data

A. Maine

Maine's current advice for both striped bass and bluefish consumption is 2 meals per month for all consumers for all striped bass and bluefish caught in any Maine waters (MeBOH 2005). It is recognized that this advice needs to be revised based on new data and this effort is part of that process.

	Acceptable Risk Level	Non Cancer Source	Body Weight	Meal Size	Exposure Duration	Cooking Loss
Maine	1/100,000	EPA RfD	70 kg	8 ounces	70 yrs	None

B.New Hampshire

New Hampshire's advice for consumption of striped bass and bluefish is 2 meals per month. This advice is for all consumers in all waters in New Hampshire (NH DES 2005, AFS 1999)

	Acceptable Risk Level	Non Cancer Source	Body Weight	Meal Size	Exposure Duration	Cooking Loss
New Hampshire	1/100,000	EPA RfD	70 kg general population	8 ounces	70 yrs	None
			61 kg preg woman			

C. Massachusetts

Massachusetts, in developing its advice for striped bass and bluefish distinguishes between the general population and the sensitive population. The sensitive population is defined as pregnant women, women who may become pregnant, nursing mothers and children under 12 years of age. For this category, it is recommended that there be no consumption of bluefish. This advisory covers all coastal waters in Massachusetts. In general, Massachusetts recommends that all fish consumers choose a variety of fish and shellfish (among which could be striped bass) and obtain them from a variety of sources.

Massachusetts has advice due to concerns about PCBs and other contaminants for certain areas of New Bedford Harbor (no consumption of fish and shellfish) and Boston Harbor (avoide consuming lobsters, flounder, soft shell clams, and other bivalves). In general Massachusetts recommends that all adult fish consumers choose a variety of fish and shellfish and obtain them from a variety of sources.

	Acceptable Risk Level	Non Cancer Source	Body Weight	Meal Size	Exposure Duration	Cooking Loss
Mass	N.A.	½ FDA Tolerance Limit	70 kg general population, 60 kg adult female	8 ounces	70 yrs	None

D. Rhode Island

Rhode Island recommends that the general population eat no more than 1 meal per month of bluefish or striped bass. Rhode Island recommends that pregnant women, nursing women, women planning a pregnancy and young children (under 6 years of age) should not consume any striped bass or bluefish. This advisory covers all coastal waters in Rhode Island. (RI DoH 2005).

	Acceptable Risk Level	Non Cancer Source	Body Weight	Meal Size	Exposure Duration	Cooking Loss
Rhode Island	N.A.	FDA Tolerance (loosely based)	Risk management evaluation			None

E. Connecticut
Connecticut's advice for striped bass and bluefish cover all coastal waters along the state. The striped bass advisory is less than 1 meal per month for the general population and no consumption for the sensitive population. The sensitive population is defined as pregnant women, women planning on becoming pregnant within a year, children under 6 and nursing women. Connecticut's bluefish advisory is also divided between the general and sensitive population (with the same definition of the sensitive population) but with the addition of distinctions on the size of the bluefish. The general population should limit consumption of bluefish between 13 and 25" to 1 meal per month, while fish over 25" should be consumed no more than every other month. For the sensitive population,

bluefish between 13 and 25” can be consumed once per month, but bluefish greater than 25” should not be consumed. (CtDPH 2005, Rusnak 2005, AFS 1999)

	Acceptable Risk Level	Non Cancer Source	Body Weight	Meal Size	Exposure Duration	Cooking Loss
Connecticut	1/10,000	Great Lakes Protocol	70 kg	8 ounces	70 yrs	50%

F. New York

New York is distinctive in that they have had a large PCB source to a major tributary with a striped bass spawning/residence locale (the Hudson River) (see Figure 2). The advice for Hudson River striped bass is divided at Catskill: for the Hudson River north of Catskill, the New York State Department of Health (NYSDOH) advises everyone to EAT NO striped bass. For the Hudson River south of Catskill and the Upper and Lower Bays of New York Harbor, East River, Harlem River, Raritan Bay West of Wolfe's Pond Park and Long Island Sound West of Wading River, NYSDOH advises that infants, children under the age of 15 and women of childbearing age EAT NO striped bass, while all others are advised to eat no more than one meal per month.

NYSDOH advises everyone to EAT NO striped bass from the Arthur Kill, Kill Van Kull and Newark Bay. For Raritan Bay east of Wolfe's Pond Park, Long Island Sound east of the Wading River, Block Island Sound, Peconic Bay, Gardiners Bay, Jamaica Bay, and Long Island south shore waters, everyone is advised to eat no more than one meal per week of striped bass.

For bluefish caught in the Hudson River, the Upper Bay of New York Harbor, Arthur Kill, Kill Van Kull, East River, Harlem River, Newark Bay and Raritan Bay west of Wolfe's Pond Park, NYSDOH advises that infants, children under the age of 15 and women of childbearing age EAT NONE and other people are advised to eat no more than one meal per month. For bluefish caught in the Lower Bay of New York Harbor, Raritan Bay east of Wolfe's Pond Park, Long Island Sound, Block Island Sound, Peconic Bay, Gardiners Bay, Jamaica Bay and Long Island south shore waters, everyone is advised to eat no more than one meal per week. (NYSDOH 2007, AFS 1999).

When reviewing fish contaminant data to determine fish advisories for a specific fish species, water body or region, NYSDOH considers the following:

- fish contaminant levels, including fish sampling characteristics (e.g., number and type of samples, species, age, length, percent lipid, sample location, etc.) and patterns of contamination;
- health risks;
- populations at greater potential risk;
- the FDA marketplace standard (e.g., 2 ppm for PCBs);
- health benefits; and
- risk communication issues.

G. New Jersey

New Jersey's advice for striped bass and bluefish covers all coastal waters. Infants, children, pregnant women, nursing mothers and women of childbearing age should not consume any striped bass or bluefish. For the general population, New Jersey uses a 1/10,000 cancer risk for PCB fish consumption advisories. The general population should eat no more than 4 meals per year of bluefish that are >6 pounds or 24 inches, and 1 meal per month of bluefish that are <6 pounds or 24 inches and legal sized striped bass. (Buchanan 2008, NJDEP 2006, AFS 1999)

	Acceptable Risk Level	Non Cancer Source	Body Weight	Meal Size	Exposure Duration	Cooking Loss
New Jersey	1/10,000	EPA RfD	70 kg for general population	8 ounces	70 yrs	None
			62 kg for women of childbearing age			

H. Pennsylvania

Pennsylvania's advice for striped bass covers the Delaware Estuary from the tidal portion of all Pennsylvania tributaries and the Schuylkill River to the Fairmount Dam (Bucks, Philadelphia and Delaware Counties). No one should eat striped bass at a rate of more than 1 meal per month from these waters. There are no advisories that impact bluefish in the state of Pennsylvania (AFS 1999, Pa DEP 2005).

	Acceptable Risk Level	Non Cancer Source	Body Weight	Meal Size	Exposure Duration	Cooking Loss
Pennsylvania		Great Lakes Protocol	70 kg	8 ounces	70 yrs	50%

I. Delaware

Delaware's advice for striped bass is divided into northern and southern waters, where northern waters are defined as the eastern end of the C&D Canal to the New Jersey Pennsylvania border. The southern end is defined as the eastern end of C&D Canal to Cape Henlopen. There is a no consumption health advisory for striped bass caught in the northern locale. For southern fish, the general population can consume 1 meal per year, women of childbearing age can consume 1 (6 ounce) meal per year and children can consume one (3 ounce) meal per year. For bluefish greater than 14" the recommendations are to eat no more than one 8 ounce meal per year for the general public and no consumption for women o fchildbearing age and children. Bluefish less than 14" long can be eaten at a rate of one meal per month. (De DNR 2008, Greene 2008, AFS 1999).

