# Changes in contaminants in winter flounder, lobster, and caged mussels in Massachusetts and Cape Cod Bays and Boston Harbor: 1995-2006

Massachusetts Water Resources Authority

Environmental Quality Department
Report 2008-09

Citation:

Kane-Driscoll S, Edwards M, Pembroke A, Nestler EC, and C Gurshin. 2008. Changes in contaminants in winter flounder, lobster, and caged mussels in Massachusetts and Cape Cod **Bays and Boston Harbor: 1995-2006**. Boston: Massachusetts Water Resources Authority. Report 2008-09. 73 p.

# Changes in contaminants in winter flounder, lobster, and caged mussels in Massachusetts and Cape Cod Bays and Boston Harbor: 1995-2006

**submitted to**

**Massachusetts Water Resources Authority**
**Environmental Quality Department**
**100 First Avenue**
**Charlestown Navy Yard**
**Boston, MA 02129**
**(617) 242-6000**

**prepared by**

**Susan Kane-Driscoll[1]**
**Melanie Edwards[2]**
**Ann Pembroke[3]**
**Eric Nestler[3]**
**Chris Gurshin[3]**

**[1]Exponent**
**8 Winchester Place, Suite 303**
**Winchester, MA 01890**

**[2]Exponent**
**15375 SE 30th Place, Suite 250**
**Bellevue, WA 98007**

**[3]Normandeau Associates, Inc.**
**25 Nashua Road**
**Bedford, NH 03110**

**June 2008**

# TABLE OF CONTENTS

**Page**

**1.0 INTRODUCTION....1**

**2.0 METHODS....8**

2.1 DATA HANDLING....8
2.2 STATISTICAL METHODS....8
2.2.1 BACI Analysis....9
2.2.2 Analysis of Variance....10

**3.0 MUSSELS....11**

3.1 BIOLOGY, ECOLOGY, AND BIOACCUMULATION....11
3.1.1 Distribution and Movement....11
3.1.2 Feeding Ecology....11
3.1.3 Bioaccumulation and Indicator Species Potential....11
3.1.4 Previous MWRA Findings....12
3.2 RESULTS OF THE BACI....13
3.2.1 Outfall Site....13
3.2.2 Deer Island Light....18
3.2.3 Large Navigation Buoy....19
3.3 RESULTS OF THE ANOVA....20

**4.0 LOBSTER....28**

4.1 BIOLOGY, ECOLOGY, AND BIOACCUMULATION....28
4.1.1 Distribution and Movement....28
4.1.2 Habitat and Feeding Ecology....29
4.1.3 Bioaccumulation....30
4.1.4 Suitability as an Indicator Species....30
4.1.5 Previous MWRA Findings....30
4.2 RESULTS OF THE BACI....31
4.3 RESULTS OF THE ANOVA....37

**5.0 WINTER FLOUNDER....46**

5.1 BIOLOGY, ECOLOGY, AND BIOACCUMULATION....46
5.1.1 Distribution and Movement....46
5.1.2 Bioaccumulation....47
5.1.3 Suitability as an Indicator Organism....47
5.1.4 Previous MWRA Findings....48
5.2 RESULTS OF THE BACI....48
5.3 RESULTS OF THE ANOVA....53

**6.0 COMPARISON TO THRESHOLDS....61**

6.1 COMPARISON TO FDA LEVELS AND EPA RISK-BASED CONCENTRATIONS FOR HUMAN HEALTH....61

6.2 COMPARISON OF MUSSELS TO EPA EQUILIBRIUM PARTITIONING BENCHMARKS FOR THE PROTECTION OF BENTHIC ORGANISMS ..... 61

**7.0 SUMMARY AND RECOMMENDATIONS FOR CHANGES TO THE MONITORING PROGRAM ..... 66**

7.1 MUSSELS ..... 66
7.2 LOBSTER ..... 67
7.3 WINTER FLOUNDER ..... 67

**8.0 CONCLUSIONS ..... 68**

**9.0 REFERENCES ..... 69**

APPENDIX A DATA
APPENDIX B STATISTICAL ANALYSES

# LIST OF FIGURES

**Page**

Figure 1-1. Boston Harbor and the bays with Outfall Site ..... 2

Figure 1-2. Mussel collection and deployment locations ..... 3

Figure 1-3. Flounder monitoring locations ..... 4

Figure 1-4. Lobster monitoring locations ..... 5

Figure 3-1. Comparison of lead concentrations measured in mussel soft tissue between control and impact locations before and after relocation of the outfall ..... 15

Figure 3-2. Comparison of PCB concentrations measured in mussel soft tissue between control and impact locations before and after relocation of the outfall ..... 16

Figure 3-3. Comparison of high molecular weight (HMW) PAH concentrations measured in mussel soft tissue between control and impact locations before and after relocation of the outfall ..... 17

Figure 3-4. Comparison of chlordane concentrations measured in mussel soft tissue between control and impact locations before and after relocation of the outfall ..... 18

Figure 3-5. Lead concentrations in mussel soft tissue after the outfall went on-line ..... 23

Figure 3-6. High molecular weight (HMW) PAH concentrations in mussel soft tissue after the outfall went on-line ..... 24

Figure 3-7. Chlordane concentrations in mussel soft tissue after the outfall went on-line ..... 25

Figure 3-8. Mercury concentrations in mussel soft tissue after the outfall went on-line ..... 26

Figure 3-9. PCB concentrations in mussel soft tissue after the outfall went on-line ..... 27

Figure 4-1. Comparison of PCB concentrations measured in lobster meat between control and impact locations before and after relocation of the outfall ..... 33

Figure 4-2. Comparison of chlordane concentrations measured in lobster meat between control and impact locations before and after relocation of the outfall ..... 34

Figure 4-3. Comparison of lead concentrations measured in lobster hepatopancreas between control and impact locations before and after relocation of the outfall ..... 35

Figure 4-4. Comparison of copper concentrations measured in lobster hepatopancreas between control and impact locations before and after relocation of the outfall ..... 36

Figure 4-5. Comparison of high molecular weight (HMW) PAH concentrations measured in lobster hepatopancreas between control and impact locations before and after relocation of the outfall ..... 37

Figure 4-6. Chlordane concentrations in lobster meat after the outfall went on-line ..... 40

Figure 4-7. Mercury concentrations in lobster meat after the outfall went on-line ..... 41

Figure 4-8. PCB concentrations in lobster hepatopancreas tissue after the outfall went on-line ..... 42

Figure 4-9. High molecular weight (HMW) PAH concentrations in lobster hepatopancreas tissue after the outfall went on-line ..... 43

Figure 4-10. Cadmium concentrations in lobster hepatopancreas tissue after the outfall went on-line ..... 44

Figure 4-11. Copper concentrations in lobster hepatopancreas tissue after the outfall went on-line ..... 45

Figure 5-1. Comparison of 4,4'-DDE concentrations measured in flounder fillet between control and impact locations before and after relocation of the outfall ..... 50

Figure 5-2. Comparison of mercury concentrations measured in flounder fillet between control and impact locations before and after relocation of the outfall ..... 51

Figure 5-3. Comparison of mercury concentrations measured in flounder liver between control and impact locations before and after relocation of the outfall ..... 52

Figure 5-4. Comparison of PCB concentrations measured in flounder liver between control and impact locations before and after relocation of the outfall ..... 53

Figure 5-5. Chlordane concentrations in flounder fillet tissue after the outfall went on-line ..... 57

Figure 5-6. Mercury concentrations in flounder fillet tissue after the outfall went on-line ..... 58

Figure 5-7. Lead concentrations in flounder liver tissue after the outfall went on-line ..... 59

Figure 5-8. Chlordane concentrations in flounder liver tissue after the outfall went on-line ..... 60

# LIST OF TABLES

**Page**

Table 1-1. Full list of target analytes ..... 6

Table 3-1. Summary of Before/After Conclusions from the BACI Analysis of Concentrations in Mussel Tissue at the Outfall Site and the Large Navigation Buoy ..... 14

Table 3-2. Summary of Before/After Conclusions from the BACI Analysis of Concentrations in Mussel Soft Tissue at Deer Island Light. ..... 19

Table 3-3. Summary of Comparisons between Locations by Year for Mussel Soft Tissue. ..... 21

Table 4-1. Summary of Before/After Conclusions from the BACI Analysis of Concentrations in Lobster Meat and Lobster Hepatopancreas at the Outfall Site. ..... 32

Table 4-2. Summary of Comparisons between Locations by Year for Lobster Meat. ..... 38

Table 4-3. Summary of Comparisons between Locations by Year for Lobster Hepatopancreas. ..... 39

Table 5-1. Summary of Before/After Conclusions from the BACI Analysis of Concentrations in Flounder Fillet and Liver Tissue at the Outfall Site. ..... 49

Table 5-2. Summary of Comparisons between Locations by Year for Flounder Fillet ..... 54

Table 5-3. Summary of Comparisons between Locations by Year for Flounder Liver. ..... 55

Table 6-1. Comparison of 2006 Tissue Concentrations with Threshold Levels. ..... 63

Table 6-2. Calculation of the Sum of Toxic Units for 34 PAHs Measured in Mussel Tissue. ..... 64

# EXECUTIVE SUMMARY

This report addresses various questions related to the Fish and Shellfish component of the Massachusetts Water Resources Authority's (MWRA) Harbor and Outfall Monitoring program for Boston Harbor and Massachusetts Bay. In September 2000, MWRA moved the outfall that discharges wastewater from the MWRA Deer Island Treatment Plant (DITP) in Boston Harbor to a new outfall diffuser system located 9.5 miles from the DITP in Massachusetts Bay (Figure 1-1). The goal of this report is to examine whether levels of contaminants in flounder, lobster, or mussels have changed as a result of the relocation of the outfall, and whether current levels of contaminants in fish and shellfish are significantly different among organisms collected from the area of the outfall, Boston Harbor, and reference sites in Cape Cod Bay. A secondary goal of this report is to examine whether current levels of contaminants in the edible tissue of fish and shellfish collected near the outfall present a risk to human health or to the environment. This report also makes recommendations in regard to the future monitoring for toxic contaminants in fish and shellfish.

## MUSSELS

Concentrations of contaminants in caged mussels deployed in the vicinity of the outfall were expected to increase after the effluent was diverted to the outfall in 2000. Post-relocation concentrations of lead, PCBs, high molecular weight PAHs, total PAHs, chlordane and 4,4'-DDE were significantly greater at the Outfall Site after taking into account any changes at the Control site in Cape Cod Bay. However, current concentrations of these contaminants are below MWRA threshold levels and U.S. Food and Drug Administration (FDA) action limits. The FDA action levels represent limits at or above which FDA will take legal action to remove products from the market. In addition, current concentrations of PAHs in mussels at all locations were below U.S. Environmental Protection Agency (EPA) benchmarks for the protection of aquatic organisms, and concentrations of lead, mercury, chlordane, and 4,4'-DDE were below EPA screening-level human health risk-based concentrations (RBCs). Note, however, that the EPA RBCs, which are based on conservative estimates of the rates of consumption of fish or shellfish, do not constitute regulation or guidance and are used primarily to screen out chemicals as contaminants of concern in an initial phse of a risk assessment. Average concentrations of PCBs exceeded the EPA screening-level RBC at all locations, although concentrations of PCBs at the Outfall Site were significantly lower than concentrations at Cape Cod Bay, indicating a broader regional distribution of PCBs. These results provide an important support for ending the mussel monitoring program.

## LOBSTER

Concentrations of contaminants in lobsters at the Outfall Site did not increase as a result of the relocation of the outfall. Concentrations of all contaminants were below MWRA thresholds and available FDA action limits, and concentrations of most contaminants were also below EPA screening-level RBCs. Although concentrations of PCBs exceeded the EPA screening-level RBC at all locations, current (2006) concentrations of PCBs in lobsters from the Outfall Site are not significantly different from concentrations at Cape Cod Bay, indicating a broader regional distribution of PCBs. These findings support ending the lobster monitoring program.

## FLOUNDER

Concentrations of contaminants in flounders at the Outfall Site did not increase as a result of the relocation of the outfall. Concentrations of all contaminants in flounder were below FDA action limits and MWRA thresholds. Concentrations of all contaminants, except PCBs, were below EPA screening-level RBCs. Concentrations of PCBs at all locations exceeded the EPA screening-level RBC, and 2006 concentrations of PCBs in flounder liver and fillet from the Outfall Site were significantly higher than concentrations at Cape Cod Bay. These findings support modifying the flounder monitoring program by eliminating the measurements of toxic contaminants.

# 1.0 INTRODUCTION

In September 2000, the Massachusetts Water Resources Authority (MWRA) diverted its wastewater discharge from the mouth of Boston Harbor to a new outfall diffuser system in Massachusetts Bay, 9.5 miles from the Deer Island Treatment Plant (DITP, Figure 1-1). Prior to the startup of the new outfall, MWRA implemented a long-term Harbor and Outfall Monitoring (HOM) program for Boston Harbor, Massachusetts Bay, and Cape Cod Bay, as required by the Federal Court Record of Decision and by MWRA's National Pollutant Discharge Elimination System Permit. These require MWRA to monitor the effluent and ambient receiving waters in accordance with a monitoring plan (MWRA 1991, 1997, 2004), which was developed in response to the U.S. Environmental Protection Agency's (EPA's) Supplemental Environmental Impact Statement (SEIS; U.S. EPA 1998). The purpose of the HOM program is to ensure compliance with the permit, to assess whether the outfall has effects beyond the area identified in the SEIS as acceptable, and to collect data for use in outfall management (Hunt et al. 2006). As part of the HOM program, MWRA has collected tissue chemistry data to assess the environmental impact of the effluent on fish and shellfish (MWRA 1991, 1997, 2004). Blue mussels collected from a reference location were deployed for 60 days at monitoring sites near the outfall, in Boston Harbor, and in Cape Cod Bay (Figure 1-2). Indigenous winter flounder and American lobster were also collected from several locations in Boston Harbor and Massachusetts Bay (Figures 1-3 and 1-4, respectively). The tissues of these three indicator species were analyzed for a suite of target analytes (Table 1-1). This report focuses on results for cadmium, copper, lead, and mercury, and the organics 4,4'-DDE, chlordane, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs). In order to assess potential outfall impacts, tissue chemistry data were compared to established contingency plan thresholds (MWRA 2001, 2004).

The primary objectives of this report are to provide information to support MWRA's planning for future monitoring, and to provide the public and regulatory agencies with information about current levels and trends in contaminants in fish and shellfish collected from the area of the outfall, Boston Harbor, and the Cape Cod Bay reference sites. Specifically, this report addresses the following:

1. Have the levels of contaminants in tissues of fish and shellfish around the outfall changed since discharge from the outfall began?

2. Are the current levels of contaminants in fish and shellfish different among the outfall, Boston Harbor, and a reference site?

3. Do the current levels of contaminants in the edible tissue of fish and shellfish around the outfall represent a risk to human health or the environment?

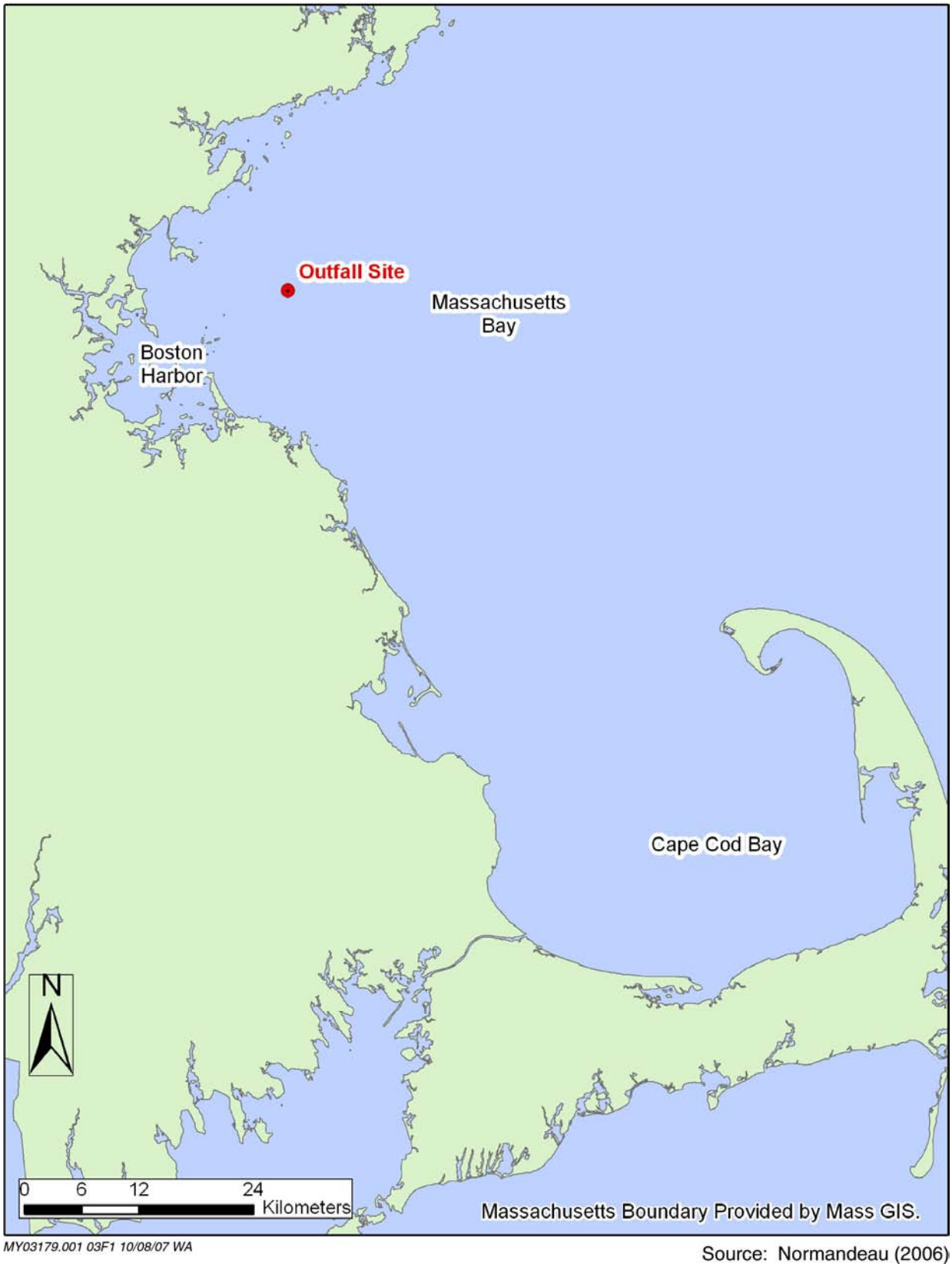



Figure 1-1. Boston Harbor and the bays with Outfall Site

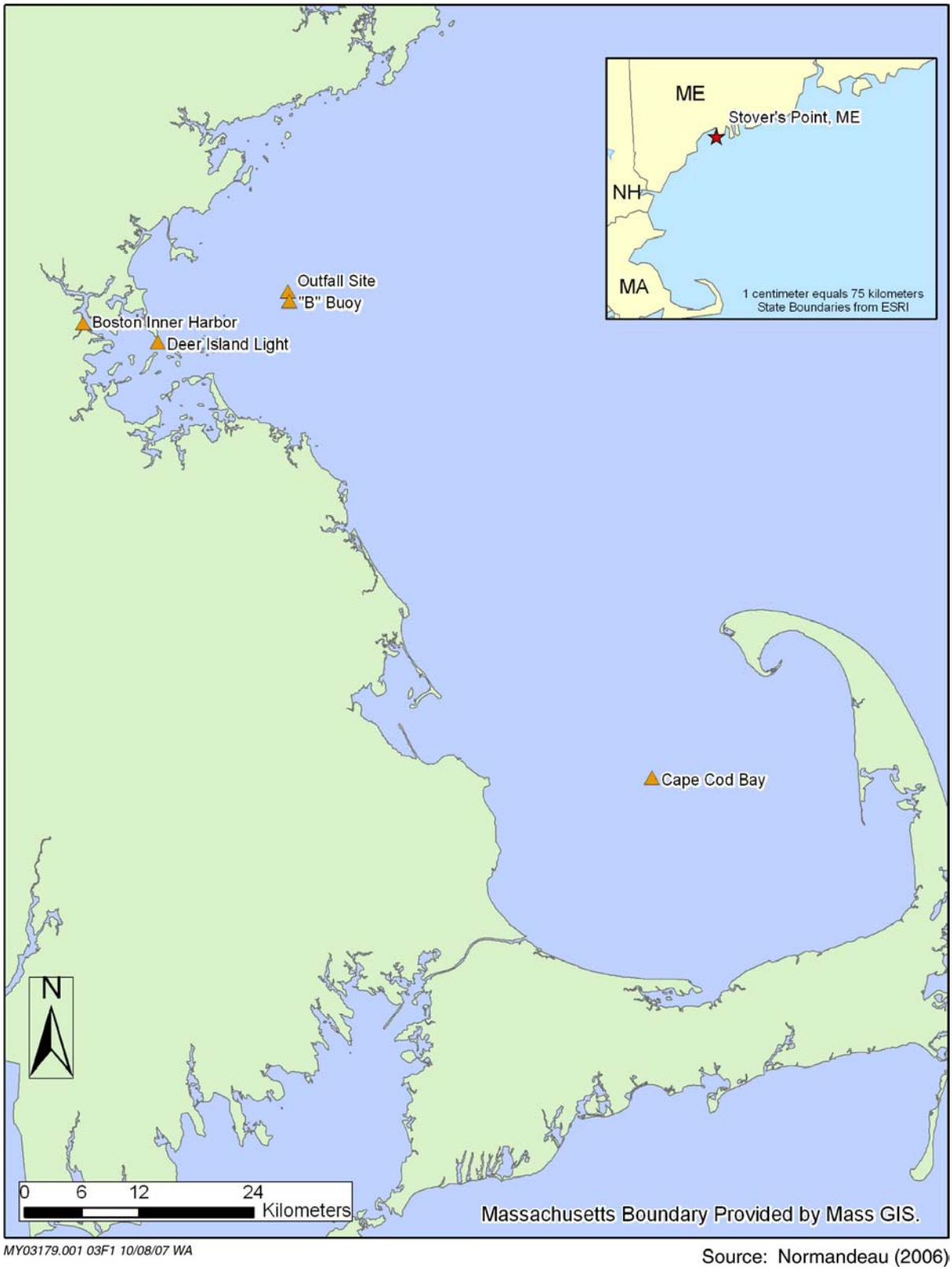



Figure 1-2. Mussel collection and deployment locations

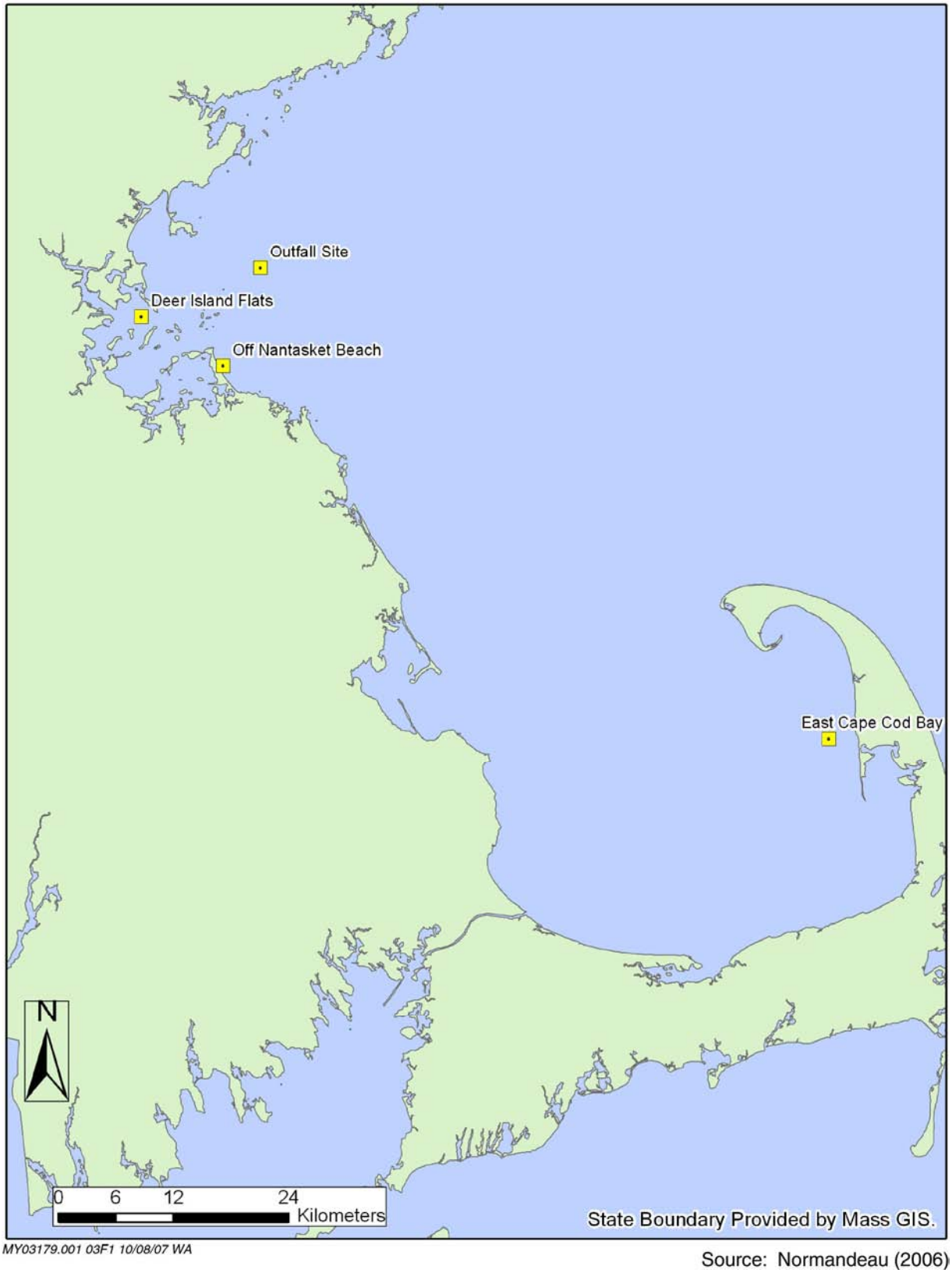



Figure 1-3. Flounder monitoring locations

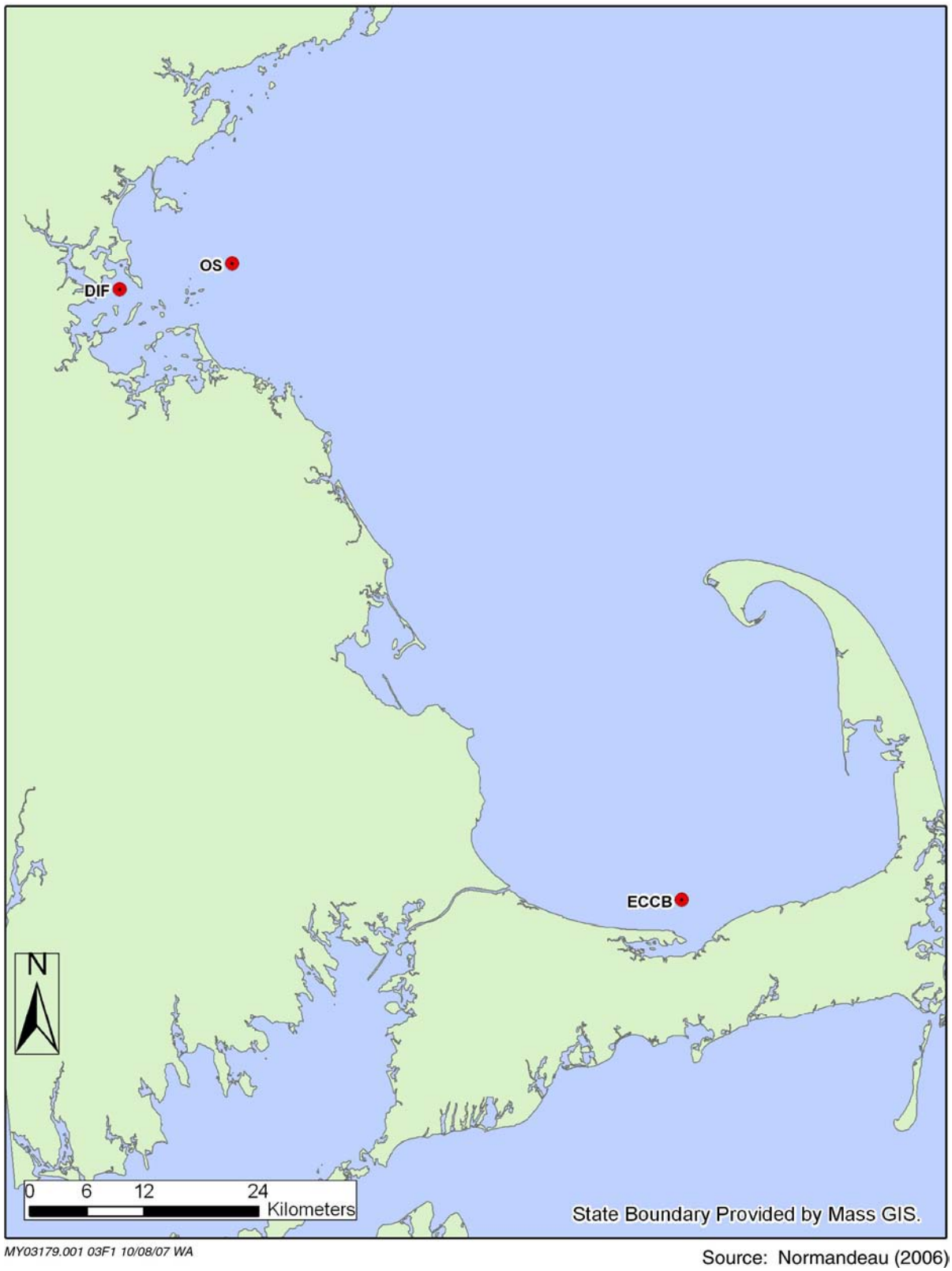



Figure 1-4. Lobster monitoring locations

**Table 1-1. Full list of target analytes**

| **Trace Metals** | **Polynuclear Aromatic Hydrocarbons (PAHs)** |
|---|---|
| Cadmium | 1-Methylnaphthalene |
| Chromium | 1-Methylphenanthrene |
| Copper | 2,3,5-Trimethylnaphthalene |
| Lead | 2,6-Dimethylnaphthalene |
| Mercury | 2-Methylnaphthalene |
| Nickel | Acenaphthene |
| Silver | Acenaphthylene |
| Zinc | Anthracene |
| | Benz[a]anthracene |
| **Pesticides** | Benzo[a]pyrene |
| 4,4 DDD olefin (DDMU) | Benzo[b]fluoranthene |
| Aldrin | Benzo[e]pyrene |
| cis-Chlordane | Benzo[ghi]perylene |
| Dieldrin | Benzo[k]fluoranthene |
| Endrin | Benzothiazole |
| Heptachlor | Biphenyl |
| Heptachlor epoxide | C1-Chrysenes |
| Hexachlorobenzene | C2-Chrysenes |
| Lindane | C3-Chrysenes |
| Mirex | C4-Chrysenes |
| o,p'-DDD | C1-Dibenzothiophenes |
| o,p'-DDE | C2-Dibenzothiophenes |
| o,p'-DDT | C3-Dibenzothiophenes |
| p,p'-DDD | C1-Fluoranthenes/pyrenes |
| p,p'-DDE | C2-Fluoranthenes/pyrenes |
| p,p'-DDT | C3-Fluoranthenes/pyrenes |
| trans-Nonachlor | C1-Fluorenes |
| | C2-Fluorenes |
| **Polychlorinated Biphenyls** | C3-Fluorenes |
| 2,4'-Dichlorobiphenyl | C1-Naphthalenes |
| 2,2',5-Trichlorobiphenyl | C2-Naphthalenes |
| 2,4,4'-Trichlorobiphenyl | C3-Naphthalenes |
| 2,2',3,5'-Tetrachlorobiphenyl | C4-Naphthalenes |
| 2,2',5,5'-Tetrachlorobiphenyl | C1-Phenanthrenes/anthracenes |
| 2,3',4,4'-Tetrachlorobiphenyl | C2-Phenanthrenes/anthracenes |
| 3,3',4,4'-Tetrachlorobiphenyl | C3-Phenanthrenes/anthracenes |
| 2,2',4,5,5'-Pentachlorobiphenyl | C4-Phenanthrenes/anthracenes |
| 2,3,3',4,4'-Pentachlorobiphenyl | Chrysene |
| 2,3',4,4',5-Pentachlorobiphenyl | Dibenz[a,h]anthracene |
| 3,3',4,4',5-Pentachlorobiphenyl | Dibenzofuran |
| 2,2',3,3',4,4'-Hexachlorobiphenyl | Dibenzothiophene |
| 2,2',3,4,4',5'-Hexachlorobiphenyl | Fluoranthene |
| 2,2',4,4',5,5'-Hexachlorobiphenyl | Fluorene |

| **Polychlorinated Biphenyls (cont.)** | **Polynuclear Aromatic Hydrocarbons (cont.)** |
|---|---|
| 2,2',3,3',4,4',5-Heptachlorobiphenyl | Indeno[1,2,3-cd]pyrene |
| 2,2',3,4,4',5,5'-Heptachlorobiphenyl | Naphthalene |
| 2,2',3,4',5,5',6-Heptachlorobiphenyl | Perylene |
| 2,2',3,3',4,4',5,6-Octachlorobiphenyl | Phenanthrene |
| 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl | Pyrene |
| Decachlorobiphenyl | |

# 2.0 METHODS

## 2.1 DATA HANDLING

Because various laboratories have generated the tissue chemistry data, this report examines analytes that demonstrated consistency of analytical quantitation over the course of the HOM program. The subset examined in this report includes cadmium, copper, lead, and mercury, and the organics, 4,4'-DDE (the predominant isomer of total DDT), chlordane, PCBs, and PAHs. Chlordane, PCBs, and PAHs were evaluated as sums. Chlordane is the sum of *cis*-chlordane and *trans*-nonachlor. In the statistical evaluation, PCBs is the sum of congeners 138 and 153, the predominant isomers of total PCBs. For comparison to risk-based criteria, total PCBs is the sum of all 20 reported congeners. Low molecular weight (LMW) and high molecular weight (HMW) PAHs are summed according to the historical National Oceanic and Atmospheric Administration (NOAA) list of compounds (see Table 1-1 for a complete list). This includes 12 analytes each for the HMW PAH and LMW PAH sums. Seven of the 12 LMW PAH analytes on the NOAA list were reported in all samples with PAH results, while the five additional analytes were reported for only a subset of samples. For this reason, LMW PAH are summed two ways—as the sum of all 12 analytes, and as the sum of only the 7 most commonly reported analytes. This approach dictates that total PAHs also be summed two ways, based on which LMW PAH sum is included. The other analytes analyzed are mercury, lead, cadmium, copper, and 4,4'-DDE.

The statistical evaluations were conducted using data reported on a dry-weight basis, surrogate corrected organic contaminant data, and undetected results included at half the detection limit (Appendix A). The comparisons to risk-based criteria were conducted using wet-weight basis results. When calculating the summed compounds, undetected results were included at half of the detection limit when the sum included both detected and undetected results. If all chemicals in a sum were undetected then the maximum detection limit was reported rather than the sum of the detection limits. This value was then included in the statistical analysis at half. If all chemicals were detected then the summed compound was simply the sum of the results.

## 2.2 STATISTICAL METHODS

Two approaches were taken to evaluate whether concentrations at the Outfall Site were significantly different from other locations and times. A before-after control impact (BACI) model was used to assess whether concentrations prior to the relocation of the outfall were significantly different from concentrations after the relocation, and whether differences were related to the relocation of the outfall. Additionally, data for each year following the outfall relocation were evaluated using an analysis of variance (ANOVA) to compare concentrations among locations. Locations examined included the Outfall Site (OS), Cape Cod Bay (CCB and ECCB), and Deer Island Light and Flats (DIL and DIF, respectively) for all tissue types, as well as Boston Inner Harbor (IH) and the Large Navigation Buoy (LNB) for mussel tissue. For mussel tissues the Outfall Site was represented by stations OSM, OS-M1, OS-M2, OS-M3, OS-M4, OS-M5, and OS-M6. Note that prior to 2001, mussels could not be deployed at the Outfall Site since the outfall was still being constructed. Therefore, prior to 2001 mussels deployed at the Large Navigation Buoy are used to represent conditions at the Outfall Site (for more detail see Nestler et al. 2007). All statistical analyses used a

$\log_{10}$-transformation of the concentrations to meet the underlying method assumptions of homogeneous variability and normality. Normal probability and residual plots showed that $\log_{10}$-transformations of all data provided consistently better adherence to the statistical assumptions.

### 2.2.1 BACI Analysis

The BACI model is a complex ANOVA that includes factors for period (i.e., before and after) and location (control and impact), as well as an interaction term and a term to adjust for year-to-year variability (Smith 2002). The complete BACI model fit initially was of the following form:

$$X_{ijk} = \mu + \alpha_i + \tau_{k(i)} + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

where:

$X_{ij}$ = $\log_{10}$(concentration) for the ith period at the jth location in the kth year

$\mu$ = overall mean

$\alpha_i$ = main effect of period (before v. after)

$\tau_{k(i)}$ = year within period (year-to-year variability within each period)

$\beta_j$ = main effect of location (control v. impact)

$(\alpha\beta)_{ij}$ = interaction term between period and location

$\varepsilon_{ijk}$ = error (unaccounted-for variability).

