Pilot Study: Chemical Contaminant Concentrations in Juvenile Atlantic Menhaden (*Brevoortia tyrannus)* from New Jersey Coastal Estuarine Waters (2009)

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2013

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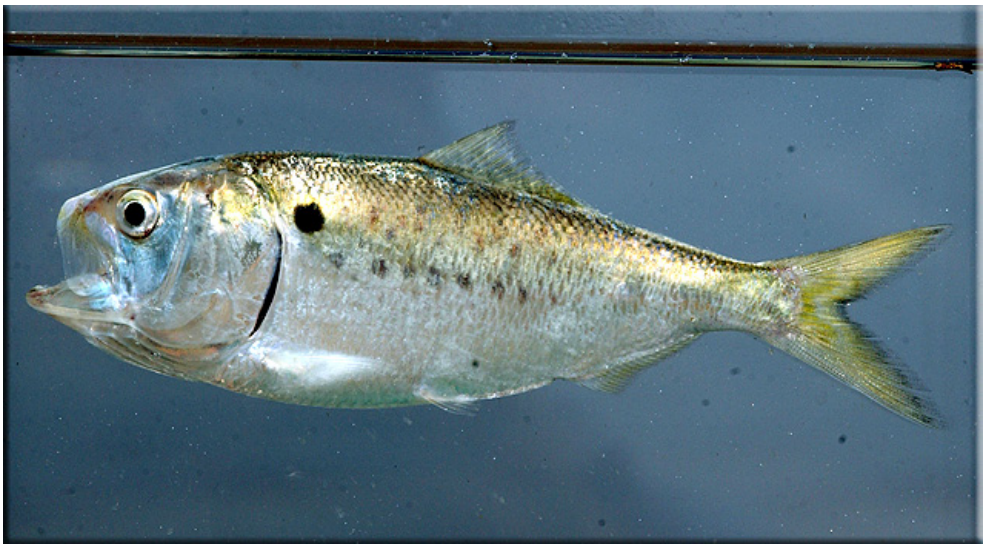
INTRODUCTION

This study provided data on concentrations and patterns of contaminants in juvenile Atlantic menhaden, supplementing pilot data developed by NJDEP/OS. The primary goal of the study is to determine the usefulness of menhaden as an index for estuarine contamination. In addition, sample material was delivered to NJDEP/OS and analyzed for PCB concentrations using ELISA (Enzyme-linked Immunosorbent Assay) methodology. Thus, the data provided here are compared with the ELISA results to investigate the potential for ELISA analysis to provide accurate, cost effective and efficient determination for contaminants.

BACKGROUND

The Atlantic Menhaden, *Brevoortia tyrannus* is one of the most abundant finfish species in New Jersey's coastal estuarine waters. A member of the herring family (Clupeidae), menhaden is the second most economically important species harvested in the United States (NOAA 2012).



Menhaden is processed for its oil, protein meal and solubles, which are used in a variety of products, including foods for humans (e.g., in production of margarine), livestock (including foods and supplements for cows, pigs, poultry and mink), pets, and aquaculture species. Menhaden is also used as bait in commercial and recreational fishing. Menhaden is a pelagic feeder. Post larvae feed on zooplankton. Juveniles and adults filter phytoplankton and suspended detritus. Menhaden is an invaluable food source for estuarine and marine predatory fish, mammals and birds (NOAA 2112). Menhaden has high lipid content, increasing its potential for bioaccumulation of various contaminants. Its life history involves nursery use of estuaries and adult use of near shore oceanic waters (Rodgers 1989).

Menhaden's importance as a food source for wild animals, domesticated animals and humans, combined with its high potential for bioaccumulation of some contaminants, make it a potentially important link in exposure of consumers to contaminants. Estuary-specific signatures of contaminants accumulated as juveniles may provide excellent indicators of contaminant sources. Because of its abundance, large-scale movements between habitats, and high mortality to fishing and natural mortality, menhaden may be important in transport of contaminants between different habitats and locations. For example, out-migration and harvesting of menhaden may be a significant part of contaminant loss from estuaries, with concomitant importance as inputs to oceanic and terrestrial/freshwater systems.

In 2000 and 2001, juvenile menhaden were collected from the Raritan River and Barnegat Bay and adult menhaden from the Atlantic Ocean by NJDEP/OS personnel. These samples were analyzed by ANSP for an array of chemical contaminants (Ashley 2002). These results suggest further study of the potential of using the estuary-specific contaminant signatures of juvenile Atlantic menhaden as a seasonal sentinel species for chemical contamination is warranted.

OBJECTIVES

The objectives of the study are:

1) Identify chemical contaminant levels in juvenile Atlantic menhaden from several waterways throughout the state including sites in Raritan River and Delaware River/Estuary.

2) Investigate differences in contaminant concentrations and patterns among and within estuaries, for use in identifying estuary-specific contaminant signatures. Fish samples were analyzed for a suite of chemical contaminants including PCBs, organo-chlorinated pesticides and mercury.