<table>
<tr><th></th><th>Acceptable Risk Level</th><th>Non Cancer Source</th><th>Body Weight</th><th>Meal Size</th><th>Exposure Duration</th><th>Cooking Loss</th></tr>
<tr><td rowspan="3">Delaware</td><td rowspan="3">1/100,000</td><td rowspan="3">EPA RfD</td><td>71.8 kg for general pop</td><td>8 ounces for general population</td><td rowspan="3">30 yrs</td><td rowspan="3">None</td></tr>
<tr><td>63.6 kg for women of childbearing age</td><td>6 ounces for women of childbearing age</td></tr>
<tr><td>14.5 kg for children 0-6 yrs old</td><td>3 ounces for children 0-6 yrs old</td></tr>
</table>

J. Maryland

Maryland has no advisory for bluefish. Maryland's advice for striped bass covers only the waters of the Chesapeake Bay and its tributaries. The advice for striped bass varies by fishing season, fish size and population at risk, with the size and date requirements integrated with the states fishing regulations. For striped bass caught between May 16th and December 15th (less than 28 inches long) the general population can consume two 8 ounce meals per month, women of childbearing age (women who are pregnant or may become pregnant, or are nursing) and children under 6 can consume one 3 ounce meal per month. For fish caught between April 15th and May 15th, greater than 28" long, the general population can consume one 8 ounce meal a month, women of childbearing age (women who are pregnant or may become pregnant, or are nursing) can consume 10 six ounce meals per year, and children under 6 can consume 10 three ounce meals per year (MDE 2005, AFS 1999).

	Acceptable Risk Level	Non Cancer Source	Body Weight	Meal Size	Exposure Duration	Cooking Loss
Maryland	1:100,000	EPA RfD	78.5 kgs general population	8 oz general population	30 yrs for general population and women of child-bearing age	30 % - general population only
			64 kg women of childbearing age	6 ounces for women of childbearing age		
			14.5 kg for children 0-6 yrs old	3 ounces for children 0-6 yrs old	6 years for children 0-6	

K. Virginia

Virginia also has no advisory specific to bluefish. Virginia's advisory for striped bass covers the waters of the Chesapeake Bay and its tributaries. The advice for Virginia is no more than 2 meals per month for all consumers of striped bass. (VaDOH 2005, AFS 1999) Virginia does not give specific advice regarding striped bass outside the Chesapeake Bay and its tributaries.

	Acceptable Risk Level	Non Cancer Source	Body Weight	Meal Size	Exposure Duration	Cooking Loss
Virginia	1/100,000	EPA RfD	70 kg	8 ounces	30 yrs	None

L. North Carolina

North Carolina does not have specific advice for striped bass or bluefish (NC DHS 2005).

	Acceptable Risk Level	Non Cancer Source	Body Weight	Meal Size	Exposure Duration	Cooking Loss
North Carolina	NA	EPA RfD	70 kg	6 ounces cooked	70 yrs	50 %

M. South Carolina

South Carolina does not have specific advice for striped bass or bluefish (SC DHEC 2005, AFS 1999).

	Acceptable Risk Level	Non Cancer Source	Body Weight	Meal Size	Exposure Duration	Cooking Loss
South Carolina	1/10,000	EPA RfD/Great Lakes Protocol	70 kgs	8 ounces		50 %

N. Georgia

Georgia does not have specific advice for striped bass or bluefish (GaDNR 2005, AFS 1999)

	Acceptable Risk Level	Non Cancer Source	Body Weight	Meal Size	Exposure Duration	Cooking Loss
Georgia	NA	EPA RfD	70 kg	4-8 ounces	30 yrs	None

O. Florida

Florida does not have specific advice for striped bass or bluefish (FL DoH 2005, AFS 1999).

	Acceptable Risk Level	Non Cancer Source	Body Weight	Meal Size	Exposure Duration	Cooking Loss
Florida	1/1,000,000	EPA RfD	70 kg	8 ounces		None

III. Definitions of the sensitive population

There is evidence that some portions of the human population (e.g., the fetus in pregnant women, and young children) are more sensitive to some environmental contaminants than other contaminants. Both mercury and PCBs are examples of chemicals that differentially exert their impacts on sensitive populations. Given the evidence for the health benefits of fish, many states develop fish consumption advisories to allow less restrictive consumption of fish for those individuals who are considered to be less sensitive (often termed the "general population") to environmental contaminants. This strategy is a common practice when developing health advisories recommending restrictions on fish consumption. However, the definitions of sensitive populations varies among the states (see table 5-1 below).

Table 5-1: State Definitions of Sensitive Population

State	Sensitive Population	
	Sensitive Women	Children aged less than (years)
Maine	Pregnant women, women who may get pregnant, nursing women	8
New Hampshire	Pregnant women, women who may get pregnant, nursing women	7
Massachusetts	Pregnant women, women who may get pregnant, nursing mothers	12
Rhode Island	Pregnant women, women planning a pregnancy, nursing women	6
Connecticut	Pregnant women, women planning on becoming pregnant within a year, nursing women	6
New York	Women of childbearing age	15; and infants
New Jersey	Women of childbearing age, pregnant women, nursing mothers	age not defined; infants
Pennsylvania	Women of childbearing age	age not defined

Delaware	Women of childbearing age	age not defined
Maryland	Pregnant women, women who may become pregnant, nursing women	6
Virginia	Pregnant women, women who may become pregnant, nursing mothers	age not defined; "young"
North Carolina	Women of childbearing age (15 to 44 years), pregnant women, nursing women	15
South Carolina	Pregnant women, women who plan to become pregnant soon, nursing mothers	14
Georgia	Pregnant women, women who plan to become pregnant soon, nursing mothers	6
Florida	Women of childbearing age	10

As seen in the above table, both the definition of sensitive women and the age cutoff for children varies significantly. Development of consistent advice would greatly benefit from a definition of the population at risk that is consistent from state to state. In other words, regional advice that the sensitive population should not consume a particular fish is not really consistent if each state defines that person differently.

IV. Contaminant reduction due to trimming and cooking

Many states do not assume any loss of lipophilic contaminants while cooking (indeed, this approach is most warranted when considering contaminants that are not lost during the cooking process, such as with mercury). Striped bass and bluefish are unusual, however, in that many of the early studies on loss of contaminants through cooking were specific to PCBs and these species. Table 5-1 summarizes studies on the effects of trimming and cooking on PCB content of bluefish and striped bass fillets. In these studies, skin-on fillets were taken from both sides of the fish, one of the fillets was analyzed raw and intact, while the other fillet was trimmed and/or cooked as described in Table 5-2. The individual fillets were analyzed for PCBs (Aroclors), and percent PCB loss from trimming/cooking for each fillet pair was calculated, e.g., as follows:

$$\% \text{ PCB Loss} = \frac{\text{PCBs in intact raw fillet} - \text{PCBs in trimmed/cooked filet}}{\text{PCBs in intact raw fillet}} \times 100$$

Table 5-2 shows that these studies varied in how they reported the effect of cooking/trimming on PCB content: PCB mass (e.g., ug); PCB concentration (e.g., ug/kg) on a wet weight basis (most frequent measure in Table 5-2) or PCB concentration on a dry weight basis. These distinctions are important because, while all cooking methods result in some loss of PCB mass (primarily via melting-off of the fat in which PCBs are concentrated), the effect of these losses on PCB wet weight concentration can be partially or even totally offset by moisture loss during cooking.

Review of Table 5-2 indicates that just removal (and not cooking) of fillet fat and skin in these two species results in considerable reductions in fillet wet weight PCB concentrations, from 27% (Sanders and Haynes, 1988) to 56% (Salama et al., 1998 – sample size of 1) – sample in bluefish; and 57% (White et al., 1985) in the only striped bass trimming study. The effect of just cooking on wet weight PCB concentrations varies considerably (probably due to variations in individual specimens, and cooking methods): from an 8% increase (baked – Trotter and Corneliussen, 1989) to a 55% decrease (smoked – Salama et al., 1998 –sample size of one) in bluefish; and from a 4% increase (steamed) to a 21% decrease in striped bass (Armbruster et al., 1987). As would be expected, a study in which cooking and trimming were used together (Armbruster et al., 1989) resulted in the greatest reductions in PCB content: removal of bluefish fillet skin and fat followed by baking, broiling, frying or poaching resulted in 60-71 % decreases in fillet PCB concentrations.

In 1993 the Great Lakes Fish Advisory Task force released the "Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory to promote consistency in Great Lakes states fish advisories (based on PCBs) and the methods used to derive them. Regarding assumptions on PCB loss via cooking trimming for risk assessment, the protocol states: "The states agreed to the use of a 50% reduction factor for most species. The Task Force reviewed a number of documents related to contaminant reduction through various preparations methods (See Appendix II). The Task Force realizes that there may be inter-species variances in contaminant reduction by following the suggested guidelines, but feel the 50% reduction factor provides adequate representation of the various species encountered by consumers of sport fish."

EPA (1992) recommends the use of cooking and trimming loss only when data on local methods of preparation are available and when it is known how it will impact the contaminant of concern.