Type 3 sums of squares were used to account for the inconsistent number of samples within each period and at each location. Significance was determined at a 95 percent confidence level (alpha = 0.05).

A stepwise approach was used to reduce the complexity of the final model by removing components that were not significant. If the interaction term was not significant, it was removed and the model was refit. However, if the interaction term was significant, the interaction term and the main effect terms for period and location remained in the model, i.e., only the year-to-year variability might be removed, and the main effect term remained in the model even if they were not significant. A sequential approach of removing individual terms that were not significant continued until the model included only significant terms. Note that in some cases the year-to-year variability can be large due to the specifics of the laboratory analyses (e.g., elevated detection limits). In such cases, accounting for this variability substantially influences the interpretation of the BACI results.

Although a significant term in an ANOVA indicates a difference, it does not identify the specific nature of the difference. Therefore, following the ANOVA, pair-wise comparisons were used to evaluate the specific nature of the concentration differences. The most sensitive (smallest critical value) pair-wise comparison method was used in all cases. Primarily, Fisher's least significant difference and Tukey's methods were used, though in some cases Sidak's method was more powerful. In every instance, the overall confidence level across all comparisons was maintained at 95 percent.

The conclusions that can be drawn from the BACI analyses depend upon whether or not the interaction term is significant. For models without a significant interaction term, the main effect term for period reflects an *overall* change in concentration between periods, and the main effect term for

location reflects an *overall* difference between locations. However, a significant interaction term indicates important differences in the results that are not consistent across periods or locations. For example, a significant interaction can result from a difference between locations that is not the same for each period. Alternatively, a significant interaction can result from a change between periods that is not the same for each location. Thus, if the interaction term is significant, conclusions drawn from the main effects are of little value since they can mask important interactions. Therefore, if the interaction term is significant, the interaction term takes precedence over the main effects in the interpretation of the results, and conclusions based on the main effects are not considered.

Because the intent of this analysis is to examine the change that is attributable to the relocation of the outfall, rather than to other factors such as changes in treatment technology, laboratory analyses, or sample collection, the "before" period should encompass a time period that minimizes these other factors. However, to maximize the power of the test, it has been suggested that the "before," or baseline, period should be as long as possible. To address these concerns, we conducted two BACI analyses, one defining the "before" period as 1995–2000, and one as 1998–2000, to account for changes in sampling and analysis that might have contributed to the variability in the samples. For example, prior to 1998, changes in the wastewater treatment process (e.g., discharge of sludge, primary vs. secondary treatment) are likely to contribute to variability. In addition, prior to 1995, differences in the laboratory analyses are likely to contribute to the variability. Finally, prior to 1995, certain samples consisted of individual organisms rather than composites, and certain lobster samples were likely collected immediately upon migrating into the harbor.

The Outfall Site was considered the impact location. Concentrations of contaminants at the Outfall Site were expected to increase after the relocation of the outfall. The Large Navigation Buoy was also considered an impact site for mussels. Another BACI model was fit to the mussel tissue data using Deer Island Light as the impact location. Concentrations of contaminants were expected to decline at Deer Island Light after the relocation of the outfall. Although originally included in the monitoring program because of concerns that the effluent could impact Cape Cod Bay, there was no indication of impact and the Cape Cod locations were used as the control locations in the BACI analyses.

### 2.2.2 Analysis of Variance

A simpler ANOVA was used to assess differences in concentration between locations. The Outfall Site, East Cape Cod Bay, and Deer Island Flats were compared for flounder and lobster tissue samples. The Outfall Site, Cape Cod Bay, Deer Island Light, Boston Inner Harbor, and the Large Navigation Buoy were compared for mussel tissue contaminants. Separate comparisons were conducted for 2001, 2002, 2003, and 2006. Tissue contaminant monitoring did not occur consistently in 2004 and 2005. Results from additional locations that were not consistently sampled during these years were also excluded. These included flounder samples from Broad Sound (BS) (2002 only) and off of Nantasket Beach (NB) (2002 and 2006 only). Following the ANOVA for each year, pair-wise comparisons between locations were evaluated using an overall 95 percent confidence level. The most sensitive (smallest critical value) pair-wise comparison method was used, which in all cases was Tukey's method.

# 3.0 MUSSELS

## 3.1 BIOLOGY, ECOLOGY, AND BIOACCUMULATION

### 3.1.1 Distribution and Movement

The blue mussel (*Mytilus edulis*) is a common bivalve mollusk in coastal waters of the Arctic, North Pacific, and North Atlantic oceans (Newell 1989). Several aspects of the biology and natural history of the blue mussel make it a good indicator organism. One such aspect is their widespread distribution and abundance. In the western North Atlantic, blue mussels range from Labrador to Cape Hatteras, North Carolina (Newell 1989). They are common in the littoral and sublittoral zones (<99 m depth) throughout this range, and can be collected easily from the rocky intertidal zone, where they are often abundant. As an indicator organism, availability is a practical and logistical necessity.

Blue mussels are semi-sessile organisms that anchor to secure substrates using byssal threads secreted from glands in the animal's foot (Newell 1989). Mussels can reposition themselves, and achieve some limited mobility by adjusting the lengths of their byssal threads or secreting new ones. This enables them to avoid being smothered by accumulating sediments, to position more favorably in water currents, and even to move to the outside edge of mussel clumps. This also allows mussels to re-attach and position themselves for feeding, when deployed in cages as a sentinel organism, therefore the area in which they are exposed is well defined.

### 3.1.2 Feeding Ecology

Mussels are also ecologically important, both as a prey item to fish and wildlife in coastal ecosystems and as a filter feeder. Blue mussels are active suspension feeders, filtering organic particles from the water column and increasing water clarity. Adult mussels feed by pumping seawater through gills, which retain suspended particles. Phytoplankton are the dominant food item in the diet of blue mussels, but bacteria attached to detritus also serve as an important source of protein to the mussel. Filter feeding is an important pathway for exposure of mussels to contaminants in the water column.

### 3.1.3 Bioaccumulation and Indicator Species Potential

The tendency for mussels to bioaccumulate contaminants makes them useful biomonitoring organisms. For example, although mussels and other mollusks do possess active mixed-function oxygenase enzyme systems, the rate at which mussels can metabolize and eliminate organic contaminants, such as PAHs, is much slower than in vertebrates (Stegeman and Lech 1991). Although bioaccumulation of organic contaminants by invertebrates is influenced by a variety of biochemical and environmental factors, the concentration of organic contaminants in tissues of invertebrates does reflect the concentration of contaminant in the environment (Hellou 1996). Mussels and other aquatic invertebrates also accumulate heavy metals from the aquatic environment, but the net accumulation is not predictable by simple chemical partition coefficients, such as those that describe the affinity of an organic contaminant between water and lipid. Uptake of heavy metals by facilitated diffusion follows simple diffusion laws, but there may be corresponding automatic loss of metal from the body when the external concentration falls (Rainbow 1996). Digestive uptake of metals by invertebrates is fundamentally different than in vertebrates, since invertebrates possess the ability to take up metals by both extracellular and intracellular digestion, while vertebrates rely only

on the former (Roesijadi and Robinson 1994). The ultimate fate of various metals depends on how the particular organism handles the specific metal. As a general rule, heavy metals reach body concentrations in aquatic invertebrates that are orders of magnitude greater than external concentrations (Eisler 1981). Some species, such as mollusks, have physiological processes that store detoxified metals that are accumulated in excess of metabolic requirements.

All of the previously mentioned factors make mollusks a preferred organism for use in monitoring studies (Mix and Schaffer 1983; James 1989; O'Connor and Lauenstein 2006). In addition, mussels are also an important seafood product. Wild stocks support commercial fisheries, and farm-raised mussels are important in the aquaculture industry. As a seafood item, the public is interested in contaminant levels in mussels.

Blue mussels have become a widely used indicator of human-caused contamination. Since 1986, this organism has been used in the Mussel Watch Project, a monitoring program run by the National Status and Trends Program of NOAA to assess spatial distributions and temporal trends in contaminants (O'Connor 1998). Mussel Watch employs indigenous mussels to monitor contaminant concentrations in coastal and estuarine waters of the United States. The Gulfwatch program, a chemical contaminant-monitoring program for the Gulf of Maine, also uses indigenous blue mussels (Chase et al. 2001). By contrast, in MWRA's monitoring program, blue mussels are collected from a reference location and are then deployed in cages and recovered from Boston Harbor, Massachusetts Bay, and Cape Cod Bay. Regardless of whether indigenous populations or caged mussels are used, these national and regional databases can be used to help interpret MWRA's local results (see Hunt et al. 2006; Hunt et al. 2007).

### 3.1.4 Previous MWRA Findings

Concentrations of contaminants in fish and shellfish in the HOM program have been reported in a series of monitoring reports (http://www.mwra.state.ma.us/harbor/enquad/trlist.html). In the early part of the period after the outfall was relocated (2001–2003) concentrations of certain contaminants (mercury, lead, total DDT, total PCBs, total PAHs, total chlordane, dieldrin, hexachlorobenzene, lindane, and HMW PAH) were significantly higher in mussels deployed at the Outfall Site than during the pre-discharge period (1998–2000) (Wisneski et al. 2004). However, average post-discharge concentrations of some of these contaminants (mercury and lead) at the Outfall Site were similar to concentrations in pre-deployment mussels or were within the historical range measured at the Outfall Site throughout the program (most pesticides).

Total chlordane was an exception, being significantly higher in mussels deployed at the Outfall Site during the early post-discharge period in comparison to pre-discharge levels, and higher at the Outfall Site than at any other station in 2001 and 2002. In 2006, however, levels of chlordane trended substantially downward at the Outfall Site and were at or near historical lows at all stations (Nestler et al. 2007).

Similar to chlordane, concentrations of HMW PAH and total PAHs (mostly because of the contribution of HMW PAH) increased at the Outfall Site coincident with outfall startup. Although HMW PAHs at the Outfall Site were elevated in the post-discharge period (2001–2006) in comparison to pre-discharge, concentrations were lower in 2006 than in the earlier period (2001–2003) (Nestler et al. 2007).

Concentrations of total PAHs and total chlordane in mussels deployed at the Outfall Site exceeded contingency plan caution levels in 2001 and 2002, and PAH thresholds were exceeded in 2003 (Hunt et al. 2006). As a result of these exceedances, an investigative study was conducted to examine factors affecting contaminant levels and to assess the potential for environmental impact (Hunt et al. 2002). This study found that measured levels of PAHs and chlordane in mussels were below levels associated with impacts to growth and other chronic adverse impacts to aquatic organisms. In 2006, concentrations of total PAHs and chlordane were lower, and none of the contaminants exceeded the U.S. Food and Drug Administration (FDA) action limits or MWRA caution or warning thresholds.

## 3.2 RESULTS OF THE BACI

The BACI analyses address the question of whether contaminant levels at the impact sites changed since the outfall was relocated, and whether the observed changes were likely related to the relocation of the outfall. Changes that occurred at both the impact and the control locations are not likely to be related to the relocation of the outfall. As noted above, the "before" period is defined in two ways, as 1995–2000 and as 1998–2000, to account for changes in sampling and analysis that might have contributed to the variability in the samples. Note that there were no mussel samples collected at Cape Cod Bay during 1995–1997.

While BACI statistics were calculated for the 1995–2000 "before" period, interpretation of these results is hampered by lack of suitable control data (i.e., Cape Cod Bay). Therefore, only the results of the analysis using the 1998–2000 "before" period are discussed. All results (employing both the 1995–2000 and 1998–2000 "before" data) can be found in Appendix B (Tables B-1, B-2, and B-3 and Figures B-1 through B-8). The box plots use a log scale on the y-axis so that the distribution of the data can be visualized most effectively. The top part of each BACI table (Tables B-1, B-2, and B-3) presents the *P*-values for the various components of the final ANOVA model. After fitting the ANOVA, pair-wise comparisons were performed to evaluate the nature of the specific differences. The second part of each table presents conclusions that are based on the pair-wise comparison results. As previously noted in Section 2.2.1, if the interaction term is significant, conclusions drawn from the main effects are of little value since they can mask important interactions. Therefore, when the interaction term is significant, the interaction term takes precedence over the main effects in the interpretation of the results, and conclusions based on the main effects are not indicated in the lower portions of the BACI tables. Keep in mind that an impact from the relocation of the outfall can only be indicated by a significant interaction term but a significant interaction term does not necessarily indicate an impact as a result of the outfall relocation.

### 3.2.1 Outfall Site

Detailed results of the BACI analyses comparing the Outfall Site to the Cape Cod Bay control site are presented in Table B-1 in Appendix B. Table 3-1 summarizes only the before/after comparisons from these models. All contaminants, except mercury, have a significant interaction term, indicating a *potential* for an effect from relocation of the outfall. For mercury, concentrations at both locations are greater after relocation than before.This was also true for lead (Figure 3-1) but the increase at the Outfall Site was significantly more than the increase observed at Cape Cod Bay, likely indicative of an effect from relocation of the outfall. Although LWM PAHs have a significant interaction term and location differences, after accounting for year-to-year variability, concentrations after relocation decreased more at the Outfall Site than at Cape Cod Bay compared to before relocation.

**Table 3-1. Summary of Before/After Conclusions from the BACI Analysis of Concentrations in Mussel Tissue at the Outfall Site and the Large Navigation Buoy.**

| | Before/After Main Effect | Interaction Term | Before vs. After Assessment (before = 1998–2000) | | Outfall Effect Likely? | Explanation |
|---|---|---|---|---|---|---|
| **Outfall Site** | | | CCB | OS | | |
| Lead | NE | Signif. | After > Before | After > Before | Yes | outfall larger increase |
| Mercury | Signif. | Not Signif. | After > Before | After > Before | No | both increased after |
| PCBs | NE | Signif. | -- | After > Before | Yes | outfall increased after |
| HMW PAHs | NE | Signif. | -- | After > Before | Yes | outfall increased after |
| LMW PAHs (7) | NE | Signif. | Before > After | Before > After | No | no increase after |
| Total PAHs (19) | NE | Signif. | Before > After | After > Before | Yes | outfall increased after |
| Chlordane | NE | Signif. | Before > After | After > Before | Yes | outfall increased after |
| 4,4'-DDE | NE | Signif. | -- | After > Before | Yes | outfall increased after |
| **Large Navigation Buoy** | | | CCB | LNB | | |
| Lead | Signif. | Not Signif. | After > Before | After > Before | No | both increased after |
| Mercury | NE | Signif. | After > Before | After > Before | No | LNB smaller increase |
| PCBs | NE | Signif. | -- | After > Before | Yes | LNB increased after |
| HMW PAHs | NE | Signif. | -- | After > Before | Yes | LNB increased after |
| LMW PAHs (7) | NE | Signif. | Before > After | Before > After | No | no increase after |
| Total PAHs (19) | NE | Signif. | Before > After | After > Before | Yes | LNB increased after |
| Chlordane | NE | Signif. | Before > After | After > Before | Yes | LNB increased after |
| 4,4'-DDE | Not Signif. | Not Signif. | -- | -- | No | no increase after |

**Note:** Significance was determined using a 0.05 level (95 percent confidence)

-- - indicates no significant difference between before and after periods
BACI - Before-After-Control-Impact statistical analysis
CCB - Cape Cod Bay
LNB - Large navigation buoy
NE - not evaluated due to significance of interaction term
OS - Outfall location (includes stations OSM, OS-M1, OS-M2, OS-M3, OS-M4, OS-M5, and OS-M6)
PAH - polycyclic aromatic hydrocarbon
PCB - polychlorinated biphenyl
Chlordane: Sum of *cis*-chlordane and *trans*-nonachlor
LMW PAH (7): Sum of 7 low-molecular-weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene)
HMW PAH (12): Sum of 12 high-molecular-weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)
Total PAH (19): Sum of LMW PAH and HMW PAH
PCB: Sum of congeners 138 and 153

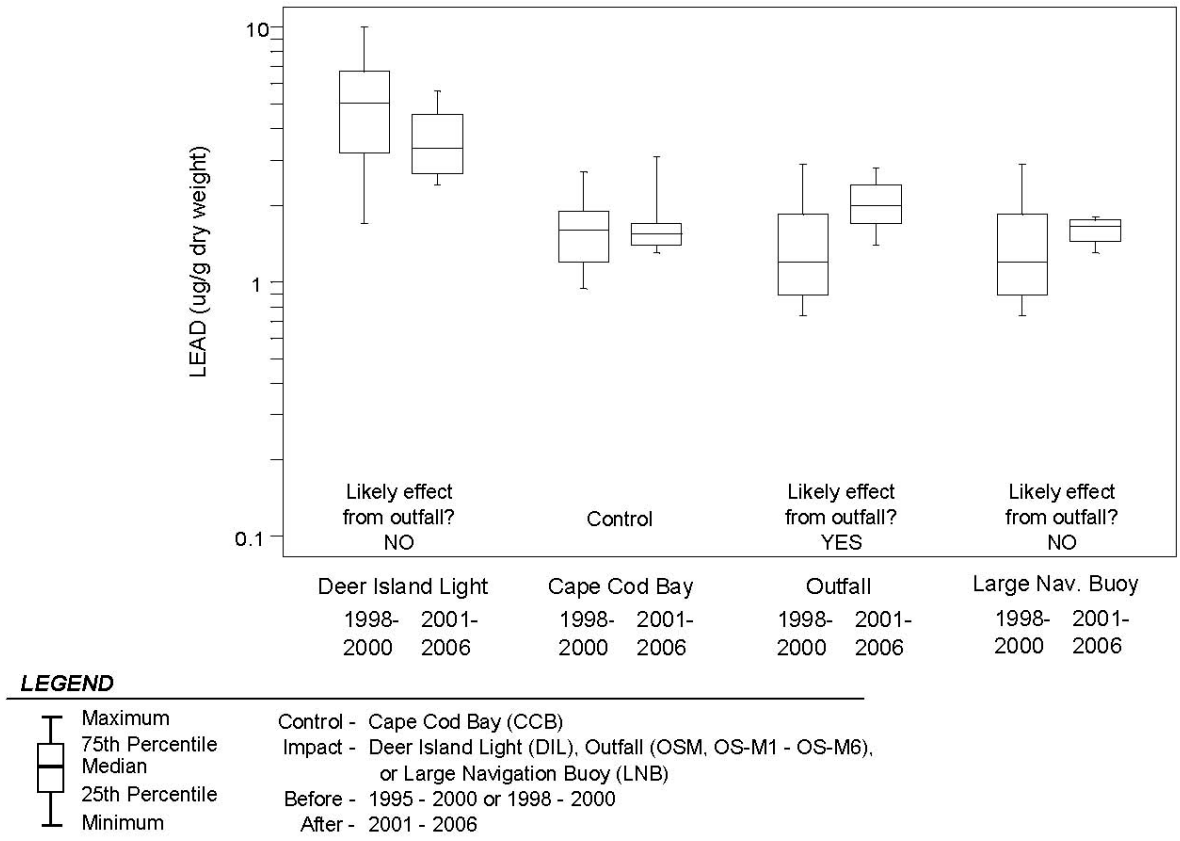



Figure 3-1. Comparison of lead concentrations measured in mussel soft tissue between control and impact locations before and after relocation of the outfall

Concentrations of all other contaminants, PCBs (Figure 3-2), HMW PAHs (Figure 3-3), total PAHs, chlordane (Figure 3-4), and 4,4'-DDE, have significant interaction terms and concentrations significantly *greater* at the Outfall Site after relocation than before, without a similar change at the control site.

Thus, concentrations of lead, PCBs, HMW PAHs, total PAHs, chlordane, and 4,4'-DDE in mussels at the Outfall Site have significantly increased since relocation of the outfall.

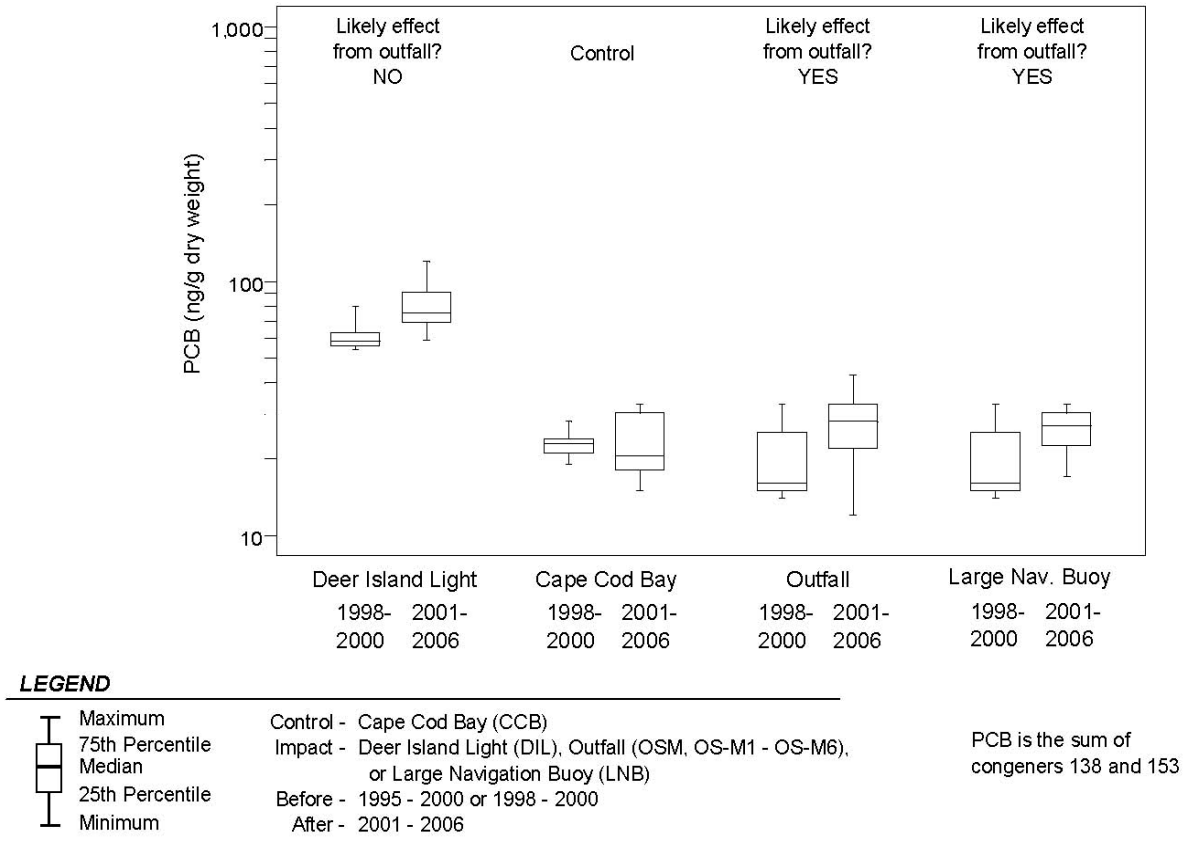



Figure 3-2. Comparison of PCB concentrations measured in mussel soft tissue between control and impact locations before and after relocation of the outfall

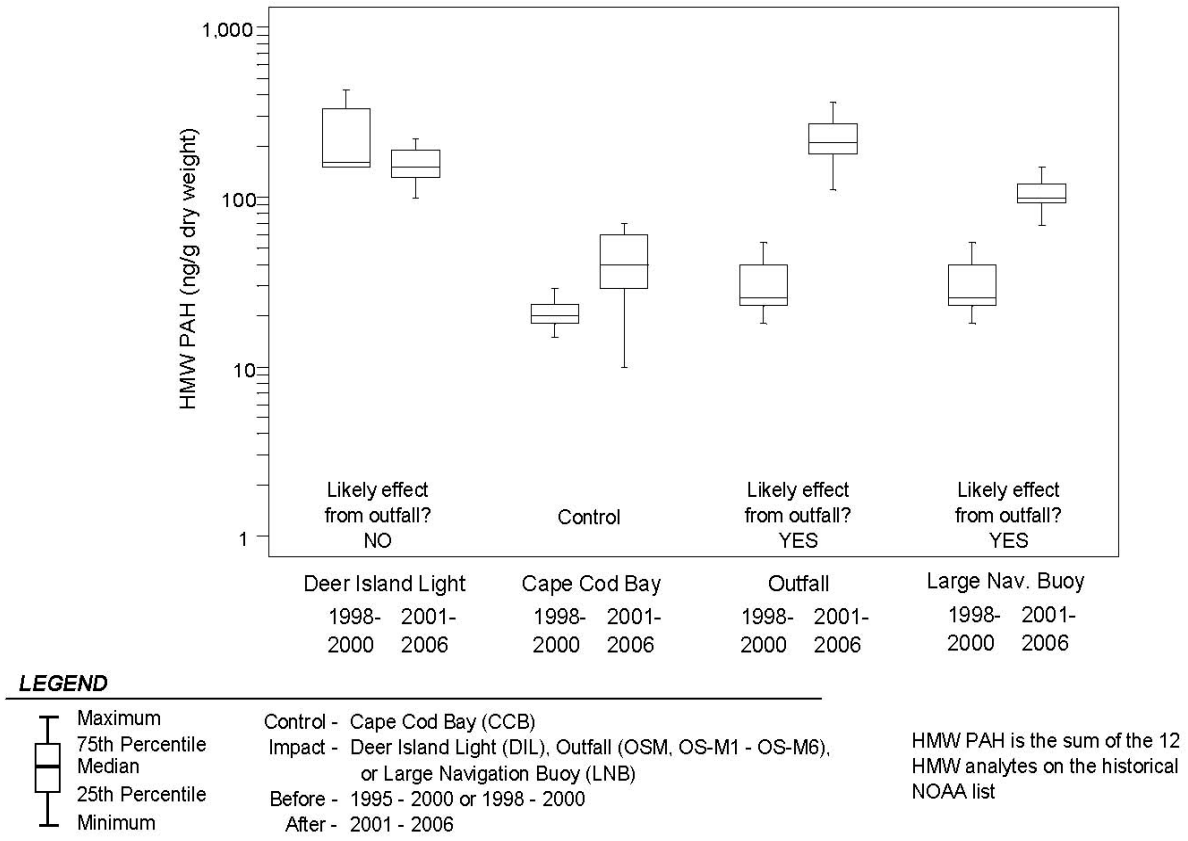



Figure 3-3. Comparison of high molecular weight (HMW) PAH concentrations measured in mussel soft tissue between control and impact locations before and after relocation of the outfall

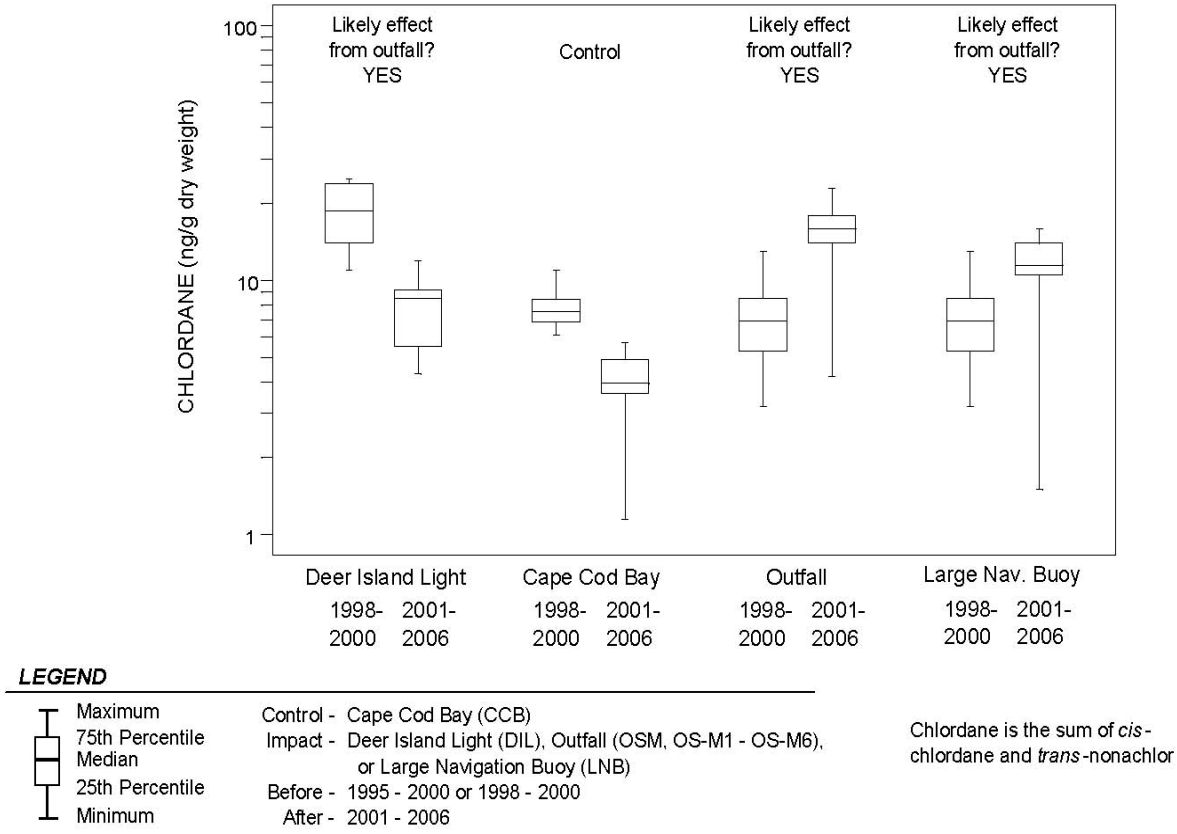



Figure 3-4. Comparison of chlordane concentrations measured in mussel soft tissue between control and impact locations before and after relocation of the outfall

### 3.2.2 Deer Island Light

Detailed results of the BACI analyses comparing concentrations at Deer Island Light with the Cape Cod Bay control site are presented in Table B-2 in Appendix B. Table 3-2 summarizes only the before/after comparisons from these models. Note that concentrations at Deer Island Light were expected to decline after the outfall was relocated away from Deer Island in 2000. The interaction terms were not significant for lead, mercury, LMW PAHs, total PAHs, and 4,4'-DDE. These compounds, except mercury, have significantly lower concentrations at both locations after relocation, but the change at Deer Island Light was not significantly more than at Cape Cod Bay, therefore the decrease cannot be attributed to the relocation. In contrast, chlordane also shows significantly lower concentrations at both locations after relocation, but the change at Deer Island Light is significantly larger than at the control site, likely indicative of impact from the outfall relocation. Concentrations of mercury were higher at both locations after relocation compared to the period before relocation. HMW PAHs showed no significant difference between periods for either location (Figure 3-3). Only PCBs (Figure 3-2) have a significant interaction term due to differences between periods at Deer Island Light than at the control site. However, post-relocation

concentrations of PCBs at Deer Island Light were significantly higher in comparison to the before period, contrary to expectations following movement of the outfall away from Deer Island Light.

**Table 3-2. Summary of Before/After Conclusions from the BACI Analysis of Concentrations in Mussel Soft Tissue at Deer Island Light.**

| | Before/After Main Effect | Interaction Term | Before vs. After Assessment (before = 1998–2000) | | Outfall Effect Likely? | Explanation |
|---|---|---|---|---|---|---|
| **Deer Island Light** | | | CCB | DIL | | |
| Lead | Signif. | Not Signif. | Before > After | Before > After | No | both decreased after |
| Mercury | Signif. | Not Signif. | After > Before | After > Before | No | no decrease after |
| PCBs | NE | Signif. | -- | After > Before | No | no decrease after |
| HMW PAHs | NE | Signif. | -- | -- | No | no decrease after |
| LMW PAHs (7) | Signif. | Not Signif. | Before > After | Before > After | No | both decreased after |
| Total PAHs (19) | Signif. | Not Signif. | Before > After | Before > After | No | both decreased after |
| Chlordane | NE | Signif. | Before > After | Before > After | Yes | DIL larger decrease |
| 4,4'-DDE | Signif. | Not Signif. | Before > After | Before > After | No | both decreased after |

**Note:** Significance was determined using a 0.05 level (95 percent confidence)
-- - indicates no significant difference between before and after periods
BACI - Before-After-Control-Impact statistical analysis
CCB - Cape Cod Bay
DIL - Deer Island Light
NE - not evaluated due to significance of interaction term
PAH - polycyclic aromatic hydrocarbon
PCB - polychlorinated biphenyl
Chlordane: Sum of *cis*-chlordane and *trans*-nonachlor
LMW PAH (7): Sum of 7 low-molecular-weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene)
HMW PAH (12): Sum of 12 high-molecular-weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)
Total PAH (19): Sum of LMW PAH and HMW PAH
PCB: Sum of congeners 138 and 153

Thus, in general, the results for mussels at Deer Island Light indicate no change between periods or similar changes at both locations that are not attributable to the relocation of the outfall away from Deer Island Light. Only chlordane concentrations show evidence of an effect due to the relocation of the outfall away from Deer Island Light.

### 3.2.3 Large Navigation Buoy

Detailed results of the BACI analyses comparing concentrations at the Large Navigation Buoy with the Cape Cod Bay control site are presented in Table B-3 in Appendix B. Table 3-1 summarizes only the before/after comparisons from these models. All contaminants, except lead and 4,4'-DDE, have a significant interaction term, indicating a *potential* for an effect from relocation of the outfall (see Figure 3-1 for lead). Concentrations of PCBs, HMW PAHs, total PAHs, and chlordane have significant interaction terms and concentrations significantly *greater* at the Outfall Site after relocation than before, without a similar change at the control site (Figures 3-2, 3-3, and 3-4). Although LWM PAHs have a significant interaction term and location differences, after accounting

for year-to-year variability, post-relocation concentrations lowered more at the Outfall Site than Cape Cod Bay. For mercury, concentrations at both locations are greater after relocation than before but the increase was smaller at the Large Navigation Buoy than at the control site.

## 3.3 RESULTS OF THE ANOVA

This section addresses the question of whether current contaminant levels in mussels are different among the Outfall Site, Boston Harbor, and a reference site. Figures B-9 to B-16 in Appendix B show the measured concentrations at each location for each year of data analyzed. Results of the ANOVA analyses for each year since the relocation of the outfall are presented in Table 3-3 and Table B-4 of Appendix B. Tukey's multiple comparison test was used to test for pair-wise differences between locations at an overall 95 percent confidence level. Table 3-3 and Table B-4 present the comparisons of locations listed in each row to locations listed in each column for the various years. The location abbreviation entered at the intersection of each row-by-column comparison indicates the location that has a significantly higher concentration. Dashed entries indicate no significant difference in concentration between locations.

In general, concentrations of most compounds in most years tend to be highest at the Inner Harbor, next highest at Deer Island Light, lower at the Outfall Site, and lowest at Cape Cod Bay and the Large Navigation Buoy (e.g., Figure 3-5 for lead). HMW PAHs (2003 only) and chlordane (2001–2003) were exceptions, however, with concentrations at the Outfall Site that were significantly higher than at Deer Island Light (Figures 3-6 and 3-7). In addition, 2006 concentrations of mercury (Figure 3-8) at the Outfall Site are not significantly different from those at Cape Cod Bay, and 2006 concentrations of PCBs (Figure 3-9) are significantly *lower* at the Outfall Site in comparison to Cape Cod Bay.

**Table 3-3. Summary of Comparisons between Locations by Year for Mussel Soft Tissue.**

| | 2001 | | | | 2002 | | | | 2003 | | | | 2006 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OS | DIL | CCB | IH | OS | DIL | CCB | IH | OS | DIL | CCB | IH | OS | DIL | CCB | IH |
| **Lead** | | | | | | | | | | | | | | | | |
| | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | |
| DIL | DIL | | | | DIL | | | | DIL | | | | DIL | | | |
| CCB | -- | DIL | | | OS | DIL | | | -- | DIL | | | -- | DIL | | |
| IH | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | | IH | -- | IH | |
| LNB | nd | nd | nd | nd | OS | DIL | -- | IH | -- | DIL | -- | IH | -- | DIL | -- | IH |
| **Mercury** | | | | | | | | | | | | | | | | |
| | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | 0.0086 | |
| DIL | -- | | | | -- | | | | -- | | | | -- | | | |
| CCB | OS | -- | | | OS | DIL | | | OS | -- | | | -- | -- | | |
| IH | -- | IH | IH | | IH | -- | IH | | IH | IH | IH | | IH | -- | -- | |
| LNB | nd | nd | nd | nd | OS | DIL | LNB | IH | OS | DIL | -- | IH | -- | -- | -- | IH |
| **PCB** | | | | | | | | | | | | | | | | |
| | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | |
| DIL | DIL | | | | DIL | | | | DIL | | | | DIL | | | |
| CCB | -- | DIL | | | OS | DIL | | | OS | DIL | | | CCB | DIL | | |
| IH | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | | IH | -- | IH | |
| LNB | OS | DIL | -- | IH | -- | DIL | LNB | IH | -- | DIL | LNB | IH | -- | DIL | -- | IH |
| **HMW PAH** | | | | | | | | | | | | | | | | |
| | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | |
| DIL | -- | | | | -- | | | | OS | | | | -- | | | |
| CCB | OS | DIL | | | OS | DIL | | | OS | DIL | | | OS | DIL | | |
| IH | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | |
| LNB | OS | DIL | LNB | IH | OS | -- | LNB | IH | OS | -- | LNB | IH | OS | -- | LNB | IH |
| **LMW PAH (12)** | | | | | | | | | | | | | | | | |
| | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | 0.0001 | |
| DIL | DIL | | | | -- | | | | -- | | | | -- | | | |
| CCB | -- | DIL | | | OS | DIL | | | OS | DIL | | | OS | DIL | | |
| IH | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | |
| LNB | -- | DIL | -- | IH | -- | -- | LNB | IH | OS | -- | LNB | IH | OS | -- | -- | IH |
| **Total PAH (24)** | | | | | | | | | | | | | | | | |
| | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | |
| DIL | -- | | | | -- | | | | OS | | | | -- | | | |
| CCB | OS | DIL | | | OS | DIL | | | OS | DIL | | | OS | DIL | | |
| IH | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | |
| LNB | OS | DIL | LNB | IH | OS | -- | LNB | IH | OS | -- | LNB | IH | OS | -- | LNB | IH |

| | 2001 | | | | 2002 | | | | 2003 | | | | 2006 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OS | DIL | CCB | IH | OS | DIL | CCB | IH | OS | DIL | CCB | IH | OS | DIL | CCB | IH |
| **Chlordane** | | | | | | | | | | | | | | | | |
| | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | 0.0002 | |
| DIL | OS | | | | OS | | | | OS | | | | -- | | | |
| CCB | OS | DIL | | | OS | DIL | | | OS | DIL | | | OS | DIL | | |
| IH | OS | IH | IH | | OS | IH | IH | | IH | IH | IH | | -- | -- | IH | |
| LNB | OS | LNB | LNB | -- | OS | LNB | LNB | -- | OS | -- | LNB | IH | -- | -- | -- | IH |
| **4,4'-DDE** | | | | | | | | | | | | | | | | |
| | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | 0.0001 | |
| DIL | DIL | | | | -- | | | | DIL | | | | DIL | | | |
| CCB | CCB | DIL | | | OS | DIL | | | -- | DIL | | | -- | -- | | |
| IH | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | | IH | -- | -- | |
| LNB | OS | DIL | CCB | IH | -- | DIL | LNB | IH | -- | DIL | -- | IH | -- | DIL | -- | IH |

**Note:** *P*-value is from the ANOVA model. Tukey's multiple comparison test was used to test for pariwise differences between locations at an overall 95 percent confidence level.
Location abreviation indicates location has significantly higher concentration.