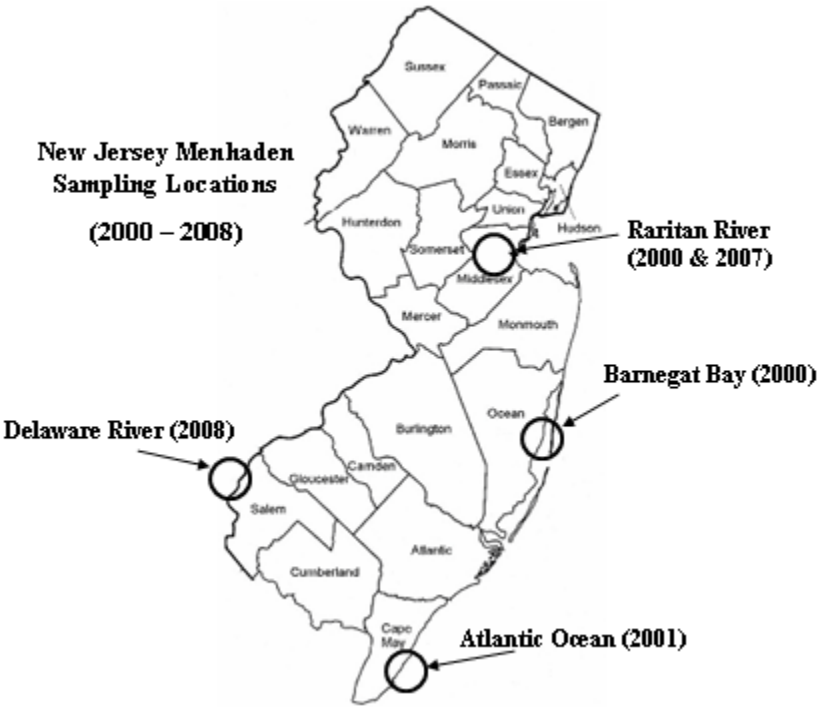
3) Compare data from this study with data collected in 2000 and 2001 from the Atlantic Ocean, Raritan Bay and Barnegat Bay.

4) Investigate feasibility of utilizing ELISA techniques for the quantification of contaminants by comparative analysis using traditional GC/MS and ELISA techniques.

METHODS

A. Fish Collections

All fish were collected by personnel of NJDEP from the Division of Fish and Wildlife and Office of Science using throw nets and haul nets. Samples were kept on wet ice until sorted and stored frozen at NJDEP laboratories. Samples were delivered to ANSP, handled and transferred according to standard QA/QC procedures, including chain-of-custody tracking. Specimens were held frozen in ANSP freezer at 0 F until analysis**.**



B. Sample preparation

Whole fish were coarsely minced. Composites were formed from whole bodies of each of three specimens. Individuals within composites were of similar size to the extent permitted by specimen availability, so that composites had approximately equal contributions from each specimen. Portions of sample homogenates (i.e., homogenized composite samples prior to any extraction) were delivered to NJDEP/OS personnel for ELISA analyses.

C. Chemical Analyses

All tissue samples were analyzed for a suite of congener specific polychlorinated biphenyls (PCBs) and organo-chlorinated pesticides (OCPs) at ANSP, Patrick Center for Environmental Research. (See Table 1)

Table 1. Analyte List for New Jersey juvenile Atlantic Menhaden Contamination study

Organochlorinated Pesticides	**Polychlorinated biphenyls** (PCBs)[1]					
BHC (α, β,Δ) and Lindane	**1**	**31,28**	**74**	**134,144**	**185**	**205**
Heptachlor	**3**	**33,21,5**	**70,76**	**107**	**174**	**206**
Heptachlor epoxide	**4,10**	**22**	**66,95**	**149**	**177**	**209**
Chlordanes (gamma and alpha)	**6**	**45**	**91**	**118**	**201,171**	
Nonachlors (cis and trans)	**7**	**46**	**56,60**	**131**	**172,197**	
Dieldrin	**8,5**	**52**	**101**	**146**	**180**	
DDDs (o,p and p,p)	**11**	**49**	**99**	**132,153,105**	**193**	
DDEs (o,p and p,p)	**19**	**48,47**	**83**	**141**	**191**	
DDTs (o,p and p,p)	**12,13**	**44**	**97**	**137,176**	**199**	
Aldrin	**18**	**37,42**	**81,87**	**163,138**	**170,190**	
Endosulfan I and II	**17**	**41,71**	**85**	**158**	**201**	
Endrin	**24,27**	**40**	**136**	**129,178**	**203,196**	
Oxychlordane	**29**	**100**	**77,110**	**187,182**	**189**	
Total Mercury (T Hg)	**25**	**63**	**82**	**183**	**207**	
	26		**151**	**128**	**194**	

[1] PCB congeners appearing as pairs or triplets will coelute and will be reported as sum.