Table 5-2: Summary of Studies on PCB Loss in Bluefish and Striped Bass Fillets Via Trimming and Cooking.					
Species	Pre-Cook Trimming	Cooking	Sample Size	Average change in PCB content	Reference
Bluefish	Skin, dorsal fat & belly flap	None	21	27% decrease in PCB concentration (wet weight)	Sanders and Haynes, 1988
Bluefish	None	Bake, skin and drippings discarded	20	8% increase in PCB concentration ((wet weight, due to water loss); 27% decrease in PCB mass	Trotter and Corneliussen, 1989
Bluefish	Skin, dorsal fat, lateral line fat & belly flap	None	10	56% decrease in PCB concentration (wet weight)	Armbruster et al., 1989
	Skin, dorsal fat, lateral line fat & belly flap	Bake	10	68% decrease in PCB concentration (wet weight)	Armbruster et al., 1989
	Skin, dorsal fat, lateral line fat & belly flap	Broil	10	71% decrease in PCB concentration (wet weight)	Armbruster et al., 1989
	Skin, dorsal fat, lateral line fat & belly flap	Fry	10	68% decrease in PCB concentration (wet weight)	Armbruster et al., 1989
	Skin, dorsal fat, lateral line fat & belly flap	Poach	10	60% decrease in PCB concentration (wet weight)	Armbruster et al., 1989

Species	Pre-Cook Trimming	Cooking	Sample Size	Average change in PCB content	Reference
Bluefish	None	Smoke	1	55% decrease in PCB concentration (wet weight); 65% decrease in PCB mass	Salama et al., 1998
	None	Micowave bake	1	48% decrease in PCB concentration (wet weight); 60% decrease in PCB mass	Salama et al., 1998
	Skin	Charbroil	1	29% decrease in PCB concentration (wet weight); 47% decrease in PCB mass	Salama et al., 1998
	None	Charbroil	1	18% decrease in PCB concentration (wet weight); 37% decrease in PCB mass	Salama et al., 1998
	None	Pan fry	1	No change in PCB concentration; 27% decrease in PCB mass	Salama et al., 1998
	None	Bake	1	No change in PCB concentration; 39% decrease in PCB mass	Salama et al., 1998

Species	Pre-Cook Trimming	Cooking	Sample Size	Average change in PCB content	Reference
Striped bass	Skin and fat	None	15	57% decrease in PCB concentration (wet weight)	White et al., 1985
Striped bass	[skin removed from all fillets both raw (comparison) and cooked (before cooking)	Bake	8	21% decrease in PCB concentration (dry weight)	Armbruster et al., 1987.
	[skin removed from all fillets both raw (comparison) and cooked (before cooking)	Broil	9	12% decrease in PCB concentration (dry weight)	Armbruster et al., 1987.
	[skin removed from all fillets both raw (comparison) and cooked (before cooking)	Fry	9	15% decrease in PCB concentration (dry weight)	Armbruster et al., 1987.
	[skin removed from all fillets both raw (comparison) and cooked (before cooking)	Microwave	8	20% decrease in PCB concentration (dry weight)	Armbruster et al., 1987.
	[skin removed from all fillets both raw (comparison) and cooked (before cooking)	Poach	8	13% decrease in PCB concentration (dry weight)	Armbruster et al., 1987.
	[skin removed from all fillets both raw (comparison) and cooked (before cooking)	Steam	8	4% increase in PCB concentration (dry weight)	Armbruster et al., 1987.

V. Advisories in Spawning Locations

Striped bass are distinctive compared to bluefish in that the population is divided into groups that spawn in specific estuaries (as discussed in the biology chapter). Each spawning location contains resident fish (e.g., males and juveniles) as well as migratory fish (larger females). These two populations will contain different PCB loadings. Additionally, these spawning locations may or may not be impacted by localized PCB sources. This is relevant in the development of a regional advisory in that these spawning locations may have higher or lower levels of PCB contamination compared to the migratory stock of which they become a part.

For striped bass, these spawning/residence regions include the Hudson River, the Delaware Estuary, the Chesapeake Bay, and the Albermarle Sound/Roanoke River. Of these locations, the Hudson River (Forti 2005, Buchanan 2005), the Delaware Estuary (Greene 2005, Buchanan 2005) and the Chesapeake Bay (Beaman 2005) have advisories that impact spawning/resident fish as opposed to migratory fish. There are no specific advisories for the Albermarle Sound/Roanoke River. The concentrations of PCBs found in these fish are discussed in the data chapter, but are difficult to compare due to state to state variations in sampling technique, analytical methodology, etc.

VI. Conclusions

There is much variation in the parameters used by states to develop health advisories. However, despite the variations in state methodologies, there are only a limited number of advisories possible and the advisories do not vary as much as the methods that produced them.

While there is a significant literature associated with cooking and trimming loss associated with PCBs in striped bass and bluefish, there is still little information on local cooking preparation methods. Hence, it does not make sense to incorporate a cooking/trimming loss component into the development of a shared advisory. A state may choose, however, to include supplemental information about cooking loss when communicating their advisories.

The impact of spawning locations on any proposed recommendation for coastal advisories should be evaluated. It may be some logic for consistent advice among migratory striped bass, but it doesn't necessarily follow that spawning locations should fall under that consistency. Spawning locations contain different fish (from the migratory stock) and may or may not be impacted by PCB point sources. This issue does not appear to be a concern for migratory bluefish.

VII. Recommendations

A more productive effort may be to develop common advisories as a risk management decision rather than focus on changing methodologies to be consistent from state to state. In other words, many New England states already advise the sensitive population not to consume striped bass and bluefish, even though their techniques for developing that advice differs.

For the same reasons, it is also not recommended that consistent methodology regarding cooking and trimming loss be adopted. It is true there are a fair number of studies that deal with cooking and trimming loss in striped bass and bluefish and there is some consistency among these studies. However, at this point it is not worthwhile to recommend consistent use of cooking and trimming loss recommendations along the Atlantic Coast.

Uniformity would be valuable in the definition of the sensitive population. Agreement on how the sensitive population is defined would clarify risk communication from state to state.

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Chapter 6: Conclusions and Recommendations

I. Introduction

The primary objective of the Workgroup was to: "Prepare a document assessing the feasibility of developing a common coastal advisory for striped bass and bluefish due to PCBs. "Common" may be the whole Atlantic coast, or it may be regional (New England, Mid-Coast, Southern) depending on what the data suggests. Additionally, we recognize that while the objective is to work towards a common advisory, there may be states that participate in this process that do not sign on to any advisory we finally develop."

Results from this process yielded important insight about information that states utilize from scientific disciplines as divergent as fisheries biology and management, chemistry, and toxicology. This information is necessary in order to arrive at advice that balances the need to raise public awareness for contaminant exposure while enabling constituents in each jurisdiction with the opportunity to make informed choices that serve their interests. It is a complex issue with many facets. Some of these facets include policy decisions that are beyond the scope of this report.

The findings of each subworkgroup provide valuable information about PCBs in striped bass and bluefish, and about how the information is applied to the process of creating fish advisories. It is clear that among Atlantic coastal states, multiple approaches with the same intent can be employed to create fish advisories. Several analytical methods are available to identify and quantify PCB tissue concentrations. Variations in biological attributes for each species, such as spawning, migration, abundance, and seasonality, play an important role in understanding how and why each jurisdiction regulates the conservation and harvest of these fish stocks. A review of the toxicological basis for assessing hazard and exposure to PCBs from striped bass and bluefish provided several approaches for consideration. The current public advice associated with exposure to PCBs through consumption has been presented for participating jurisdictions.

While it may be feasible for some states to agree on common advice, it may be difficult to put into practice or may not be supported by the existing science as described in this report. Some barriers to developing common advice from a scientific perspective include migratory and breeding patterns, lack of information for both concentrations in fish and PCB toxicity endpoints and variations in techniques of doing risk assessments. From a practical perspective, some barriers include political jurisdictions (states develop advice and gather data relevant for their own locales) and variations in techniques in doing risk management. Nevertheless, the environmental longevity of PCBs combined with public desire to enjoy catching and consuming striped bass and bluefish means human exposure to PCBs is unlikely to abate anytime soon. The level of project participation across a large geographic region of the Atlantic coast reflects continued concern for the situation.