-- - indicates no significant difference in concentration between locations
CCB - Cape Cod Bay
DIL - Deer Island Light
IH - Boston inner harbor
LNB - Large navigation buoy
nd - no data available
OS - outfall location (includes stations OSM, OS-M1, OS-M2, OS-M3, OS-M4, OS-M5, and OS-M6)
PAH - polycyclic aromatic hydrocarbon
PCB - polychlorinated biphenyl
Chlordane: Sum of *cis*-chlordane and *trans*-nonachlor
LMW PAH (12): Sum of 12 low molecular weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene, 1-methylnaphthalene, 1-methylphenanthrene, 2,3,5-triethylnaphthalene, 2,6-dimethylnaphthalene, and 2-methylnaphthalene)
HMW PAH: Sum of 12 high molecular weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)
Total PAH (24): Sum of LMW PAH and HMW PAH
PCB: Sum of congeners 138 and 153

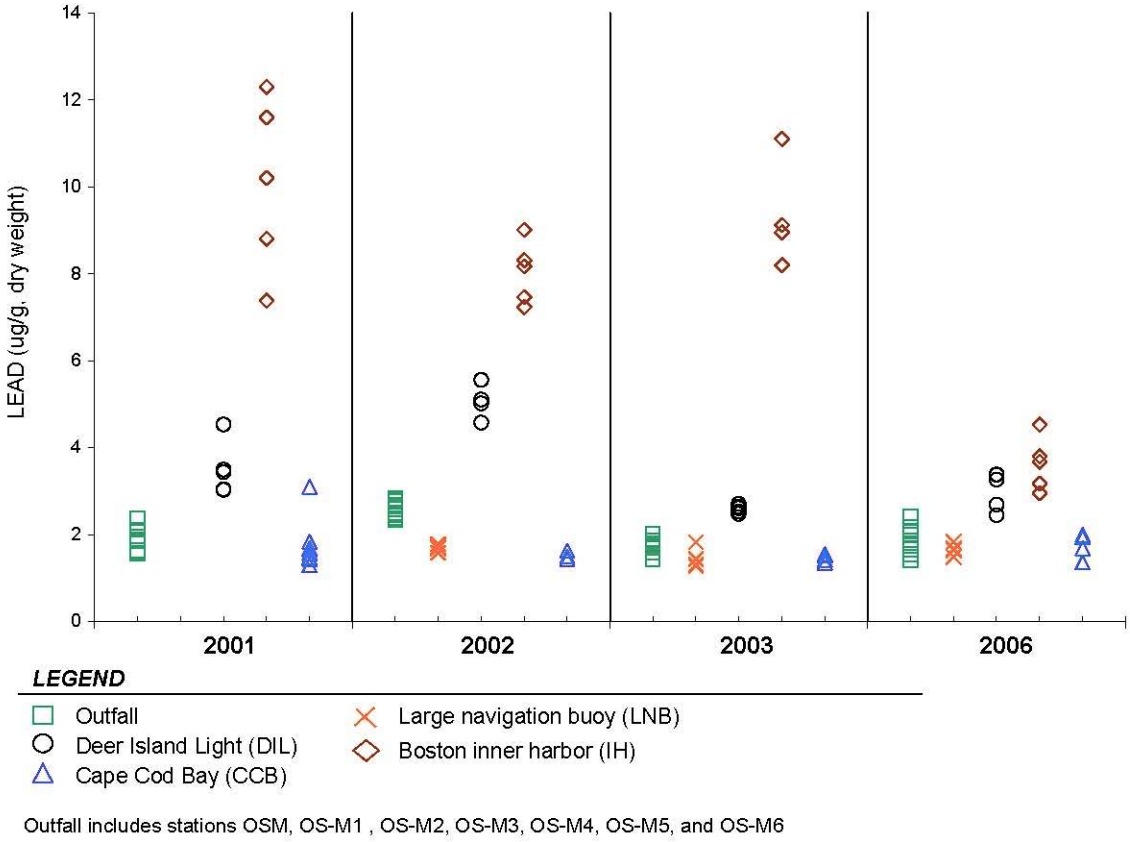



Figure 3-5. Lead concentrations in mussel soft tissue after the outfall went on-line

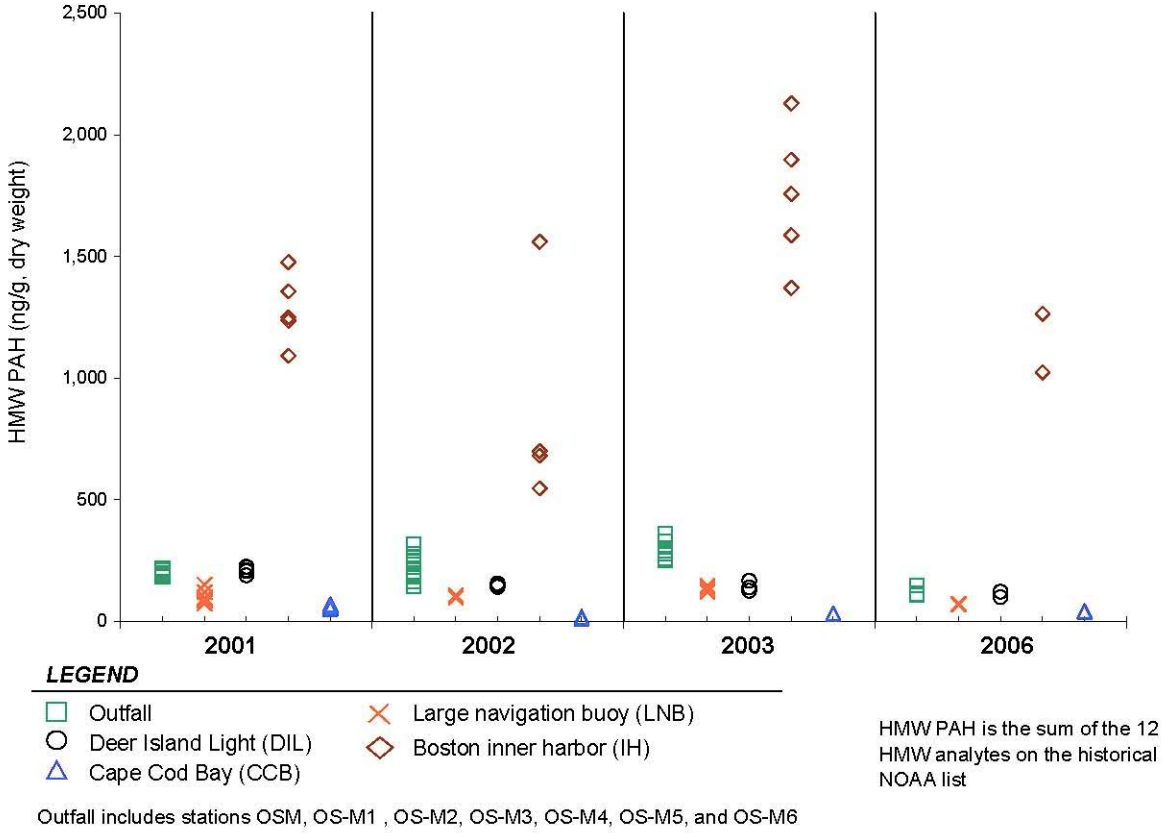



Figure 3-6. High molecular weight (HMW) PAH concentrations in mussel soft tissue after the outfall went on-line

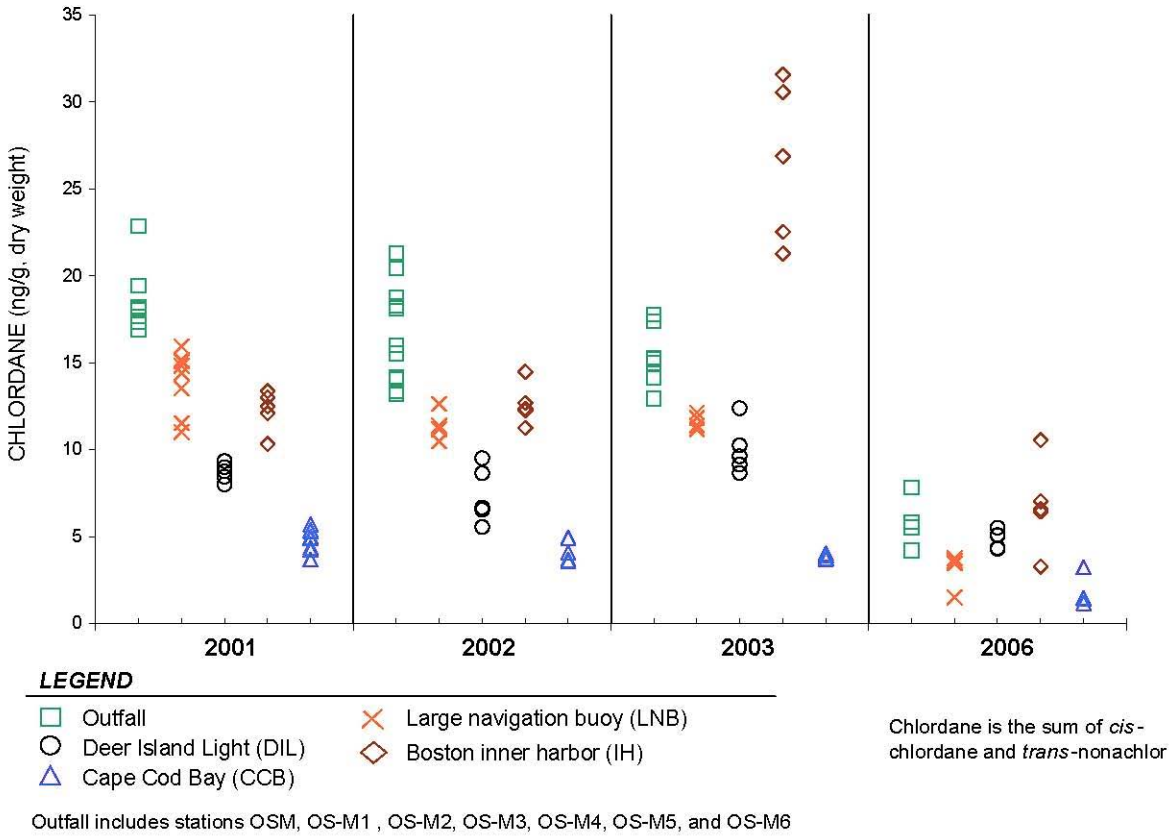



Figure 3-7. Chlordane concentrations in mussel soft tissue after the outfall went on-line

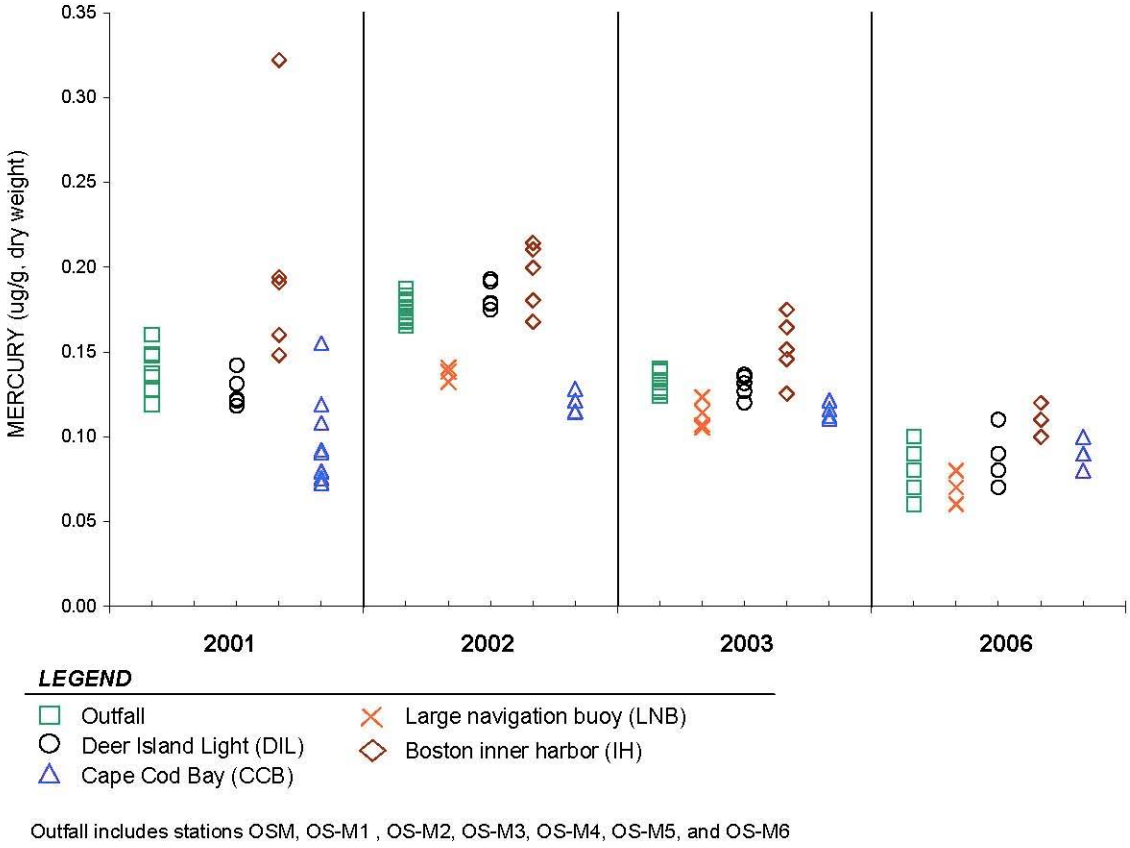



Figure 3-8. Mercury concentrations in mussel soft tissue after the outfall went on-line

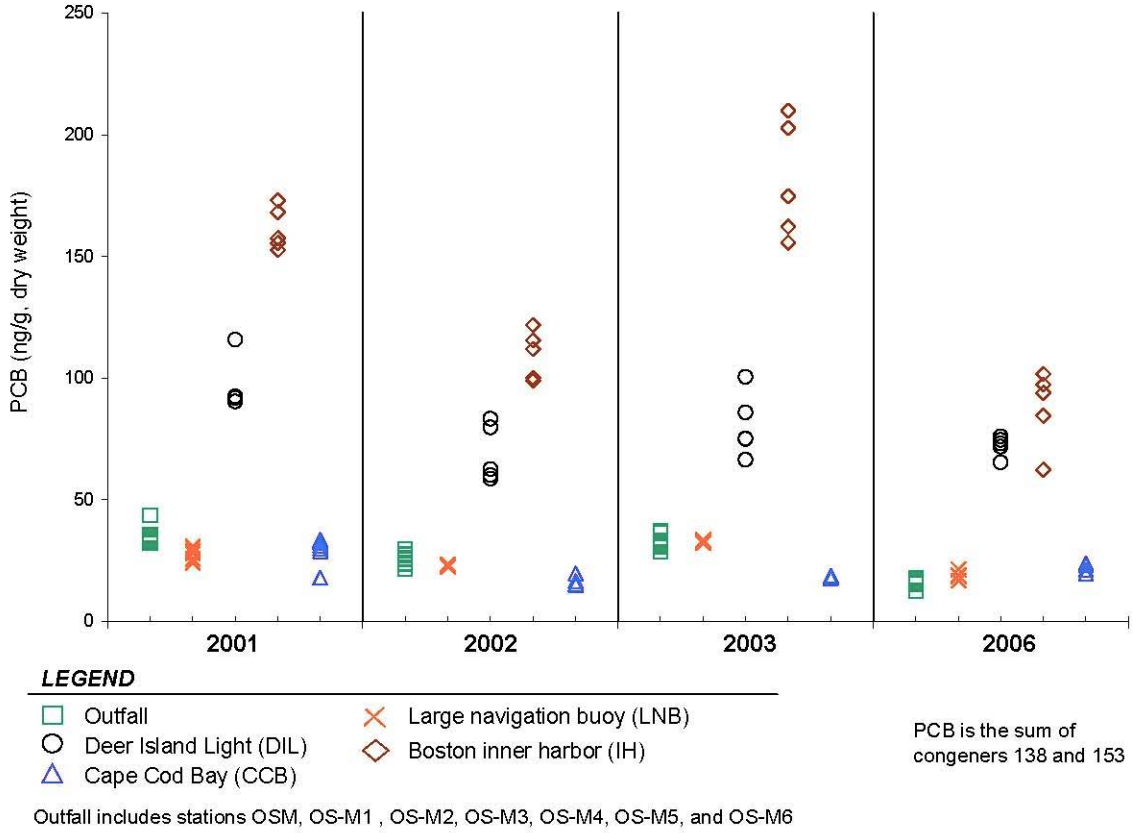



Figure 3-9. PCB concentrations in mussel soft tissue after the outfall went on-line

# 4.0 LOBSTER

## 4.1 BIOLOGY, ECOLOGY, AND BIOACCUMULATION

### 4.1.1 Distribution and Movement

American lobster (*Homarus americanus*) range from Labrador south to North Carolina and from the intertidal zone to a depth of 720 m, but major concentrations of lobster are in the Gulf of Maine and coastal waters of New Brunswick and Nova Scotia (MacKenzie and Moring 1985). American lobsters are widely distributed in coastal waters in the northeastern United States. Similar to many marine animals, adult lobsters display seasonal movements, which include nomadism, migration, and homing that are characterized by varying scales. In general, the annual scale of movement is driven in part by thermal advantages.

Tagging studies have shown that movements of juvenile and adult lobsters in inshore populations are generally local, with seasonal movements less than 25 km (Lawton and Lavalli 1995). In a tagging study off Maine, 2,882 tagged American lobsters were released at three locations and by 2.5 years later, 88% of the recaptures were within 9.3 km of the release site and about 1% were recaptured more than 18.5 km from the release site (Krouse 1981). Correlated walk models using telemetry data of lobster populations in the Gulf of St. Lawrence showed two movement behaviors: residents and dispersers (Bowlby et al. 2007). While resident lobsters generally remain within the release area, dispersers typically make rapid movements away from release sites in autumn and a slow return in the spring (Bowlby et al. 2007). In a similar study of 8,503 recaptures, lobsters (51–152 mm carapace length) traveled an average distance that ranged from 2 to 19 km among the release sites in the Gulf of St. Lawrence (Comeau and Savoie 2002). The distances traveled in the study by Comeau and Savoie (2002) were not correlated to size, sex, or years at large. Ultrasonic telemetry and tag/recapture of lobsters in and around Great Bay estuary and coastal New Hampshire showed movements of less than 5 km toward the coast (Watson et al. 1999). In this study lobsters were tracked for up to a year and showed site-specific residency times of 2 to 4 weeks followed by rapid movement to new locations. Lobsters show greater growth in response to the warmer estuarine temperatures during summer, but move downriver toward the coast during spring and fall to avoid low salinity events (Watson et al. 1999). Lobsters respond to storm disturbances with movements of 5 km or less in horizontal displacement (Haakonsen and Anoruo 1994). The impression held by commercial fishers of the occurrence of large seasonal inshore-offshore migrations of inshore populations of adult lobsters is likely explained by temperature-related differences in catchability and seasonal removal by high fishing pressure (Lawton and Lavalli 1995).

A portion of some inshore lobster populations has been observed moving over long distances. Recapture of 4,304 lobsters tagged and released in inshore areas off southwestern Nova Scotia showed that 69% of immature lobsters and 40% of mature lobsters were recaptured less than 18.5 km from the release sites (Campbell and Stasko 1985). About 20% of the mature lobsters in this study were recaptured over 92.6 km (50 nautical miles) from the release site. In a similar study, Campbell and Stasko (1986) showed that lobsters tagged and released at three locations in the Bay of Fundy made movements indicating some intermixing of populations within the Bay of Fundy and throughout the Gulf of Maine and adjoining Continental Shelf. The seasonal shallow-deep migration of mature lobsters that Campbell and Stasko (1986) observed was possibly associated with optimizing

temperature exposure for molting, growth, gonadal development, and egg development, with distances and directions of movement dependent on local topography.

Long distance movements of tagged lobsters from offshore populations have shown some lobsters make seasonal migrations. Off southern New England, approximately 20% of offshore lobster populations migrate inshore in spring and summer and migrate offshore in the fall and winter (Cooper and Uzmann 1971). Offshore lobsters from the Scotian Shelf and eastern Gulf of Maine make seasonal migrations to Georges and Browns Banks (Lawton and Lavalli 1995). It is thought that these movements are made to maintain an 8–14°C temperature range, resulting in faster growth (Lawton and Lavalli 1995). Rates of movement over ground for migratory offshore lobsters range from 7.4 to 9.3 km per day (Lawton and Lavalli 1995). Tag-recapture studies of offshore lobsters have shown examples of homing behavior as well (Lawton and Lavalli 1995). Ovigerous lobsters of offshore populations move to shallower offshore areas such as Georges and Browns Banks during summer months, often returning to the same location in successive years (Lawton and Lavalli 1995).

### 4.1.2 Habitat and Feeding Ecology

Juvenile lobsters prefer to settle on cobble beds, probably to avoid predation (Palma et al. 1998; Castro et al. 2001). Lobsters also inhabit kelp beds, particularly around the perimeter (Bologna and Steneck 1993). The selective habitat-seeking behavior and lower post-settlement mortality of lobsters are consistent with their lower fecundity and later onset of reproductive maturity, as compared to other crustaceans. Because there is a positive relationship between larval density and settlement, any process that affects the density of larval lobsters available for settlement may result in a change in the density of benthic stages. The density of lobsters from new recruits to sexually mature females can be predicted based on larval mortality rates, postlarval abundance, and available habitat for settlement (Incze et al. 2003).

Presence of physical shelter that can be used to escape predation is an important factor for small lobsters (Spanier et al. 1998, Castro et al. 2001). Lack of shelter causes lobsters to modify their behavior and places them at a greater risk of predation. Intraspecific shelter competition may drive declines of preharvestable-sized lobsters in shallow coastal zones and increase their abundance in offshore and deep waters (Steneck 2006). In small-scale experiments, Steneck (2006) showed that large lobsters leave or avoid areas of high population density and intense competition for low populated areas with less shelter competition.

Changes in water temperature can affect lobster catches. Increases in lobster catch have been correlated with increasing water temperature (Fogarty 1988; Campbell et al. 1991). Higher water temperature increases the activity level of lobsters, making them more likely to enter traps. Catch rates are shown to increase with higher bottom water temperatures and decrease with lower water temperatures 24 hours prior to traps being hauled (Drinkwater et al. 2006). Relative abundance of lobster and mean surface water temperatures in June through November in previous years are also correlated. Huntsman (1923; cited in Harding et al. 1983) hypothesized that warm summer surface water stimulates rapid growth of planktonic larvae so that the larval stages are completed and settlement occurs before the onset of cooler temperatures halts development. Dow (1977) also found significant correlations between sea surface temperature and lobster catches 4 to 7 years later. A similar relationship was found between water temperature and lobster catch in Maine six years later

(Fogarty 1988), and in Nova Scotia four years (Campbell et al. 1991) and six to eight years later (Koeller 1998).

Peak feeding season for adult lobsters is between June and July, but feeding activity may remain high through September for males and through February for females (Lawton and Lavalli 1995). Activity of lobsters is generally highest during the night, but offshore lobsters and inshore lobsters inhabiting turbid waters may also be active during daylight (Lawton and Lavalli 1995). Daily foraging activity is typically limited to around 100 m to 2 km (Lawton and Lavalli 1995).

### 4.1.3 Bioaccumulation

The ability of aquatic invertebrates to take up contaminants from the environment has been well documented (Mix 1984; Roesijadi and Robinson 1994). In contrast to mollusks, which tend to have lower rates of metabolism and elimination of organic contaminants, certain species of crustaceans can metabolize organic contaminants relatively rapidly (James 1989). However, rates of metabolism by the American lobster, *H. americanus*, are slow and organic contaminants tend to accumulate in the hepatopancreas. For example, the half-life of a single dose of benzo[a]pyrene within *H. americanus* was estimated to be more than 2 months (Bend et al. 1981). Much less is known about the mechanisms and rates of elimination of metals from aquatic organisms than is known about the uptake and accumulation. The variety of mechanisms used to eliminate metals is complex and specific to the species and to the metal. Observed rates of release are often described by a two-compartment model, in which metals are more easily mobilized and exchanged from a rapidly releasing compartment than from a slowly releasing compartment in which metals are tightly bound (Roesijadi and Robinson 1994). Rapid accumulation and relatively slow rates of elimination contribute to the usefulness of the American lobster as a monitoring organism.

### 4.1.4 Suitability as an Indicator Species

As mentioned, lobsters make seasonal long-distance migrations between inshore and offshore waters. While lobsters have been easily available in Boston Harbor and Cape Cod Bay during the summer and early fall, they have rarely been available at the Outfall Site until the fall (Lefkovitz et al. 2001; Nestler et al 2007). It is the prevailing view among lobstermen that lobsters reach the area of the outfall in early to mid fall as part of their offshore migration. The rapid accumulation but relatively slow rate of elimination of contaminants makes lobster a good indicator species in areas where the lobsters are known to spend a considerable amount of time (e.g., Deer Island and Cape Cod Bay). However, in regions where they are more transient, like the outfall area, their benefit as an indicator species is greatly reduced.

### 4.1.5 Previous MWRA Findings

Previous HOM documents have reported that the highest levels of organic contaminants tended to be found in lobsters collected from Deer Island Flats in Boston Harbor and the lowest levels were typically found at East Cape Cod Bay (Nestler et al. 2007). In general, 2006 concentrations in lobster meat were comparable to, or at the lower end of, the historical range across all stations. Concentrations in hepatopancreas of several organic compounds increased in 2006 in comparison to 2003. For example, the concentrations of 4,4'-DDE at all locations were dramatically higher in 2006 than in previous years, matching historical highs at Deer Island Flats and East Cape Cod Bay. Increases were also observed in chlordane and selected PAHs at some locations. Levels of PCB

congeners 138 and 153 were generally comparable to historical levels. Concentrations of metals in 2006 were also generally within historical ranges. A few metals, however, were at the upper end of the historical range, including nickel at Deer Island Flats and zinc at the Outfall Site (Nestler et al. 2007).

## 4.2 RESULTS OF THE BACI

The BACI analyses address the question of whether contaminant levels at the Outfall Site have changed since the outfall was relocated, and whether the observed changes were likely related to the relocation. As noted above, the "before" period is defined in two ways, as 1995–2000 and as 1998–2000, to account for changes in sampling and analysis that might have contributed to the variability in the samples. All results (employing both the 1995–2000 and 1998–2000 "before" data) can be found in Appendix B (Tables B-5 and B-6 and Figures B-17 through B-30). The top part of each BACI table presents the *P*-values for the various components of the final ANOVA model. After fitting the ANOVA, pair-wise comparisons are performed to evaluate the nature of the specific differences. The second part of each table presents conclusions that are based on the pair-wise comparison results. As previously noted in Section 2.2.1, if the interaction term is significant, conclusions drawn from the main effects are of little value since they can mask important interactions. Therefore, when the interaction term is significant, the interaction term takes precedence over the main effects in the interpretation of the results, and conclusions based on the main effects are not indicated in the lower portions of the BACI tables. Keep in mind that an impact from the relocation of the outfall can only be indicated by a significant interaction term, but a significant interaction term does not necessarily indicate an impact from the outfall relocation.

Results of the BACI for lobster meat are presented in Tables 4-1 and B-5, Figures 4-1 and 4-2 and Figures B-17 to B-20. Table 4-1 summarizes only the before/after comparisons from these models. None of the results for lobster meat showed significant interactions that would indicate a potential for an effect from relocation of the outfall. None of the interaction terms for any of the parameters were significant when employing the 1998–2000 "before" data. Only chlordane showed a significant interaction when using the 1995–2000 "before" data, but in that case, the concentration of chlordane significantly decreased in the later period. Concentrations of PCBs (Figure 4-1) and 4,4'-DDE showed no change between time periods, whereas mercury and chlordane (Figure 4-2) were significantly lower at both stations after relocation of the outfall.

Results of the BACI analyses for lobster hepatopancreas are presented in Tables 4-1 and B-6, Figures 4-3 through 4-5, and Figures B-21 to B-30. Table 4-1 summarizes only the before/after comparisons from the BACI models. Of the 20 analyses, only concentrations of lead in the comparison using the 1995–2000 data had a significant interaction term (Table B-6). In this case, lead increased only at East Cape Cod Bay, but did not significantly change at the Outfall Site, between time periods (Figures 4-3 and B-23). In most other cases, concentrations decreased or stayed the same after relocation of the outfall. Cadmium and copper significantly increased at both sites after relocation when employing the 1995–2000 "before" data (Figures 4-4 and B-22 for copper). Although total PAHs and HMW PAH (Figure 4-5) concentrations show a possible increase at the Outfall Site, this difference was not statistically significant because of the large variability during the period after relocation. In summary, none of the results for lobster hepatopancreas indicate a potential for an effect from relocation of the outfall.

**Table 4-1. Summary of Before/After Conclusions from the BACI Analysis of Concentrations in Lobster Meat and Lobster Hepatopancreas at the Outfall Site.**

| | Before/After Main Effect | Interaction Term | Before vs. After Assessment (before = 1998–2000) | | Outfall Effect Likely? | Explanation |
|---|---|---|---|---|---|---|
| **Lobster Meat** | | | ECCB | OS | | |
| Mercury | Signif. | Not Signif. | Before > After | Before > After | No | no increase after |
| PCBs | Not Signif. | Not Signif. | -- | -- | No | no increase after |
| Chlordane | Signif. | Not Signif. | Before > After | Before > After | No | no increase after |
| 4,4'-DDE | Not Signif. | Not Signif. | -- | -- | No | no increase after |
| | | | | | | |
| **Lobster Hepatopacreas** | | | ECCB | OS | | |
| Cadmium | Not Signif. | Not Signif. | -- | -- | No | no increase after |
| Copper | Not Signif. | Not Signif. | -- | -- | No | no increase after |
| Lead | Not Signif. | Not Signif. | -- | -- | No | no increase after |
| Mercury | Signif. | Not Signif. | Before > After | Before > After | No | no increase after |
| PCBs | Signif. | Not Signif. | Before > After | Before > After | No | no increase after |
| HMW PAHs | Not Signif. | Not Signif. | -- | -- | No | no increase after |
| LMW PAHs (7) | Not Signif. | Not Signif. | -- | -- | No | no increase after |
| Total PAHs (19) | Not Signif. | Not Signif. | -- | -- | No | no increase after |
| Chlordane | Signif. | Not Signif. | Before > After | Before > After | No | no increase after |
| 4,4'-DDE | Signif. | Not Signif. | Before > After | Before > After | No | no increase after |

**Note:** Significance was determined using a 0.05 level (95 percent confidence)

-- - indicates no significant difference between before and after periods

BACI - Before-After-Control-Impact statistical analysis

ECCB - East Cape Cod Bay

OS - Outfall location

PAH - polycyclic aromatic hydrocarbon

PCB - polychlorinated biphenyl

Chlordane: Sum of *cis*-chlordane and *trans*-nonachlor

LMW PAH (7): Sum of 7 low-molecular-weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene)

HMW PAH (12): Sum of 12 high-molecular-weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)

Total PAH (19): Sum of LMW PAH and HMW PAH

PCB: Sum of congeners 138 and 153

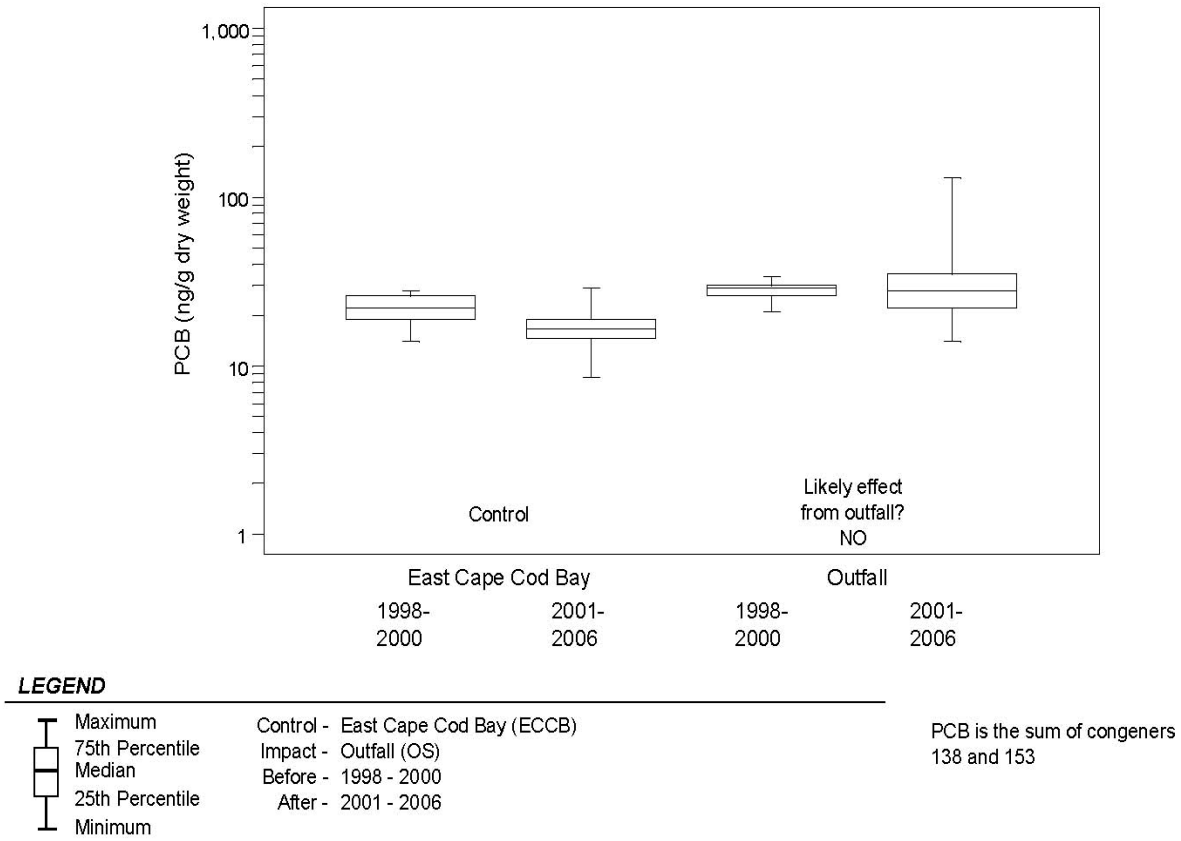



Figure 4-1. Comparison of PCB concentrations measured in lobster meat between control and impact locations before and after relocation of the outfall