I. Mercury

a) Extractions and Analyses:

Approximately 0.5 g of each tissue homogenate was digested using 10 mL nitric acid in a CEM microwave digestion system. Carefully cleaned 55 ml Teflon vessels were used for all digestions. Mercury analysis was subsequently accomplished on a Perkin Elmer FIMS 400 Cold Vapor AA following manufacturer's specifications.

b) Analytical Quality Assurance:

The PE FIMS 400 was calibrated using working standard dilutions of J.T. Baker stock Standard (1000µg/mL) from 0.5 to 20.0µg/L. (Table 2.) Calibration blanks, working stock standards and instrument duplicates were analyzed to insure instrument performance and accuracy throughout the sample run. Sample blanks, duplicates, spikes (1.0 µg Hg), and standard reference materials (SRM) were digested with the samples to insure adequate digestion recoveries. The QA samples were analyzed at 10 to 15% frequency throughout the study. The samples were digested in three runs in 2009.

A 10 µg/L initial calibration check standard was prepared from a BDH stock standard of 1000 µg/mL which is different from the calibration stock standard. The recoveries were 91% and 95% with an average recovery of 93% ± 3%.

The SRM used was NIST's (National Institute of Standards and Technology) SRM 1946, with a certified value of 0.433 µg/g ± 0.009 µg/g wet weight as shown in Table 2. This SRM was chosen because it is within the range of expected concentrations in unknown samples. Percent recovery for SRM 1946 ranged from 85% to 89% with an average recovery of 88% ± 2%.

The continuing calibration standards were all within 91% to 111% of their 7 different concentrations. The relative percent difference (RPD) for sample duplicates ranged from 4.7 to 73%. The highest RPD was usually for samples with low concentrations. Sample spikes of 1 µg were added to 10% of the samples and analyzed for recoveries between 72% and 103%. Digestion blanks ranged from 0.00µg/g to 0.02µg/g. The method detection limit (MDL) based on the analysis of 4 replicate samples of a low mercury standard (1.0ug/L) has a value of 0.03 µg/g wet weight. The instrument detection limit (IDL) is based on the repeated analysis of 19 digestion blanks and has a value of 0.03µg/L.

II. Polychlorinated Biphenyls and Organochlorine Pesticides:

a) Extractions and Analyses:

Homogenized fish samples were stored frozen until extraction. Samples were thawed and ~2 g of the homogenate was sub-sampled using a Teflon coated spatula. Approximately 30 g of Na_2SO_4 (previously baked at 450°C for four hours) was added to the sub-sample to eliminate water. The dried sample was placed into a Soxhlet extractor (using DCM rinsed glass wool as filter) with ca. 200 mL dichloromethane (DCM) for a minimum of 18 hours. The extracts were sub-sampled for gravimetric lipid determination. For this, a known volume of extract (1.0 mL) was transferred to a pre-weighed aluminum pan. The samples were placed into a fume hood and allowed to evaporate for at least 12 hours. The residue remaining (lipid) was weighed and percent lipid was calculated. Lipids were removed from sample extracts by gel permeation chromatography (GPC) using DCM as the mobile phase. The collected fraction containing analytes was concentrated by roto-evaporation and an N_2 stream. Solid-liquid chromatography using florisil was done as an additional clean-up step. Using this technique, PCBs (as well as heptachlor, nonachlors, and DDEs) were eluted from the chromatographic column containing florosil using petroleum ether (F1 fraction). The remaining organochlorine pesticides were eluted using 50:50 petroleum ether and dichloromethane (F2 fraction).

Congener-specific PCBs and organochlorine pesticides (Table 1) were analyzed using an Agilent 6890 gas chromatograph equipped with a ^{63}Ni electron capture detector and a 5% phenylmethyl silicon capillary column. The identification and quantification of PCB congeners followed the '610 Method' (Swackhamer, 1987) in which the identities and concentrations of each congener in a mixed Aroclor standard (25:18:18 mixture of Aroclors 1232, 1248 and 1262) were determined by calibration with individual PCB congener standards. Congener identities in the sample extracts were based on their chromatographic retention times relative to the internal standards added (PCBs 30 and 204). In cases where two or more congeners could not be chromatographically resolved, the combined concentrations were reported (Table 1). Organochlorine pesticides were identified and quantified based on comparisons (retention times and peak areas) with a known calibration standard prepared from individual compounds.

b) Analytical Quality Assurance:

Surrogate Recoveries:

Analyte loss through analytical manipulations was assessed by the addition of surrogate PCB congeners 14, 65 and 166 prior to extraction by Soxhlet apparatus. These surrogates were not industrially prepared and therefore are not present in the environment. Average recoveries of congeners 14, 65 and 166 were 87% ± 7%, 82% ± 8% and 86% ± 8% (Calculated by averaging the recoveries of all analyzed samples). All reported values for PCB and OCP concentrations in this study were not corrected for analyte loss.