II. Discussion from Subworkgroups

The effort to evaluate the feasibility of common coastal advisories was divided into four subworkgroups: Data, Biology, Health Effects, and Advisories. A summary of the findings and major conclusions that are relevant to the issue of developing common advice follows:

A. Data Subworkgroup

The key objectives of the data subworkgroup included:

- compile and describe existing data on PCBs in striped bass and bluefish along the Atlantic coast. This was completed and reported in the data chapter.
- possibly assess feasibility of developing a centralized database accessible by all coastal states. The feasibility of this was assessed, and while it is clear it is difficult due to variations in analytical techniques and sampling protocols, it is also clear that this is an objective that should be pursued.
- possibly evaluate the feasibility of developing a common methodology for analyzing and reporting PCB data in striped bass and bluefish. This item was discussed extensively in subworkgroup meetings and in the data chapter. It was felt that different analytical methodologies serve different purposes and that states should preserve options to meet the needs of their sampling programs.
- evaluate relationships between pcb concentration and length in striped bass and bluefish.

The primary conclusions of the data subworkgroup include:

There is clearly more data available on PCBs in striped bass over bluefish. Additionally, data collected vary from state to state based on the objectives within the sampling program for that state. Hence, direct comparisons of interstate data are difficult due to variability in sampling, analysis and true differences in fish populations. However, distinguishing between populations of striped bass (migratory vs. breeding vs. estuarine) shows relative consistency among striped bass which are migrating vs. those which are resident. These data do indicate that PCB concentrations have declined in striped bass and bluefish since the 1980s. For striped bass there was no apparent length-PCB relationship for fish collected from Long Island Sound and the Hudson River. There was a strong positive length-PCB relationship for bluefish throughout much of the range in which they are found. Secondary objectives included analyzing the feasibility of a common database and analytical methodology for PCB concentrations in striped bass and bluefish.

B. Biology Subworkgroup

The key objectives of the biology subworkgroup included:

- summarizing information about movement and populations of striped bass and bluefish up and down the coast. That objective was completed and is discussed in the biology chapter.
- provide technical resources for other subworkgroups. The objective of providing technical advice was met and was invaluable to the other subworkgroups and to the process as a whole.

To summarize, migratory striped bass are found from Florida north to Maine, but their importance as a fishery in Florida, Georgia and South Carolina are very limited. These southern states also have populations of non-migratory riverine striped bass. The major spawning locations for striped bass include the Hudson River, the Delaware Estuary, the Chesapeake Bay, and Albermarle Sound/Roanoke River. Adult female striped bass migrate north over the summer, then overwinter off the coast of Virginia/North Carolina. Adult males and juveniles tend to stay in local waters.

Bluefish are found from Florida to Maine, but they are not important fisheries in Georgia and South Carolina. Bluefish along the Atlantic Coast are considered one population.

C. Health Effects Subworkgroup

The key objectives of the Health Effects subworkgroup include:

- summarizing information on different estimates of toxicity used by the states and federal programs in developing advisories and more generally review literature on the toxicology of PCBs. This objective was met and is described in the Health Effects Chapter.
- possibly assess and review EPA's development of a benchmark dose for PCBs. This objective was not met as the EPA's benchmark dose analysis is not available for public review.
- possibly evaluate the feasibility of developing a toxicity value based on the current literature. This objective was met and it was determined that developing a toxicity value is a goal worthy of future work.
- assess the risks and benefits of striped bass and bluefish by comparing their omega-3 fatty acid content with their PCB concentration.

Additional conclusions of the Health Effects group include that epidemiological studies have demonstrated behavioral deficits resulting from in utero exposure to PCBs. Given existing body burdens and dietary sources of PCBs in the general population, the recommendation is made that any advisory for striped bass or bluefish should not appreciably increase the body burden of PCBs in females.

D. Advisories Subworkgroup

The key objective of the Advisory Subworkgroup was to summarize the current advisories and fish tissue action levels for striped bass and bluefish along the Atlantic Coast. That objective was met and is discussed in the Advisory chapter.

Additionally, it was determined that while there is great variation from state to state as to how advisories for bluefish and striped bass are developed, there are also many similarities that can be used to build consensus. Perhaps more importantly, the existing recommendations (even given the various methods for derivation) have enough similarities to think about developing consistent advice on a regional basis. This is especially true of the northeast states (with relatively consistent advisories) and the southeast states (without advisories). The mid Atlantic state advisories are dominated by spawning location specific advisories and a lack of advisories on coastal waters impacting migratory fish.

III. Proposed Core Consumption Advisories

Possible coastal or regional advice for striped bass and bluefish need to incorporate information on the concentrations of PCBs in fish, the movement of fish, toxicology and existing advice. Variations in advisories, however, reflect the real uncertainties, as well as variations in methodology and philosophy from jurisdiction to jurisdiction.

The Health Effects Chapter summarized approaches for developing fish consumption advisories for PCBs as follows: 1) based on FDA's tolerance for commercial fish; 2) risk-based approaches taking into account non-cancer and cancer risk targets and toxicity values such as the US EPA's Reference Dose or Cancer Potency Factors, ATSDR's Minimum Risk Level, or the Great Lakes Health Protection Value; 3) body burden approach based upon the analysis that current US body burdens may already be within the range where neurodevelopmental effects have been observed in epidemiology studies.

The Health Effects Chapter elaborates on Option #2 by developing consumption guidelines consistent with US EPA's guidance for developing fish consumption advisories for sportcaught fish (US EPA, 2000), and exposure and toxicity value inputs that are used in at least some states in the region. This analysis is generally consistent with a one meal per month advisory at current striped bass and bluefish concentrations although less consumption would be advised strictly from a de minimis (1 in 100,000) cancer risk perspective.

A limitation of using the FDA or risk-based approaches is that they do not take into account the results of recent epidemiological studies showing significant associations between serum levels of PCBs and reduced performance of children on neuropsychological tests, which were mostly published after the establishment of the FDA tolerance or the PCB toxicity values. These studies of children from the US

(Michigan, North Carolina, New York, and Massachusetts), Canada, the Netherlands, Germany, and the Faroe Island are supportive of one another, and the observed effects are supported by results of animal and mechanistic studies. These studies provide useful information, which is lacking for most chemicals, on the relationship between a biomarker of exposure (PCBs in serum) and biological effects (reduces scores of tests). Such data can improve the quality of a risk assessment, particularly the dose-response assessment (NRC, 2006).

Quantitatively characterizing the relationship between exposure and effect (e.g., via a benchmark dose analysis) is the preferred method for identifying effect levels in a dose-response assessment. It is beyond the scope of this workgroup. In lieu of such an analysis, the Health Effects Chapter performed a semi-quantitative analysis to identify possible or likely effect levels. This analysis focused mainly on results for the Oswego cohort because they had relatively low exposures compared to other cohorts. Moreover, the existence of causal relationship and effect levels (likely to vary with neuropsychological test) in the cohort are strongly supported by linear regression analysis of the multiple endpoints that repeatedly (over 9 years) showed a significant ($p < 0.05$) monotonic relationship between PCB exposure and reduced scores.

The analysis included a visual inspection of histograms of test results (exposure group vs. mean test score) conducted on children of the Oswego cohort from age 48 hours to 9.5 years, and was supported by limited statistical analysis of between-group differences. Inspection of the data identifies a possible effect level for some endpoints at the middle-tertile and a definite effect level for many endpoints at the highest-tertile. If the middle-tertile is chosen as the effect level of the Oswego cohort (sampled in 1991-1994), then the range of serum PCB concentrations in the tertile substantially overlaps the estimated serum PCB concentrations in women of the US population (sampled in 2001-2002).