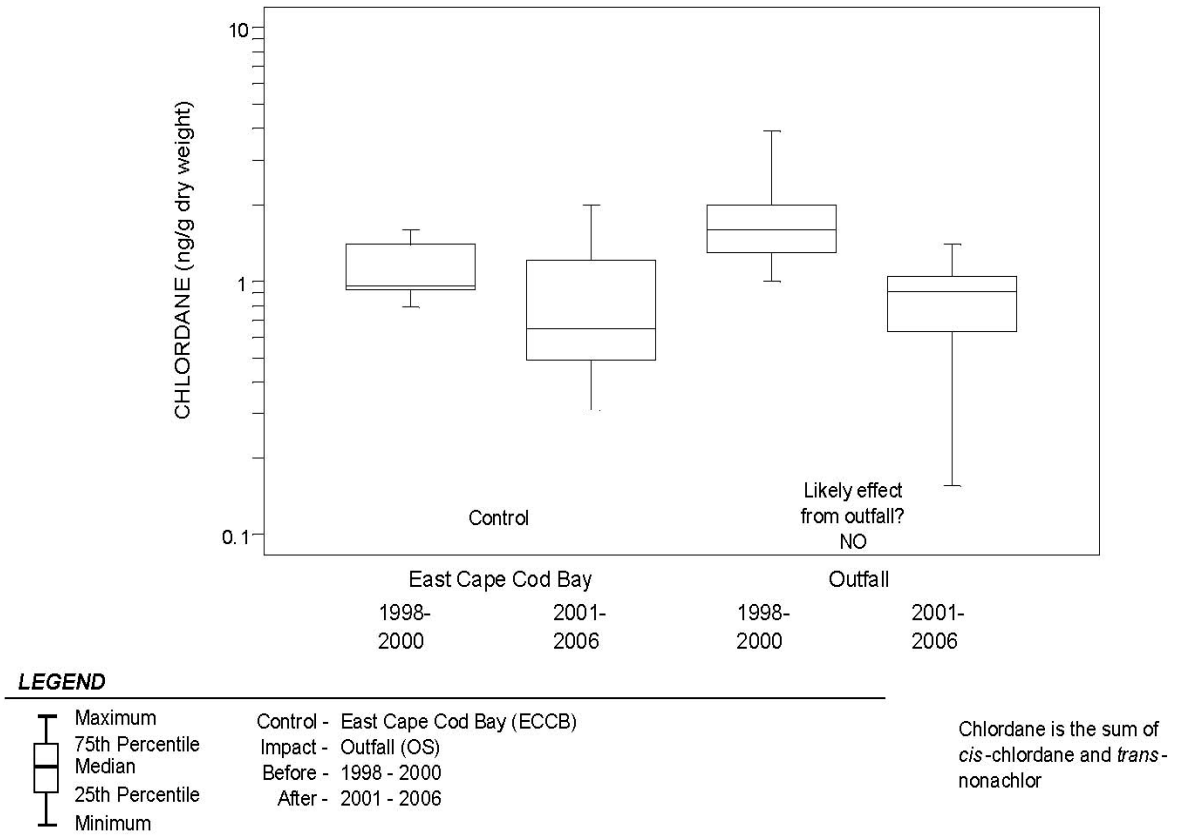



Figure 4-2. Comparison of chlordane concentrations measured in lobster meat between control and impact locations before and after relocation of the outfall

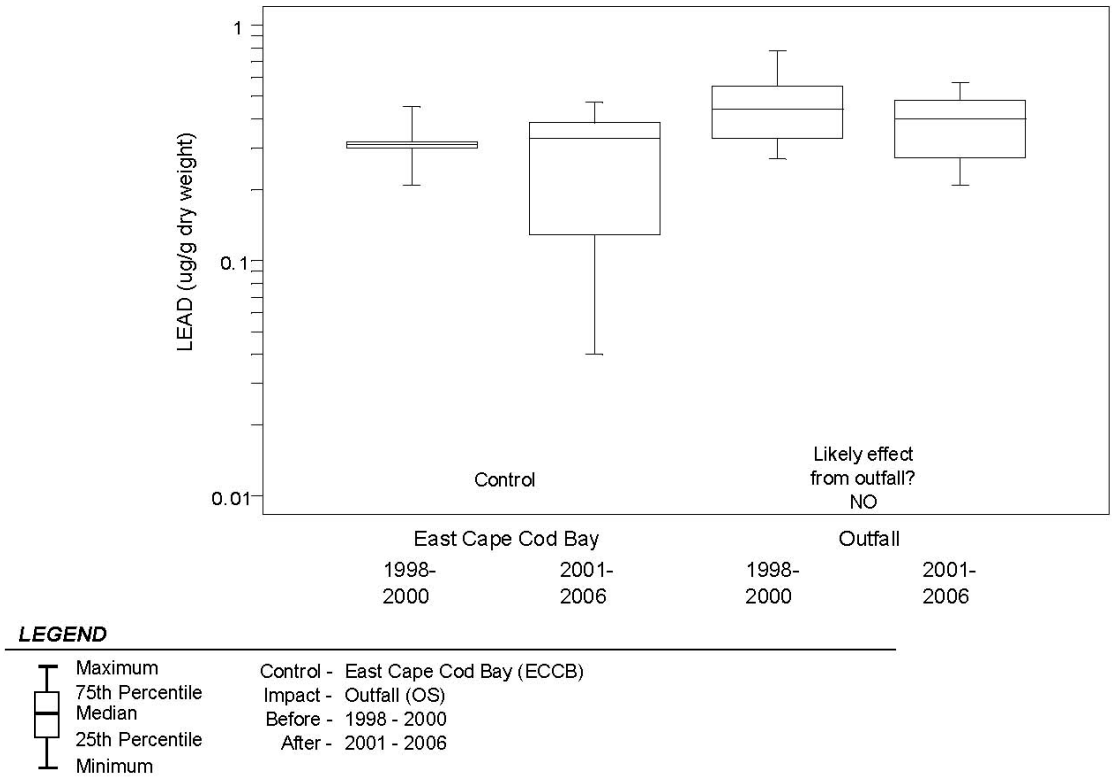



Figure 4-3. Comparison of lead concentrations measured in lobster hepatopancreas between control and impact locations before and after relocation of the outfall

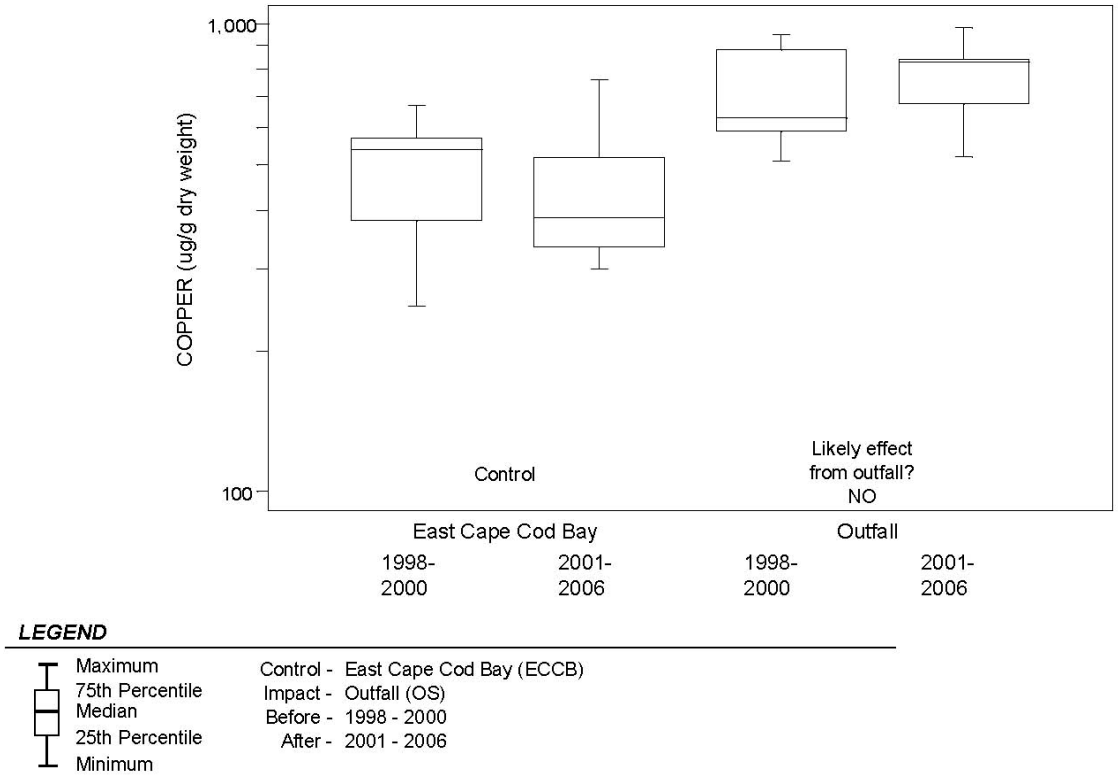



Figure 4-4. Comparison of copper concentrations measured in lobster hepatopancreas between control and impact locations before and after relocation of the outfall

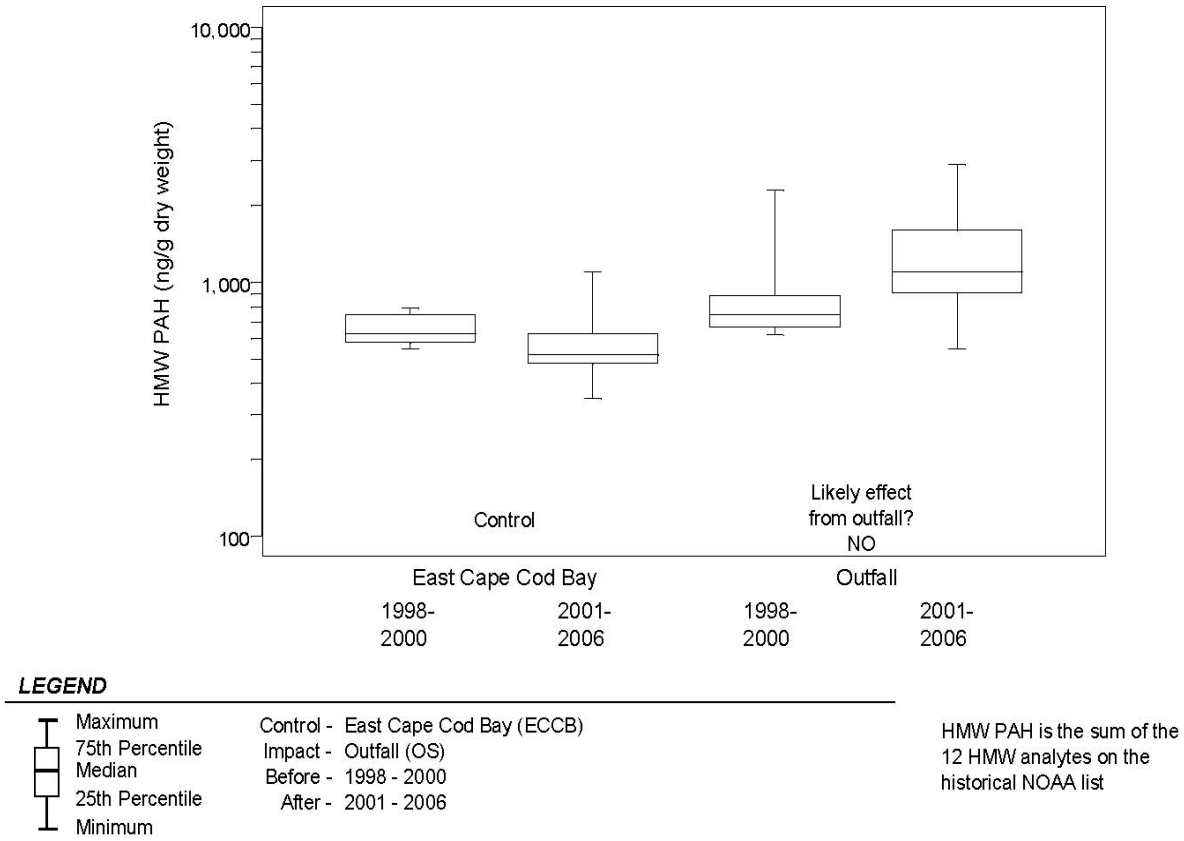



Figure 4-5. Comparison of high molecular weight (HMW) PAH concentrations measured in lobster hepatopancreas between control and impact locations before and after relocation of the outfall

## 4.3 RESULTS OF THE ANOVA

This section addresses the question of whether contaminant levels in lobster meat and lobster hepatopancreas are different between the Outfall Site, Deer Island Flats in Boston Harbor, and the East Cape Cod Bay reference site. Results of the ANOVA analyses are presented in Tables 4-2 and 4-3. Complete results and associated figures are included in Appendix B (Tables B-7 and B-8 and Figures B-31 through B-44).

Results of the lobster meat ANOVAs can be found in Tables 4-2 and B-7, Figures 4-6 and 4-7 and Figures B-31 to B-34. The post-diversion results from Table 4-2 are consistent with historical data. Concentrations of organic contaminants in lobster collected at Deer Island Flats have had higher concentrations than those collected at the outfall, which had higher concentrations than those collected in Cape Cod Bay. One notable exception was that lobster meat collected in 2006 at the Outfall Site had lower chlordane concentrations than those collected at Cape Cod Bay (Figure 4-6). Mercury levels in Cape Cod Bay lobsters meat have usually been lower than both Deer Island and

Outfall lobsters but the latter two sites have never shown a clear pattern of either site having the highest concentration (Figure 4-7).

Lobster hepatopancreas results can be found in Tables 4-3 and B-8, Figures 4-8 to 4-11, and Figures B-35 to B-44. Similar to the lobster meat, organic contaminants in the hepatopancreas have always tended to be highest (sometimes significantly, other times only numerically) in Deer Island lobsters and lowest in those collected from Cape Cod Bay (Figures 4-8 and 4-9 show PCB and HMW PAH concentrations). Metals have shown a more variable pattern with no consistency as to which of the three stations is statistically or numerically highest or lowest (see Table 4-3 and Figures 4-10 and 4-11 for cadmium and copper).

**Table 4-2. Summary of Comparisons between Locations by Year for Lobster Meat.**

| | 2001 | | 2002 | | 2003 | | 2006 | |
|---|---|---|---|---|---|---|---|---|
| | OS | DIF | OS | DIF | OS | DIF | OS | DIF |
| **Mercury** | | | | | | | | |
| | *P*-value = | 0.0040 | *P*-value = | 0.1545 | *P*-value = | 0.0076 | *P*-value = | 0.0060 |
| DIF | -- | | -- | | -- | | -- | |
| ECCB | OS | DIF | -- | -- | OS | DIF | OS | DIF |
| **PCB** | | | | | | | | |
| | *P*-value = | 0.1370 | *P*-value = | 0.0238 | *P*-value = | 0.0548 | *P*-value = | 0.0359 |
| DIF | -- | | -- | | -- | | -- | |
| ECCB | -- | -- | -- | DIF | -- | -- | -- | DIF |
| **Chlordane** | | | | | | | | |
| | *P*-value = | 0.0048 | *P*-value = | 0.0102 | *P*-value = | 0.0001 | *P*-value = | 0.0013 |
| DIF | -- | | -- | | DIF | | DIF | |
| ECCB | OS | DIF | -- | DIF | OS | DIF | ECCB | -- |
| **4,4'-DDE** | | | | | | | | |
| | *P*-value = | 0.9982 | *P*-value = | 0.0595 | *P*-value = | 0.0091 | *P*-value = | 0.0047 |
| DIF | -- | | -- | | DIF | | -- | |
| ECCB | -- | -- | -- | -- | -- | DIF | OS | DIF |

**Note:** *P*-value is from the ANOVA model. Tukey's multiple comparison test was used to test for pariwise differences between locations at an overall 95 percent confidence level.
Location abreviation indicates location has significantly higher concentration.
-- - indicates no significant difference in concentration between locations
DIF - Deer Island Flats
ECCB - East Cape Cod Bay
OS - outfall location
PCB - polychlorinated biphenyl
Chlordane: Sum of *cis*-chlordane and *trans*-nonachlor
PCB: Sum of congeners 138 and 153

**Table 4-3. Summary of Comparisons between Locations by Year for Lobster Hepatopancreas.**

| | | 2001 | | 2002 | | 2003 | | 2006 | |
|---|---|---|---|---|---|---|---|---|---|
| | | OS | DIF | OS | DIF | OS | DIF | OS | DIF |
| **Cadmium** | | | | | | | | | |
| | | *P*-value = | 0.0019 | *P*-value = | 0.4837 | *P*-value = | 0.8189 | *P*-value = | 0.0244 |
| | DIF | OS | | -- | | -- | | OS | |
| | ECCB | -- | ECCB | -- | -- | -- | -- | -- | -- |
| **Copper** | | | | | | | | | |
| | | *P*-value = | 0.3682 | *P*-value = | 0.0150 | *P*-value = | 0.0233 | *P*-value = | 0.0550 |
| | DIF | -- | | -- | | -- | | -- | |
| | ECCB | -- | -- | OS | DIF | OS | -- | OS | -- |
| **Lead** | | | | | | | | | |
| | | *P*-value = | 0.7932 | *P*-value = | 0.5357 | *P*-value = | 0.2521 | *P*-value = | 0.0028 |
| | DIF | -- | | -- | | -- | | -- | |
| | ECCB | -- | -- | -- | -- | -- | -- | OS | DIF |
| **Mercury** | | | | | | | | | |
| | | *P*-value = | 0.2691 | *P*-value = | 0.0519 | *P*-value = | 0.0005 | *P*-value = | 0.0062 |
| | DIF | -- | | -- | | -- | | OS | |
| | ECCB | -- | -- | -- | -- | OS | DIF | OS | -- |
| **PCB** | | | | | | | | | |
| | | *P*-value = | 0.0184 | *P*-value = | 0.0009 | *P*-value = | 0.0224 | *P*-value = | 0.1116 |
| | DIF | -- | | DIF | | -- | | -- | |
| | ECCB | -- | DIF | OS | DIF | -- | DIF | -- | -- |
| **HMW PAH** | | | | | | | | | |
| | | *P*-value = | 0.0097 | *P*-value = | 0.0115 | *P*-value = | 0.0001 | *P*-value = | 0.0013 |
| | DIF | DIF | | -- | | -- | | DIF | |
| | ECCB | -- | DIF | -- | DIF | OS | DIF | -- | DIF |
| **LMW PAH (12)** | | | | | | | | | |
| | | *P*-value = | 0.0001 | *P*-value = | 0.0210 | *P*-value = | 0.0001 | *P*-value = | 0.0044 |
| | DIF | DIF | | -- | | OS | | DIF | |
| | ECCB | OS | DIF | -- | DIF | OS | DIF | -- | DIF |
| **Total PAH (24)** | | | | | | | | | |
| | | *P*-value = | 0.0104 | *P*-value = | 0.0098 | *P*-value = | 0.0001 | *P*-value = | 0.0013 |
| | DIF | DIF | | -- | | -- | | DIF | |
| | ECCB | -- | DIF | -- | DIF | OS | DIF | -- | DIF |
| **Chlordane** | | | | | | | | | |
| | | *P*-value = | 0.0002 | *P*-value = | 0.0018 | *P*-value = | 0.1075 | *P*-value = | 0.0888 |
| | DIF | DIF | | -- | | -- | | -- | |
| | ECCB | OS | DIF | OS | DIF | -- | -- | -- | -- |
| **4,4'-DDE** | | | | | | | | | |
| | | *P*-value = | 0.0861 | *P*-value = | 0.0066 | *P*-value = | 0.0001 | *P*-value = | 0.0249 |
| | DIF | -- | | -- | | DIF | | DIF | |
| | ECCB | -- | -- | -- | DIF | -- | DIF | -- | -- |

**Note:** *P*-value is from the ANOVA model. Tukey's multiple comparison test was used to test for pariwise differences between locations at an overall 95 percent confidence level.
Location abreviation indicates location has significantly higher concentration.

-- - indicates no significant difference in concentration between locations
DIF - Deer Island Flats
ECCB - East Cape Cod Bay
OS - outfall location
PAH - polycyclic aromatic hydrocarbon
PCB - polychlorinated biphenyl
Chlordane: Sum of *cis*-chlordane and *trans*-nonachlor
LMW PAH (12): Sum of 12 low molecular weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene, 1-methylnaphthalene, 1-methylphenanthrene, 2,3,5-triethylnaphthalene, 2,6-dimethylnaphthalene, and 2-methylnaphthalene)
HMW PAH: Sum of 12 high molecular weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)
Total PAH (24): Sum of LMW PAH and HMW PAH
PCB: Sum of congeners 138 and 153

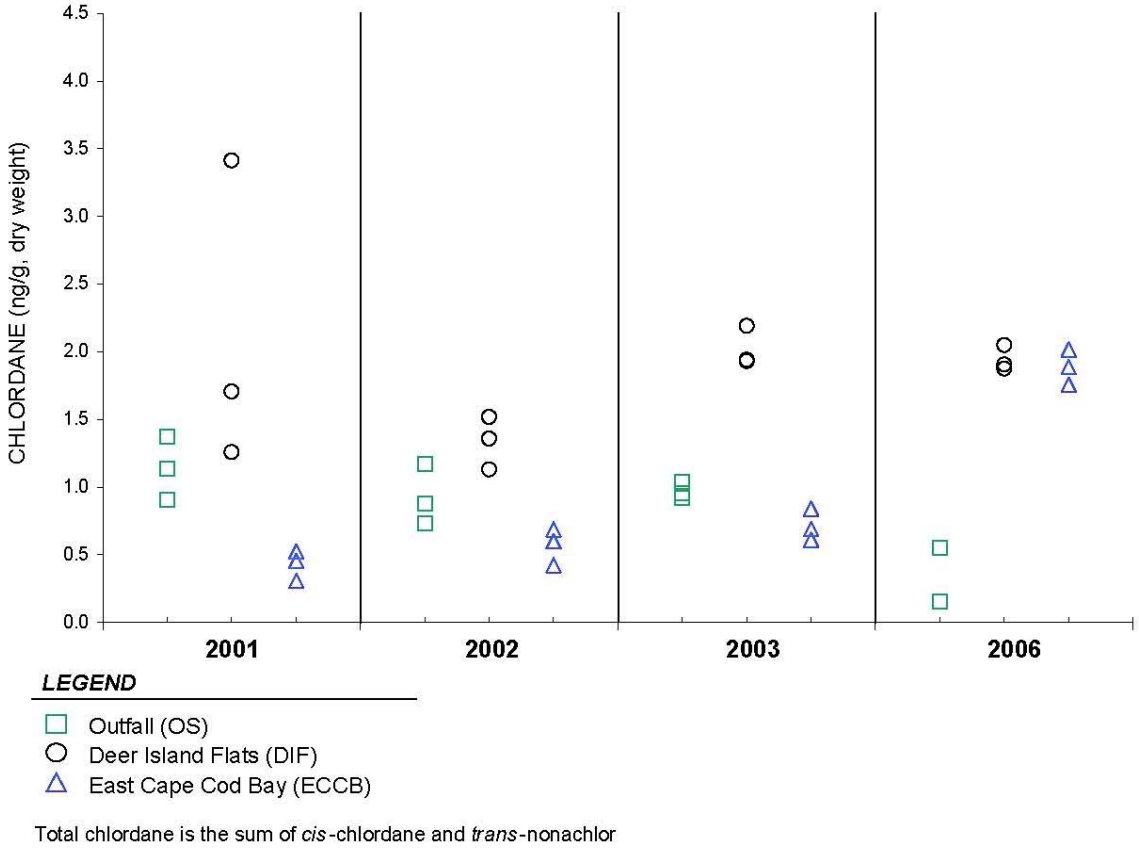



Figure 4-6. Chlordane concentrations in lobster meat after the outfall went on-line

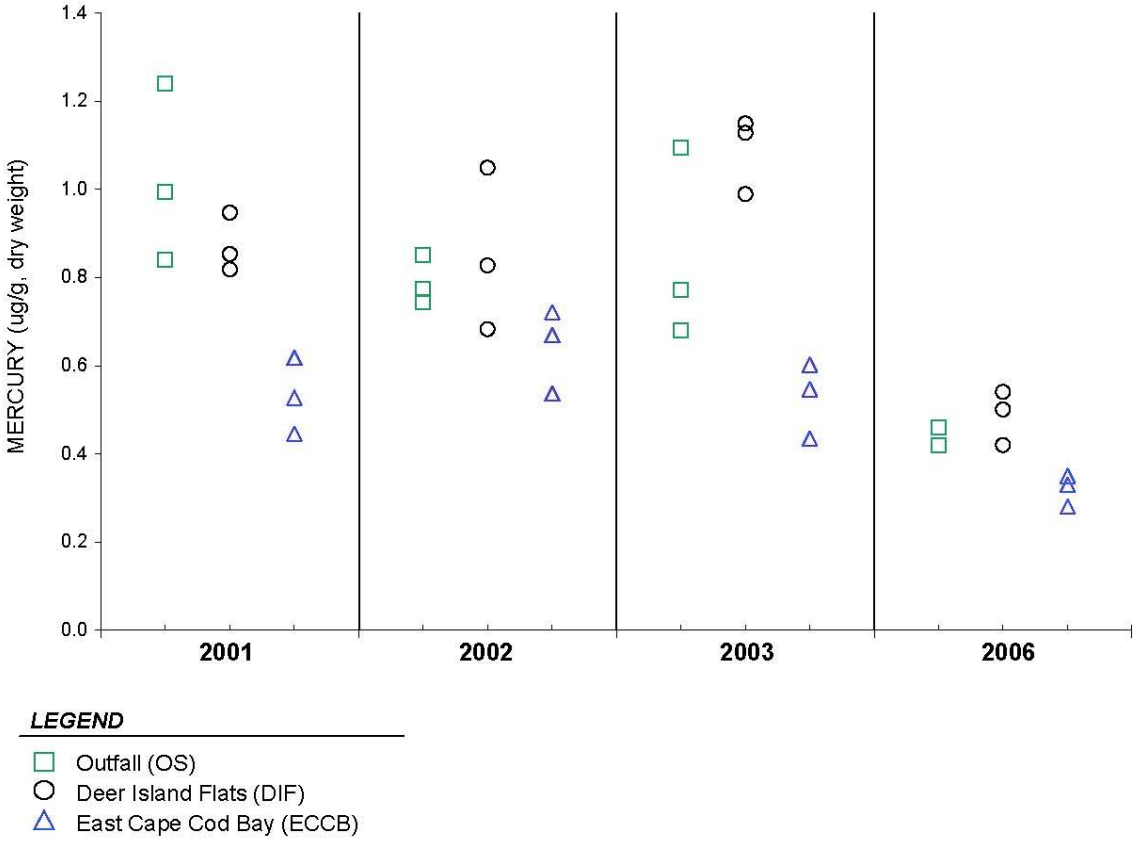



Figure 4-7. Mercury concentrations in lobster meat after the outfall went on-line

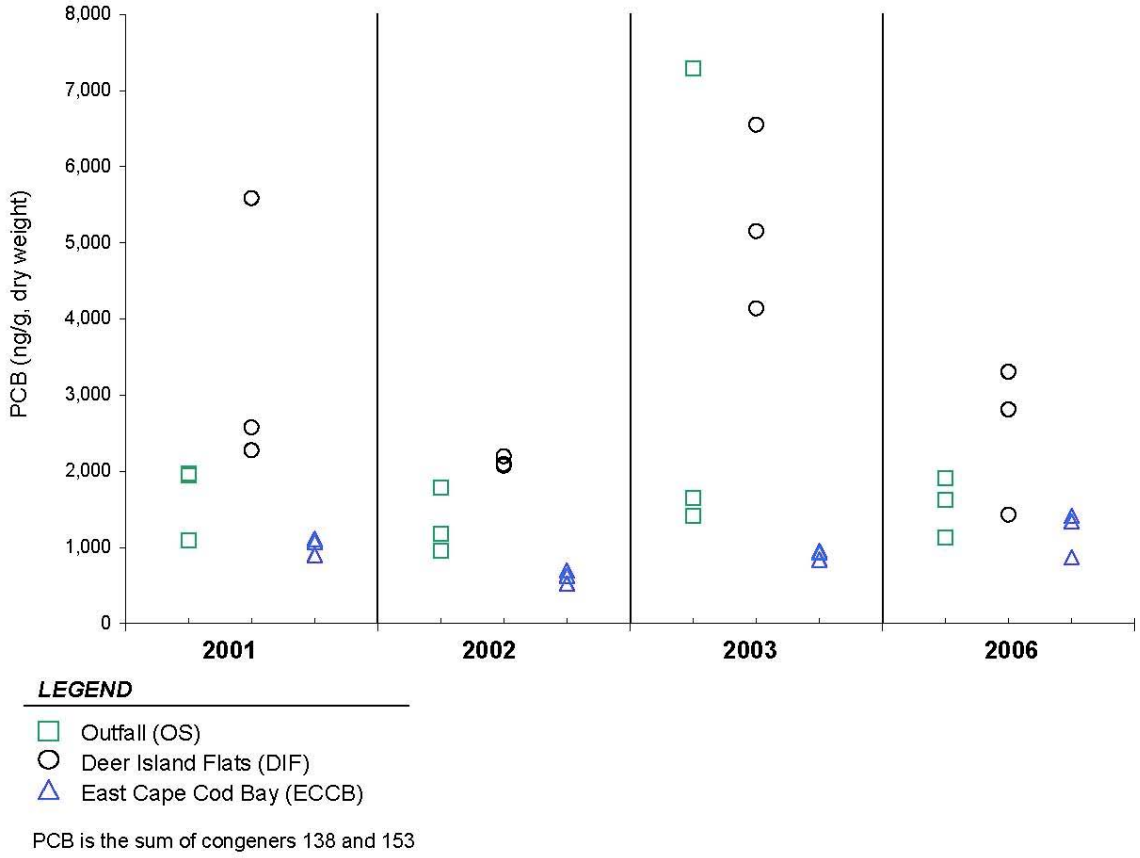
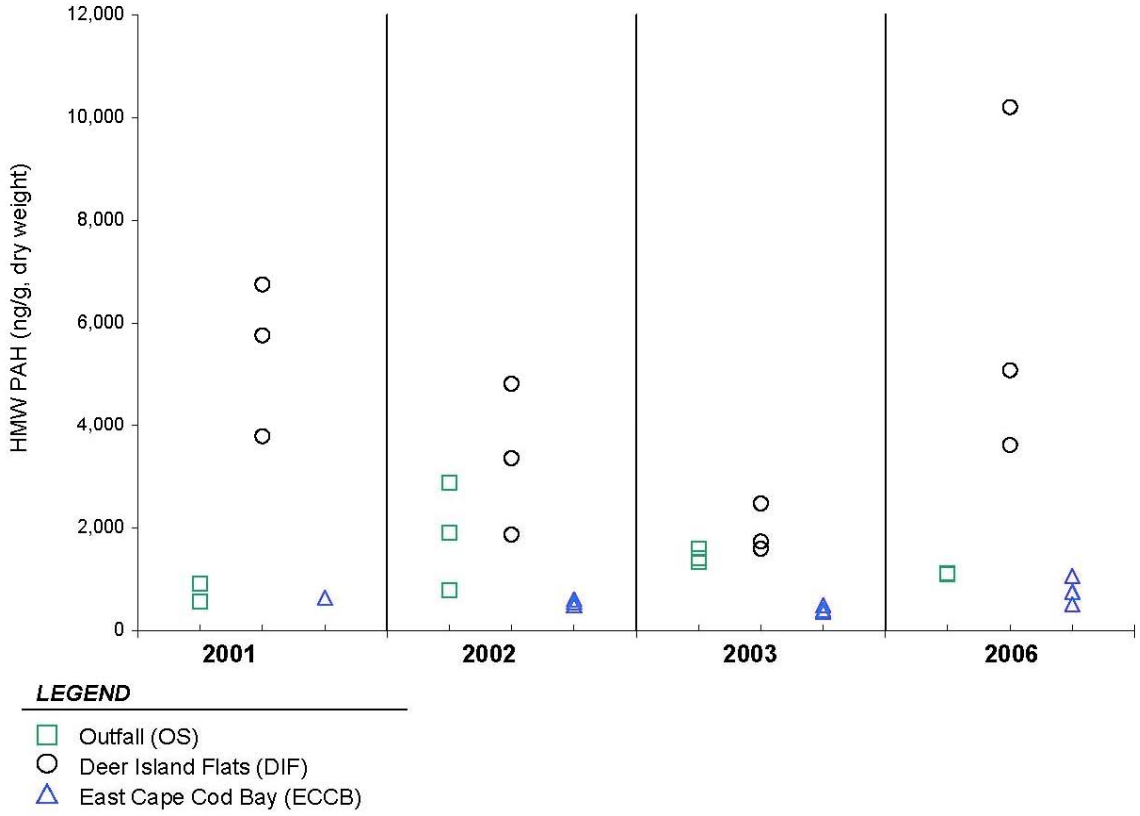



Figure 4-8. PCB concentrations in lobster hepatopancreas tissue after the outfall went on-line




HMW PAH is the sum of the 12 HMW analytes on the historical NOAA list

Figure 4-9. High molecular weight (HMW) PAH concentrations in lobster hepatopancreas tissue after the outfall went on-line

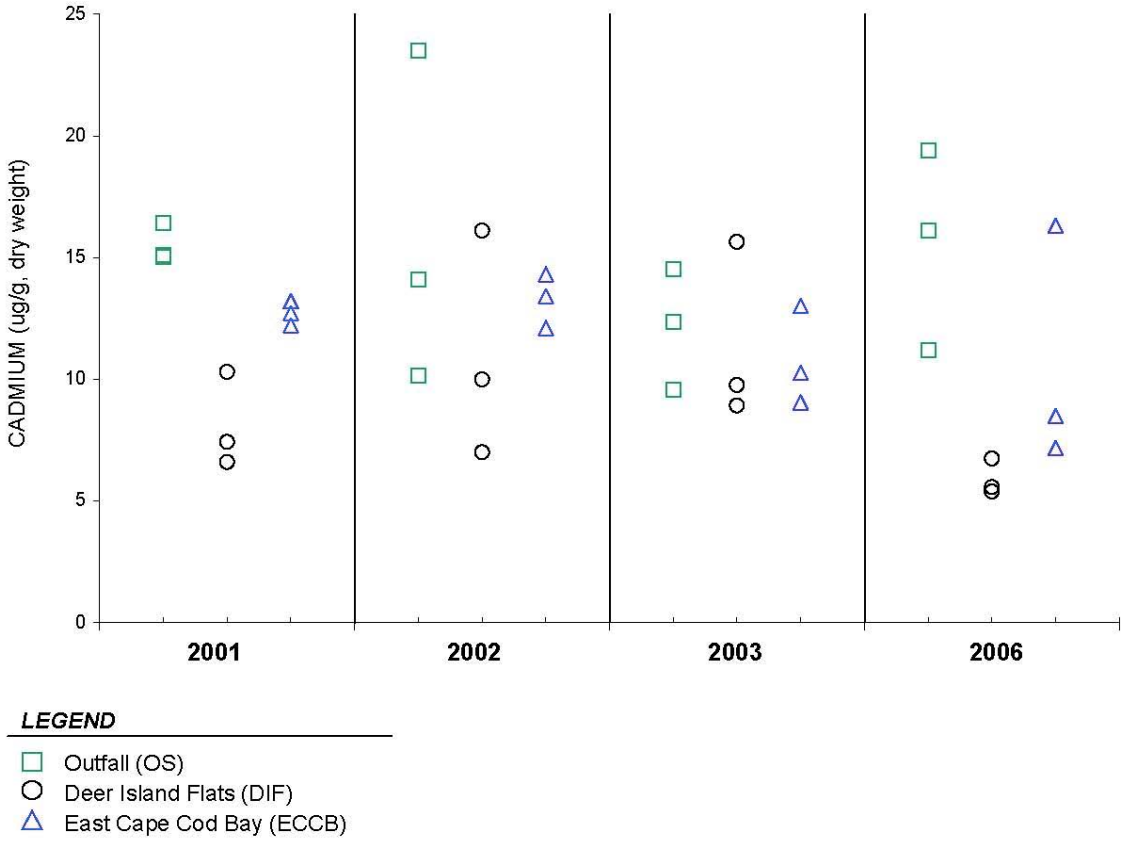



Figure 4-10. Cadmium concentrations in lobster hepatopancreas tissue after the outfall went on-line

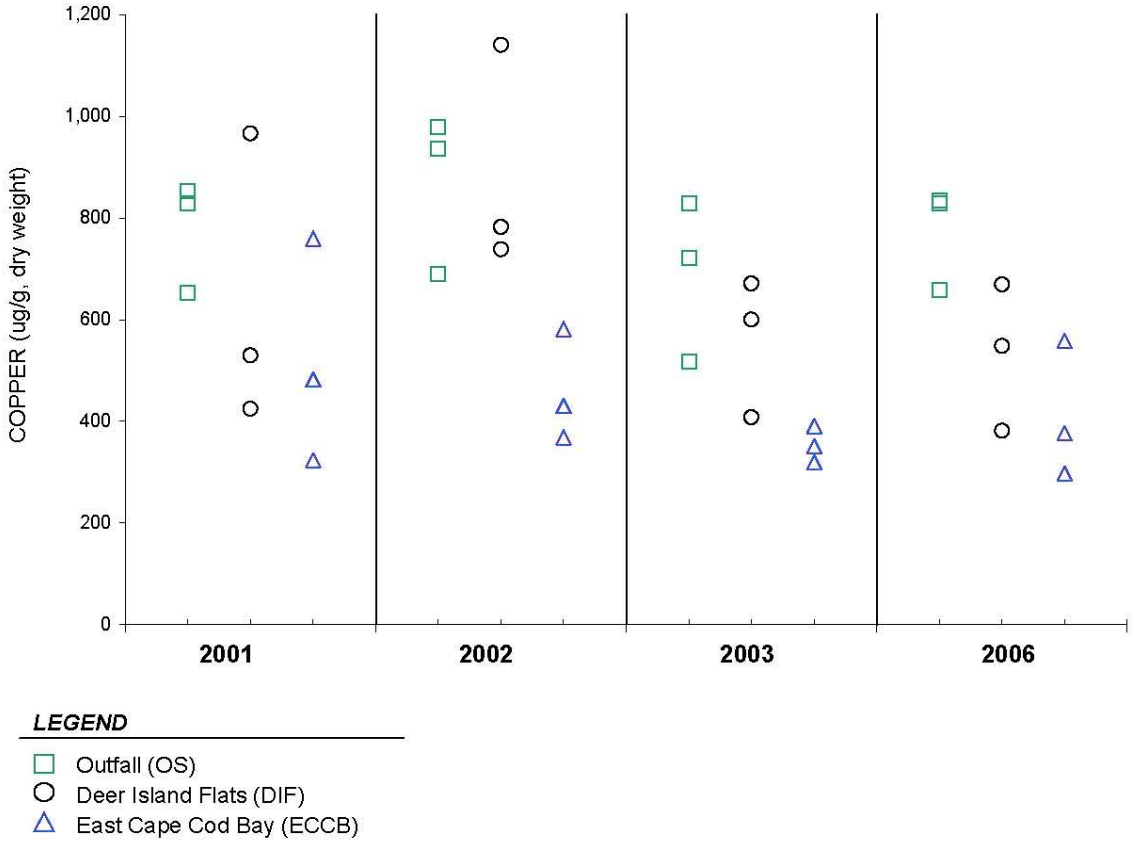



Figure 4-11. Copper concentrations in lobster hepatopancreas tissue after the outfall went on-line

# 5.0 WINTER FLOUNDER

## 5.1 BIOLOGY, ECOLOGY, AND BIOACCUMULATION

### 5.1.1 Distribution and Movement

Winter flounder (*Pleuronectes americanus*) range from Labrador to Georgia (Scott and Scott 1988), but are most common from Nova Scotia to New Jersey (Perlmutter 1947). Populations of winter flounder are composed of reproductively isolated fish that spawn in specific estuaries or coastal embayments (Lobell 1939; Perlmutter 1947; Saila 1961). Differences in seasonal depth stratification and onshore-offshore distributions may in large part be explained by the behavioral responses to temperature and light as shown in experimental studies of thermoregulatory and diel behavior (Casterlin and Reynolds 1982). In addition, spatial distribution and movements of winter flounder depend on the life stage.