Detection Limits:

Matrix blanks (5) were generated to monitor possible laboratory contamination and to calculate the detection limits for PCBs and OCPs. Each matrix blank, consisting of approximately 30 g of clean Na_2SO_4, was analyzed using the same procedures as the samples. Average surrogate recoveries for these blanks were 84%, 79% and 87% for PCBs 14, 65 and 166, respectively. Chromatograms of most blanks were void of significant peaks suggesting that little contamination through laboratory exposure occurred.

The detection limits for PCBs and OCPs were calculated as the mass plus three times the standard deviation of the mass divided by the average extraction mass (2.14g). The matrix blank-based detection limits for PCBs and OCPs ranged from 0.001 ng/g to 1.24 ng/g wet weight (Tables 3-5). Based on the average of 5 matrix blanks, the detection limit for total PCBs (the sum of all quantified PCB congeners) was 7.28 ng/g wet weight.

Analytical Accuracy:

National Institute for Standards and Technology (NIST) standard reference material (SRM 1946, Lake Superior Fish Tissue) was used to evaluate extraction efficiency and analytical accuracy. Using two trials, PCB congener recoveries ranged from 4% (congeners 77+110) to 87% (congener 201). Although the concentrations for a few PCB congeners were well above or below the NIST certified values, average recoveries were 88% (excluding 6 outliers). It is important to note that our values were not corrected for surrogate loss prior to the comparisons.

Concentrations for OCPs were also assessed using SRM 1946. Generally, recoveries ranged from 42% (alpha BHC) to 119% (lindane) with an average recovery of 83% (excluding an outlier). The apparent outlier for OCPs in these trials was cis nonachlor, with a recovery of 14%.

Analytical Precision:

To assess precision of the organic contaminant analyses, sample duplicates of randomly selected samples were performed at a frequency of 10%. To assess precision, relative percent differences were calculated between duplicate analyses. The mean relative percent difference (RPD) for total PCBs was 16. The mean RPD for total DDX's and total Chlordanes were 18 and 18, respectively. The average RPD for total PCBs on a congener specific basis was 19.

Additional Quality Assurance:

Additions of known volumes of calibration standards to matrix blanks (spiked samples) were used to further evaluate quality assurance of the analytical procedure. Analytes were quantified and resulting masses were compared to the masses initially spiked into the matrix prior to extraction. With an average recovery of 86%, most PCB congener recoveries ranged from 62% (congener 31+28) to 120 % (congener 85). Three congener fell below 44% (congeners 107,134 and 189), while two others exceeded 120% (congeners 99 and 131). The sum of these 'outlier' congeners represent <6% of the total mass in most fish tissues. Recoveries such as these reflect the difficulty in quantifying congeners whose masses in spiked standards (and in actual samples) are very low. Spike recoveries were also assessed for OCPs. The average recovery value for OCPs was 67%, with most recoveries ranging between 23% (endrin) to 116% (beta BHC), with extreme outliers of 5% (aldrin), 9% (cis nonachlor) and 391% (o,p DDT).

III. Enzyme-linked Immunosorbent Assay (ELISA) Fish Extract Methods

Enzyme-linked immunosorbent assay (ELISA) from Strategic Diagnostics Inc. (SDI) is a rapid test that uses antibodies and color change to identify a substance. The SDI, RaPID Assay® Kit, ELISA is an analytic biochemical assay that uses a solid-phase enzyme immunoassay to detect the presence of a substance in a liquid or wet sample. In order to analyze fish extracts several modifications to the standard ELISA test methods, as described below were necessary.

Strategic Diagnostics Inc. RaPID Assay® Kit

On October 28, 2009 researchers from the NJDEP, OS received 45 archived fish extracts from ANSP for use in Enzyme-linked Immunosorbent Assay (ELISA) testing. The fish extracts had been previously analyzed by ANSP and determined values for Total PCBs. All sample documentations were provided by ANSP. The sample identification numbers that the Academy utilized for the original PCB analysis were used in this ELISA study. The fish tissue extracts were stored at the NJDEP, OS, Arctic Parkway Laboratory freezer at 4oC.

All ELISA tests were conducted by NJDEP/OS personnel on November 5, 2009. The 45 ANSP fish tissue extracts were analyzed utilizing a PCB in soil immunoassay test kit from Strategic Diagnostics Inc. (SDI). One hundred microliters (100 uL) of fish tissue extract were transferred by pipette (Hamilton variable volume digital pipettor) to the plastic test tubes provided by SDI.

The solvent extracts, which are incompatible with the immunoassay method, were evaporated to dryness under a gentle stream of nitrogen gas (Air Products Purified Grade Nitrogen, 99.999%) at a flow rate of 3 liters per minute as measured by bubble flow meter prior to the four (4) outlet stainless steel evaporation manifold (J.T.Baker Inc.). The extracts were reconstituted utilizing the Diluent solution provided by SDI in the test kits to a volume of 200 uL as called for by the method protocols. Standard calibration procedures were followed and were within acceptable limits to allow the analysis to proceed.