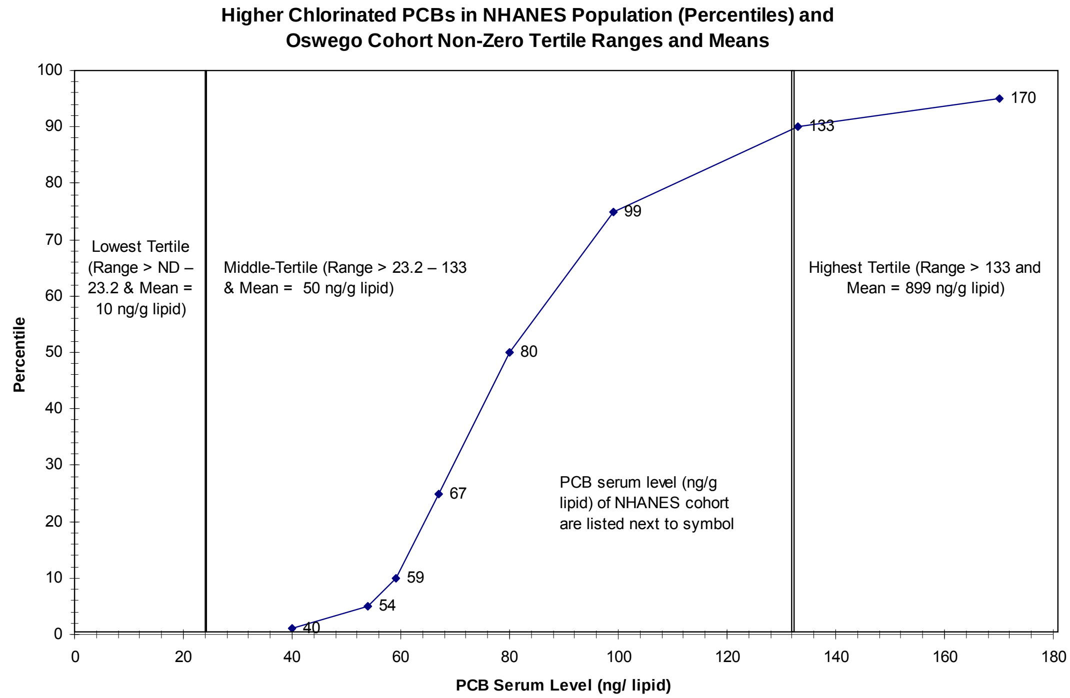

Figure 6-1: Relationship between higher chlorinated PCBs in NHANES population (percentiles) and Oswego Cohort Non-Zero Tertile Ranges and Means

If, however, the highest tertile is chosen as the effect level for the Oswego cohort, then the range of serum PCB concentrations in the tertile is found only in women > 90 percentile of estimated serum PCB concentrations. In either case, the margins-of-exposure between an estimate of an effect level in the Oswego cohort and current background levels in the US population are small. It is also important to note that the data on the concentrations of PCBs and omega-3 fatty acid in fish suggests that, with the exception of smaller bluefish, striped bass and bluefish contain a significantly higher amount of PCBs per gram of omega-3 fatty acids than common commercially available fish (e.g., tuna, salmon, flounder, catfish, and cod). These observations suggest that the current PCB body burdens of US women (expressed as ng/g lipid serum of higher chlorinated PCBs) are substantial relative to observed effects levels and so should be considered in the development of advisories for PCBs in bluefish and striped bass.

The Health Effects Chapter described several approaches in which body burden could be incorporated into the risk assessment process for striped bass and bluefish advisories. Unfortunately, all of these options have uncertainties due to data limitations. One method would be using biokinetic modeling to identify an acceptable incremental increase over background for a particular source (such as striped bass and bluefish). Unfortunately, the biokinetic models are not available. The second option would be to identify background daily dose of PCBs in the US diet and identify a relative source contribution which striped bass or bluefish could not exceed. While there are some measures of PCBs in food, the data are not considered adequate to calculate cumulative dietary exposure.   Finally, one approach would be to use the assumption that if there are no special precautions taken for foods which are commonly eaten, that dose can be used as a benchmark for comparing to striped bass or bluefish. In other words a consumption rate of striped bass or bluefish could be acceptable if it does not contribute more than is typically provided by other dietary sources. This would require identification of appropriate consumption rates to convert the limited data on PCBs in food to typical doses. Additionally, it makes the presumption, perhaps not unreasonable, that even though we are not acting on levels currently in the diet, that those levels are acceptable.

Thus, a quantitative assessment of the change in body burden or background exposure due to striped bass/bluefish consumption has limitations and has not been developed in this document.   However, these considerations can still be a qualitative factor when setting advisories, being part of a risk management framework that balances prudent avoidance to minimize adverse outcomes with the desire to maximize fish nutrient benefits and utilization of the resource.

The considerations raised in the Health Effects Chapter have fed into the deliberations of the Advisory Subworkgroup (Chapter 5). Their finding, is that it may be least efficient for states to harmonize advisories by agreeing on the risk assessment methodologies and options laid out in the Health Effects Chapter. Rather, the goal should be to work from the advice that is already in place and see if and where consistencies can be developed. This is a risk management based decision and can qualitatively incorporate the information about health benefits, risk-based targets, body burden relative to background dietary exposure, and the nature of the fisheries in each location. This is the approach that is presented in the next section.

A. Striped Bass

Striped bass along the east coast are distinctive in that there are both breeding and estuarine locations (data reported in Table 2-3) that contain one population of striped bass (males and females) and a coastal migratory population (predominantly mature females, data reported in Table 2-1). Some states may have both populations and the PCB burden may vary depending on point sources. For example, New York has both a migratory and resident population, the resident population is strongly influenced by the Hudson River with its associated PCB contamination. These breeding populations that are or are not impacted by point sources should have advice developed by the states surrounding these breeding sites, as they understand the PCB sources and fish consumption habits in these areas.

Migratory fish (consisting of contaminated Hudson River fish as well as less contaminated fish from other locations) can also be caught off the Atlantic Coast. Migratory fish, however, will consist of a mix of mature females (at different times in different locations) from different breeding stocks (with a range of PCB levels) (as well as mature males, but they generally fall below the size limits for recreational harvest). As a mixed population (from which anglers sample over the season), they could be expected to have a different contaminant burden and can be a candidate for consistent advice. The data shows (Table 2-2) average levels of PCBs in coastal migratory striped bass that range around 100 to 400 ppb (with the exception of older New York data at 1175 in 1994).

i. Proposed Sensitive Subpopulation Advice for Striped Bass

The health effects group suggests that separate advice for a sensitive subpopulation may be derived for PCBs (as is the case with methylmercury). The advisory chapter notes that how subpopulation is defined is not consistent from state to state. Given that one concern with PCBs is developmental effects, and that PCB body burden is influenced by lifetime exposure, a reasonable definition of the sensitive subpopulation might be women of reproductive age and young girls. That subpopulation will consist of women from roughly 50 years old and younger. This advice is also reasonably consistent with the National Academy of Sciences Institute of Medicine recommendation that exposure to dioxins be minimized for this group, beginning in early childhood (IOM 2003). That said, several states have expressed concern with the exclusion of young boys from this sensitive subpopulation. There are two rationales for including young boys, ease of risk communication, and reducing cancer risk among young boys. As there are years of experience and effort in encouraging individuals to follow sport caught fish advice based on mercury contamination, there is some logic in making the sensitive population as consistent as possible with these existing recommendations for ease in risk communication. Secondly, there is a cancer risk associated with PCB ingestion, and young children, due to the ratio of ingestion rate to body size, will have increased exposure relative to an adult consuming the same product. Figure 6-2 plots weight normalized fish ingestion rates (from EPA 1999) at various age groups, and it shows that on a per weight basis, children between 1 and 8) consume more fish than older children and adults (roughly 9 and above).

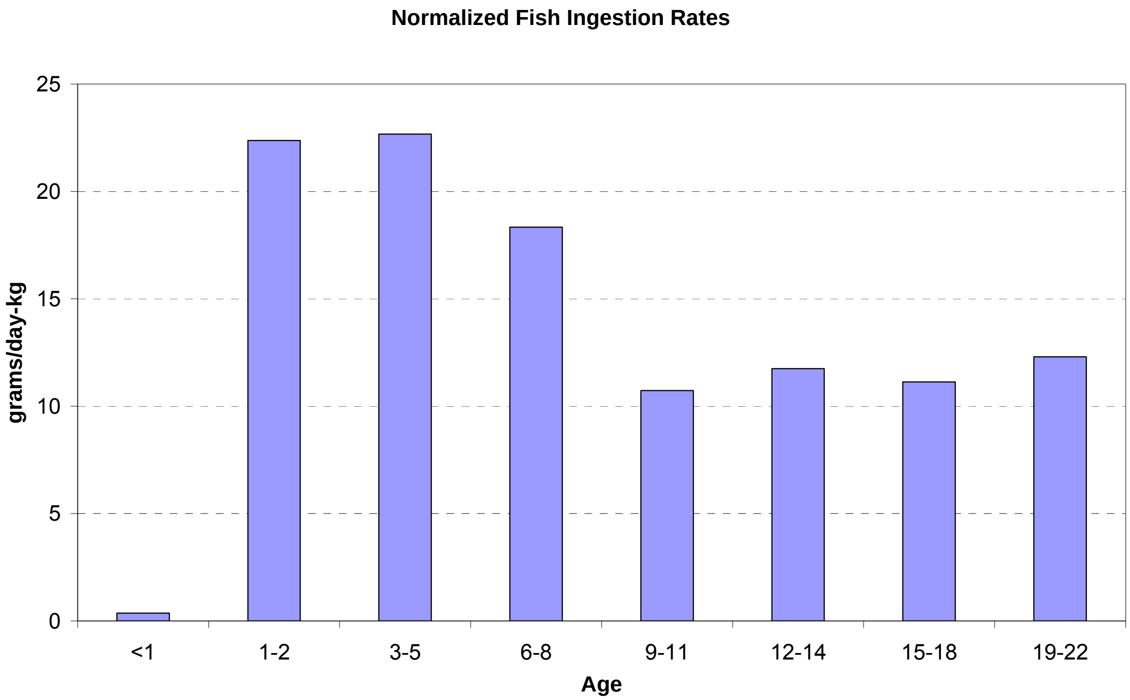

Figure 6-2: Children's Normalized Fish Ingestion Rates (EPA 1999).