Depending on the season and geography, adult winter flounder can be found on a variety of substrates, including hard bottom in offshore areas, such as Georges Bank, and sand in shallow coastal habitats. Preferred temperatures for adult winter flounder are 10 to 15°C, but they survive temperatures ranging from –1.4 to 19.3°C. As a result of the protection of antifreeze proteins that are seasonally secreted in their blood serum, winter flounder are less susceptible to freezing or cold shock than to heat shock (Klein-MacPhee 2002). Adult winter flounder are mostly found in salinities above 22 ppt, but may tolerate salinity as low as 15 ppt (Pereira et al. 1999). Winter flounder are sensitive to dissolved oxygen below 3 ppm but may tolerate as low as 2 ppm dissolved oxygen at the expense of reduced growth (Klein-MacPhee 2002).

Adults are thought to enter inshore spawning areas in fall or early winter and spawn in late winter or early spring, with peak spawning in Massachusetts Bay during February and March. Adult winter flounder populations may have biased sex ratios. During an extensive mark-recapture study by Howe and Coates (1975) from 1960 to 1965, the female to male sex ratio of the 12,151 tagged winter flounder was 2.3:1 (about 70% female). Similarly, Saila (1961) reported 70% female of the 601 winter flounder tagged in a separate study. Fecundity of mature females ranges from approximately 220,000 eggs at age 3 to over 1.8 million eggs at age 15 (Saila et al. 1997). Winter flounder spawn during periods of low water temperature (e.g., 0–2.8°C near Gloucester, Massachusetts [Klein-MacPhee 2002]). Climatic factors influence timing of spawning and larval development (Sogard et al. 2001). Spawning sites generally occur in areas of estuaries where larvae would be minimally displaced by tidal movement (Crawford and Carey 1985).

A 10-year tagging study at 21 locations off the coast of Massachusetts north of Cape Cod showed that movements of winter flounder are generally localized and confined to inshore waters within 10 km of their release location (Howe and Coates 1975). For example, recaptured adult winter flounder that were tagged and released in Boston Harbor during 1960 and 1961 traveled an average distance of 3.4 and 2.2 km, respectively (Howe and Coates 1975). East and south of Cape Cod, the recapture study reported average seasonal movements of 5.7 to 61.2 km in a southeastward direction that was related to water temperature-depth contours. The average straight-line distance of winter flounder was approximately 10 miles based on recapture up to 730 days after release off Rhode Island during

winter (Saila 1961). Saila (1961) also observed greatest dispersion during June-November and the least movement during November to June in areas associated with breeding grounds.

### 5.1.2 Bioaccumulation

In comparison to invertebrates, rates of metabolism and elimination of organic contaminants in fish are relatively rapid. Rates of metabolism of PAH in fish are strongly induced by exposure to PAHs and planar halogenated hydrocarbons. Even in fish with induced rates of metabolism, halogenated hydrocarbons are metabolized more slowly than PAHs (Stegeman and Hahn 1994). Rapid metabolism and elimination of organic contaminants can result in reduced tissue concentrations. For example, metabolism of benz[a]acridine was estimated to reduce the bioaccumulation of that compound by nearly an order of magnitude (Varanasi and Stein 1991). Concentrations of compounds, such as PAHs, in fish tissue are therefore not routinely measured in monitoring programs. Concentrations of more persistent compounds in tissue, such as chlorinated biphenyls and pesticides, are, however, typically used as measures of environmental exposure of fish. As with invertebrates, fish can take up metals and maintain homeostasis up to certain levels by binding metals to inducible metal-binding ligands such as metallothionein, and sequestration of metals in lysosomes, inclusion bodies, and mineral concretions (DiGuilio et al. 1995). Specific patterns of accumulation and internal distribution depend upon the route of exposure, tissue, species, and life stage. Uptake of mercury is almost entirely in the form of methylmercury, and nearly all of the mercury in fish tissue is methylmercury. Most uptake of methylmercury is from the diet. Inorganic mercury is absorbed much less efficiently across the gut and gills and is eliminated more rapidly than methylmercury (Weiner and Spry 1996). Food chain structure influences the uptake and concentration of methylmercury in fish, and piscivorous fish usually contain higher concentrations than do co-occurring fish of lower trophic levels (Weiner and Spry 1996). The concentrations of mercury in fish tissue also tend to increase with the size or age of the fish. Adult winter flounder spend most of their time on or near the bottom, feeding opportunistically on polychaete worms, mollusks, crustaceans, other invertebrates, fish eggs, small fish, and vegetation (Klein-MacPhee 2002). Therefore, flounder tend to have lower levels of mercury than fish at higher trophic levels.

### 5.1.3 Suitability as an Indicator Organism

Juvenile winter flounder were widely used for pollution monitoring in areas south of Cape Cod because movement during this life stage is limited to inshore natal waters. Several tagging studies have shown that adult winter flounder make seasonal inshore-offshore migrations related to preferred water temperature and spawning activity. In Massachusetts Bay, winter flounder may leave inshore waters during the summer if water temperatures rise above the preferred temperature range of 12–15°C. Over the course of a year, the majority of individuals limit their movements from inshore waters to a few kilometers offshore. Populations may consist of a mixture of reproductively active, migratory adults and non-spawning or non-migratory adults. Bioaccumulation of potential contaminants in adult winter flounder in Massachusetts Bay will be dependent on differential exposure time at inshore spawning grounds and offshore waters during the summer. For this reason, the adult winter flounder are less ideal as a monitoring species, as compared to young of the year.

### 5.1.4 Previous MWRA Findings

Previous analyses of the monitoring data for flounder found that the spatial distribution of the levels of contaminants in flounder fillet and liver is consistent with regional distributions of sediment contamination; levels are higher in Boston Harbor than offshore in Massachusetts Bay and Cape Cod Bay (Hunt et al. 2006; Nestler et al. 2007). Mercury levels in edible tissue were found to be higher than expected in 2003, although still lower than contingency plan thresholds (Nestler et al. 2007). Total PCBs were also found to be higher in the post-discharge period, possibly as a result of the wetter/snowier weather during 2000–2002, which may have resulted in increased flux of contamination in precipitation and runoff (Hunt et al. 2006). Reports also found that levels of metals in liver are often highest at the Outfall Site, but tend to be more variable than levels of organic contaminants, show no clear temporal trend, and are comparable during the pre- and post-discharge period (Nestler et al. 2007).

## 5.2 RESULTS OF THE BACI

The BACI analyses address the question of whether contaminant levels at the Outfall Site changed since the relocation, and whether the observed changes were likely related to the relocation of the outfall. As noted above, the "before" period is defined in two ways, as 1995–2000 and as 1998–2000, to account for changes in sampling and analysis that might have contributed to the variability in the samples. All results (employing both the 1995–2000 and 1998–2000 "before" data) can be found in Appendix B (Tables B-9 and B-10 and Figures B-45 through B-58). The top part of each BACI table presents the *P*-values for the various components of the final ANOVA model. After fitting the ANOVA, pair-wise comparisons were performed to evaluate the nature of the specific differences. The second part of each table presents conclusions that are based on the pair-wise comparison results. As previously noted in Section 2.2.1, if the interaction term is significant, conclusions drawn from the main effects are of little value since they can mask important interactions. Therefore, when the interaction term is significant, the interaction term takes precedence over the main effects in the interpretation of the results, and conclusions based on the main effects are not indicated in the lower portions of the BACI tables. Keep in mind that an impact from the relocation of the outfall can only be indicated by a significant interaction term, but a significant interaction term does not necessarily indicate an impact from the outfall relocation.

The BACI results for flounder fillet can be found in Tables 5-1 and B-9, Figures 5-1 and 5-2, and Figures B-45 to B-48. Table 5-1 summarizes only the before/after comparisons from these models. None of the interaction terms were significant when comparing either the 1995–2000 or the 1998–2000 pre-periods to post-diversion flounder tissue. This indicates that changes in concentrations observed at the outfall were not significantly different between before and after relocation of the outfall (see 4,4,'-DDE in Figure 5-1) or that any change observed was not significantly different than the change observed at the control site (see mercury in Figure 5-2).

**Table 5-1. Summary of Before/After Conclusions from the BACI Analysis of Concentrations in Flounder Fillet and Liver Tissue at the Outfall Site.**

| | Before/After Main Effect | Interaction Term | Before vs. After Assessment (before = 1998 - 2000) | | Outfall Effect Likely? | Explanation |
|---|---|---|---|---|---|---|
| **Flounder Fillet** | | | ECCB | OS | | |
| Mercury | Signif. | Not Signif. | After > Before | After > Before | No | both increased after |
| PCBs | Not Signif. | Not Signif. | -- | -- | No | no increase after |
| Chlordane | Signif. | Not Signif. | Before > After | Before > After | No | no increase after |
| 4,4'-DDE | Not Signif. | Not Signif. | -- | -- | No | no increase after |
| | | | | | | |
| **Flounder Liver** | | | ECCB | OS | | |
| Cadmium | Not Signif. | Not Signif. | -- | -- | No | no increase after |
| Copper | Signif. | Not Signif. | Before > After | Before > After | No | no increase after |
| Lead | Not Signif. | Not Signif. | -- | -- | No | no increase after |
| Mercury | Signif. | Not Signif. | Before > After | Before > After | No | no increase after |
| PCBs | Signif. | Not Signif. | After > Before | After > Before | No | both increased after |
| HMW PAHs | Not Signif. | Not Signif. | -- | -- | No | no increase after |
| LMW PAHs (7) | Not Signif. | Not Signif. | -- | -- | No | no increase after |
| Total PAHs (19) | Not Signif. | Not Signif. | -- | -- | No | no increase after |
| Chlordane | Not Signif. | Not Signif. | -- | -- | No | no increase after |
| 4,4'-DDE | Not Signif. | Not Signif. | -- | -- | No | no increase after |

**Note:** Significance was determined using a 0.05 level (95 percent confidence)

-- - indicates no significant difference between before and after periods
BACI - Before-After-Control-Impact statistical analysis
ECCB - East Cape Cod Bay
OS - Outfall location
PAH - polycyclic aromatic hydrocarbon
PCB - polychlorinated biphenyl
Chlordane: Sum of *cis*-chlordane and *trans*-nonachlor
LMW PAH (7): Sum of 7 low-molecular-weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene)
HMW PAH (12): Sum of 12 high-molecular-weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)
Total PAH (19): Sum of LMW PAH and HMW PAH
PCB: Sum of congeners 138 and 153

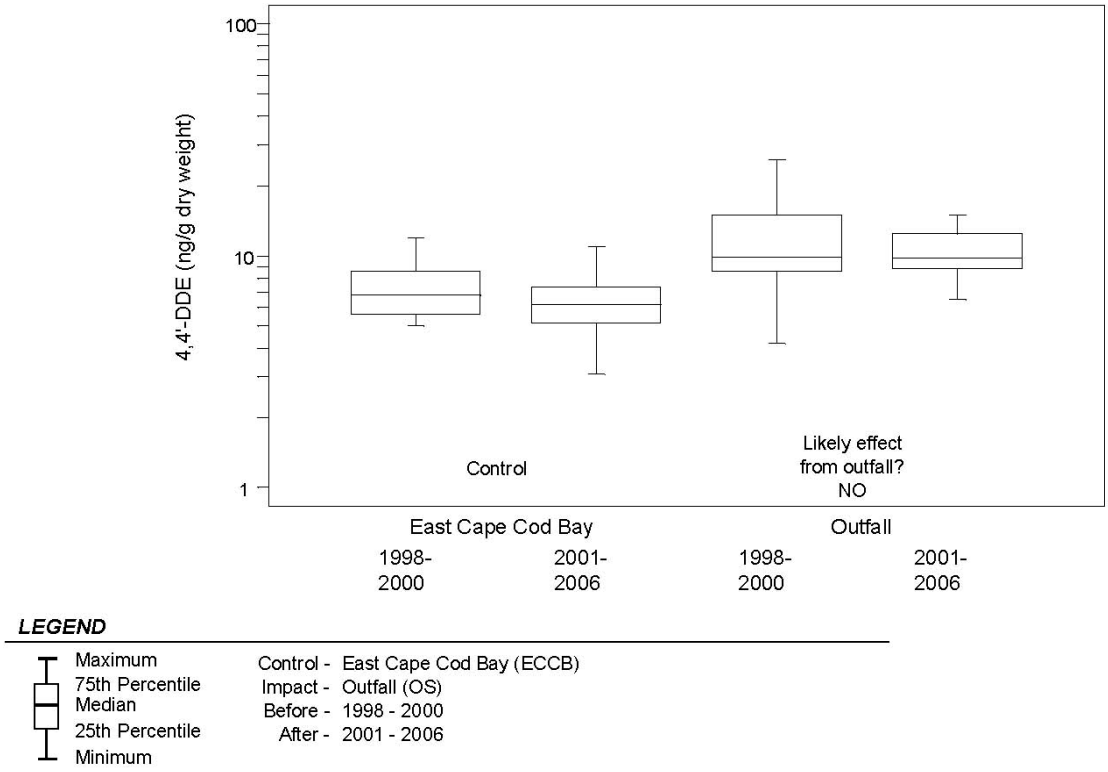






Figure 5-1. Comparison of 4,4'-DDE concentrations measured in flounder fillet between control and impact locations before and after relocation of the outfall

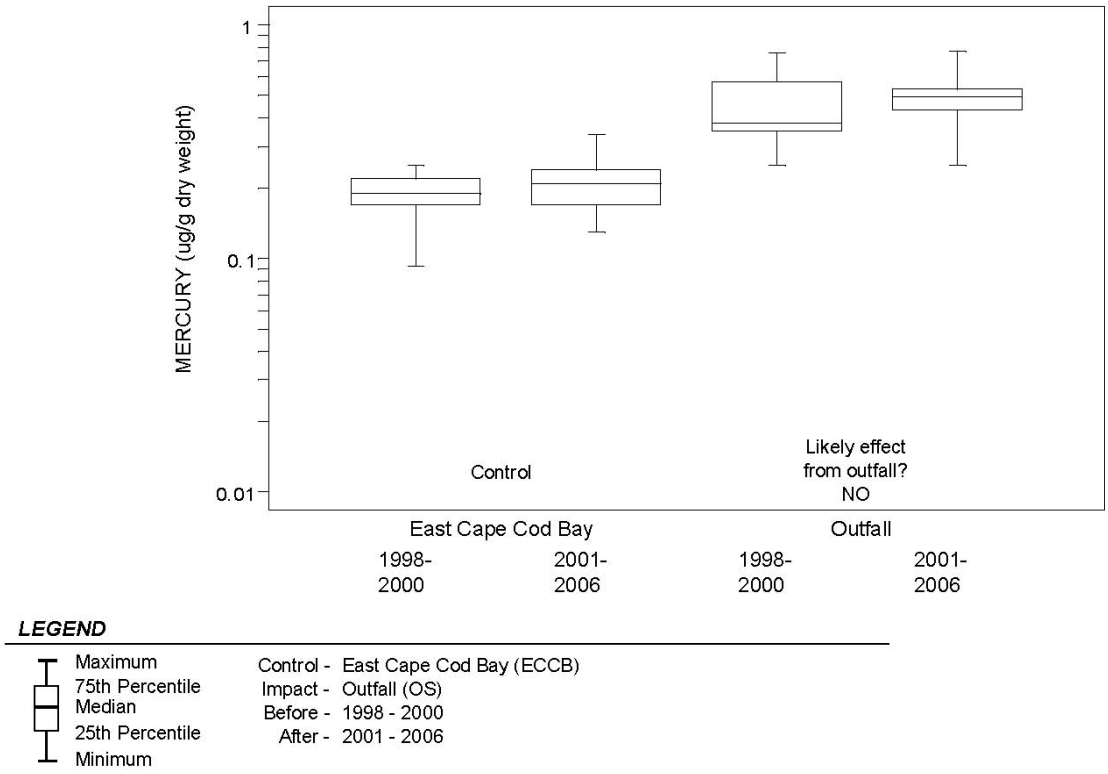



Figure 5-2. Comparison of mercury concentrations measured in flounder fillet between control and impact locations before and after relocation of the outfall

Flounder liver results can be found in Tables 5-1 and B-10, Figures 5-3 and 5-4, and Figures B-49 to B-58. Table 5-1 presents only the before/after comparisons whereas Table B-10 presents the complete results for the BACI models. None of the parameters for either comparison period had a significant interaction term except mercury when using the 1995–2000 before period. While mercury concentrations stayed the same between periods at the Outfall Site, they decreased in flounder livers from Cape Cod Bay (Figure 5-3). This is not strong evidence for an outfall effect because of the lack of significant change in concentration at the Outfall Site. Most other parameters were either lower or the same at both sites after relocation of the outfall. When using the 1998–2000 period definition, only PCBs were significantly higher after the diversion but this was observed at both sites (Figure 5-4).

Thus, none of the results suggest that concentrations of contaminants in winter flounder increased as a result of the relocation of the outfall.

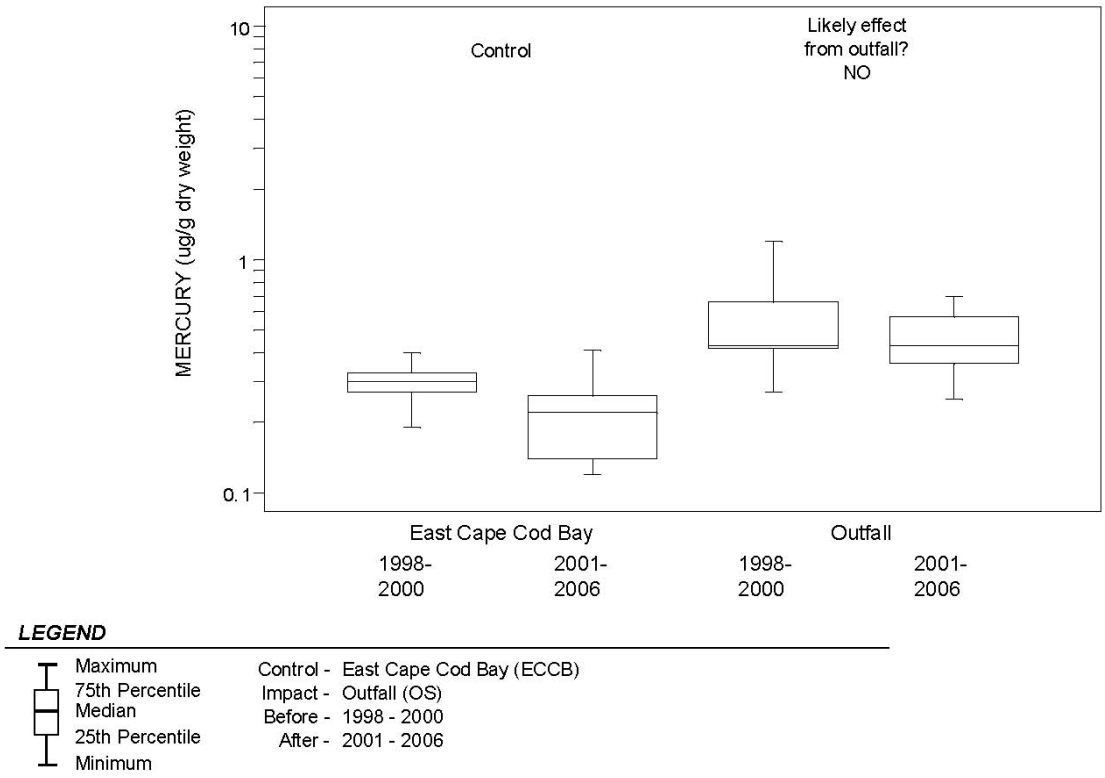



Figure 5-3. Comparison of mercury concentrations measured in flounder liver between control and impact locations before and after relocation of the outfall

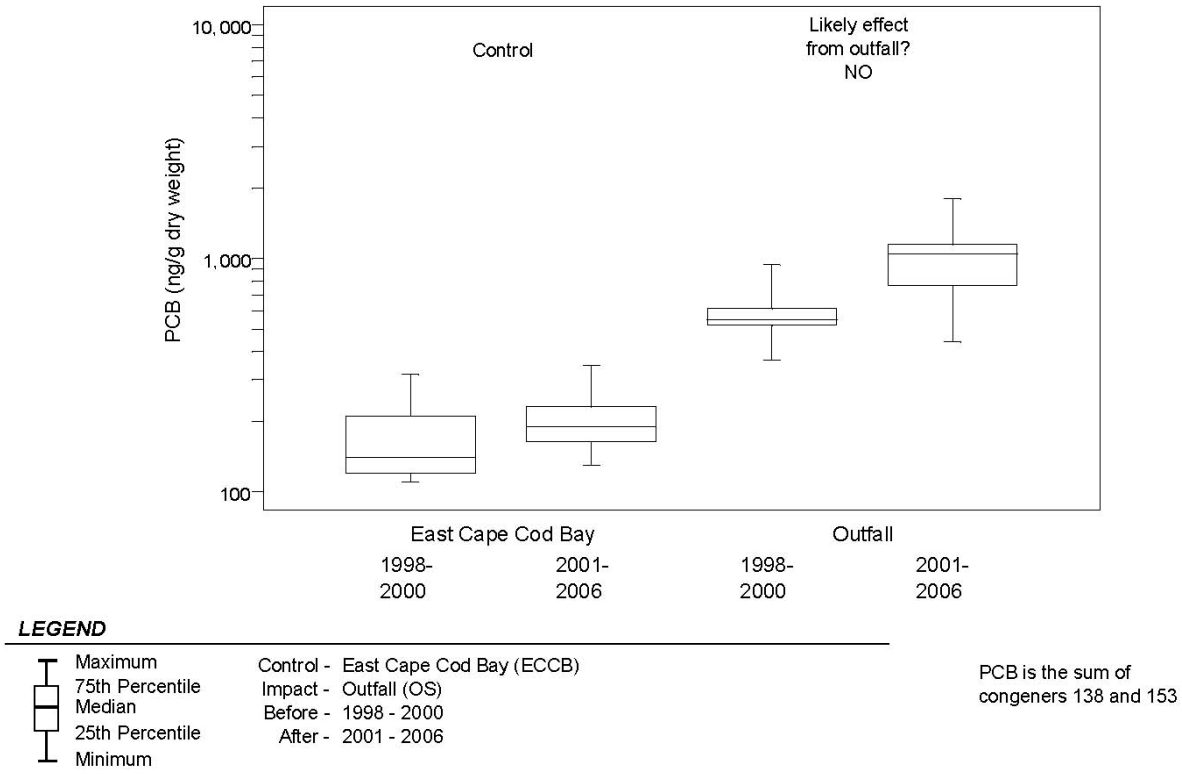



Figure 5-4. Comparison of PCB concentrations measured in flounder liver between control and impact locations before and after relocation of the outfall

## 5.3 RESULTS OF THE ANOVA

This section addresses the question of whether current contaminant levels in flounder fillet and liver are different among the Outfall Site, Deer Island Flats in Boston Harbor, and the East Cape Cod Bay reference site. Results of the ANOVA analyses for flounder tissue are presented in Table 5-2 for fillet and Table 5-3 for liver. Appendix B includes these results along with figures presenting the measured concentrations in flounder fillet and liver for each of the years compared in these analyses (Tables B-11 and B-12 and Figures B-59 through B-72).

**Table 5-2. Summary of Comparisons between Locations by Year for Flounder Fillet.**

| | | 2001 | | 2002 | | 2003 | | 2006 | |
|---|---|---|---|---|---|---|---|---|---|
| | | OS | DIF | OS | DIF | OS | DIF | OS | DIF |
| **Mercury** | | | | | | | | | |
| | | *P*-value = | 0.0057 | *P*-value = | 0.0330 | *P*-value = | 0.0034 | *P*-value = | 0.0039 |
| | DIF | -- | | -- | | OS | | -- | |
| | ECCB | OS | DIF | OS | -- | OS | -- | OS | -- |
| **PCB** | | | | | | | | | |
| | | *P*-value = | <0.0001 | *P*-value = | 0.0011 | *P*-value = | 0.0008 | *P*-value = | 0.0001 |
| | DIF | DIF | | -- | | -- | | DIF | |
| | ECCB | OS | DIF | OS | DIF | OS | DIF | OS | DIF |
| **Chlordane** | | | | | | | | | |
| | | *P*-value = | 0.0001 | *P*-value = | <0.0001 | *P*-value = | 0.0037 | *P*-value = | 0.0011 |
| | DIF | DIF | | DIF | | DIF | | DIF | |
| | ECCB | -- | DIF | OS | DIF | -- | DIF | -- | DIF |
| **4,4'-DDE** | | | | | | | | | |
| | | *P*-value = | 0.0001 | *P*-value = | 0.0123 | *P*-value = | 0.0088 | *P*-value = | 0.0002 |
| | DIF | DIF | | -- | | -- | | DIF | |
| | ECCB | -- | DIF | -- | DIF | -- | DIF | OS | DIF |

**Note:** *P*-value is from the ANOVA model. Tukey's multiple comparison test was used to test for pariwise differences between locations at an overall 95 percent confidence level.
Location abreviation indicates location has significantly higher concentration.
-- - indicates no significant difference in concentration between locations
DIF - Deer Island Flats
ECCB - East Cape Cod Bay
OS - outfall location
PCB - polychlorinated biphenyl
Chlordane: Sum of *cis*-chlordane and *trans*-nonachlor
PCB: Sum of congeners 138 and 153

**Table 5-3. Summary of Comparisons between Locations by Year for Flounder Liver.**

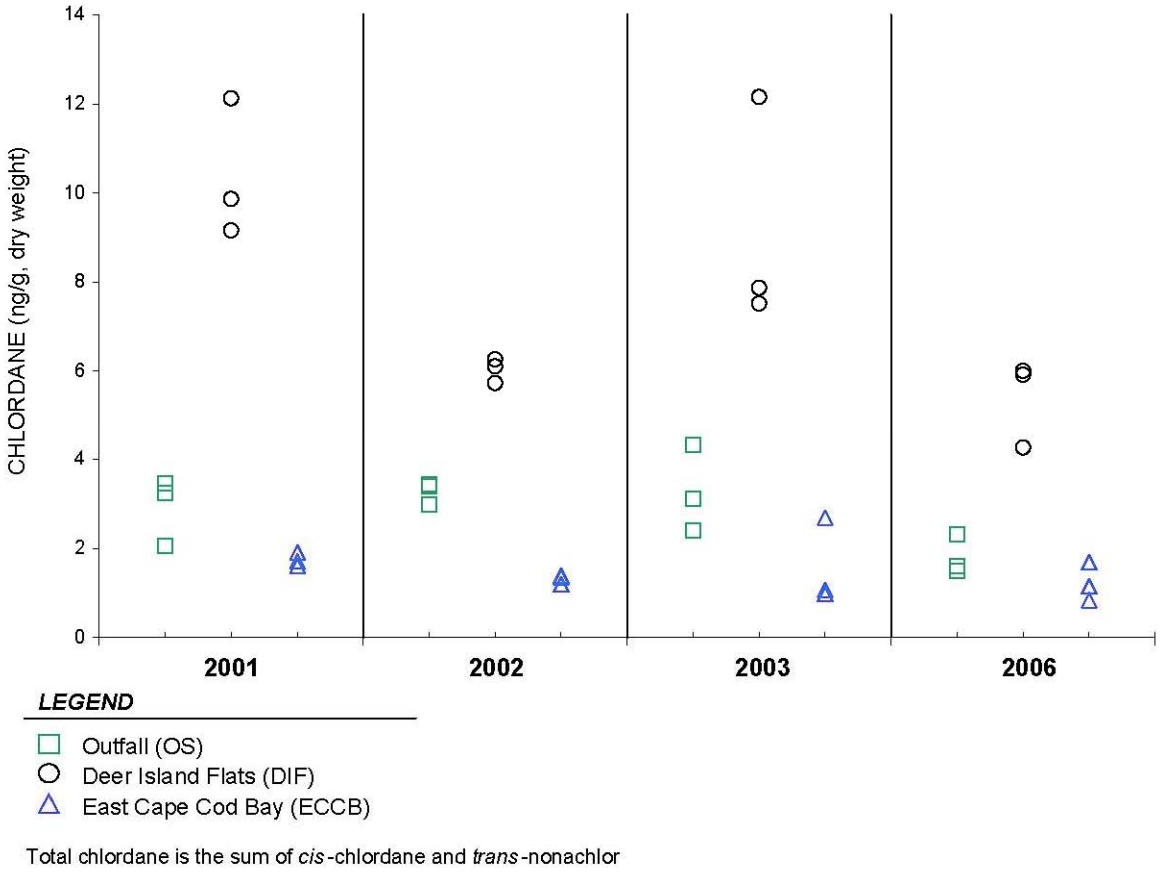
| | 2001 | | 2002 | | 2003 | | 2006 | |
|---|---|---|---|---|---|---|---|---|
| | OS | DIF | OS | DIF | OS | DIF | OS | DIF |
| **Cadmium** | | | | | | | | |
| | *P*-value = | 0.2683 | *P*-value = | 0.7645 | *P*-value = | 0.1964 | *P*-value = | 0.5250 |
| DIF | -- | | -- | | -- | | -- | |
| ECCB | -- | -- | -- | -- | -- | -- | -- | -- |
| **Copper** | | | | | | | | |
| | *P*-value = | 0.3518 | *P*-value = | 0.1699 | *P*-value = | 0.0122 | *P*-value = | 0.1009 |
| DIF | -- | | -- | | OS | | -- | |
| ECCB | -- | -- | -- | -- | -- | -- | -- | -- |
| **Lead** | | | | | | | | |
| | *P*-value = | 0.0023 | *P*-value = | 0.0380 | *P*-value = | 0.4579 | *P*-value = | 0.0103 |
| DIF | OS | | -- | | -- | | OS | |
| ECCB | OS | -- | OS | -- | -- | -- | OS | -- |
| **Mercury** | | | | | | | | |
| | *P*-value = | 0.0114 | *P*-value = | 0.0034 | *P*-value = | 0.0055 | *P*-value = | 0.0684 |
| DIF | -- | | -- | | OS | | -- | |
| ECCB | OS | DIF | OS | -- | OS | -- | -- | -- |
| **PCB** | | | | | | | | |
| | *P*-value = | <0.0001 | *P*-value = | 0.0026 | *P*-value = | 0.0001 | *P*-value = | 0.0001 |
| DIF | -- | | -- | | -- | | DIF | |
| ECCB | OS | DIF | OS | DIF | OS | DIF | OS | DIF |
| **HMW PAH** | | | | | | | | |
| | *P*-value = | 0.0004 | *P*-value = | 0.1736 | *P*-value = | 0.0130 | *P*-value = | 0.0328 |
| DIF | -- | | -- | | -- | | -- | |
| ECCB | OS | DIF | -- | -- | -- | DIF | OS | -- |
| **LMW PAH (12)** | | | | | | | | |
| | *P*-value = | 0.0012 | *P*-value = | 0.2996 | *P*-value = | 0.0565 | *P*-value = | 0.8452 |
| DIF | DIF | | -- | | DIF | | -- | |
| ECCB | OS | DIF | -- | -- | -- | -- | -- | -- |
| **Total PAH (24)** | | | | | | | | |
| | *P*-value = | 0.0031 | *P*-value = | 0.2247 | *P*-value = | 0.0228 | *P*-value = | 0.8596 |
| DIF | DIF | | -- | | DIF | | -- | |
| ECCB | OS | DIF | -- | -- | -- | -- | -- | -- |
| **Chlordane** | | | | | | | | |
| | *P*-value = | <0.0001 | *P*-value = | 0.0006 | *P*-value = | 0.0002 | | |
| DIF | DIF | | DIF | | DIF | | nd | |
| ECCB | OS | DIF | OS | DIF | OS | DIF | nd | nd |
| **4,4'-DDE** | | | | | | | | |
| | *P*-value = | 0.0001 | *P*-value = | 0.0290 | *P*-value = | 0.0020 | | |
| DIF | -- | | -- | | -- | | nd | |
| ECCB | OS | DIF | -- | DIF | OS | DIF | nd | nd |

**Note:** *P*-value is from the ANOVA model. Tukey's multiple comparison test was used to test for pariwise differences between locations at an overall 95 percent confidence level.
Location abreviation indicates location has significantly higher concentration.

-- - indicates no significant difference in concentration between locations
DIF - Deer Island Flats
ECCB - East Cape Cod Bay
nd - no data available
OS - outfall location
PAH - polycyclic aromatic hydrocarbon
PCB - polychlorinated biphenyl
Chlordane: Sum of *cis*-chlordane and *trans*-nonachlor
LMW PAH (12): Sum of 12 low molecular weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene, 1-methylnaphthalene, 1-methylphenanthrene, 2,3,5-triethylnaphthalene, 2,6-dimethylnaphthalene, and 2-methylnaphthalene)
HMW PAH: Sum of 12 high molecular weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)
Total PAH (24): Sum of LMW PAH and HMW PAH
PCB: Sum of congeners 138 and 153

Results of the ANOVAs for flounder fillet concentrations can be found in Tables 5-2 and B-11, Figures 5-5 and 5-6, and Figures B-59 to B-62. The post-diversion results from Table 5-2 are consistent with historical data. Organic contaminants in flounder fillet collected at Deer Island Flats have tended to have higher concentrations than those collected at the outfall, which had higher concentrations than those collected in Cape Cod Bay (see chlordane in Figure 5-5). However, mercury levels in flounder fillet tissue collected from the Outfall Site have tended to be higher concentrations than those collected at Deer Island and Cape Cod Bay (Figure 5-6).

Results for flounder liver can be found in Tables 5-3 and B-12, Figures 5-7 and 5-8, and Figures B-63 to B-72. Differences in metals concentrations between sites have shown a variable pattern with a tendency for concentrations at the Outfall Site to be significantly higher than the other two sites (Table 5-3 and Figure 5-7 for lead). PCBs, 4,4'-DDE, and chlordane in flounder livers also tended to be highest in Deer Island flounder and lowest in those collected in Cape Cod Bay (Table 5-3 and chlordane in Figure 5-8). Apparent elevations of PAHs in flounder liver in 2006 (Figures B-68 to B-70) are the result of elevated detection limits, which were approximately ten times higher in 2006 analyses for PAHs than in previous years.