All 45 samples were processed within the 15 minute time interval specified in the method. In addition, because the 15 minute interval had not expired a random set of samples were analyzed a second time for comparison.

RESULTS

Chemical Instrumentation Analysis

Analytical instrumentation data from this study are provided in Tables 2 and 3. These data are compared with menhaden tissue data from earlier studies (Tables 4 and 5). The Raritan River samples from 2000 tended to show similar (Hg and PCBs) or higher concentrations (DDX,

BHCs+lindane, chlordanes) than the 2007 samples (Table 6). In 2000, the menhaden from Barnegat Bay had lower concentrations of Hg than the other sample groups. However, concentrations of other contaminant groups were either similar to (PCBs, DDXs, and chlordanes) or higher than (BHCs+lindane) the Raritan River fish.

The menhaden collected in the Atlantic Ocean in 2001 (Tables 4-6) were larger and had higher lipid concentrations than the other fish analyzed. These oceanic fish had higher concentrations of Hg than the other samples. Within the 2007-2008 samples, fish from the Delaware River had lower concentrations of Hg, PCBs, DDXs, and chlordanes than the Raritan River fish. However, concentrations of BHCs+lindane were similar in samples from the two estuaries.

ELISA Immunoassay Test

The ELISA data generated from this study with the levels for PCBs determined by the ANSP are provided on Table 7. In addition, Figure 1 illustrates these preliminary results in graphical representation showing the ELISA contaminant level comparisons to the previously determined levels of PCBs from GC/MS instrumental analysis by the ANSP. The ELSIA test levels were not comparable from a quantification perspective, but tracked quite well with the final results of the instrumental analysis (e.g. elevated levels from the GC/MS determination were also elevated in the ELISA determination). Many factors could influence these preliminary results, but as a first simple modification of the ELISA method, the screening technique traced quite well. In this type of fish tissue research the labor intensive step in the analytical process is the preparation of the tissue extract. After this step is completed, the ELISA instrumental analysis can be accomplished with limited interference. Table 7 and Figure 1 show the values that were determined by each analysis technique utilizing a common fish tissue extract method.

CONCLUSIONS AND RECOMMENDATIONS

Atlantic Menhaden, as an ecologically important fish species, food source and having a high potential for bioaccumulation of chemical contaminants, make it a significant tool in environmental chemical contamination assessment. In addition, because of its great abundance, coast wide movement during out-migration and large commercial harvest, menhaden may play a significant role in the transport of contaminants loss from estuaries, with concomitant importance as inputs to oceanic and terrestrial/freshwater systems. Estuary-specific chemical contaminant signatures accumulated during the early life stage of this species as juveniles appear to be a valuable indicator of localized (waterway specific) contamination.

Contaminant data for samples of juvenile menhaden generated in 2000, 2001 and in this study (2007-2008) collected from the Raritan River, Barnegat Bay, Delaware River revealed an interesting pattern of chemical contamination. The sample results indicate that the Raritan River contaminant data is similar for the years 2000 and 2007. Delaware River samples were generally less than Raritan River samples. The Barnegat Bay (2000) data were highest for PCBs and Lindane, but similar to Raritan River (2000) for some data. Adult ocean fish collected off of Cape May, NJ were highest for Hg, lowest for PCBs and middle level range for all other contaminants.

These geographically differencing results suggest that a more comprehensive examination into the potential of using juvenile Atlantic menhaden estuary-specific and/or contaminant specific signatures as a seasonal sentinel for chemical contamination should be undertaken. It is therefore

recommended that a larger and more detailed evaluation is needed to delineate the extent to which the estuary-specific contaminant and/ or contaminant specific signatures in this species could be utilized as a sentinel in chemical contaminant environmental assessments.

The preliminary ELISA/ PCB database generated in this pilot study suggest that the ELISA test is potentially suitable for a cost effective alternative PCB analytical method. The techniques advantage is the rapid analysis of a large batch of samples within minutes. The applicability of the modified ELISA method could be implemented as an extract screening protocol if there were a large number of extracts to evaluate.

The protocol modification used in the ELISA fish tissue testing is a necessary development at this time and is essential to using this technique as a rapid simplified and cost effective screening assessment. It is recommended that a more in depth evaluation is needed to conclude the efficacy of this approach as a tool in a scientifically sound environmental assessment.

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Table 2. Atlantic Menhaden Measurements and Mercury, PCBs and OCP Chemical Analytical Results

Sample characteristics and total concentrations of Hg, PCBs, DDXs, BHCs+Lindane, and chlordane for the 2007 NJ Juvenile Atlantic Menhaden Contaminant Study. Concentrations were determined using composites of three whole atlantic menhaden (*Brevoortia tyrannus*). Concentrations below detection limit (BDL) are in italics.