Finally, the advisories for the sensitive population in Northern states in particular, are already very close to consistent. Table 6-1 compares the advice for the sensitive population.

Table 6-1: Current Striped Bass PCB Advice for the Sensitive Population by State		
State	Sensitive Population	Advice
Maine		2 meals per month
New Hampshire		2 meals per month
Massachusetts	Pregnant women, women of childbearing age who may become pregnant, nursing mothers, and children under 12 years of age	In general, Massachusetts recommends that all fish consumers choose a variety of fish and shellfish (among which could be striped bass) and obtain them from a variety of sources.
Rhode Island	Pregnant women, nursing women, women planning a pregnancy and young children (under 6)	No consumption
Connecticut	Pregnant women, women planning to become pregnant within a year, children under 6 and nursing women	No consumption
New York	infants, children under 15 and women of childbearing age.	No consumption (W. LI Sound) to 1 meal per week (E LI Sound)
New Jersey	Infants, children, pregnant women, nursing mothers and women of childbearing age	No consumption
Delaware	Women of childbearing age and children	No advice in coastal waters (has advise for Delaware Estuary)
Maryland	Pregnant women, women who may become pregnant, nursing mothers and children and children under 6	No advice in coastal waters (has advice for Chesapeake Bay)
Virginia	Pregnant women, women who may become pregnant, nursing mothers and young children	No advice in coastal waters (has advice for Chesapeake Bay)
North Carolina	Women of childbearing age (15 to 44 years), pregnant women, nursing women, children under 15	No advice

Of these states, Maine and New Hampshire's advisory are based on the same data. Additionally, that data has been determined to be of questionable quality. This discovery led to the initiation of this effort to determine the feasibility of consistent advice along the Atlantic Coast. Maine is also distinctive in that it is the only state that follows a "slot limit" where fish between 20 and 26 inches can be kept or fish over 40 inches. All other states have a minimum length requirement of 28 inches.

Pennsylvania was not included in this evaluation as the striped bass caught in Pennsylvania waters are those which are part of the Delaware Estuary (and as a spawning location have different levels of contamination).

Maryland does not have advice (nor data) for striped bass in coastal waters (outside the Chesapeake Bay). That said, they do have a "trophy season" in the bay from April 15th to May 15th that applies to fish over 28" long. During this time, the advice is for no more than 10 six ounce meals per year for women who are pregnant or may become pregnant or are nursing. Children under 6 can consume 10 three ounce meals per year. These trophy fish are the large migratory females that are under consideration for this effort. Fish collected from these time dates average 384 ppb total PCBs (n=50; Beaman 2006 pers. comm.)

Virginia and North Carolina have data from the James River and Albermarle Sound (respectively). They do not have data on the overwintering population of striped bass (a mix of all spawning locations) for which there is a fishery.

South Carolina, Georgia, and Florida are not impacted by migratory striped bass – local striped bass tend to be riverine and migrate up and down stream depending on temperature gradient. These southern states also do not have a large recreational fishery for striped bass (see figures 3-3, 3-4 and 3-6). From that perspective, there may not be a need for regional consistent advice for striped bass.

The concentrations of PCBs in these migratory fish, support a meal per month consumption limit using standard risk based methods. The toxicological benchmarks, on which these estimates are based, however, do not take into account the new epidemiological studies showing neurodevelopmental effects children exposed in utero. For that reason, a majority of states feel a no-consumption advisory for recreationally caught striped bass is warranted for the sensitive population. Hence, the workgroup recommends a one meal per month baseline advisory for everyone, with a strong recommendation to no consumption for the sensitive population.

Proposed consumption advice for striped bass for the sensitive population in these states could be:

one meal per month, with a majority of states recommending no consumption for women who may get pregnant and young women and girls.

While this is a proposal that states may chose to adopt or not, some modifications to the proposal on a state by state basis might include listing boys with the sensitive population.

ii. Proposed General Population Advice for Striped Bass

As discussed in the advisory and health effects chapter, it is not uncommon to differentiate between the sensitive population and the general population when evaluating effects from developmental toxicants. The general population is, for these purposes considered adult women who are not going to have children, boys and men.

The Table 6-2 compares the advice for the general population:

Table 6-2: Current Striped Bass PCB Advice for the General Population	
State	Advice
Maine	2 meals per month
New Hampshire	2 meals per month
Massachusetts	No specific advice for striped bass. Massachusetts recommends that consumers choose a variety of fish and shellfish and obtain them from a variety of sources.
Rhode Island	1 meal per month
Connecticut	1 meal every 2 months
New York	1 meal per week
New Jersey	1 meal per month
Delaware	No advice for coastal waters
Maryland	No advice for coastal waters
Virginia	No advice for coastal waters
North Carolina	No advice

Again, Maine and New Hampshire's advice, as discussed previously, is based on suspect data and is expected to change. Delaware and Maryland have extensive data in their breeding locations, but not for coastal fish. Maryland's advice is specific to the Chesapeake Bay. Pennsylvania is not included striped bass in Pennsylvania waters are specific to the Delaware Estuary. Again, as South Carolina, Georgia and Florida are not impacted by migratory striped bass, they would not be candidate for consistent advice. Additionally, risk based methods support a one meal per month advisory.
Proposed consumption advice for striped bass for the general population in these states could be:

one meal per month for men, boys, adult women who will not get pregnant.

The cancer and non-cancer risks associated with any advisory level established by a group of states or an individual state should be kept in mind. The Health Effects Chapter has shown that a once per month advisory and upper bound concentrations of striped bass in our regional fishery (1 ppm) would produce a cancer risk that is well above de minimis (1E-06) and that is at the upper end of the general risk range used by USEPA at waste site cleanups (1E-04). Regarding non-cancer endpoints, the daily dose from a once per month meal frequency is estimated to be 2.5 fold greater than the IRIS RfD. These doses and risks would be somewhat greater in children due to their higher intake rate per body weight. These estimates point to the importance of keeping the intake rate to 1 meal per month of striped bass or less for children and adults if the PCB level in fish is approximately 1 ppm.

B. Bluefish

Bluefish differ from striped bass in that there is generally considered to be one single population along the Atlantic coast. That said, while there appears to be a large drop in PCB concentrations from Delaware south, this drop may be an artifact of the smaller fish sizes (in the range of 300 mm vs. 500-700 mm in northern states).

Indeed, the data subworkgroup discussed the size dependence of PCBs in bluefish for both Long Island Sound and for Delaware Bay. As there not many size regulations regarding the catching and keeping of bluefish (see Table 3-4), a tiered advisory based on size is worth exploring.

The Marine Recreational Fisheries Statistics Survey (MRFSS) publishes data on the size of recreationally caught fish. The data for all fishing modes (shore fishing, charter boats, private and rental boats) and all fishing areas (inland, state and federal waters) shows an increase in the percentage of fish caught that are less than or equal to 20 inches as you move north to south (with the occasional outliers Figure XX shows these data for the years 2002 – 2006 (MRFSS 2008). It appears bluefish <20" are a higher proportion of fish caught in states south of NY compared to northern New England states. So the value of a breakpoint will have different importance in Maine compared to Delaware. Indeed, in some southern states (e.g., South Carolina to Florida) virtually all bluefish caught are less than 20".