Total chlordane is the sum of *cis*-chlordane and *trans*-nonachlor

Figure 5-5. Chlordane concentrations in flounder fillet tissue after the outfall went on-line

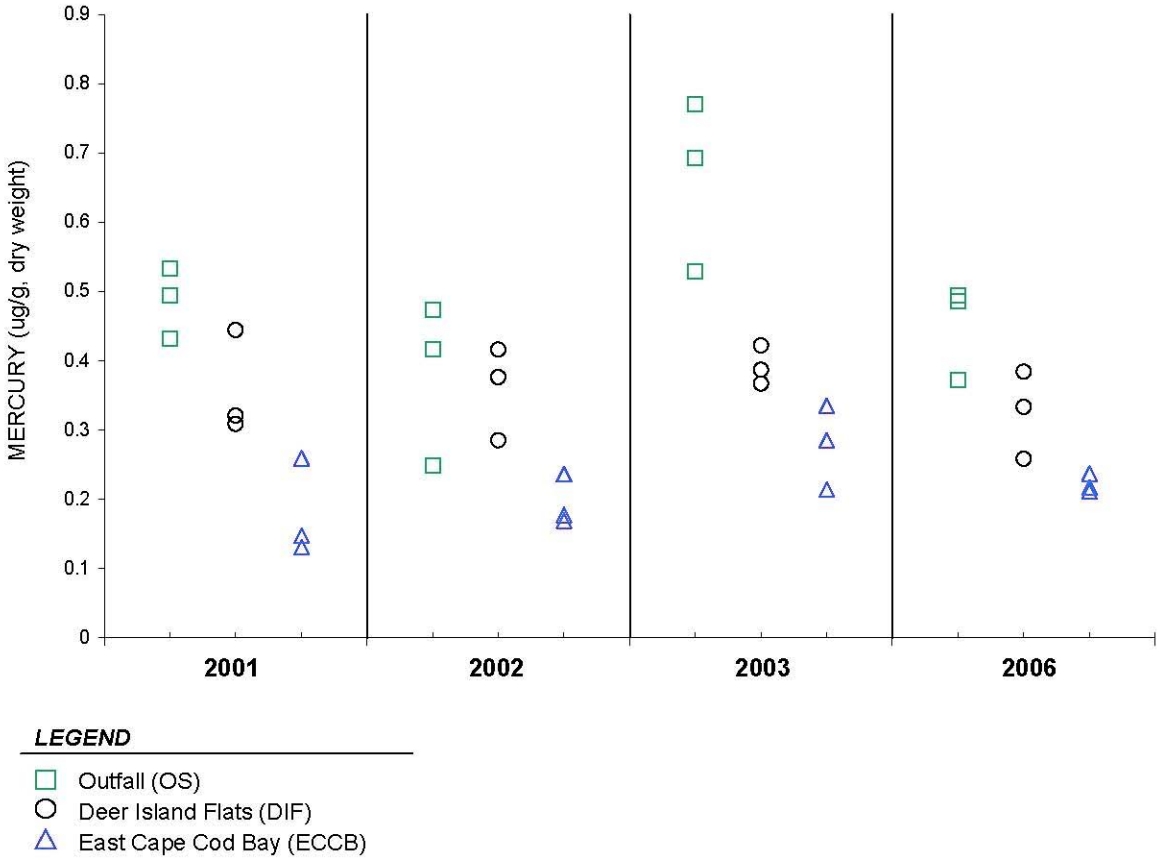



Figure 5-6. Mercury concentrations in flounder fillet tissue after the outfall went on-line

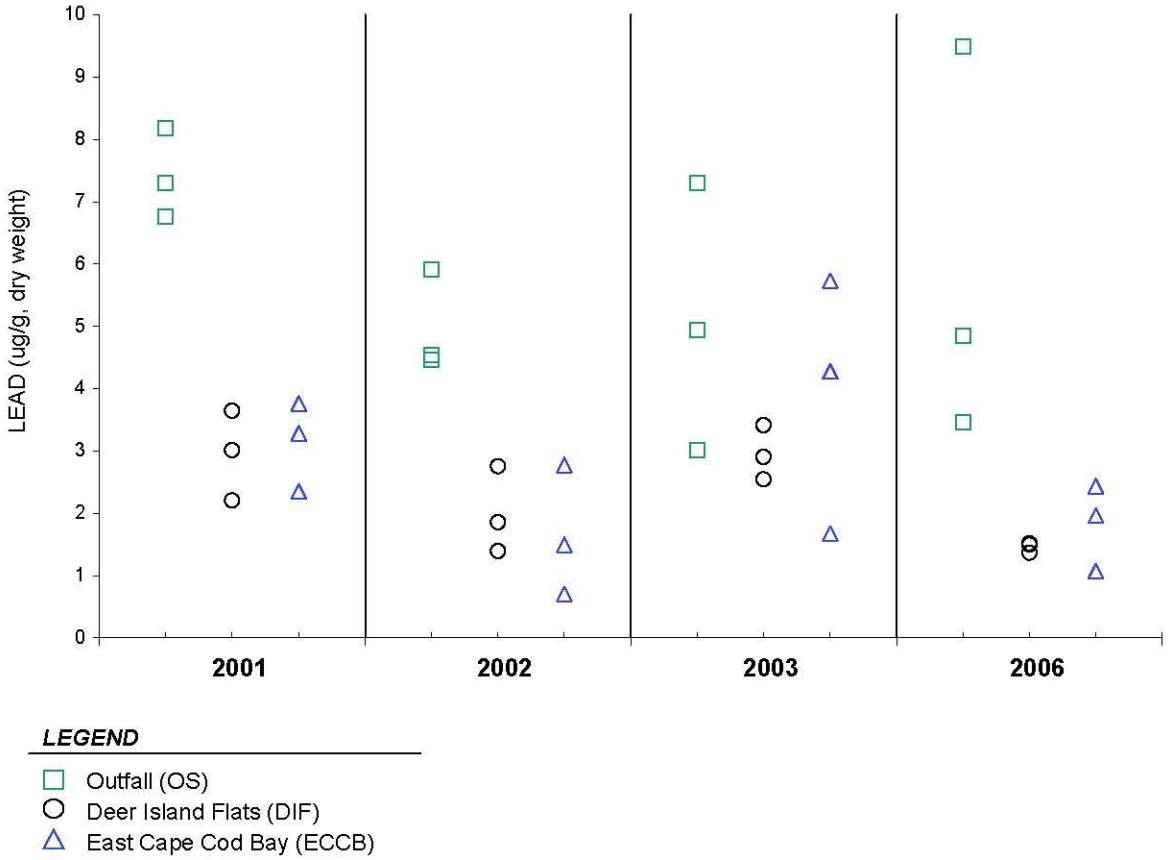



Figure 5-7. Lead concentrations in flounder liver tissue after the outfall went on-line

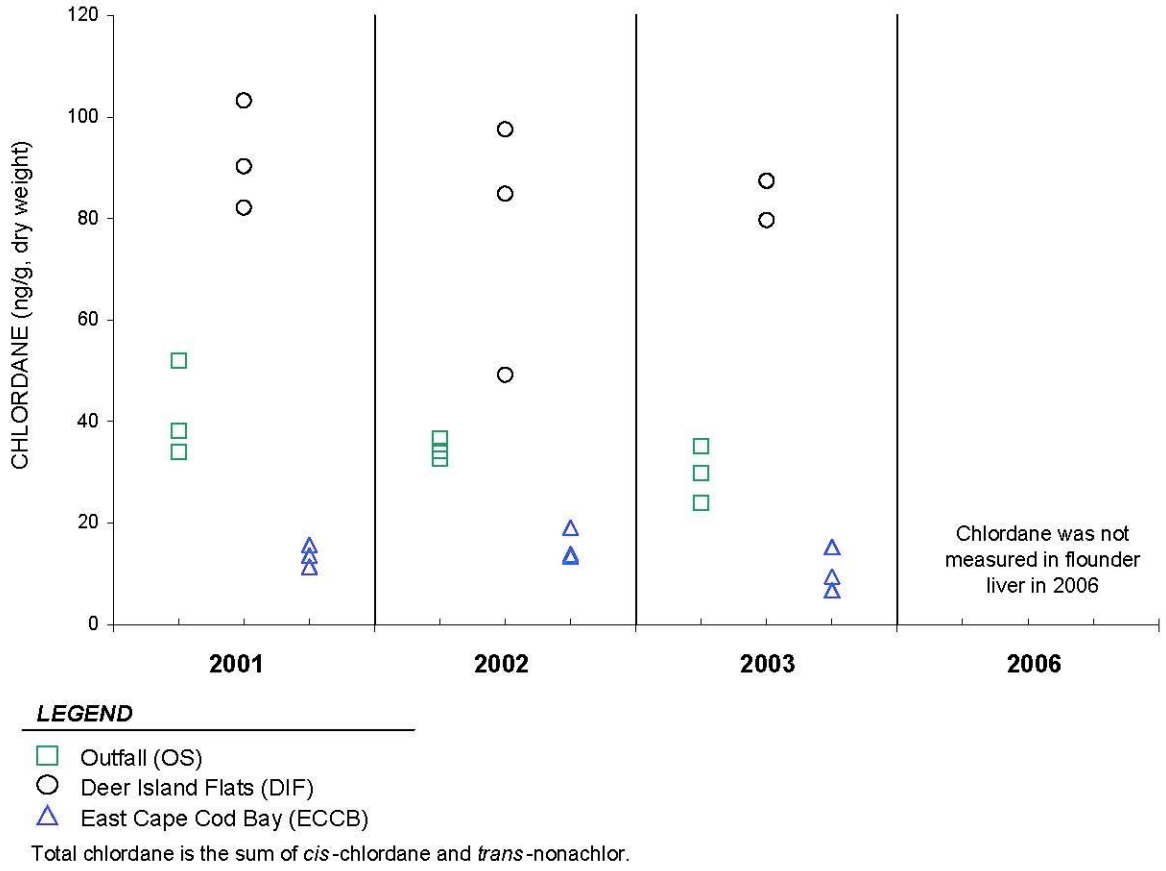



Figure 5-8. Chlordane concentrations in flounder liver tissue after the outfall went on-line

# 6.0 COMPARISON TO THRESHOLDS

This section addresses the question of whether the current levels of contaminants in edible fish and shellfish tissues near the outfall represent a risk to human health or the environment.

## 6.1 COMPARISON TO FDA LEVELS AND EPA RISK-BASED CONCENTRATIONS FOR HUMAN HEALTH

Concentrations of contaminants in fish and shellfish can be compared to the FDA action levels, tolerances, and guidance levels (U.S. FDA 2005), as well as EPA human health risk assessment risk-based concentrations (RBCs) (U.S. EPA 2007). The intent and application of these guidelines are distinct from one another. The FDA action levels and tolerances represent limits at or above which FDA will take legal action to remove products from the market. The EPA RBCs are different from the FDA values, in that they do not constitute regulation or guidance, and should not be viewed as a substitute for a site-specific risk assessment. RBCs are based on exposure scenarios that incorporate various assumptions, including assumptions related to the rate of consumption of fish or shellfish. The RBCs are used primarily to screen out chemicals as contaminants of concern in an initial risk assessment evaluation.

Both the RBCs and the FDA levels are applicable to edible tissues, but are not applicable to tissues that humans do not consume (e.g., flounder liver). The RBCs are not applied to lobster hepatopancreas because the RBCs are based on conservative estimates of the rates of consumption of fish or shellfish, which would likely overestimate the amount and frequency with which people consume hepatopancreas. Average 2006 concentrations of most contaminants for which thresholds are available were below available FDA levels and EPA RBCs in edible tissues (i.e., flounder fillet and lobster meat) at all locations (Table 6-1). This included lead, mercury, chlordane, and 4,4'-DDE. Concentrations of total PCBs (calculated as the sum of 20 congeners) were below the FDA action limit, but exceeded the EPA RBC in all tissues and at all locations. Although this analysis was conducted using one half the detection limit for compounds that were not detected, concentrations of PCBs would still substantially exceed the RBC if only detected values were considered. As noted above, exceedance of the RBC is not an indication of risk to human health, but indicates only that PCBs would not be screened out by comparison to RBCs. Note also that because sample locations in Boston Harbor receive input from a variety of point and non-point sources that are unrelated to the outfall (Hunt et al. 2006), observed concentrations of PCBs in tissues at these locations may be related to a variety of sources.

## 6.2 COMPARISON OF MUSSELS TO EPA EQUILIBRIUM PARTITIONING BENCHMARKS FOR THE PROTECTION OF BENTHIC ORGANISMS

EPA recently published equilibrium partitioning sediment benchmarks (ESBs) that can be used to estimate the toxicity of PAHs to benthic (e.g., bottom-dwelling) organisms (U.S. EPA 2003). To develop the ESBs, EPA used a data set on the narcotic toxicity of PAHs in water-only exposures to estimate a final chronic value (FCV) of 2.24 $\mu$mol PAH/g lipid. The FCV is expected to be protective of 95% of the species tested (Di Toro and McGrath 2000; Di Toro et al. 2000). The ESB approach calculates a toxic unit for each PAH as the concentration of the PAH divided by the FCV for that PAH. If the sum of the toxic units for "total PAHs" is less than or equal to 1.0, the concentration of

the PAH mixture is acceptable for the protection of benthic organisms from chronic effects. U.S. EPA (2003) defines "total PAHs" as comprising, at a minimum, the 34 PAHs that were measured in the EPA Environmental Monitoring and Assessment Program (U.S. EPA 1996). This definition is used because few databases are available that have measured a greater number of PAHs, and because the use of fewer PAHs could underestimate the total toxicity of the PAH mixture. Because the metabolic ability of mussels is low in comparison to other organisms (e.g., fish and crustaceans), mussels accumulate PAHs fairly rapidly, but eliminate them relatively slowly. Lobsters are not included in this comparison because rates of metabolism of PAHs in this species are considerably higher than in mussels and tissue concentrations are expected to be considerably lower. The concentration of PAHs in mussel tissues can be compared to the ESBs, to determine whether levels of PAHs are acceptable for the protection of these organisms. The sum of toxic units is well below 1.0 for mussel tissue samples from all locations measured in 2006, indicating that chronic narcotic effects in mussel tissues from PAHs are unlikely (Table 6-2).

**Table 6-1. Comparison of 2006 Tissue Concentrations with Threshold Levels.**

| | FDA | U.S. EPA | CCB or ECCB | | | DIF or DIL | | | OS | | | IH | LNB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Action | Region III | Mussel | Lobster | Flounder | Mussel | Lobster | Flounder | Mussel | Lobster | Flounder | Mussel | Mussel |
| Analyte | Limits | RBCs | Soft Tissue | Meat | Fillet | Soft Tissue | Meat | Fillet | Soft Tissue | Meat | Fillet | Soft Tissue | Soft Tissue |
| Lead | 1.5[a] | -- | 0.28 | | | 0.40 | | | 0.27 | | | 0.37 | 0.27 |
| Mercury | 1.0 | 0.14 | 0.014 | 0.053 | 0.039 | 0.011 | 0.081 | 0.055 | 0.012 | 0.067 | 0.080 | 0.011 | 0.012 |
| Total PCBs | 2,000 | 1.6 | 11 | 12 | 14 | 31 | 31 | 58 | 9.5 | 17 | 33 | 34 | 11 |
| Chlordane | 300 | 9.0 | 0.44 | 0.63 | 0.22 | 0.63 | 0.65 | 0.92 | 0.74 | 0.056 | 0.32 | 0.69 | 0.56 |
| 4,4'-DDE | 5,000 | 9.3 | 1.7 | 1.0 | 1.1 | 1.8 | 2.2 | 4.3 | 1.1 | 1.4 | 1.9 | 1.9 | 1.0 |

**Note:** U.S. FDA levels can be found at http://www.cfsan.fda.gov/~ear/nss3-42d.html.
U.S. EPA Region 3 RBCs can be found at: http://www.epa.gov/reg3hscd/risk/human/index.htm.
All results are reported on a wet weight basis.
Metals results are reported in µg/g, all other analytes are reported in ng/g.
Boxed values indicate exceedance of a threshold.
Undetected results were included as half the detection limit.
Mercury concentrations for fish and shellfish is methylmercury.
FDA action level for mercury in fish and shellfish is 1 ppm methylmercury in edible portion.

CCB - Cape Cod Bay
DIF - Deer Island Flats
DIL - Deer Island Light
ECCB - East Cape Cod Bay
EPA - U.S. Environmental Protection Agency
FDA - U.S. Food and Drug Administration
IH - Boston Inner Harbor
LNB - Large Navigation Buoy
OS - Outfall location
PCB - polychlorinated biphenyl
RBC - risk-based concentration
Total PCBs: Sum of 20 congeners (8,18,28,44,52,66,77,101,105,118,126,128,138,153,170,180,187,195,206, and 209)
Total Chlordane: Sum of *cis*-chlordane and *trans*-nonachlor

[a] Lead FDA action limit value of 1.5 ppm is for Crustacea; there is also a 1.7 ppm FDA guidance value for Molluscan/Shellfish.

**Table 6-2. Calculation of the Sum of Toxic Units for 34 PAHs Measured in Mussel Tissue.**

| Sample Location | SP | SP | CCB | CCB | DIL | DIL | IH | IH |
|---|---|---|---|---|---|---|---|---|
| Sample ID Number | FM061SP01 | FM061SP02 | FM063901 | FM063902 | FM0631M01 | FM0631M02 | FM063601 | FM063602 |
| Date | 06/27/06 | 06/27/06 | 08/30/06 | 08/30/06 | 08/30/06 | 08/30/06 | 08/30/06 | 08/30/06 |
| **Polycyclic Aromatic Hydrocarbons (umol/g-lipid)** | | | | | | | | |
| Benz[a]anthracene | 6.69E-05 | 5.96E-05 | 7.74E-05 | 5.57E-05 | 2.30E-04 | 2.85E-04 | 5.03E-03 | 3.85E-03 |
| Benzo[a]pyrene | 5.69E-05 | 7.46E-05 | 5.72E-05 | 5.04E-05 | 1.41E-04 | 2.44E-04 | 2.26E-03 | 1.35E-03 |
| Benzo[b]fluoranthene | 1.18E-04 | 1.16E-04 | 1.44E-04 | 9.95E-05 | 4.55E-04 | 4.50E-04 | 6.39E-03 | 4.72E-03 |
| Benzo[e]pyrene | 1.87E-04 | 2.11E-04 | 2.68E-04 | 2.42E-04 | 8.27E-04 | 8.50E-04 | 8.91E-03 | 8.27E-03 |
| Benzo[ghi]perylene | 8.99E-05 | 1.03E-04 | 1.05E-04 | 8.36E-05 | 2.82E-04 | 3.34E-04 | 1.72E-03 | 1.63E-03 |
| Benzo[k]fluoranthene | 1.16E-04 | 1.19E-04 | 1.23E-04 | 9.74E-05 | 3.74E-04 | 4.11E-04 | 5.41E-03 | 3.86E-03 |
| Chrysene | 1.79E-04 | 1.58E-04 | 1.64E-04 | 1.43E-04 | 5.68E-04 | 5.83E-04 | 8.84E-03 | 7.71E-03 |
| Dibenz[a,h]anthracene | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.56E-05 | 4.14E-05 | 4.54E-05 | 2.83E-04 | 1.95E-04 |
| Fluoranthene | 6.66E-04 | 6.22E-04 | 6.34E-04 | 5.65E-04 | 1.76E-03 | 1.94E-03 | 3.07E-02 | 3.15E-02 |
| Indeno[1,2,3-cd]pyrene | 6.65E-05 | 6.54E-05 | 4.71E-05 | 4.07E-05 | 1.45E-04 | 2.06E-04 | 1.08E-03 | 9.03E-04 |
| Perylene | 1.18E-04 | 1.08E-04 | 5.94E-05 | 5.04E-05 | 1.05E-04 | 1.20E-04 | 8.44E-04 | 6.75E-04 |
| Pyrene | 5.51E-04 | 6.41E-04 | 6.98E-04 | 5.70E-04 | 1.66E-03 | 1.61E-03 | 1.84E-02 | 1.76E-02 |
| Acenaphthene | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.34E-03 | 1.05E-03 |
| Acenaphthylene | 9.09E-05 | 8.44E-05 | 1.59E-04 | 9.82E-05 | 1.96E-04 | 1.96E-04 | 9.86E-04 | 9.72E-04 |
| Anthracene | 6.18E-05 | 7.43E-05 | 6.51E-05 | 5.23E-05 | 2.18E-04 | 2.18E-04 | 1.19E-03 | 1.21E-03 |
| Fluorene | 1.36E-04 | 1.16E-04 | 8.68E-05 | 5.29E-05 | 0.00E+00 | 1.27E-04 | 3.59E-04 | 4.55E-04 |
| Naphthalene | 3.61E-04 | 4.67E-04 | 4.35E-04 | 3.26E-04 | 5.24E-04 | 4.47E-04 | 9.76E-04 | 1.24E-03 |
| Phenanthrene | 3.11E-04 | 3.65E-04 | 2.76E-04 | 2.26E-04 | 5.03E-04 | 4.85E-04 | 9.23E-04 | 7.88E-04 |
| C1-Chrysenes | 5.82E-05 | 5.77E-05 | 6.65E-05 | 4.15E-05 | 2.05E-04 | 2.20E-04 | 3.21E-03 | 2.27E-03 |
| C1-Fluoranthenes/pyrenes | 2.59E-04 | 2.89E-04 | 3.26E-04 | 2.77E-04 | 9.58E-04 | 1.01E-03 | 1.67E-02 | 1.49E-02 |
| C2-Chrysenes | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.70E-03 | 1.18E-03 |
| C3-Chrysenes | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| C4-Chrysenes | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| C1-Fluorenes | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 9.74E-04 | 1.05E-03 |
| C1-Naphthalenes | 2.75E-04 | 3.43E-04 | 1.89E-04 | 1.43E-04 | 4.40E-04 | 4.11E-04 | 5.04E-04 | 4.21E-04 |
| C1-Phenanthrenes/anthracenes | 3.96E-04 | 5.29E-04 | 2.94E-04 | 2.40E-04 | 7.46E-04 | 6.73E-04 | 2.87E-03 | 2.65E-03 |
| C2-Fluorenes | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 4.95E-03 | 5.00E-03 |
| C2-Naphthalenes | 5.21E-04 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 4.90E-04 | 7.30E-04 | 0.00E+00 |
| C2-Phenanthrenes/anthracenes | 5.50E-04 | 7.15E-04 | 4.07E-04 | 3.13E-04 | 1.24E-03 | 1.06E-03 | 9.89E-03 | 8.24E-03 |
| C3-Fluorenes | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.03E-02 | 1.02E-02 |
| C3-Naphthalenes | 6.28E-04 | 6.13E-04 | 0.00E+00 | 2.01E-04 | 6.74E-04 | 5.31E-04 | 1.78E-03 | 1.45E-03 |
| C3-Phenanthrenes/anthracenes | 3.49E-04 | 3.57E-04 | 3.40E-04 | 3.21E-04 | 1.11E-03 | 1.11E-03 | 1.19E-02 | 9.69E-03 |
| C4-Naphthalenes | 4.14E-04 | 5.12E-04 | 0.00E+00 | 1.08E-03 | 9.79E-04 | 9.18E-04 | 5.10E-03 | 4.79E-03 |
| C4-Phenanthrenes/anthracenes | 1.30E-04 | 1.65E-04 | 1.51E-04 | 9.82E-05 | 4.87E-04 | 5.11E-04 | 5.98E-03 | 4.32E-03 |
| **Total of 34 PAHs (umol/g-lipid)** | **0.007** | **0.007** | **0.005** | **0.005** | **0.015** | **0.015** | **0.172** | **0.154** |
| **Sum-Tox Units for 34 PAHs** | **0.003** | **0.003** | **0.002** | **0.002** | **0.007** | **0.007** | **0.077** | **0.069** |

**Table 6-2. (cont.)**

| Sample Location | LNB | LNB | OS-M2 | OS-M2 | OS-M5 | OS-M5 |
|---|---|---|---|---|---|---|
| Sample ID Number | FM063B01 | FM063B02 | FM063M201 | FM063M202 | FM063M501 | FM063M502 |
| Date | 08/30/06 | 08/30/06 | 08/30/06 | 08/30/06 | 08/30/06 | 08/30/06 |
| **Polycyclic Aromatic Hydrocarbons (umol/g-lipid)** | | | | | | |
| Benz[a]anthracene | 1.70E-04 | 1.65E-04 | 3.75E-04 | 3.07E-04 | 3.97E-04 | 3.20E-04 |
| Benzo[a]pyrene | 1.19E-04 | 8.81E-05 | 1.83E-04 | 1.97E-04 | 2.87E-04 | 1.92E-04 |
| Benzo[b]fluoranthene | 2.67E-04 | 2.42E-04 | 4.93E-04 | 4.87E-04 | 5.68E-04 | 4.77E-04 |
| Benzo[e]pyrene | 5.54E-04 | 5.77E-04 | 9.83E-04 | 8.89E-04 | 9.81E-04 | 8.10E-04 |
| Benzo[ghi]perylene | 1.34E-04 | 1.58E-04 | 1.84E-04 | 2.02E-04 | 2.81E-04 | 1.85E-04 |
| Benzo[k]fluoranthene | 2.15E-04 | 2.19E-04 | 4.36E-04 | 3.88E-04 | 5.47E-04 | 3.62E-04 |
| Chrysene | 4.15E-04 | 4.34E-04 | 8.27E-04 | 7.63E-04 | 8.43E-04 | 6.22E-04 |
| Dibenz[a,h]anthracene | 2.06E-05 | 2.51E-05 | 2.68E-05 | 3.49E-05 | 4.81E-05 | 2.55E-05 |
| Fluoranthene | 6.81E-04 | 7.91E-04 | 1.24E-03 | 1.05E-03 | 1.05E-03 | 8.46E-04 |
| Indeno[1,2,3-cd]pyrene | 7.67E-05 | 7.29E-05 | 9.00E-05 | 1.10E-04 | 1.59E-04 | 1.04E-04 |
| Perylene | 5.98E-05 | 9.26E-05 | 1.29E-04 | 1.14E-04 | 1.59E-04 | 1.45E-04 |
| Pyrene | 1.30E-03 | 1.39E-03 | 2.51E-03 | 2.39E-03 | 2.12E-03 | 1.84E-03 |
| Acenaphthene | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Acenaphthylene | 1.29E-04 | 1.19E-04 | 1.57E-04 | 2.23E-04 | 2.52E-04 | 1.95E-04 |
| Anthracene | 7.84E-05 | 1.23E-04 | 1.43E-04 | 1.30E-04 | 1.32E-04 | 1.07E-04 |
| Fluorene | 8.18E-05 | 1.12E-04 | 1.16E-04 | 1.58E-04 | 0.00E+00 | 0.00E+00 |
| Naphthalene | 4.74E-04 | 6.53E-04 | 7.27E-04 | 8.53E-04 | 1.15E-03 | 1.20E-03 |
| Phenanthrene | 2.86E-04 | 3.34E-04 | 5.12E-04 | 4.34E-04 | 3.92E-04 | 3.15E-04 |
| C1-Chrysenes | 1.29E-04 | 1.32E-04 | 2.68E-04 | 2.61E-04 | 2.85E-04 | 2.42E-04 |
| C1-Fluoranthenes/pyrenes | 6.90E-04 | 8.06E-04 | 1.42E-03 | 1.25E-03 | 1.40E-03 | 1.20E-03 |
| C2-Chrysenes | 0.00E+00 | 0.00E+00 | 1.51E-04 | 0.00E+00 | 0.00E+00 | 1.32E-04 |
| C3-Chrysenes | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| C4-Chrysenes | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| C1-Fluorenes | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| C1-Naphthalenes | 3.54E-04 | 4.49E-04 | 5.14E-04 | 4.39E-04 | 8.23E-04 | 7.52E-04 |
| C1-Phenanthrenes/anthracenes | 4.09E-04 | 5.44E-04 | 7.63E-04 | 7.00E-04 | 6.22E-04 | 5.12E-04 |
| C2-Fluorenes | 0.00E+00 | 0.00E+00 | 1.45E-03 | 0.00E+00 | 0.00E+00 | 1.02E-03 |
| C2-Naphthalenes | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 3.20E-04 |
| C2-Phenanthrenes/anthracenes | 1.17E-03 | 1.15E-03 | 2.36E-03 | 2.22E-03 | 1.92E-03 | 1.67E-03 |
| C3-Fluorenes | 0.00E+00 | 0.00E+00 | 3.31E-03 | 0.00E+00 | 0.00E+00 | 2.81E-03 |
| C3-Naphthalenes | 4.15E-04 | 3.34E-04 | 6.70E-04 | 7.41E-04 | 5.77E-04 | 4.97E-04 |
| C3-Phenanthrenes/anthracenes | 9.63E-04 | 1.06E-03 | 2.25E-03 | 2.23E-03 | 1.86E-03 | 1.59E-03 |
| C4-Naphthalenes | 1.35E-03 | 1.76E-03 | 1.97E-03 | 2.04E-03 | 1.79E-03 | 1.72E-03 |
| C4-Phenanthrenes/anthracenes | 3.29E-04 | 4.39E-04 | 8.41E-04 | 8.30E-04 | 6.80E-04 | 6.70E-04 |
| **Total of 34 PAHs (umol/g-lipid)** | **0.011** | **0.012** | **0.025** | **0.019** | **0.019** | **0.021** |
| **Sum-Tox Units for 34 PAHs** | **0.005** | **0.005** | **0.011** | **0.009** | **0.009** | **0.009** |

# 7.0 SUMMARY AND RECOMMENDATIONS FOR CHANGES TO THE MONITORING PROGRAM

As described in a recent review of issues related to toxic contaminants in Boston Harbor and Massachusetts Bay (Hunt et al. 2006), reductions in source loadings and improvements to wastewater facilities have measurably reduced contaminant loadings to the system. Improvements in treatment that have improved the quality of effluent and reduced loadings to surface water and sediment provide an important justification for reducing the extent of the HOM program. For example, starting in the late 1980s and early 1990s, MWRA began to more rigorously enforce regulations that limited industrial inputs of toxic contaminants to the treatment plant influent, ended the discharge of sewage sludge into the Harbor, and increased the capacity of the DITP to treat flows from combined sewers, lessening combined sewer overflows. By 1998, most sewage was receiving secondary treatment. In September 2000, the discharge of all effluent to Boston Harbor ended as the new outfall in Massachusetts Bay was opened. Additional improvements after 2000 include the continued enhancement of secondary treatment, reductions in corrosion and associated leaching of copper and lead from water supply pipes, and programs to reduce inputs of mercury from medical and dental facilities. In addition, federal regulation of toxic chemicals, such as PCBs and DDT, has resulted in reduced loadings of those contaminants to the system. The latest MWRA effluent monitoring data indicate that loads of many contaminants to Massachusetts Bay are less than projected based on the mid-1990s pilot data (Hunt et al. 2006). For example, recent MWRA data show that individual loadings of cadmium, silver, and mercury are as much as 50% lower than projected in EPA's SEIS for the treatment plant (Hunt et al. 2006).

Corresponding declines in contaminant concentrations in surficial sediments in Boston Harbor and Massachusetts Bay have been observed. A comparison of the average concentrations of selected contaminants in outer Boston Harbor and Dorchester Bay from 1994 and 2002 showed substantial deceases in total PAHs, total PCBs, mercury, cadmium, and silver (Hunt et al. 2006). Of the contaminants measured in the sediments, only lead and copper levels do not appear to have decreased substantially during this 8-year period.

Continued detailed monitoring of effluent contaminants by MWRA will provide the information necessary to access changes of exposure of aquatic plants and animals to many MWRA-derived effluent constituents. General justifications for the reduction or elimination of the fish and shellfish monitoring program include:

- Improvements in treatment and efforts to reduce loadings of contaminants to the system have improved the quality of the effluent and reduced loadings of contaminants to surface water and sediment
- Continued extensive monitoring of the effluent will provide sufficient information on the flux of contaminants to the environment and potential changes in exposure to fish, shellfish, and other aquatic organisms.

## 7.1 MUSSELS

Although concentrations of lead, PCBs, HMW PAH, total PAHs, chlordane, and 4,4'-DDE showed significant post-discharge increases at the Outfall Site after statistical comparisons with the control

station, tissue concentrations are below most thresholds for the protection of human health and aquatic organisms. As reported in the 2006 Annual Fish and Shellfish report (Nestler et al. 2007), current concentrations are below the FDA action limits and MWRA threshold levels. In addition, 2006 concentrations of PAHs in mussels at all locations were below EPA benchmarks for the protection of aquatic organisms, and concentrations of lead, mercury, chlordane, and 4,4'-DDE were below EPA screening-level RBCs. Although concentrations of PCBs exceed the EPA screening-level RBC at all locations, post-discharge increases observed at Deer Island Light, as well as at the Outfall Site and Large Navigation Buoy, suggest that factors other than the transfer of effluent discharge may be responsible for the changes. Additionally, 2006 concentrations of PCBs were higher in mussels deployed in Cape Cod Bay than those deployed at the Outfall Site. These results provide important justifications for the elimination of the monitoring program for mussels.

In summary, the mussels deployed at the Outfall Site are placed at the edge of the zone of initial dilution, within 100 m from the actual discharge points. Mussels are deployed during the summer when stratification is strongest and effluent dilution least. Even under this worst-case scenario, tissue concentrations in mussels are only modestly higher now than before the effluent relocation. The elevated levels are well below any FDA or EPA screening levels. Only PCBs exceed the EPA screening-level RBC, but it was at all stations for all tissue types. Provided MWRA continues to regularly monitor the effluent and levels of treatment continue at current high levels, monitoring of contaminants in mussels at the outfall is likely to be redundant.

## 7.2 LOBSTER

Results indicate that concentrations of contaminants in lobsters caught at the Outfall Site did not increase as a result of the relocation of the outfall. Concentrations of all contaminants were below FDA action limits and MWRA thresholds, and concentrations of most contaminants were below EPA screening-level RBCs. Concentrations of PCBs at all locations exceeded the EPA screening-level RBC, but current concentrations of PCBs in lobsters from the Outfall Site are not significantly different from concentrations at Cape Cod Bay, indicating a broader regional distribution of PCBs. As discussed in Section 4.4, the collection of lobsters from the Outfall Site is unreliable until September to November; at which time lobstermen begin setting traps in the area as the lobster migrate out of inshore waters. Measuring contaminants in mainly migratory lobsters reduces the suitability of using lobsters as a sentinel tool for outfall impacts. For the above reasons, we recommend the elimination of the lobster-monitoring program.

## 7.3 WINTER FLOUNDER

Similar to the findings for lobster, there was no apparent increase in tissue concentrations in flounder collected at the Outfall Site after effluent diversion. Concentrations of all contaminants in flounder were below FDA action limits and MWRA thresholds, and concentrations of most contaminants were below EPA screening-level RBCs. Therefore, we see no reason to continue measuring contaminants in flounder tissue. However, since the histological analysis of flounder livers is intended to detect any deleterious results of chemical exposure, MWRA may want to continue this analysis of livers from fish collected at the Outfall Site.

# 8.0 CONCLUSIONS

This report concludes that the following lines of evidence provide support for the elimination of the monitoring program for contaminants in fish and shellfish:

- Improvements in treatment and efforts to reduce inputs of contaminants to the system have improved the quality of the effluent and reduced loadings of contaminants to surface water and sediment.
- Continued extensive monitoring of the effluent will provide sufficient information on the flux of contaminants to the environment and future potential changes in exposure to mussels and other aquatic organisms.
- Results indicate that significant increases in some concentrations of contaminants in mussels at the Outfall Site after relocation are likely related to the relocation of the outfall. However, 2006 concentrations of most contaminants are below thresholds for the protection of human health and the environment. Although 2006 concentrations of PCBs exceeded a conservative screening-level RBC, this occurred at all locations, and concentrations were significantly lower at the Outfall Site in comparison to Cape Cod Bay.
- Results indicate that concentrations of contaminants in lobsters at the Outfall Site did not increase as a result of the relocation of the outfall. Current concentrations of most contaminants are below thresholds for the protection of human health and the environment. As was observed for mussels, current concentrations of PCBs in lobsters exceeded a conservative screening-level RBC at all locations, but concentrations of PCBs are not significantly different at the Outfall Site as compared to Cape Cod Bay.
- Results indicate that concentrations of contaminants in winter flounder did not increase as a result of the relocation of the outfall. Current concentrations of most contaminants in flounder are below thresholds for the protection of human health and the environment. As in other tissues, current concentrations of PCBs in flounder exceed a conservative screening-level RBC at all locations. Current PCB concentrations in flounder are significantly higher at the Outfall Site than at Cape Cod Bay.

## 9.0 REFERENCES

Bend, J.R., M.P. James, P.J. Little and G.L. Foureman. 1981. In vitro and in vivo metabolism benzo[a]pyrene by selected marine crustacean species. In: Phyletic approaches to cancer. Dawe, C.J. et al., (eds). Japan Scientific Society Press, Tokyo.

Bologna, P.A.X. and R.S. Steneck. 1993. Kelp beds as habitat for American lobster *Homarus americanus.* Mar. Ecol. Prog. Ser. 100:127–134.

Bowlby, H.D., J.M. Hanson, and J.A. Hutchings. 2007. Resident and dispersal behavior among individuals within a population of American lobster *Homarus americanus*. Mar. Ecol. Prog. Ser. 331:207–218.

Campbell, A. and A.B. Stasko. 1985. Movements of tagged American lobsters, *Homarus americanus*, off southwestern Nova Scotia. Can. J. Fish. Aquat. Sci. 42:229–238.

Campbell, A., and A.B. Stasko. 1986. Movements of lobsters, *Homarus americanus*, tagged in the Bay of Fundy, Canada. Can. J. Fish. Aquat. Sci. 92:393–404.

Campbell, A., O.J. Noakes, and R.W. Elner. 1991. Temperature and Lobster, *Homarus americanus*, yield relationships. Can. J. Fish. Aquat. Sci. 48:2073–2082.

Casterlin, M.E., and W.W. Reynolds. 1982. Thermoregulatory behavior and diel activity of yearling winter flounder, *Pseudopleuronectes americanus* (Walbaum). Environ. Biol. Fishes 7:177–180.

Castro, K.M., J.S. Cobb, R.A. Wahle, and J. Catena. 2001. Habitat addition and stock enhancement for American lobsters, *Homarus americanus*. Mar. Freshwat. Res. 52:1253–1261.

Chase M.E., S.H. Jones, P. Hennigar, et al. 2001. Gulfwatch: Monitoring spatial and temporal patterns of trace metal and organic contaminants in the Gulf of Maine (1991–1997) with the blue mussel, *Mytilus edulis L*. Marine Pollut. Bull. 42:491–505.

Comeau, M., and F. Savoie. 2002. Movement of American lobster (*Homarus amercianus*) in the southwestern Gulf of St. Lawrence. Fish. Bull. 100:181–192.

Cooper, R.A., and J.R. Uzmann. 1971. Migrations and growth of deep-sea lobsters, *Homarus americanus.* Science 171:288–290.

Crawford, R.E., and C.G. Carey. 1985. Retention of winter flounder larvae within a Rhode Island salt pond. Estuaries 8(2b):217–227.

DiGuilio, R.T. W.H. Benson, B.M. Saunders, and P.A. Van Veld. 1995. Biochemical mechanisms: metabolism, adaptation, and toxicity. pp. 523–561. In: Fundamentals of Aquatic Toxicology. G.M. Rand (ed). Taylor & Francis, Washington, DC.

Di Toro, D.M., and J.A. McGrath. 2000. Technical basis for narcotic chemicals and polycyclic aromatic hydrocarbon criteria. II. Mixtures and sediments. Environ. Toxicol. Chem. 19:1971–1982.

Di Toro, D.M., J.A. McGrath, and D.J. Hansen. 2000. Technical basis for narcotic chemicals and polycyclic aromatic hydrocarbon criteria. I. Water and tissue. Environ. Toxicol. Chem. 19:1951–1970.