Station	Analytical Numbers	Chem ID	Ave. Length (lab)	Ave. Weight (lab)	Total Lipids	Total Hg	Total PCBs	Total DDXs	Total BHCs + Lindane	Total Chlordanes
			cm	g	%	ug/g wet	ng/g wet	ng/g wet	ng/g wet	ng/g wet
Delaware River @ Chester Island										
	F-4418a-c	2473	11.2	12.6	0.75	*0.010*	151	27	0.271	2.4
Delaware River @ Helm's Cove										
	F-4413a-c	2468	10.4	9.7	1.04	*0.010*	89	16	0.365	3.0
	F-4414a-c	2469	10.3	9.5	1.21	*0.020*	165	40	0.568	7.6
	F-4415a-c	2470	10.4	9.2	1.01	*0.020*	133	21	*0.226*	2.8
	F-4416a-c	2471	10.0	8.9	0.89	*0.010*	126	16	1.023	3.1
	F-4417a-c	2472	10.6	10.8	1.07	*0.020*	285	60	1.363	4.9
Delaware River @ Naamans Creek										
	F-4409a-c	2464	10.5	10.2	0.96	*0.010*	114	15	0.340	1.9
	F-4410a-c	2465	10.2	8.9	1.20	*0.010*	150	31	1.085	2.7
	F-4411a-c	2466	10.2	9.3	1.01	*0.020*	84	18	0.639	1.7
	F-4412a-c	2467	10.2	9.7	1.05	*0.010*	110	28	0.388	3.3
Raritan River @ Sayreville										
	F-4388a-c	2450	11.3	12.0	1.42	0.040	405	104	0.598	21.7
	F-4389a-c	2451	12.1	15.6	2.68	0.030	261	74	0.989	16.4
	F-4390a-c	2452	11.3	12.3	1.30	0.030	273	96	0.414	15.3
	F-4391a-c	2453	10.6	10.3	1.17	0.050	262	71	0.298	13.5
	F-4392a-c	2454	11.5	13.2	1.57	0.040	345	169	0.613	18.0
	F-4400a-c	2455	11.3	12.2	1.79	0.040	251	100	0.561	15.5
	F-4401a-c	2456	11.7	13.9	2.04	0.030	317	129	0.648	19.6
	F-4402a-c	2457	11.0	12.4	1.68	0.040	466	203	0.659	29.0
	F-4403a-c	2458	11.7	12.7	2.55	0.030	275	84	1.178	20.5
	F-4404a-c	2459	11.3	11.8	1.54	0.040	271	92	0.434	14.2
	F-4405a-c	2460	12.4	16.6	3.44	0.050	405	137	0.978	24.3
	F-4406a-c	2461	11.4	12.0	1.99	0.040	261	94	0.597	12.8
	F-4407a-c	2462	12.2	15.2	3.08	0.030	367	116	0.762	22.9
	F-4408a-c	2463	11.5	12.9	2.26	0.070	410	184	0.630	24.4

Table 3. Atlantic Menhaden Measurements and OCP Chemical Analytical Results

Sample characteristics and concentrations of dieldrin, endrin, aldrin, and endosulfans for the 2007 NJ Juvenile Atlantic Menhaden Contaminant Study. Concentrations were determined using composites of three whole atlantic menhaden (*Brevoortia tyrannus*). Concentrations below detection limit (BDL) are in italics. ND=non-detect.

Station	Analytical Numbers	Chem ID	Ave. Length (lab)	Ave. Weight (lab)	Total Lipids	dieldrin	endrin	aldrin	endosulfan I	endosulfan II
			cm	g	%	ng/g wet	ng/g wet	ng/g wet	ng/g wet	ng/g wet
Delaware River @ Chester Island										
	F-4418a-c	2473	11.2	12.6	0.75	1.38	0.13	0.12	0.02	0.02
Delaware River @ Helm's Cove										
	F-4413a-c	2468	10.4	9.7	1.04	1.80	*0.07*	0.20	0.03	0.03
	F-4414a-c	2469	10.3	9.5	1.21	3.86	0.26	0.38	0.04	0.05
	F-4415a-c	2470	10.4	9.2	1.01	1.60	0.22	0.17	0.02	0.04
	F-4416a-c	2471	10.0	8.9	0.89	1.61	0.16	0.13	0.04	0.02
	F-4417a-c	2472	10.6	10.8	1.07	2.24	0.15	0.16	0.03	0.05
Delaware River @ Naaman Creek										
	F-4409a-c	2464	10.5	10.2	0.96	1.14	*0.05*	0.12	0.02	0.02
	F-4410a-c	2465	10.2	8.9	1.20	2.39	*0.07*	0.19	0.02	0.05
	F-4411a-c	2466	10.2	9.3	1.01	1.40	*0.05*	0.13	0.03	0.02
	F-4412a-c	2467	10.2	9.7	1.05	1.89	*0.05*	0.20	ND	0.02
Raritan River @ Sayreville										
	F-4388a-c	2450	11.3	12.0	1.42	3.65	0.53	0.41	0.11	ND
	F-4389a-c	2451	12.1	15.6	2.68	5.24	0.47	0.61	0.07	0.12
	F-4390a-c	2452	11.3	12.3	1.30	3.21	0.37	0.39	0.04	0.58
	F-4391a-c	2453	10.6	10.3	1.17	1.77	0.57	0.21	0.02	0.37
	F-4392a-c	2454	11.5	13.2	1.57	4.41	ND	0.47	0.03	ND
	F-4400a-c	2455	11.3	12.2	1.79	4.27	0.25	0.47	0.04	0.34
	F-4401a-c	2456	11.7	13.9	2.04	5.37	0.20	0.57	0.04	0.57
	F-4402a-c	2457	11.0	12.4	1.68	5.56	ND	0.58	0.02	ND
	F-4403a-c	2458	11.7	12.7	2.55	8.06	1.14	0.13	0.09	0.56
	F-4404a-c	2459	11.3	11.8	1.54	3.79	0.34	0.42	0.03	0.53
	F-4405a-c	2460	12.4	16.6	3.44	6.82	0.84	0.66	0.05	0.15
	F-4406a-c	2461	11.4	12.0	1.99	3.58	0.35	0.36	0.04	0.67
	F-4407a-c	2462	12.2	15.2	3.08	7.49	0.86	0.73	0.05	0.22
	F-4408a-c	2463	11.5	12.9	2.26	5.51	0.85	0.47	0.04	1.37