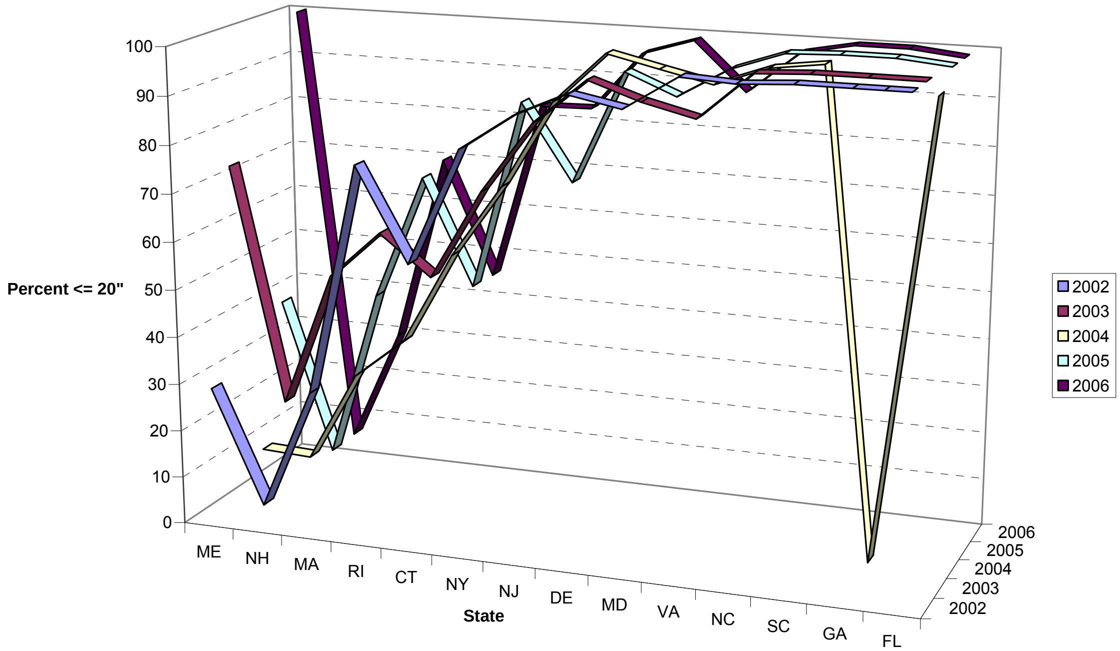

Figure 6-3: Percent Bluefish ≤ 20" Harvested by State

Table 2-4 of the data chapter supports this observation, displaying PCB concentrations in bluefish less than 508 mm (20") long. The data show relatively low concentrations south of Delaware Bay (14 ppb in Virginia to to 119 ppb in Chesapeake Bay) and for the most recent (2006) Ct/NY LI Sound data (69 ppb). Higher concentrations are typically associated with older data sets.

Similarly, Table 2-5 of the data chapter presents PCB concentrations in bluefish greater than 508 mm (20 in.). As would be expected from figure 6-3, the data are limited to Delaware north, the concentrations range from a low of 161 ppb (Maine, 2004) to 574 (Delaware 2005) for recent data, with older data having higher concentrations.

Given the PCB concentration size dependence, and given the data on size of fish caught in various locations, the workgroup recommends consistent advice for larger bluefish (where large is undefined and can vary geographically).

i. Proposed Sensitive Population Advice for Large Bluefish

Current advice for the sensitive population for bluefish along the Atlantic coast is as follows.

Table 6-3: Current Bluefish PCB Advice for the Sensitive Population		
State	Sensitive Population	Advice
Maine		2 meals per month
New Hampshire		2 meals per month
Massachusetts	Pregnant women, women of childbearing age who may become pregnant, nursing mothers, and children under 12 years of age	No consumption
Rhode Island	Pregnant women, nursing women, women planning a pregnancy and young children (under 6 years of age)	No consumption
Connecticut	Pregnant women, women planning on becoming pregnant within a year, children under 6 and nursing women.	No consumption of fish over 25”, 1 meal a month for fish between 13 and 25”
New York	Infants, children under the age of 15, women of childbearing age.	1 meal a week
New Jersey	Infants, children, pregnant women, nursing mothers and women of childbearing age	No consumption
Delaware	Women of childbearing age and children	No consumption for fish >14”, one meal a month for 14” and smaller.
Maryland	Pregnant women, women who may become pregnant, nursing mothers and children and children under 6	No advice
Virginia	Pregnant women, nursing women, women planning a pregnancy and children	No advice
North Carolina		No advice
South Carolina		No advice
Georgia		No advice
Florida		No advice

Again, the advisories for New Hampshire and Maine are based on old questionable data and are expected to be revised based on more recent data and the outcome of this effort. Additionally, Pennsylvania is not included in that they do not have any coastal marine waters where bluefish would be found. Connecticut and Delaware have advice that is specific to smaller bluefish. Connecticut’s advice is for fish less than 25” for the sensitive population 1 meal per month is acceptable. For fish larger than 25” there is no consumption for the sensitive population. Delaware has similar advice, however the cut off is 14”. Generally speaking, with the exception of New York, (and New Hampshire and Maine, whose advisory is going to change) there is no consumption for the sensitive population, for large fish or when size is not specified.

As PCB concentrations in larger (>20") bluefish are roughly twice the concentration of coastal striped bass for recent data (compare Table 2-5 to Table 2-2), risk based methods can only support an advisory of a meal every other month advisory. The Health Effects chapter discusses the concerns about developmental effects and the outdated values currently available as health benchmarks. The Health Effects chapter also suggests that other fish provide omega-3 fatty acids without the additional burden of elevated PCB levels. And given that "no consumption" is a relatively consistent advice along the coast at this point and given the evidence for neurodevelopmental effects, the workgroup recommends:

one meal every other month, with a majority of states recommending no consumption of large bluefish for women who may get pregnant and young women and girls from Coastal Marine Waters from Maine to North Carolina.

While this is a proposal that states may chose to adopt or not, some modifications to the proposal on a state by state basis might include listing boys with the sensitive population. It may not be possible to develop consistent advice for bluefish for South Carolina, Georgia, and Florida until the extent of PCB contamination in bluefish in these waters is adequately characterized. Additionally, it is clear that smaller bluefish have less contaminants, and smaller bluefish are found in differing concentrations along the coast, the distinction between large and small and the advice for the small bluefish should be a jurisdictional decision.

ii. Proposed General Population Advice for Large Bluefish

As discussed previously, the general population is considered adult women who are not going to have children, boys and men. The same qualification about cancer as discussed in the striped bass advisory would apply in this situation as well.

Unfortunately, while the concentrations for PCBs in larger bluefish are reasonably consistent the advice along the coast is significantly different. Maine and New Hampshire's advisories are based on old, questionable data. Other states categorize their advisories based on size (Ct, NJ, De).

Table 6-4: Current Bluefish PCB Advice for the General Population

State	Advice
Maine	2 meals per month
New Hampshire	2 meals per month
Massachusetts	Massachusetts recommends certain measures to reduce PCB levels in fish including taking the skin off the fish and removing the fatty and dark meat before cooking and broiling the fish to allow as much of the fat as possible to be drained away. Massachusetts recommends that consumers choose a variety of fish and shellfish and obtain them from a variety of sources.
Rhode Island	One meal per month
Connecticut	A meal every other month for fish over 25”, 1 meal a month for fish between 13 and 25”
New York	1 meal a week
New Jersey	4 meals per year of bluefish > 6 lbs or 24” or 1 meal per month of bluefish <6 pounds or 24”
Pennsylvania	No advice
Delaware	Bluefish <14” 1meal per month. >14” 1 meal per year
Maryland	No advice
Virginia	No advice
North Carolina	No advice
South Carolina	No advice
Georgia	No advice
Florida	No advice

Additionally, as stated previously, there is a clear size dependence for PCB concentrations in bluefish and larger bluefish tend to be more commonly caught in the New England states. Hence the distinction for size, and the advice for those smaller bluefish should be a decision based on local data.

Proposed consumption advice for large bluefish for the general population from Maine to North Carolina could be:

one meal every other month for men, boys, adult women who will not get pregnant.