Dow, R.L. 1977. Relationship of sea surface temperature to American and European lobster landings. J. Int. Council Explor. Sea 37(2):186–191.

Drinkwater, K.E., M.J. Tremblay, and M. Comeau. 2006. The influence of wind and temperature on the catch rate of the American lobster (*Homarus americanus*) during spring fisheries off eastern Canada. Fish. Oceanog. 15:150–165.

Eisler, R. 1981. Trace metal concentrations in marine organisms. Pergamon Press, New York.

Fogarty, M.J. 1988. Time series models of the Maine lobster fishery: The effect of temperature. Can. J. Fish. Aquat. Sci. 45:1145–1153.

Haakonsen, H.O., and A.O. Anoruo. 1994. Tagging and migration of the American lobster, *Homarus americanus.* Rev. Fish. Sci. 2:79–93.

Harding, G.C., K.F. Drinkwater, and W. P. Vass. 1983. Factors influencing the size of American lobster (*Homarus americanus*) stocks along the Atlantic coast of Nova Scotia, Gulf of St. Lawrence, and Gulf of Maine: A new synthesis. Can. J. Fish. Aquat. Sci. 40:168–184.

Hellou, J. 1996. Polycyclic aromatic hydrocarbons in marine mammals, finfish, and mollusks. pp. 229-250. In: Environmental Contaminants in Wildlife: Interpreting Tissue Concentrations. W.N. Beyer, G.H. Heinz, and A.W Redmon-Norwood (eds.). CRC Press. Boca Raton, FL.

Howe, A.B., and P.G. Coates. 1975. Winter flounder movements, growth and mortality off Massachusetts. Trans. Am. Fish. Soc. 104:13–29.

Hunt, C.D., S.L. Abramson, L.F. Lefkovitz, et al. 2002. Evaluation of 2001 mussel tissue contaminant threshold exceedance. Report 2002-05. Massachusetts Water Resources Authority, Boston.

Hunt, C.D., M. Hall, S.L. Pala, and D.T. Dahlen. 2006. A review and summary of toxic contaminants in Boston Harbor and Massachusetts Bay: 1990 to 2005. Report 2006-23. Massachusetts Water Resources Authority, Boston.

Incze, L.S., N. Wolff, and R.A. Wahle. 2003. Can scientific observations of early life stages be scaled up to the level of a fished population? A case study using *Homarus americanus*. Fish. Res. 65:33–46.

James, M.O. 1989. Biotransformation and disposition of PAH in aquatic invertebrates. pp. 69–92. In: Metabolism of Polycyclic Aromatic Hydrocarbons in the Aquatic Environment. U. Varanasi (ed). CRC Press, Boca Raton, FL.

Klein-MacPhee, G. 2002. Righteye flounders, Family Pleuronectidae. pp. 560–587. In: Bigelow and Schroeder's Fishes of the Gulf of Maine. Third Edition. B.B. Collette and G. Klein-MacPhee (eds). Smithsonian Institution Press, Washington, DC.

Koeller, P. 1998. Influence of temperature and effort on lobster catches at different temporal and spatial scales and the implications for stock assessments. Fish. Bull. 97:62–70.

Krouse, J.S. 1981. Movement, growth, and mortality of American lobsters, *Homarus americanus*, tagged along the coast of Maine. NOAA Technical Report NMFS SSRF-747. National Oceanic and Atmospheric Administration.

Lawton, P., and K.L. Lavalli. 1995. Postlarval, juvenile, adolescent, and adult ecology. pp. 47–88. In: Biology of the Lobster *Homarus americanus*. J.R. Factor (ed). Academic Press, Boston.

Lefkowitz, L.F., J.M. Neff, R. Lizotte, M. Hall. 2001. Comparison of two analytical methods for rmeasurement of chlorinated pesticides and PCB congeners in biological tissue – Trends in Boston Harbor lobster tissue. Boston: Massachusetts Water Resources. Report ENQUAD 01-02. 51 p. plus appendices.

Lobell, M.J. 1939. A biological survey of the salt waters of Long Island, 1938. Report on certain fishes. Winter flounder (*Pseudopleuronectes americanus*). Suppl. 28th Ann. Rep., NY Cons. Dep., Pt. I:63–96.

MacKenzie, C., and J.R. Moring. 1985. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic)—American lobster. FWS Biological Report 82(11.33). ACOE No. TR EL-82-4. U.S. Fish and Wildlife Service and U.S. Army Corps of Engineers.

Mix, M.C. 1984. Polycyclic aromatic hydrocarbons in the aquatic environment: occurrence and biological monitoring. In: Reviews in Environmental Toxicology, Volume 50. E. Hodgson (ed). Elsevier/North Holland, Amsterdam.

Mix, M.C., and R.L. Schaffer. 1983. Concentrations of unsubstituted polynuclear aromatic hydrocarbons in Bay mussels (*Mytilis edulis*) from Oregon, USA. Mar. Environ. Res. 9:193–209.

MWRA. 1991. Massachusetts Water Resources Authority effluent outfall monitoring plan: Phase I baseline studies. Report ENQUAD ms-02. Massachusetts Water Resources Authority, Boston, MA.

MWRA. 1997. Massachusetts Water Resources Authority effluent outfall monitoring plan: Phase II post discharge monitoring. Report ENQUAD ms-44. Massachusetts Water Resources Authority, Boston, MA.

MWRA. 2001. Massachusetts Water Resources Authority contingency plan revision 1. Report 1-ms-071. Massachusetts Water Resources Authority, Boston, MA.

MWRA. 2004. Massachusetts Water Resources Authority effluent outfall monitoring plan. Revision 1. March 2004. Report 0-ms-092. Massachusetts Water Resources Authority, Boston, MA.

Nestler, E.C., A. Pembroke, M.J. Moore, and S. Chapnick. 2007. 2006 Annual fish and shellfish report. Report 2007-06. Massachusetts Water Resources Authority, Boston, MA.

Newell, R.I.E. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (North and Mid-Atlantic)—blue mussel. FWS Biol. Rep. 82(11.102). Corps TR EL—82-4. U.S. Fish and Wildlife Service and U.S. Army Corps of Engineers.

O'Connor, T.P. 1998. Mussel watch results from 1986 to 1996. Mar. Pollut. Bull. 37:14–19.

O'Connor, T.P., and G.G. Lauenstein. 2006. Trends in chemical concentrations in mussels and oysters collected along the US coast: Update to 2003. Mar. Environ. Res. 62:261–285.

Palma, A.T., R.A. Wahle, and R.S. Steneck. 1998. Different early post-settlement strategies between American lobsters *Homarus americanus* and rock crabs *Cancer irroratus* in the Gulf of Maine. Mar. Ecol. Prog. Ser. 162:215–225.

Pereira, J.J., R. Goldberg, J.J. Ziskowski, P.L. Berrien, W.W. Morse, and D.L. Johnson. 1999. Essential fish habitat source document: Winter flounder, *Pseudopleuronectes americanus*, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-138. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center.

Perlmutter, A. 1947. The blackback flounder and its fishery in New England and New York. Bull. Bingham Oceanog. Collec. 11:1–92.

Rainbow, P.S. 1996. Heavy metals in aquatic invertebrates. pp. 405–425. In: Environmental Contaminants in Wildlife: Interpreting Tissue Concentrations. W.N. Beyer, G.H. Heinz, and A.W Redmon-Norwood (eds). CRC Press. Boca Raton, FL.

Roesijadi, G. and W.E. Robinson. 1994. Metal regulation in aquatic animals: Mechanisms of uptake, accumulation and release. pp. 387–420. In: Aquatic Toxicology: Molecular, Biochemical, and Cellular Perspectives. D.C. Malins and G.K. Ostrander (eds). CRC Press, Boca Raton, FL.

Saila, S.B. 1961. A study of winter flounder movements. Limnol. Oceanog. 6:292–298.

Saila, S.B., E. Lorda, J.D. Miller, R.A. Sher, and W.H. Howell. 1997. Equivalent adult estimates for losses of fish eggs, larvae, and juveniles at Seabrook Station with use of fuzzy logic to represent parameter uncertainty. N. Am. J. Fish. Manage. 17:811–825.

Scott, W.B., and M.G. Scott. 1988. Atlantic fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219:731.

Smith, E.P. 2002. BACI design. Volume 1. In: Encyclopedia of Environmetrics. A.H. El-Shaarawi and W.W. Piegorsch (eds). John Wiley & Sons, Ltd., Chichester, England.

Sogard, S.M., K.W. Able, and S.M. Hagan. 2001. Long-term assessment of settlement and growth of juvenile winter flounder (*Pseudopleuronectes americanus*) in New Jersey estuaries. J. Sea Res. 45:189–204.

Spanier, E., T.P. McKenzie, J.S. Cobb, and M. Clancy. 1998. Behavior of juvenile American lobsters, *Homarus americanus*, under predation risk. Mar. Biol. 130:396–406.

Stegeman, J.J. and M.E. Hahn. 1994. Biochemistry and molecular biology of monooxygenases: Current perspectives on forms, functions, and regulation of Cytochrome P450 in aquatic species. pp. 87-206. In: Aquatic Toxicology: Molecular, biochemical, and cellular perspectives. D.C. Malins and G.K. Ostrander (eds.). CRC Press, Boca Raton, FL.

Stegeman, J.J., and J.J. Lech. 1991. Cytochrome P-450 monooxygenase systems in aquatic species carcinogen metabolism and biomarkers for carcinogen and pollutant exposure. Environ. Health Perspect. 90:101–109.

Steneck, R.S. 2006. Possible demographic consequences of intraspecific shelter competition among American lobsters. J. Crustacean Biol. 26:628–638.

U.S. EPA. 1996. EMAP-estuaries Virginian Province data 1990–1993. Available at: http://www.epa.gov/emap. U.S. Environmental Protection Agency.

U.S. EPA. 1998. Boston Harbor wastewater conveyance system. Supplemental environmental impact statement (SEIS). U.S. Environmental Protection Agency, Region I, Boston, MA.

U.S. EPA. 2003. Procedures for the derivation of equilibrium partitioning sediment benchmarks (ESBs) for the protection of benthic organisms: PAH mixtures. EPA-600-R-02-013. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

U.S. EPA. 2007. Human health risk assessment risk-based concentrations. Available at: http://www.epa.gov/reg3hscd/risk/human/index.htm. U.S. Environmental Protection Agency.

U.S. FDA. 2005. National Shellfish Sanitation Program. Guide for the control of molluscan shellfish. Available at: http://www.cfsan.fda.gov/~ear/nss3-42d.html. U.S. Food and Drug Administration.

Varanasi, U., J.E. Stein, and M. Nishimoto. 1989. Biotransformation and disposition of polycyclic aromatic hydrocarbons (PAH) in fish. pp. 93–149. In: Metabolism of Polycyclic Aromatic Hydrocarbons in the Aquatic Environment. U. Varanasi (ed). CRC Press, Boca Raton, FL.

Varanasi, U., and J.E. Stein. 1991. Disposition of xenobiotic chemicals in marine organisms. Env. Health Perspect. 90:93–100.

Watson, III, W.H., A. Vetrovs, and W.H. Howell. 1999. Lobster movements in an estuary. Mar. Biol. 134:65–75.

Weiner, J.G., and D.J. Spry. 1996. Toxicological significance of mercury in freshwater fish. pp. 297–339. In: Environmental Contaminants in Wildlife: Interpreting Tissue Concentrations. W.N. Beyer, G.H. Heinz, and A.W Redmon-Norwood (eds). CRC Press. Boca Raton, FL.

Werme, C., and C.D. Hunt. 2006. 2005 Outfall monitoring overview. Report 2006-18. Massachusetts Water Resources Authority, Boston, MA.

Wisneski, C., L.F. Lefkovitz, M.J. Moore, and E. Schaub. 2004. 2003 Annual fish and shellfish report. Report 2004-11. Massachusetts Water Resources Authority, Boston, MA

# Appendix A

## Data

**Table A-1. Concentrations measured in mussel soft tissue**

| Station | Sample ID | Date | Lead | Mercury | PCBs | LMW(7)-PAH | LMW(12)-PAH | HMW-PAH | Total(19)-PAH | Total(24)-PAH | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CCB | FM9833GVX30 | 09/01/98 | | | 23 | 11 | 16 | 25 | 36 | 40 | 7.1 | 6.1 |
| CCB | FM9833GVX31 | 09/01/98 | | | 25 | 21 | 26 | 24 | 45 | 50 | 7.7 | 8.3 |
| CCB | FM9833GVX32 | 09/01/98 | | | 23 | 15 | 19 | 26 | 42 | 46 | 6.5 | 6.8 |
| CCB | FM9833GVX33 | 09/01/98 | | | 23 | 17 | 22 | 29 | 46 | 50 | 7.6 | 8.6 |
| CCB | FM9833GVX34 | 09/01/98 | | | 22 | 14 | 17 | 18 | 32 | 36 | 7.3 | 7.5 |
| CCB | FM9833GVX35 | 09/01/98 | | | 25 | 18 | 22 | 21 | 39 | 43 | 8.3 | 11 |
| CCB | FM9833GVX36 | 09/01/98 | | | 19 | 11 | 15 | 16 | 27 | 31 | 6.2 | 7.8 |
| CCB | FM9833GVX37 | 09/01/98 | | | 28 | 14 | 18 | 18 | 33 | 36 | 8.5 | 10 |
| CCB | FM9833SVW92 | 09/01/98 | 1.3 | 0.050 | | | | | | | | |
| CCB | FM9833SVW93 | 09/01/98 | 2.7 | 0.080 | | | | | | | | |
| CCB | FM9833SVW94 | 09/01/98 | 1.7 | 0.070 | | | | | | | | |
| CCB | FM9833SVW95 | 09/01/98 | 2.0 | 0.080 | | | | | | | | |
| CCB | FM9833SVW96 | 09/01/98 | 1.7 | 0.050 | | | | | | | | |
| CCB | FM9833SVW97 | 09/01/98 | 1.8 | 0.070 | | | | | | | | |
| CCB | FM9833SVW98 | 09/01/98 | 2.2 | 0.090 | | | | | | | | |
| CCB | FM9833SVW99 | 09/01/98 | 2.2 | 0.070 | | | | | | | | |
| CCB | FM9933GXD92 | 09/02/99 | | | 19 | 18 | 25 | 16 | 35 | 41 | 7.6 | 6.7 |
| CCB | FM9933GXD93 | 09/02/99 | | | 25 | 25 | 35 | 18 | 43 | 53 | 9.8 | 8.9 |
| CCB | FM9933GXD94 | 09/02/99 | | | 23 | 28 | 37 | 23 | 51 | 60 | 9.0 | 7.6 |
| CCB | FM9933GXD95 | 09/02/99 | | | 19 | 24 | 32 | 15 | 40 | 47 | 7.8 | 6.8 |
| CCB | FM9933GXD96 | 09/02/99 | | | 23 | 22 | 29 | 21 | 43 | 50 | 9.3 | 7.0 |
| CCB | FM9933GXD97 | 09/02/99 | | | 21 | 27 | 36 | 19 | 46 | 54 | 8.4 | 7.5 |
| CCB | FM9933GXD98 | 09/02/99 | | | 21 | 31 | 40 | 19 | 51 | 59 | 7.9 | 7.0 |
| CCB | FM9933GXD99 | 09/02/99 | | | 23 | 29 | 38 | 23 | 51 | 60 | 9.3 | 7.9 |
| CCB | FM9933SXE19 | 09/02/99 | 1.5 | 0.056 | | | | | | | | |
| CCB | FM9933SXE20 | 09/02/99 | 1.1 | 0.049 | | | | | | | | |
| CCB | FM9933SXE21 | 09/02/99 | 1.3 | 0.054 | | | | | | | | |
| CCB | FM9933SXE22 | 09/02/99 | 1.2 | 0.059 | | | | | | | | |
| CCB | FM9933SXE23 | 09/02/99 | 1.8 | 0.058 | | | | | | | | |
| CCB | FM9933SXE24 | 09/02/99 | 1.2 | 0.048 | | | | | | | | |
| CCB | FM9933SXE25 | 09/02/99 | 1.2 | 0.051 | | | | | | | | |
| CCB | FM9933SXE26 | 09/02/99 | 0.94 | 0.046 | | | | | | | | |
| CCB | FM011ZH80 | 08/28/01 | 3.1 | 0.16 | 30 | 16 | 20 | 51 | 66 | 71 | 9.4 | 4.4 |
| CCB | FM011ZH81 | 08/28/01 | 1.4 | 0.091 | 33 | 24 | 30 | 70 | 94 | 100 | 9.8 | 5.0 |
| CCB | FM011ZH82 | 08/28/01 | 1.8 | 0.12 | 29 | 17 | 21 | 60 | 77 | 81 | 8.7 | 4.2 |
| CCB | FM011ZH83 | 08/28/01 | 1.6 | 0.11 | 31 | 26 | 30 | 66 | 92 | 96 | 10 | 5.3 |
| CCB | FM011ZH84 | 08/28/01 | 1.3 | 0.073 | 32 | 26 | 31 | 63 | 89 | 94 | 10 | 4.9 |
| CCB | FM011ZH85 | 08/28/01 | 1.7 | 0.080 | 33 | 17 | 22 | 58 | 76 | 80 | 10 | 5.4 |
| CCB | FM011ZH86 | 08/28/01 | 1.7 | 0.092 | 33 | 17 | 20 | 56 | 73 | 77 | 11 | 5.7 |

**Table A-1. (cont.)**

| Station | Sample ID | Date | Lead | Mercury | PCBs | LMW(7)-PAH | LMW(12)-PAH | HMW-PAH | Total(19)-PAH | Total(24)-PAH | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CCB | FM011ZH87 | 08/28/01 | 1.5 | 0.076 | 18 | 17 | 21 | 61 | 78 | 82 | 7.0 | 3.7 |
| CCB | FM021V8143 | 08/27/02 | 1.6 | 0.12 | 20 | 5.7 | 6.4 | 19 | 24 | 25 | 5.6 | 4.9 |
| CCB | FM021V8144 | 08/27/02 | 1.6 | 0.13 | 16 | 5.1 | 5.9 | 10 | 15 | 16 | 5.0 | 4.1 |
| CCB | FM021V8145 | 08/27/02 | 1.5 | 0.11 | 15 | 5.0 | 5.7 | 12 | 17 | 18 | 4.1 | 3.6 |
| CCB | FM021V8146 | 08/27/02 | 1.4 | 0.12 | 15 | 5.1 | 5.8 | 14 | 19 | 20 | 4.1 | 3.6 |
| CCB | FM031T6988 | 08/26/03 | 1.5 | 0.11 | 18 | 8.1 | 12 | 29 | 37 | 41 | 5.7 | 3.7 |
| CCB | FM031T6989 | 08/26/03 | 1.5 | 0.12 | 19 | 12 | 16 | 31 | 43 | 47 | 6.5 | 3.9 |
| CCB | FM031T6990 | 08/26/03 | 1.3 | 0.12 | 19 | 9.8 | 14 | 33 | 42 | 46 | 6.2 | 3.8 |
| CCB | FM031T6991 | 08/26/03 | 1.4 | 0.11 | 18 | 10 | 14 | 30 | 40 | 44 | 6.3 | 4.0 |
| CCB | FM063901 | 08/30/06 | 1.7 | 0.090 | 24 | 12 | 17 | 38 | 50 | 55 | 13 | 3.2 |
| CCB | FM063902 | 08/30/06 | 1.4 | 0.080 | 21 | 12 | 17 | 42 | 55 | 60 | 11 | 2.9 *U* |
| CCB | FM063903 | 08/30/06 | 2.0 | 0.080 | 20 | | | | | | 8.9 | 2.3 *U* |
| CCB | FM063904 | 08/30/06 | 1.9 | 0.10 | 23 | | | | | | 8.5 | 2.9 *U* |
| DIL | M9511D1H7TC1 | 08/11/95 | 8.3 | | 58 | 62 | | 380 | 440 | | 17 | 11 |
| DIL | M9511D1H7TC2 | 08/11/95 | 11 | | 61 | 75 | | 470 | 550 | | 18 | 12 |
| DIL | M9511D1H7TC3 | 08/11/95 | 5.9 | | 59 | 68 | | 370 | 440 | | 17 | 12 |
| DIL | M9511D1H7TC4 | 08/11/95 | 8.5 | | 59 | 77 | | 410 | 480 | | 18 | 12 |
| DIL | M9511D1H7TC5 | 08/11/95 | 8.5 | | 64 | 75 | | 450 | 520 | | 17 | 11 |
| DIL | M9511D1H8TC1 | 08/11/95 | | 0.0091 | | | | | | | | |
| DIL | M9511D1H8TC2 | 08/11/95 | | 0.025 | | | | | | | | |
| DIL | M9511D1H8TC3 | 08/11/95 | | 0.070 | | | | | | | | |
| DIL | M9511D1H8TC4 | 08/11/95 | | 0.12 | | | | | | | | |
| DIL | M9511D1H8TC5 | 08/11/95 | | 0.084 | | | | | | | | |
| DIL | M9611D1H7TC1 | 08/27/96 | | | 86 | 96 | 160 | 570 | 660 | 720 | 23 | 27 |
| DIL | M9611D1H7TC2 | 08/27/96 | | | 110 | 140 | 210 | 730 | 870 | 940 | 37 | 41 |
| DIL | M9611D1H7TC3 | 08/27/96 | | | 85 | 120 | 190 | 670 | 790 | 870 | 28 | 33 |
| DIL | M9611D1H7TC4 | 08/27/96 | | | 100 | 120 | 210 | 720 | 850 | 930 | 33 | 40 |
| DIL | M9611D1H7TC5 | 08/27/96 | | | 100 | 270 | 390 | 1,300 | 1,600 | 1,700 | 36 | 44 |
| DIL | M9611D1H8TC1 | 08/27/96 | 6.3 | 0.19 | | | | | | | | |
| DIL | M9611D1H8TC2 | 08/27/96 | 8.4 | 0.21 | | | | | | | | |
| DIL | M9611D1H8TC3 | 08/27/96 | 6.1 | 0.14 | | | | | | | | |
| DIL | M9611D1H8TC4 | 08/27/96 | 5.2 | 0.13 | | | | | | | | |
| DIL | M9611D1H8TC5 | 08/27/96 | 5.3 | 0.11 | | | | | | | | |
| DIL | M9711D1H7TC1 | 08/26/97 | | | 94 | 53 | 86 | 260 | 310 | 340 | 24 | 21 |
| DIL | M9711D1H7TC2 | 08/26/97 | | | 90 | 53 | 85 | 240 | 300 | 330 | 26 | 21 |
| DIL | M9711D1H7TC3 | 08/26/97 | | | 87 | 52 | 81 | 240 | 290 | 320 | 20 | 16 |
| DIL | M9711D1H7TC4 | 08/26/97 | | | 97 | 57 | 87 | 250 | 310 | 340 | 26 | 20 |
| DIL | M9711D1H7TC5 | 08/26/97 | | | 95 | 65 | 99 | 320 | 380 | 410 | 28 | 22 |
| DIL | M9711D1H8TC1 | 08/26/97 | 7.0 | 0.11 | | | | | | | | |

**Table A-1. (cont.)**

| Station | Sample ID | Date | Lead | Mercury | PCBs | LMW(7)-PAH | LMW(12)-PAH | HMW-PAH | Total(19)-PAH | Total(24)-PAH | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DIL | M9711D1H8TC2 | 08/26/97 | 8.4 | 0.086 | | | | | | | | |
| DIL | M9711D1H8TC3 | 08/26/97 | 9.4 | 0.064 | | | | | | | | |
| DIL | M9711D1H8TC4 | 08/26/97 | 7.5 | 0.020 | | | | | | | | |
| DIL | M9711D1H8TC5 | 08/26/97 | 6.8 | 0.033 | | | | | | | | |
| DIL | FM9821GVX17 | 08/10/98 | | | 58 | 29 | 50 | 150 | 180 | 200 | 13 | 24 |
| DIL | FM9821GVX18 | 08/10/98 | | | 54 | 33 | 58 | 160 | 190 | 220 | 12 | 23 |
| DIL | FM9821GVX19 | 08/10/98 | | | 55 | 47 | 76 | 150 | 200 | 220 | 12 | 22 |
| DIL | FM9821GVX20 | 08/10/98 | | | 58 | 36 | 62 | 160 | 200 | 220 | 13 | 24 |
| DIL | FM9821GVX21 | 08/10/98 | | | 59 | 44 | 72 | 150 | 190 | 220 | 13 | 25 |
| DIL | FM9821SVW79 | 08/10/98 | 2.7 | 0.090 | | | | | | | | |
| DIL | FM9821SVW80 | 08/10/98 | 3.2 | 0.10 | | | | | | | | |
| DIL | FM9821SVW81 | 08/10/98 | 3.8 | 0.11 | | | | | | | | |
| DIL | FM9821SVW82 | 08/10/98 | 1.7 | 0.080 | | | | | | | | |
| DIL | FM9821SVW83 | 08/10/98 | 6.0 | 0.11 | | | | | | | | |
| DIL | FM0031YE54 | 08/28/00 | 7.0 | 0.15 | | | | | | | | |
| DIL | FM0031YE55 | 08/28/00 | 6.6 | 0.18 | | | | | | | | |
| DIL | FM0031YE56 | 08/28/00 | 10 | 0.17 | | | | | | | | |
| DIL | FM0031YE57 | 08/28/00 | 4.2 | 0.14 | | | | | | | | |
| DIL | FM0031YE58 | 08/28/00 | 6.7 | 0.16 | | | | | | | | |
| DIL | FM0031YE77 | 08/28/00 | | | 56 | 83 | 130 | 430 | 510 | 560 | 11 | 11 |
| DIL | FM0031YE78 | 08/28/00 | | | 80 | | | | | | 17 | 16 |
| DIL | FM0031YE79 | 08/28/00 | | | 62 | 97 | 150 | 400 | 500 | 550 | 13 | 14 |
| DIL | FM0031YE80 | 08/28/00 | | | 65 | 58 | 90 | 300 | 360 | 390 | 13 | 14 |
| DIL | FM0031YE81 | 08/28/00 | | | 63 | 69 | 110 | 330 | 400 | 440 | 13 | 14 |
| DIL | FM011ZH67 | 08/27/01 | 3.4 | 0.12 | 92 | 25 | 40 | 220 | 250 | 260 | 13 | 9.0 |
| DIL | FM011ZH68 | 08/27/01 | 3.0 | 0.12 | 92 | 27 | 40 | 210 | 240 | 250 | 13 | 8.4 |
| DIL | FM011ZH69 | 08/27/01 | 3.0 | 0.12 | 90 | 23 | 36 | 210 | 230 | 240 | 12 | 8.0 |
| DIL | FM011ZH70 | 08/27/01 | 3.5 | 0.13 | 92 | 32 | 44 | 220 | 250 | 270 | 12 | 8.7 |
| DIL | FM011ZH71 | 08/27/01 | 4.5 | 0.14 | 120 | 22 | 34 | 190 | 210 | 220 | 14 | 9.3 |
| DIL | FM021V8126 | 08/26/02 | 5.1 | 0.19 | 83 | 28 | 39 | 150 | 180 | 190 | 11 | 9.5 |
| DIL | FM021V8127 | 08/26/02 | 4.6 | 0.18 | 80 | 25 | 35 | 140 | 170 | 180 | 9.9 | 8.6 |
| DIL | FM021V8128 | 08/26/02 | 5.0 | 0.18 | 60 | 23 | 31 | 150 | 180 | 180 | 8.3 | 6.6 |
| DIL | FM021V8129 | 08/26/02 | 5.6 | 0.17 | 63 | 29 | 40 | 160 | 180 | 200 | 7.8 | 6.5 |
| DIL | FM021V8130 | 08/26/02 | 5.6 | 0.19 | 59 | 30 | 42 | 150 | 180 | 190 | 7.1 | 5.5 |
| DIL | FM031T6971 | 08/26/03 | 2.5 | 0.12 | 66 | 15 | 27 | 130 | 140 | 150 | 10 | 8.6 |
| DIL | FM031T6972 | 08/26/03 | 2.6 | 0.13 | 75 | 15 | 27 | 130 | 140 | 150 | 11 | 9.1 |
| DIL | FM031T6973 | 08/26/03 | 2.7 | 0.13 | 75 | 16 | 27 | 130 | 140 | 150 | 11 | 9.6 |
| DIL | FM031T6974 | 08/26/03 | 2.5 | 0.14 | 86 | 21 | 33 | 140 | 160 | 170 | 12 | 10 |
| DIL | FM031T6975 | 08/26/03 | 2.6 | 0.14 | 100 | 22 | 36 | 170 | 190 | 200 | 14 | 12 |

**Table A-1. (cont.)**

| Station | Sample ID | Date | Lead | Mercury | PCBs | LMW(7)-PAH | LMW(12)-PAH | HMW-PAH | Total(19)-PAH | Total(24)-PAH | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DIL | FM0631M01 | 08/30/06 | 2.4 | 0.080 | 76 | 17 | 25 | 99 | 120 | 120 | 16 | 5.5 |
| DIL | FM0631M02 | 08/30/06 | 2.7 | 0.070 | 74 | 19 | 30 | 120 | 140 | 150 | 16 | 4.3 |
| DIL | FM0631M03 | 08/30/06 | 3.4 | 0.090 | 73 | | | | | | 18 | 4.3 |
| DIL | FM0631M04 | 08/30/06 | 3.3 | 0.070 | 65 | | | | | | 10 | 5.1 |
| DIL | FM0631M05 | 08/30/06 | 3.4 | 0.11 | 72 | | | | | | 11 | 5.1 |
| IH | M9511D6H7TC1 | 08/11/95 | 6.9 | | 160 | 130 | | 1,300 | 1,400 | | 41 | 22 |
| IH | M9511D6H7TC2 | 08/11/95 | 8.1 | | 150 | 130 | | 1,300 | 1,400 | | 40 | 21 |
| IH | M9511D6H7TC3 | 08/11/95 | 8.7 | | 160 | 140 | | 1,300 | 1,400 | | 46 | 24 |
| IH | M9511D6H7TC4 | 08/11/95 | 8.8 | | 160 | 130 | | 1,200 | 1,300 | | 42 | 20 |
| IH | M9511D6H7TC5 | 08/11/95 | 10 | | 140 | 130 | | 1,200 | 1,300 | | 33 | 17 |
| IH | M9511D6H8TC1 | 08/11/95 | | 0.23 | | | | | | | | |
| IH | M9511D6H8TC2 | 08/11/95 | | 0.031 | | | | | | | | |
| IH | M9511D6H8TC3 | 08/11/95 | | 0.058 | | | | | | | | |
| IH | M9511D6H8TC4 | 08/11/95 | | 0.069 | | | | | | | | |
| IH | M9511D6H8TC5 | 08/11/95 | | 0.011 | | | | | | | | |
| IH | M9611D6H7TC1 | 08/27/96 | | | 200 | 140 | 190 | 2,400 | 2,600 | 2,600 | 55 | 36 |
| IH | M9611D6H7TC2 | 08/27/96 | | | 170 | 160 | 210 | 2,600 | 2,800 | 2,800 | 36 | 33 |
| IH | M9611D6H7TC3 | 08/27/96 | | | 220 | 150 | 200 | 2,200 | 2,300 | 2,400 | 44 | 26 |
| IH | M9611D6H7TC4 | 08/27/96 | | | 150 | 140 | 180 | 2,000 | 2,200 | 2,200 | 33 | 29 |
| IH | M9611D6H7TC5 | 08/27/96 | | | 210 | 130 | 190 | 1,900 | 2,100 | 2,100 | 44 | 24 |
| IH | M9611D6H8TC1 | 08/27/96 | 8.1 | 0.14 | | | | | | | | |
| IH | M9611D6H8TC2 | 08/27/96 | 11 | 0.099 | | | | | | | | |
| IH | M9611D6H8TC3 | 08/27/96 | 8.6 | 0.14 | | | | | | | | |
| IH | M9711D6H7TC1 | 08/26/97 | | | 300 | 100 | 120 | 1,200 | 1,300 | 1,400 | 52 | 36 |
| IH | M9711D6H7TC2 | 08/26/97 | | | 240 | 100 | 130 | 1,100 | 1,200 | 1,200 | 50 | 24 |
| IH | M9711D6H7TC3 | 08/26/97 | | | 270 | 120 | 150 | 1,300 | 1,400 | 1,400 | 37 | 25 |
| IH | M9711D6H7TC4 | 08/26/97 | | | 250 | 160 | 190 | 1,700 | 1,800 | 1,800 | 40 | 29 |
| IH | M9711D6H7TC5 | 08/26/97 | | | 310 | 130 | 150 | 1,500 | 1,600 | 1,600 | 52 | 29 |
| IH | M9711D6H8TC1 | 08/26/97 | 5.1 | 0.39 | | | | | | | | |
| IH | M9711D6H8TC2 | 08/26/97 | 14 | 0.34 | | | | | | | | |
| IH | M9711D6H8TC3 | 08/26/97 | 8.3 | 0.23 | | | | | | | | |
| IH | M9711D6H8TC4 | 08/26/97 | 9.3 | 0.23 | | | | | | | | |
| IH | M9711D6H8TC5 | 08/26/97 | 13 | 0.41 | | | | | | | | |
| IH | FM9832GVX12 | 08/31/98 | | | 180 | 140 | 170 | 1,900 | 2,100 | 2,100 | 25 | 28 |
| IH | FM9832GVX13 | 08/31/98 | | | 140 | 120 | 140 | 1,600 | 1,700 | 1,700 | 24 | 21 |
| IH | FM9832GVX14 | 08/31/98 | | | 170 | 140 | 170 | 1,800 | 1,900 | 1,900 | 25 | 23 |
| IH | FM9832GVX15 | 08/31/98 | | | 200 | 220 | 270 | 2,200 | 2,400 | 2,500 | 29 | 31 |
| IH | FM9832GVX16 | 08/31/98 | | | 180 | 130 | 160 | 1,800 | 2,000 | 2,000 | 24 | 24 |
| IH | FM9832SVW74 | 08/31/98 | 3.3 | 0.11 | | | | | | | | |

**Table A-1. (cont.)**

| Station | Sample ID | Date | Lead | Mercury | PCBs | LMW(7)-PAH | LMW(12)-PAH | HMW-PAH | Total(19)-PAH | Total(24)-PAH | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IH | FM9832SVW75 | 08/31/98 | 4.2 | 0.11 | | | | | | | | |
| IH | FM9832SVW76 | 08/31/98 | 4.4 | 0.11 | | | | | | | | |
| IH | FM9832SVW77 | 08/31/98 | 4.1 | 0.10 | | | | | | | | |
| IH | FM9832SVW78 | 08/31/98 | 4.5 | 0.12 | | | | | | | | |
| IH | FM9931GXD79 | 08/30/99 | | | 150 | 100 | 130 | 2,100 | 2,200 | 2,300 | 23 | 18 |
| IH | FM9931GXD80 | 08/30/99 | | | 170 | 110 | 150 | 2,500 | 2,600 | 2,600 | 28 | 23 |
| IH | FM9931GXD81 | 08/30/99 | | | 180 | 150 | 190 | 2,600 | 2,700 | 2,800 | 28 | 23 |
| IH | FM9931GXD82 | 08/30/99 | | | 150 | 140 | 180 | 2,700 | 2,800 | 2,900 | 27 | 22 |
| IH | FM9931GXD83 | 08/30/99 | | | 190 | 180 | 230 | 2,700 | 2,900 | 2,900 | 28 | 23 |
| IH | FM9931SXE06 | 08/30/99 | 4.1 | 0.10 | | | | | | | | |
| IH | FM9931SXE07 | 08/30/99 | 5.4 | 0.10 | | | | | | | | |
| IH | FM9931SXE08 | 08/30/99 | 5.2 | 0.10 | | | | | | | | |
| IH | FM9931SXE09 | 08/30/99 | 3.6 | 0.084 | | | | | | | | |
| IH | FM9931SXE10 | 08/30/99 | 5.2 | 0.11 | | | | | | | | |
| IH | FM0036YE49 | 08/28/00 | 11 | 0.16 | | | | | | | | |
| IH | FM0036YE50 | 08/28/00 | 14 | 0.18 | | | | | | | | |
| IH | FM0036YE51 | 08/28/00 | 16 | 0.22 | | | | | | | | |
| IH | FM0036YE52 | 08/28/00 | 12 | 0.16 | | | | | | | | |
| IH | FM0036YE53 | 08/28/00 | 12 | 0.17 | | | | | | | | |
| IH | FM0036YE72 | 08/28/00 | | | 230 | 210 | 280 | 2,200 | 2,400 | 2,500 | 35 | 27 |
| IH | FM0036YE73 | 08/28/00 | | | 200 | 180 | 250 | 1,900 | 2,100 | 2,100 | 28 | 21 |
| IH | FM0036YE74 | 08/28/00 | | | 210 | 180 | 240 | 1,900 | 2,100 | 2,100 | 32 | 25 |
| IH | FM0036YE75 | 08/28/00 | | | 240 | 200 | 280 | 2,300 | 2,500 | 2,600 | 38 | 33 |
| IH | FM0036YE76 | 08/28/00 | | | 250 | 240 | 320 | 2,600 | 2,900 | 3,000 | 40 | 35 |
| IH | FM011ZH62 | 08/27/01 | 10 | 0.19 | 160 | 93 | 120 | 1,200 | 1,300 | 1,400 | 18 | 12 |
| IH | FM011ZH63 | 08/27/01 | 12 | 0.19 | 170 | 110 | 140 | 1,500 | 1,600 | 1,600 | 20 | 13 |
| IH | FM011ZH64 | 08/27/01 | 7.4 | 0.15 | 160 | 62 | 85 | 1,200 | 1,300 | 1,300 | 21 | 13 |
| IH | FM011ZH65 | 08/27/01 | 12 | 0.32 | 170 | 94 | 120 | 1,400 | 1,500 | 1,500 | 17 | 12 |
| IH | FM011ZH66 | 08/27/01 | 8.8 | 0.16 | 150 | 83 | 110 | 1,100 | 1,200 | 1,200 | 17 | 10 |
| IH | FM021V8121 | 08/26/02 | 8.2 | 0.20 | 120 | 47 | 66 | 550 | 590 | 610 | 16 | 12 |
| IH | FM021V8122 | 08/26/02 | 9.0 | 0.21 | 99 | 76 | 110 | 1,600 | 1,600 | 1,700 | 13 | 11 |
| IH | FM021V8123 | 08/26/02 | 7.2 | 0.17 | 100 | 61 | 84 | 700 | 760 | 780 | 15 | 13 |
| IH | FM021V8124 | 08/26/02 | 7.5 | 0.18 | 110 | 59 | 74 | 680 | 740 | 750 | 16 | 12 |
| IH | FM021V8125 | 08/26/02 | 8.3 | 0.21 | 120 | 56 | 74 | 700 | 760 | 770 | 17 | 14 |
| IH | FM031T6966 | 08/26/03 | 11 | 0.16 | 200 | 110 | 220 | 2,100 | 2,200 | 2,300 | 30 | 31 |
| IH | FM031T6967 | 08/26/03 | 8.2 | 0.15 | 160 | 79 | 150 | 1,600 | 1,700 | 1,700 | 25 | 23 |
| IH | FM031T6968 | 08/26/03 | 9.1 | 0.18 | 170 | 83 | 160 | 1,800 | 1,800 | 1,900 | 25 | 27 |
| IH | FM031T6969 | 08/26/03 | 9.0 | 0.15 | 210 | 92 | 200 | 1,900 | 2,000 | 2,100 | 31 | 32 |
| IH | FM031T6970 | 08/26/03 | 8.2 | 0.13 | 160 | 65 | 140 | 1,400 | 1,400 | 1,500 | 23 | 21 |