Table 4. Atlantic Menhaden Measurements and Mercury, PCBs and OCP Chemical Analytical Results

Sample characteristics and concentrations of dieldrin, endrin, aldrin, and endosulfans for atlantic menhaden (*Brevoortia tyrannus*) analyzed under the 1998 NJ Toxics Contaminant Study (2000 Supplemental). Concentrations were determined using composites of whole atlantic menhaden. Total concentrations were not below detection limits (BDLs). ND=non-detect, * = no datum.

Station	Year collected	Analytical Numbers	Chem ID	Fish per composite	Ave. Length (lab)	Ave. Weight (lab)	Total Lipids	dieldrin	endrin	aldrin	endosulfan I	endosulfan II
					cm	g	%	ng/g wet	ng/g wet	ng/g wet	ng/g wet	ng/g wet
Atlantic Ocean, Atlantic City to Cape May												
	2001	F-2704a-c	4164	3	35.0	445.8	15.16	8.19	27.52	6.70	1.51	2.22
	2001	F-2705a-c	4165	3	35.2	452.4	10.62	ND	4.61	4.67	11.97	1.14
	2001	F-2706a-c	4166	3	33.7	414.1	13.06	ND	1.27	2.52	9.01	1.45
	2001	F-2707a-c	4167	3	34.3	418.4	14.28	6.02	ND	2.69	1.38	0.99
Barnegat Bay												
	2000	F-2700a-o	3962	15	13.4	25.0	4.71	1.19	1.82	1.72	3.05	0.61
	2000	F-2701a-o	3963	15	13.6	27.2	2.05	2.05	0.95	ND	2.69	1.09
	2000	F-2702a-o	3964	15	13.5	26.0	4.77	11.27	0.87	3.53	46.62	2.07
Raritan River												
	2000	F-2696a-t	3958	20	8.6	5.9	*	6.23	ND	0.33	5.04	0.66
	2000	F-2697a-t	3959	20	8.7	6.1	3.58	6.28	ND	2.08	6.71	0.74
	2000	F-2698a-t	3960	20	8.5	6.0	3.45	8.69	2.84	2.08	5.69	1.17
	2000	F-2699a-t	3961	20	8.5	5.9	3.07	7.36	1.07	1.34	9.53	1.11

Table 5. Atlantic Menhaden Measurements and OCP Chemical Analytical Results

Sample characteristics and total concentrations of Hg, PCBs, DDXs, BHCs+Lindane, and chlordane for atlantic menhaden (*Brevoortia tyrannus*) analyyzed under the 1998 NJ Toxics Contaminant Study (2000 Supplemental). Concentrations were determined using composites of whole atlantic menhaden. Total concentrations were not below detection limits (BDLs). * = no datum