A summary of the proposed consumption advice for recreationally caught striped bass and bluefish is presented in Table 6-5

Table 6-5: Proposed Consumption Advice for Recreationally Caught Striped Bass and Bluefish		
	women who may get pregnant and young women and girls.	men, boys, adult women who will not get pregnant
Striped Bass		
Coastal Marine Waters from Maine to North Carolina	1 meal per month to no consumption	1 meal per month
Coastal Marine Waters from South Carolina to Florida	No Need for Consistent Advice	
Large Bluefish		
Coastal Marine Waters from Maine to North Carolina	1 meal every other month to no consumption	1 meal every other month
Coastal Marine Waters from South Carolina to Florida	Not possible to develop advice without more data	
Small Bluefish (where size distinction is a local decision)		
Coastal Marine Waters from Maine to Florida	Advice to vary by state based on data and local conditions	

IV. Risk Communication

Although there was no official subworkgroup dealing with risk communication issues, this topic came up in the deliberations of most groups, especially the subworkgroup looking at consumption advisories. It is worthwhile to remember that the purpose of issuing fish consumption advisories is to change individuals behavior. One of the underlying assumptions in undertaking this entire report is that developing more consistent advisories could help in risk communication. It is well documented, that when attempting to change behavior or communicate a health message, simplicity and clarity of the message improves compliance (NCI 2002, Doak et al. 1996). In the case of migratory coastal fish, consistency of advice could simplify risk communication and improve adoption of advisories. This is particularly the case for states with shared water bodies (such as New York and Connecticut sharing Long Island Sound) but also the case for individuals traveling on vacation (and having only to remember one simple set of advice)

If it is possible to develop consistent advice by region for striped bass, or a coast wide advisory for bluefish, then a communication plan should be developed to publicize this information. This would provide a great opportunity to get our message out and hopefully reach a broader segment of the population. Any announcement by the state participating in this study could have a great impact and could generate a lot of media interest. This presents us with an opportunity to greatly expand our risk communication efforts. There should be ongoing discussions among the participating states to develop a coordinated final communication plan. Much of this will depend on if states can come to consensus about consistent advisories. However at a minimum the following communication efforts could be undertaken:

- Develop a press release announcing the completion of the report and summarizing its conclusions.
- Each state issues a similar version of the press release.
- Ask EPA headquarters to participate in a press announcement nationally.
- Work with other regional and national partners (National Marine Fisheries) on a release.
- If the states agree to consistent advisories, then this advice should be announced in a series of coordinated press releases and fact sheets and fact sheets for the general public.
- Post the report and associated material on a central web site and make it available to the general public and other professionals.
- Distribute the executive summary for a broader audience.

V. Uncertainties and Research Recommendations

Perhaps the greatest value of this document is in clearly laying out the areas where further research will fill data gaps and reduce uncertainties. Each subworkgroup identified recommendations for the particular chapter. A summary of these recommendations as they relate to furthering the development of coordinated advice in the future is discussed below.

A. Data Subworkgroup

Assess the feasibility of conducting a comprehensive coastwide sampling and analysis program to measure PCBs in striped bass and bluefish. This study should include archiving of fish tissue for potential future analysis (e.g., to compare future tissue concentrations of emerging contaminants to archived samples). NOAA conducted a similar PCB study in the mid-1980s for bluefish. Federal agencies, such as NOAA, EPA and FDA should be contacted to determine feasibility and funding.

Develop a searchable common repository for striped bass and bluefish PCB data, to include data from coastal states with fisheries. Invite participation from federal agencies and academic institutions that produce PCB data for these species.

Acknowledge that multiple methods exist for the determination and quantitation of PCBs. Encourage states to include reference materials along with PCB sample analyses, as well as a standardized approach for determining total extractable organics (TEO, “lipids”).

The objective is to ensure the data generated is accurate for each chosen analytical method.

Data on other contaminants in striped bass and bluefish should be considered and assessed (i.e., on a wet weight basis). Contaminant data (e.g., PCBs) should also be normalized to TEO content and evaluated, with due consideration of any bias due to various lipid extraction methods.

B. Biology Subworkgroup

As any particular state will be impacted by different populations of striped bass, any PCB sampling program should be tailored to the biology of the striped bass inhabiting the waters. For example, states visited by migratory striped bass, for example, should vary their sampling times to capture different migratory stocks entering the waters. While the times of arrival are not consistent enough to allocated particular breeding populations to arrival times, it is the case that different populations will arrive at different times. An angler will be sampling randomly from these populations over the season and a sampling program should capture this.

States that are impacted by both migratory fish and that have a breeding population will need to tailor their sampling regime to capture both local fish as well as migratory fish.

Finally, southern states with resident non-migratory populations of striped bass will be measuring local sources of contamination and hence have a simpler sampling scheme.

An alternative possibility for sampling would be to sample the large migratory female striped bass that winter offshore of North Carolina. This population would represent a mix of the various stocks as would be seen migrating up and down the coast. Additional populations of overwintering striped bass include the mouth of the Hudson River and the mouth of the Chesapeake Bay. A similar strategy could be applied for bluefish, where the larger overwintering adults could be sampled off the coast of Virginia.

Depending on the location of the sampling program, it may also be worthwhile to sex the fish collected, as the female striped bass are the sex that are migrating up and down the coast while males tend to be resident.

C. Health Effects Subworkgroup

Characterization of the relationship between exposure and effect – namely using benchmark dose analysis to identify if there is an apparent threshold and to provide a point of departure for the development of a toxicity value, such as an RfD. To derive an RfD, a pharmacokinetic model would have to be used (and developed) to convert from body burden to maternal intake.

Gather information on levels of PCBs in dietary sources and consumption patterns with in the general population. This is particularly of value if the objective is to limit population exposure through the diet to this class of contaminants.

D. Advisory Subworkgroup

Rather than focus on state to state consistency in risk assessment techniques, focus on existing similarities in advice and build on those similarities.

Develop uniformity in the definition of the sensitive population. Agreement would greatly simplify risk communication from state to state.

E. Organizational Subworkgroup

Perhaps the largest single obstacle to understanding the contaminant concentrations in striped bass and bluefish is lack of coastwide synoptic data. This is particularly acute with bluefish. Ideally a program to analyze fish along the coast (as suggested by the data group) using consistent collection techniques and analytical methods would eliminate much of this uncertainty. A scaled down version may be possible by sampling the overwintering populations of striped bass and bluefish as described by the biology subworkgroup. Sampling the overwintering population would also provide data to identify the need for advice for North Carolina's midwinter striped bass fishery. Contaminants other than PCBs should ideally also be included and fish tissue archived for future analysis.

VI. Conclusions

In conclusion there are several action items that can be identified:

This effort suggests it is feasible in some situations to develop consistent advisories for coastal populations of striped bass and bluefish based on PCBs. Striped bass are distinct, however, in that there are several populations breeding in specific locations that impact their contaminant load. In other situations, the uncertainties or lack of data limits the feasibility of developing consistent advice. That said, there was surprising consistency of advice among some states given the varied methods for developing advice. Proposed advice was developed and areas of further discussion or modification from state to state were specified. Whether or not to proceed with the concept of developing consistent regional advice is a decision to be made by individual states. The proposed advice is:

Table 6-6: Proposed Consumption Advice for Recreationally Caught Striped Bass and Bluefish		
	women who may get pregnant and young women and girls.	men, boys, adult women who will not get pregnant
Striped Bass		
Coastal Marine Waters from Maine to North Carolina	1 meal per month to no consumption	1 meal per month
Coastal Marine Waters from South Carolina to Florida	No Need for Consistent Advice	
Large Bluefish		
Coastal Marine Waters from Maine to North Carolina	1 meal every other month to no consumption	1 meal every other month
Coastal Marine Waters from South Carolina to Florida	Not possible to develop advice without more data	
Small Bluefish (where size distinction is a local decision)		
Coastal Marine Waters from Maine to Florida	Not possible to develop advice without more data	

An issue of further discussion among states if and when they develop consistent advice would be whether or not to put young boys in the sensitive population.

This effort identified a need for a coastwide evaluation of contaminants in striped bass and bluefish. This study should involve federal agencies, should include archiving of samples and should include the development of a searchable common repository to store newly developed data as well as existing state data. A possible pilot study could include the sampling of the winter migratory fish (striped bass and possibly bluefish) found offshore of Virginia/North Carolina. These fish may accurately represent the mixed population moving along the Atlantic Coast. Additionally, any survey should include paired measurements of contaminants as well as omega-3 fatty acids.

This effort identified a gap in the toxicological research and the updating of the toxicity benchmarks for regulatory use. To sufficiently evaluate and develop advisories, a benchmark dose analysis should be performed. Additionally, it would be valuable to have more extensive background data on PCB levels in other foods.

Polychlorinated biphenyls have not been produced for commercial uses for over 30 years. While an impressive amount of research has been published on their effects on the environment and in human populations, it is clear there are areas where further research is sorely needed. It is unfortunate that we are in the position of having to recommend any limitations to what should be a healthy food source.

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