Station	Year collected	Analytical Numbers	Chem ID	Fish per composite	Ave. Length (lab)	Ave. Weight (lab)	Total Lipids	Total Hg	Total PCBs	Total DDXs	Total BHCs + Lindane	Total Chlor-danes
					cm	g	%	ug/g wet	ng/g wet	ng/g wet	ng/g wet	ng/g wet
Atlantic Ocean, Atlantic City to Cape May												
	2001	F-2704a-c	4164	3	35.0	445.8	15.16	0.647	77	102	20.173	19.0
	2001	F-2705a-c	4165	3	35.2	452.4	10.62	0.136	113	78	107.259	28.7
	2001	F-2706a-c	4166	3	33.7	414.1	13.06	0.091	120	70	60.526	19.0
	2001	F-2707a-c	4167	3	34.3	418.4	14.28	0.060	104	98	47.342	13.2
Barnegat Bay												
	2000	F-2700a-o	3962	15	13.4	25.0	4.71	0.002	243	99	32.518	24.5
	2000	F-2701a-o	3963	15	13.6	27.2	2.05	0.001	308	110	61.529	35.9
	2000	F-2702a-o	3964	15	13.5	26.0	4.77	0.006	766	285	166.618	84.4
Raritan River												
	2000	F-2696a-t	3958	20	8.6	5.9	*	0.039	269	144	1.830	27.2
	2000	F-2697a-t	3959	20	8.7	6.1	3.58	0.032	413	267	4.949	63.5
	2000	F-2698a-t	3960	20	8.5	6.0	3.45	0.034	352	262	4.315	55.9
	2000	F-2699a-t	3961	20	8.5	5.9	3.07	0.046	373	245	3.272	51.8

Table 6. Average Atlantic Menhaden Measurements and Chemical Analytical Results

Average concentrations of Hg, PCBs, DDX's, BHCs+Lindane, and chlordanes per waterbody for the NJ Juvenile Atlantic Menhaden Contaminant Study and atlantic menhaden (*Brevoortia tyrannus*) collected under the 1998 NJ Toxics Program (2000 Supplemental) and the 2007 menhaden study. Concentrations were determined using composites of whole atlantic menhaden.

Waterbody	Year collected	Number of Composites	Fish per composite	Ave. Comp. Total Length (lab)	Ave. Comp. Total Weight (lab)	Ave. Total Lipids	Ave. Total Hg	Ave. Total PCBs	Ave. Total DDXs	Ave. Total BHCs + Lindane	Ave. Total Chlor-danes
				cm	g	%	ug/g wet	ng/g wet	ng/g wet	ng/g wet	ng/g wet
Delaware River	2008	10	3	10.4	9.9	1.02	0.014	141	27	0.627	3.3
Raritan River	2007	14	3	11.5	13.1	2.04	0.040	326	118	0.668	19.2
Raritan River	2000	4	20	8.6	6.0	3.37	0.038	352	229	4.179	49.6
Barnegat Bay	2000	3	15	13.5	26.1	3.84	0.003	439	165	86.888	48.3
Atlantic Ocean, Atlantic City to Cape May	2001	4	3	34.6	432.7	13.28	0.233	104	87	58.825	20.0

Table 7. Results of ELISA Testing on Samples Extract

ANSP Sample ID #	Volume of Extract Processed (uL)	ANSP Total PCBs (ng/g)	NJDEP PCB ELISA (ppb)	Note
5464	100 uL	35.88	6.36	
5465	100 uL	37.19	9.81	
5466	100 uL	37.13	4.14	
5467	100 uL	31.09	3.98	
5468	100 uL	29.64	4.15	
5469	100 uL	27.68	4.64	
5470	100 uL	26.1	2.82	
5471	100 uL	26.28	2.03	
5472	100 uL	35.54	0.0012	ND
5473	100 uL	16.42	1.55	
5473 Dup	100 uL	35.43	5.67	
5474	100 uL	33.29	5.48	
5475	100 uL	31.28	5.49	
5475 Dup	100 uL	34.94	4.95	
5476	100 uL	38.63	6.55	
5477	100 uL	77.2	7.73	
5478	100 uL	53.05	ND	
5479	100 uL	59.62	8.76	
5480	100 uL	42.6	6.72	
5481	100 uL	38.43	7.29	
5482	100 uL	37.1	7.77	
5483	100 uL	33.72	5.11	
5483 Dup	100 uL	44.01	0.001	ND
5484	100 uL	24.4	4.59	
5485	100 uL	45.36	7.599	
5486	100 uL	41.68	5.55	
5487	100 uL	40.1	6.33	
5488	100 uL	49.09	4.82	
5489	100 uL	32.1	6.27	
5851	100 uL	24	2.45	
5851 Dup	100 uL	27.06	3.38	
5852	100 uL	37.26+	6.78	
5861	100 uL	13	1.4	
5862	100 uL	87.85	16.83	
5862 Dup	100 uL	109.58	17.25	
5863	100 uL	12.6	2.5	
5864	100 uL	19.8	ND	
5865	100 uL	41.42	11.33	
5866	100 uL	35.59	7.66	
5867	100 uL	22.08	4.37	
5892	100 uL	31.85	4.76	
5893	100 uL	26.35	5.69	
5894	100 uL	19.13	1.49	
5895	100 uL	32.52	ND	
5895 Dup	100 uL	32.66	4.79	
5895 Trip	100 uL	34.24	7.01	

Figure 1: Graphical Comparison of PCB Concentrations in Fish Extracts by GC/MS and ELISA Immunoassay Methodologies