**Table A-1. (cont.)**

| Station | Sample ID | Date | Lead | Mercury | PCBs | LMW(7)-PAH | LMW(12)-PAH | HMW-PAH | Total(19)-PAH | Total(24)-PAH | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IH | FM063601 | 08/30/06 | 3.8 | 0.10 | 94 | 59 | 74 | 1,300 | 1,300 | 1,300 | 22 | 6.4 |
| IH | FM063602 | 08/30/06 | 3.0 | 0.11 | 84 | 51 | 63 | 1,000 | 1,100 | 1,100 | 17 | 7.0 |
| IH | FM063603 | 08/30/06 | 3.2 | 0.10 | 97 | | | | | | 11 | 6.6 |
| IH | FM063604 | 08/30/06 | 3.7 | 0.10 | 100 | | | | | | 26 | 11 |
| IH | FM063605 | 08/30/06 | 4.5 | 0.12 | 62 | | | | | | 14 | 3.3 |
| LNB | FM011ZP19 | 08/27/01 | | | 31 | 22 | 28 | 97 | 120 | 120 | 6.4 | 15 |
| LNB | FM011ZP20 | 08/27/01 | | | 29 | 29 | 33 | 74 | 100 | 110 | 5.6 | 14 |
| LNB | FM011ZP21 | 08/27/01 | | | 26 | 15 | 19 | 85 | 100 | 100 | 5.4 | 12 |
| LNB | FM011ZP22 | 08/27/01 | | | 24 | 22 | 27 | 150 | 170 | 180 | 5.1 | 11 |
| LNB | FM011ZP23 | 08/27/01 | | | 30 | 28 | 35 | 120 | 150 | 160 | 6.8 | 16 |
| LNB | FM011ZP24 | 08/27/01 | | | 28 | 19 | 23 | 93 | 110 | 120 | 6.0 | 14 |
| LNB | FM011ZP25 | 08/27/01 | | | 28 | 35 | 44 | 94 | 130 | 140 | 6.0 | 15 |
| LNB | FM011ZP26 | 08/27/01 | | | 29 | 20 | 25 | 93 | 110 | 120 | 5.9 | 15 |
| LNB | FM021V8139 | 08/26/02 | 1.7 | 0.14 | 23 | 12 | 22 | 100 | 110 | 120 | 6.3 | 13 |
| LNB | FM021V8140 | 08/26/02 | 1.7 | 0.13 | 23 | 11 | 20 | 110 | 120 | 130 | 6.6 | 11 |
| LNB | FM021V8141 | 08/26/02 | 1.8 | 0.14 | 22 | 12 | 23 | 110 | 120 | 130 | 6.2 | 10 |
| LNB | FM021V8142 | 08/26/02 | 1.6 | 0.14 | 23 | 11 | 21 | 98 | 110 | 120 | 6.7 | 11 |
| LNB | FM031T6984 | 08/26/03 | 1.3 | 0.11 | 33 | 12 | 23 | 120 | 130 | 140 | 6.7 | 12 |
| LNB | FM031T6985 | 08/26/03 | 1.8 | 0.12 | 33 | 13 | 24 | 130 | 150 | 160 | 6.7 | 12 |
| LNB | FM031T6986 | 08/26/03 | 1.3 | 0.11 | 32 | 14 | 24 | 140 | 160 | 170 | 6.7 | 11 |
| LNB | FM031T6987 | 08/26/03 | 1.4 | 0.11 | 33 | 13 | 24 | 140 | 150 | 160 | 6.4 | 11 |
| LNB | FM063B01 | 08/30/06 | 1.5 | 0.070 | 17 | 14 | 22 | 73 | 86 | 95 | 6.5 | 3.4 |
| LNB | FM063B02 | 08/30/06 | 1.8 | 0.080 | 19 | 15 | 26 | 68 | 84 | 94 | 7.9 *U* | 3.7 |
| LNB | FM063B03 | 08/30/06 | 1.7 | 0.060 | 19 | | | | | | 6.1 | 3.6 |
| LNB | FM063B04 | 08/30/06 | 1.6 | 0.080 | 21 | | | | | | 8.6 | 3.0 *U* |
| OSM | M9611D4H7TC1 | 08/27/96 | | | 34 | 33 | 53 | 50 | 83 | 100 | 11 | 5.9 |
| OSM | M9611D4H7TC2 | 08/27/96 | | | 38 | 34 | 60 | 57 | 91 | 120 | 13 | 8.2 |
| OSM | M9611D4H7TC3 | 08/27/96 | | | 41 | 39 | 64 | 63 | 100 | 130 | 13 | 7.5 |
| OSM | M9611D4H7TC4 | 08/27/96 | | | 37 | 35 | 71 | 54 | 88 | 120 | 11 | 6.6 |
| OSM | M9611D4H7TC5 | 08/27/96 | | | 34 | 34 | 70 | 57 | 91 | 130 | 12 | 6.7 |
| OSM | M9611D4H8TC1 | 08/27/96 | 2.1 | 0.27 | | | | | | | | |
| OSM | M9611D4H8TC2 | 08/27/96 | 1.3 | 0.081 | | | | | | | | |
| OSM | M9611D4H8TC3 | 08/27/96 | 1.5 | 0.21 | | | | | | | | |
| OSM | M9611D4H8TC4 | 08/27/96 | 1.6 | 0.071 | | | | | | | | |
| OSM | M9611D4H8TC5 | 08/27/96 | 1.4 | 0.091 | | | | | | | | |
| OSM | M9711D4H7TC1 | 08/26/97 | | | 33 | 30 | 43 | 23 | 53 | 65 | 8.5 | 5.6 |
| OSM | M9711D4H7TC2 | 08/26/97 | | | 33 | 25 | 40 | 25 | 49 | 65 | 8.7 | 6.2 |
| OSM | M9711D4H7TC3 | 08/26/97 | | | 32 | 42 | 94 | 28 | 70 | 120 | 8.8 | 5.4 |
| OSM | M9711D4H7TC4 | 08/26/97 | | | 31 | 33 | 52 | 28 | 61 | 80 | 9.5 | 6.2 |

**Table A-1. (cont.)**

| Station | Sample ID | Date | Lead | Mercury | PCBs | LMW(7)-PAH | LMW(12)-PAH | HMW-PAH | Total(19)-PAH | Total(24)-PAH | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OSM | M9711D4H7TC5 | 08/26/97 | | | 35 | 26 | 40 | 24 | 50 | 65 | 11 | 7.0 |
| OSM | M9711D4H8TC1 | 08/26/97 | 2.0 | 0.0052 *U* | | | | | | | | |
| OSM | M9711D4H8TC2 | 08/26/97 | 1.8 | 0.0052 *U* | | | | | | | | |
| OSM | M9711D4H8TC3 | 08/26/97 | 2.0 | 0.14 | | | | | | | | |
| OSM | M9711D4H8TC4 | 08/26/97 | 2.4 | 0.20 | | | | | | | | |
| OSM | M9711D4H8TC5 | 08/26/97 | 2.2 | 0.18 | | | | | | | | |
| OSM | FM9822GVX22 | 08/10/98 | | | 27 | 15 | 19 | 23 | 37 | 42 | 8.2 | 10 |
| OSM | FM9822GVX23 | 08/10/98 | | | 27 | 14 | 19 | 20 | 33 | 38 | 7.8 | 10 |
| OSM | FM9822GVX24 | 08/10/98 | | | 29 | 16 | 23 | 23 | 39 | 46 | 9.1 | 12 |
| OSM | FM9822GVX25 | 08/10/98 | | | 33 | 16 | 20 | 23 | 39 | 43 | 9.6 | 12 |
| OSM | FM9822GVX26 | 08/10/98 | | | 21 | 8.9 | 13 | 18 | 27 | 31 | 6.1 | 6.9 |
| OSM | FM9822GVX27 | 08/10/98 | | | 28 | 16 | 20 | 22 | 38 | 42 | 8.6 | 8.7 |
| OSM | FM9822GVX28 | 08/10/98 | | | 27 | 14 | 19 | 21 | 36 | 40 | 8.2 | 13 |
| OSM | FM9822GVX29 | 08/10/98 | | | 24 | 13 | 19 | 22 | 36 | 42 | 7.3 | 8.1 |
| OSM | FM9822SVW84 | 08/10/98 | 2.8 | 0.10 | | | | | | | | |
| OSM | FM9822SVW85 | 08/10/98 | 2.0 | 0.090 | | | | | | | | |
| OSM | FM9822SVW86 | 08/10/98 | 1.5 | 0.080 | | | | | | | | |
| OSM | FM9822SVW87 | 08/10/98 | 2.1 | 0.080 | | | | | | | | |
| OSM | FM9822SVW88 | 08/10/98 | 2.1 | 0.080 | | | | | | | | |
| OSM | FM9822SVW89 | 08/10/98 | 2.9 | 0.10 | | | | | | | | |
| OSM | FM9822SVW90 | 08/10/98 | 2.1 | 0.090 | | | | | | | | |
| OSM | FM9822SVW91 | 08/10/98 | 1.7 | 0.090 | | | | | | | | |
| OSM | FM9932GXD84 | 09/02/99 | | | 16 | 15 | 20 | 29 | 43 | 48 | 5.4 | 7.2 |
| OSM | FM9932GXD85 | 09/02/99 | | | 15 | 16 | 21 | 28 | 43 | 49 | 5.0 | 6.3 |
| OSM | FM9932GXD86 | 09/02/99 | | | 16 | 15 | 20 | 23 | 38 | 43 | 5.6 | 7.0 |
| OSM | FM9932GXD87 | 09/02/99 | | | 15 | 17 | 23 | 25 | 42 | 48 | 4.7 | 8.4 |
| OSM | FM9932GXD88 | 09/02/99 | | | 18 | 18 | 24 | 29 | 47 | 53 | 6.3 | 7.8 |
| OSM | FM9932GXD89 | 09/02/99 | | | 15 | 17 | 22 | 25 | 42 | 47 | 4.9 | 6.8 |
| OSM | FM9932GXD90 | 09/02/99 | | | 18 | 16 | 22 | 25 | 41 | 47 | 6.4 | 7.7 |
| OSM | FM9932GXD91 | 09/02/99 | | | 16 | 16 | 22 | 26 | 42 | 48 | 5.3 | 6.5 |
| OSM | FM9932SXE11 | 09/02/99 | 0.79 | 0.052 | | | | | | | | |
| OSM | FM9932SXE12 | 09/02/99 | 1.1 | 0.056 | | | | | | | | |
| OSM | FM9932SXE13 | 09/02/99 | 1.2 | 0.065 | | | | | | | | |
| OSM | FM9932SXE14 | 09/02/99 | 1.2 | 0.066 | | | | | | | | |
| OSM | FM9932SXE15 | 09/02/99 | 0.96 | 0.057 | | | | | | | | |
| OSM | FM9932SXE16 | 09/02/99 | 1.2 | 0.080 | | | | | | | | |
| OSM | FM9932SXE17 | 09/02/99 | 0.79 | 0.061 | | | | | | | | |
| OSM | FM9932SXE18 | 09/02/99 | 1.4 | 0.063 | | | | | | | | |
| OSM | FM0034YE59 | 08/28/00 | 1.2 | 0.13 | | | | | | | | |

**Table A-1. (cont.)**

| Station | Sample ID | Date | Lead | Mercury | PCBs | LMW(7)-PAH | LMW(12)-PAH | HMW-PAH | Total(19)-PAH | Total(24)-PAH | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OSM | FM0034YE60 | 08/28/00 | 0.83 | 0.10 | | | | | | | | |
| OSM | FM0034YE61 | 08/28/00 | 0.89 | 0.10 | | | | | | | | |
| OSM | FM0034YE62 | 08/28/00 | 0.97 | 0.11 | | | | | | | | |
| OSM | FM0034YE63 | 08/28/00 | 0.85 | 0.13 | | | | | | | | |
| OSM | FM0034YE64 | 08/28/00 | 0.89 | 0.10 | | | | | | | | |
| OSM | FM0034YE65 | 08/28/00 | 1.2 | 0.13 | | | | | | | | |
| OSM | FM0034YE66 | 08/28/00 | 0.74 | 0.10 | | | | | | | | |
| OSM | FM0034YE82 | 08/28/00 | | | 14 | 100 | 160 | 54 | 160 | 210 | 3.7 | 3.2 |
| OSM | FM0034YE83 | 08/28/00 | | | 16 | 67 | 97 | 39 | 110 | 140 | 4.7 | 4.7 |
| OSM | FM0034YE84 | 08/28/00 | | | 15 | 68 | 100 | 38 | 110 | 140 | 4.4 | 5.1 |
| OSM | FM0034YE85 | 08/28/00 | | | 15 | 74 | 110 | 43 | 120 | 150 | 4.2 | 4.2 |
| OSM | FM0034YE86 | 08/28/00 | | | 17 | 60 | 88 | 44 | 100 | 130 | 5.2 | 5.8 |
| OSM | FM0034YE87 | 08/28/00 | | | 15 | 50 | 74 | 42 | 92 | 120 | 4.5 | 5.5 |
| OSM | FM0034YE88 | 08/28/00 | | | 16 | 79 | 130 | 41 | 120 | 170 | 4.8 | 5.1 |
| OSM | FM0034YE89 | 08/28/00 | | | 14 | 65 | 100 | 44 | 110 | 150 | 4.0 | 4.5 |
| OS-M1 | FM011ZP11 | 08/27/01 | 2.4 | 0.16 | | | | | | | | |
| OS-M1 | FM011ZP12 | 08/27/01 | 1.6 | 0.14 | | | | | | | | |
| OS-M1 | FM011ZP13 | 08/27/01 | 1.8 | 0.15 | | | | | | | | |
| OS-M1 | FM011ZP14 | 08/27/01 | 1.6 | 0.12 | | | | | | | | |
| OS-M1 | FM011ZP15 | 08/27/01 | 1.9 | 0.14 | | | | | | | | |
| OS-M1 | FM011ZP16 | 08/27/01 | 2.1 | 0.15 | | | | | | | | |
| OS-M1 | FM011ZP17 | 08/27/01 | 2.0 | 0.15 | | | | | | | | |
| OS-M1 | FM011ZP18 | 08/27/01 | 1.6 | 0.13 | | | | | | | | |
| OS-M1 | FM011ZP27 | 08/27/01 | | | 32 | 20 | 27 | 210 | 230 | 240 | 7.3 | 17 |
| OS-M1 | FM011ZP28 | 08/27/01 | | | 34 | 17 | 24 | 190 | 210 | 210 | 7.4 | 17 |
| OS-M1 | FM011ZP29 | 08/27/01 | | | 33 | 18 | 26 | 210 | 230 | 230 | 7.4 | 18 |
| OS-M1 | FM011ZP30 | 08/27/01 | | | 36 | 17 | 24 | 200 | 220 | 220 | 7.5 | 18 |
| OS-M1 | FM011ZP31 | 08/27/01 | | | 35 | 20 | 27 | 190 | 210 | 220 | 8.0 | 19 |
| OS-M1 | FM011ZP32 | 08/27/01 | | | 43 | 22 | 30 | 220 | 240 | 250 | 9.7 | 23 |
| OS-M1 | FM011ZP33 | 08/27/01 | | | 35 | 18 | 26 | 180 | 200 | 210 | 7.5 | 18 |
| OS-M1 | FM011ZP34 | 08/27/01 | | | 35 | 21 | 28 | 190 | 210 | 220 | 7.7 | 18 |
| OS-M1 | FM021V8131 | 08/26/02 | 2.6 | 0.17 | 26 | 21 | 47 | 240 | 260 | 290 | 8.5 | 21 |
| OS-M1 | FM021V8132 | 08/26/02 | 2.6 | 0.17 | 24 | 17 | 41 | 230 | 250 | 270 | 7.6 | 18 |
| OS-M1 | FM021V8133 | 08/26/02 | 2.4 | 0.17 | 26 | 19 | 45 | 270 | 280 | 310 | 8.0 | 20 |
| OS-M1 | FM021V8134 | 08/26/02 | 2.3 | 0.19 | 25 | 23 | 49 | 280 | 300 | 320 | 8.0 | 19 |
| OS-M1 | FM031T6976 | 08/26/03 | 2.0 | 0.13 | 33 | 18 | 36 | 290 | 310 | 330 | 6.7 | 15 |
| OS-M1 | FM031T6977 | 08/26/03 | 1.7 | 0.13 | 37 | 21 | 42 | 360 | 380 | 400 | 8.5 | 17 |
| OS-M1 | FM031T6978 | 08/26/03 | 1.7 | 0.14 | 36 | 22 | 38 | 330 | 350 | 370 | 8.3 | 18 |
| OS-M1 | FM031T6979 | 08/26/03 | 1.4 | 0.12 | 33 | 16 | 30 | 280 | 290 | 310 | 7.0 | 14 |

**Table A-1. (cont.)**

| Station | Sample ID | Date | Lead | Mercury | PCBs | LMW(7)-PAH | LMW(12)-PAH | HMW-PAH | Total(19)-PAH | Total(24)-PAH | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OS-M2 | FM021V8135 | 08/26/02 | 2.8 | 0.17 | 25 | 15 | 22 | 150 | 160 | 170 | 7.0 | 13 |
| OS-M2 | FM021V8136 | 08/26/02 | 2.7 | 0.18 | 30 | 12 | 18 | 160 | 180 | 180 | 8.5 | 14 |
| OS-M2 | FM063M201 | 08/30/06 | 1.7 | 0.070 | 16 | 24 | 39 | 150 | 170 | 180 | 10 | 7.8 |
| OS-M2 | FM063M202 | 08/30/06 | 1.8 | 0.070 | 16 | 20 | 30 | 110 | 130 | 140 | | 5.8 |
| OS-M2 | FM063M203 | 08/30/06 | 2.2 | 0.090 | 15 | | | | | | 8.6 | |
| OS-M2 | FM063M204 | 08/30/06 | 1.5 | 0.080 | 12 | | | | | | 7.8 | |
| OS-M3 | FM021V8147 | 08/05/02 | 2.8 | 0.18 | 23 | 12 | 18 | 320 | 330 | 340 | 7.2 | 16 |
| OS-M3 | FM021V8148 | 08/05/02 | 2.8 | 0.18 | 22 | 12 | 17 | 200 | 210 | 210 | 6.9 | 14 |
| OS-M3 | FM021V8149 | 08/05/02 | 2.7 | 0.17 | 25 | 11 | 16 | 250 | 260 | 260 | 8.3 | 18 |
| OS-M4 | FM031T6980 | 08/26/03 | 1.8 | 0.14 | 32 | 18 | 32 | 290 | 310 | 320 | 7.8 | 15 |
| OS-M4 | FM031T6981 | 08/26/03 | 1.6 | 0.13 | 31 | 15 | 28 | 250 | 270 | 280 | 6.3 | 13 |
| OS-M5 | FM021V8137 | 08/26/02 | 2.5 | 0.18 | 28 | 16 | 67 | 190 | 200 | 260 | 7.3 | 13 |
| OS-M5 | FM021V8138 | 08/26/02 | 2.4 | 0.17 | 27 | 15 | 37 | 180 | 200 | 220 | 7.7 | 16 |
| OS-M5 | FM063M501 | 08/30/06 | 2.0 | 0.10 | 17 | 20 | 36 | 110 | 130 | 150 | 11 | 4.2 |
| OS-M5 | FM063M502 | 08/30/06 | 2.1 | 0.080 | 16 | 23 | 39 | 110 | 130 | 150 | 4.7 | 5.5 |
| OS-M5 | FM063M503 | 08/30/06 | 1.4 | 0.060 | 18 | | | | | | 5.8 | |
| OS-M5 | FM063M504 | 08/30/06 | 2.4 | 0.090 | 17 | | | | | | 6.5 | |
| OS-M6 | FM031T6982 | 08/26/03 | 1.7 | 0.13 | 28 | 16 | 30 | 260 | 270 | 290 | 6.6 | 15 |
| OS-M6 | FM031T6983 | 08/26/03 | 1.9 | 0.14 | 31 | 16 | 31 | 250 | 270 | 280 | 6.4 | 15 |

**Note:** Concentrations reported as pg/g for metals and ng/g for all other compounds, rounded to two significant figures.

CCB - Cape Cod Bay
DIL - Deer Island Light
IH - Boston inner harbor
LNB - large navigation buoy
Outfall location includes stations OSM, OS-M1, OS-M2, OS-M3, OS-M4, OS-M5, and OS-M6

PCB: Sum of congeners 138 and 153
LMW PAH (7): Sum of 7 low molecular weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene)
LMW PAH (12): Sum of 12 low molecular weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene, 1-methylnaphthalene, 1-methylphenanthrene, 2,3,5-triethylnaphthalene, 2,6-dimethylnaphthalene, and 2-methylnaphthalene)
HMW PAH: Sum of 12 high molecular weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)
Total PAH (19): Sum of LMW PAH (7) and HMW PAH
Total PAH (24): Sum of LMW PAH (12) and HMW PAH
Chlordane: Sum of *cis*- chlordane and *trans*- nonachlor

**Table A-2. Concentrations measured in edible lobster meat**

| Station | Sample ID | Date | Mercury | PCBs | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|
| DIF | L95111000C1 | 07/25/95 | 0.80 | 35 | 10 | 1.2 |
| DIF | L95111000C2 | 07/25/95 | 1.0 | 42 | 12 | 1.2 *U* |
| DIF | L95111000C3 | 07/25/95 | 0.028 | 60 | 15 | 1.1 |
| DIF | L96111000C1 | 08/26/96 | 0.72 | 91 | 30 | 5.0 |
| DIF | L96111000C2 | 08/26/96 | 0.91 | 120 | 18 | 4.5 |
| DIF | L96111000C3 | 08/26/96 | 0.95 | 68 | 17 | 3.9 |
| DIF | L97111000C1 | 08/01/97 | 1.6 | 220 | 83 | 8.2 |
| DIF | L97111000C2 | 08/01/97 | 1.5 | 51 | 16 | 3.8 |
| DIF | L97111000C3 | 08/01/97 | 1.3 | 81 | 24 | 6.6 |
| DIF | VZST11 | 09/15/98 | 0.71 | 46 | 10 | 5.0 |
| DIF | VZST12 | 09/15/98 | 0.78 | 53 | 10 | 3.7 |
| DIF | VZST13 | 09/15/98 | 0.81 | 39 | 8.8 | 3.6 |
| DIF | FL9911C1 | 07/29/99 | 0.93 | 56 | 16 | 4.5 |
| DIF | FL9911C2 | 07/29/99 | 0.78 | 66 | 18 | 4.7 |
| DIF | FL9911C3 | 07/29/99 | 1.3 | 51 | 14 | 4.8 |
| DIF | FL0011C1 | 08/11/00 | 0.62 | 69 | 6.5 | 3.0 |
| DIF | FL0011C2 | 08/11/00 | 0.98 | 18 | 4.0 | 1.9 |
| DIF | FL0011C3 | 08/11/00 | 0.64 | 26 | 4.7 | 2.2 |
| DIF | FL0111-C1 | 07/10/01 | 0.85 | 25 | 5.4 | 1.7 |
| DIF | FL0111-C2 | 07/10/01 | 0.95 | 41 | 9.1 | 3.4 |
| DIF | FL0111-C3 | 07/10/01 | 0.82 | 19 | 4.8 | 1.3 |
| DIF | FL0211C1 | 08/02/02 | 0.68 | 39 | 8.2 | 1.1 |
| DIF | FL0211C2 | 08/02/02 | 0.83 | 37 | 7.8 | 1.5 |
| DIF | FL0211C3 | 08/02/02 | 1.0 | 37 | 6.7 | 1.4 |
| DIF | FL0311C1 | 08/19/03 | 1.1 | 69 | 11 | 1.9 |
| DIF | FL0311C2 | 08/19/03 | 0.99 | 63 | 12 | 1.9 |
| DIF | FL0311C3 | 08/19/03 | 1.1 | 74 | 11 | 2.2 |
| DIF | FL06110C1 | 07/25/06 | 0.50 | 57 | 14 | 3.8 *U* |
| DIF | FL06110C2 | 07/25/06 | 0.54 | 58 | 14 | 3.8 *U* |
| DIF | FL06110C3 | 07/25/06 | 0.42 | 51 | 11 | 4.1 *U* |
| ECCB | L95115000C1 | 07/18/95 | 0.53 | 43 | 18 | 0.73 |
| ECCB | L95115000C2 | 07/18/95 | 0.63 | 29 | 12 | 1.2 *U* |
| ECCB | L95115000C3 | 07/18/95 | 0.44 | 26 | 8.8 | 0.60 |
| ECCB | L96115000C1 | 08/06/96 | 1.1 | 32 | 13 | 1.9 |
| ECCB | L96115000C2 | 08/06/96 | 1.0 | 26 | 10 | 1.6 |
| ECCB | L96115000C3 | 08/06/96 | 0.74 | 29 | 13 | 1.5 |
| ECCB | L97115000C1 | 07/23/97 | 1.1 | 32 | 14 | 2.1 |
| ECCB | L97115000C2 | 07/23/97 | 1.0 | 30 | 11 | 1.3 |
| ECCB | L97115000C3 | 07/23/97 | 0.85 | 30 | 12 | 2.2 |
| ECCB | VZST91 | 09/24/98 | 0.67 | 28 | 9.9 | 1.6 |
| ECCB | VZST92 | 09/24/98 | 0.61 | 19 | 6.3 | 1.4 |
| ECCB | VZST93 | 09/24/98 | 0.51 | 27 | 9.3 | 1.4 |
| ECCB | FL9915C1 | 09/09/99 | 0.78 | 23 | 8.9 | 0.96 |
| ECCB | FL9915C2 | 09/09/99 | 0.79 | 19 | 8.1 | 0.92 |
| ECCB | FL9915C3 | 09/09/99 | 0.57 | 26 | 11 | 1.0 |
| ECCB | FL0015C1 | 07/19/00 | 0.47 | 17 | 4.1 | 0.93 |
| ECCB | FL0015C2 | 07/19/00 | 0.59 | 14 | 2.5 | 0.79 |
| ECCB | FL0015C3 | 07/19/00 | 0.92 | 22 | 5.4 | 0.95 |
| ECCB | FL0115-C1 | 09/07/01 | 0.45 | 18 | 6.4 | 0.45 |
| ECCB | FL0115-C2 | 09/07/01 | 0.53 | 15 | 5.4 | 0.31 |
| ECCB | FL0115-C3 | 09/07/01 | 0.62 | 19 | 6.6 | 0.53 |
| ECCB | FL0215C1 | 08/14/02 | 0.72 | 8.6 | 2.8 | 0.69 |
| ECCB | FL0215C2 | 08/14/02 | 0.67 | 15 | 4.3 | 0.42 |
| ECCB | FL0215C3 | 08/14/02 | 0.54 | 17 | 4.9 | 0.60 |
| ECCB | FL0315C1 | 10/06/03 | 0.60 | 16 | 3.7 | 0.61 |
| ECCB | FL0315C2 | 10/06/03 | 0.43 | 19 | 7.3 | 0.69 |

**Table A-2. (cont.)**

| Station | Sample ID | Date | Mercury | PCBs | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|
| ECCB | FL0315C3 | 10/06/03 | 0.55 | 14 | 4.2 | 0.84 |
| ECCB | FL06150C1 | 09/07/06 | 0.33 | 26 | 6.6 | 4.0 *U* |
| ECCB | FL06150C2 | 09/07/06 | 0.35 | 13 | 5.4 | 3.8 *U* |
| ECCB | FL06150C3 | 09/07/06 | 0.28 | 29 | 6.4 | 3.5 *U* |
| OS | L95114000C1 | 07/25/95 | 0.67 | 40 | 12 | 1.3 |
| OS | L95114000C2 | 07/25/95 | 1.0 | 44 | 13 | 0.75 |
| OS | L95114000C3 | 07/25/95 | 1.6 | 51 | 14 | 1.4 |
| OS | L96114000C1 | 08/26/96 | 1.4 | 59 | 17 | 4.3 |
| OS | L96114000C2 | 08/26/96 | 1.2 | 48 | 14 | 3.9 |
| OS | L96114000C3 | 08/26/96 | 0.65 | 53 | 15 | 3.2 |
| OS | L97114000C1 | 08/01/97 | 1.3 | 37 | 9.8 | 1.2 |
| OS | L97114000C2 | 08/01/97 | 1.1 | 80 | 31 | 3.2 |
| OS | L97114000C3 | 08/01/97 | 0.99 | 55 | 17 | 4.0 |
| OS | VZST41 | 09/07/98 | 0.87 | 34 | 9.1 | 3.9 |
| OS | VZST42 | 09/07/98 | 1.0 | 22 | 5.7 | 1.6 |
| OS | VZST43 | 09/07/98 | 1.1 | 29 | 7.8 | 2.6 |
| OS | FL9914C1 | 11/12/99 | 1.4 | 34 | 7.5 | 1.4 |
| OS | FL9914C2 | 11/12/99 | 0.87 | 26 | 7.2 | 1.6 |
| OS | FL9914C3 | 11/12/99 | 0.88 | 29 | 7.4 | 2.0 |
| OS | FL0014C1 | 08/24/00 | 1.0 | 30 | 5.6 | 1.3 |
| OS | FL0014C2 | 08/24/00 | 1.0 | 29 | 5.2 | 1.0 |
| OS | FL0014C3 | 08/24/00 | 0.73 | 21 | 3.5 | 1.2 |
| OS | FL0114-C1 | 08/22/01 | 1.2 | 26 | 6.2 | 1.4 |
| OS | FL0114-C2 | 08/22/01 | 0.84 | 22 | 5.2 | 0.90 |
| OS | FL0114-C3 | 08/22/01 | 0.99 | 31 | 7.2 | 1.1 |
| OS | FL0214C1 | 10/04/02 | 0.74 | 23 | 4.0 | 0.87 |
| OS | FL0214C2 | 10/04/02 | 0.85 | 35 | 7.0 | 1.2 |
| OS | FL0214C3 | 10/04/02 | 0.77 | 14 | 3.6 | 0.73 |
| OS | FL0314C1 | 09/10/03 | 0.68 | 28 | 4.7 | 1.0 |
| OS | FL0314C2 | 09/10/03 | 1.1 | 21 | 3.7 | 0.92 |
| OS | FL0314C3 | 09/10/03 | 0.77 | 130 | 6.1 | 0.95 |
| OS | FL06140C1 | 10/09/06 | 0.42 | 49 | 7.6 | 0.31 *U* |
| OS | FL06140C2 | 10/09/06 | 0.46 | 31 | 12 | 0.31 *U* |
| OS | FL06140C3 | 10/09/06 | 0.46 |  | 8.9 | 0.55 |

**Note:** Concentrations reported as pg/g for metals and ng/g for all other compounds, rounded to two significant figures.

DIF - Deer Island Flats
ECCB - East Cape Cod Bay
OS - outfall location

PCB: Sum of congeners 138 and 153
Chlordane: Sum of *cis*- chlordane and *trans*- nonachlor

**Table A-3. Concentrations measured in lobster hepatopancreas**

| Station | Sample ID | Date | Cadmium | Copper | Lead | Mercury | PCBs | LMW(7)-PAH | LMW(12)-PAH | HMW-PAH | Total(19)-PAH | Total(24)-PAH | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DIF | L95111000C1 | 07/25/95 | 5.7 | 430 | 0.21 | 0.30 | 1,100 | 380 | | 2,000 | 2,300 | | 380 | 62 |
| DIF | L95111000C2 | 07/25/95 | 5.4 | 220 | 0.22 | 0.33 | 1,600 | 200 | | 1,200 | 1,400 | | 470 | 16 |
| DIF | L95111000C3 | 07/25/95 | 4.8 | 320 | 0.34 | 0.41 | 2,900 | 300 | | 2,100 | 2,400 | | 790 | 40 |
| DIF | L96111000C1 | 08/26/96 | 3.7 | 650 | 0.51 | 0.25 | 3,200 | 240 | | 4,400 | 4,600 | | 1,200 | 230 |
| DIF | L96111000C2 | 08/26/96 | 3.6 | 490 | 0.26 | 0.22 | 2,800 | 250 | | 3,300 | 3,600 | | 930 | 180 |
| DIF | L96111000C3 | 08/26/96 | 2.7 | 310 | 0.27 | 0.14 | 2,200 | 310 | | 9,000 | 9,300 | | 920 | 180 |
| DIF | L97111000C1 | 08/01/97 | 9.1 | 810 | 0.45 | 0.27 | 5,200 | 1,500 | | 6,300 | 7,900 | | 2,100 | 180 |
| DIF | L97111000C2 | 08/01/97 | 5.9 | 440 | 0.29 | 0.53 | 1,800 | 81 | | 1,100 | 1,100 | | 20 *U* | 100 |
| DIF | L97111000C3 | 08/01/97 | 6.0 | 670 | 0.43 | 0.49 | 1,900 | 150 | | 1,200 | 1,400 | | 780 | 120 |
| DIF | VZST11 | 09/15/98 | 2.6 | 600 | 0.15 | 0.24 | 3,800 | 250 | 380 | | | | 910 | 230 |
| DIF | VZST12 | 09/15/98 | 3.6 | 690 | 0.30 | 0.27 | 3,500 | 370 | 500 | | | | 800 | 240 |
| DIF | VZST13 | 09/15/98 | 5.8 | 540 | 0.24 | 0.27 | 3,300 | 240 | 360 | | | | 860 | 230 |
| DIF | FL9911C1 | 07/29/99 | 5.1 | 890 | 0.49 | 0.33 | 4,700 | 260 | 350 | 3,300 | 3,500 | 3,600 | 1,100 | 120 |
| DIF | FL9911C2 | 07/29/99 | 3.9 | 870 | 0.58 | 0.30 | 4,300 | 170 | 270 | 3,300 | 3,400 | 3,500 | 1,200 | 120 |
| DIF | FL9911C3 | 07/29/99 | 4.7 | 930 | 0.50 | 0.28 | 4,600 | 200 | 300 | 4,200 | 4,400 | 4,500 | 1,200 | 160 |
| DIF | FL0011C1 | 08/11/00 | 7.3 | 520 | 0.29 | 0.24 | 4,400 | 350 | 550 | 7,000 | 7,400 | 7,600 | 520 | 130 |
| DIF | FL0011C2 | 08/11/00 | 5.8 | 340 | 0.28 | 0.32 | 900 | 210 | 340 | 2,800 | 3,000 | 3,100 | 160 | 52 |
| DIF | FL0011C3 | 08/11/00 | 6.2 | 510 | 0.33 | 0.23 | 2,300 | 620 | 830 | 7,800 | 8,400 | 8,600 | 650 | 70 |
| DIF | FL0111-C1 | 07/10/01 | 6.6 | 420 | 0.28 | 0.19 | 2,600 | 270 | 390 | 6,700 | 7,000 | 7,100 | 560 | 79 |
| DIF | FL0111-C2 | 07/10/01 | 10 | 970 | 0.48 | 0.32 | 5,600 | 230 | 350 | 3,800 | 4,000 | 4,100 | 1,000 | 100 |
| DIF | FL0111-C3 | 07/10/01 | 7.4 | 530 | 0.41 | 0.25 | 2,300 | 390 | 560 | 5,800 | 6,200 | 6,300 | 590 | 93 |
| DIF | FL0211C1 | 08/02/02 | 10 | 780 | 0.33 | 0.33 | 2,200 | 800 | 1,000 | 4,800 | 5,600 | 5,800 | 440 | 60 |
| DIF | FL0211C2 | 08/02/02 | 16 | 1,100 | 0.52 | 0.41 | 2,100 | 640 | 760 | 3,300 | 4,000 | 4,100 | 400 | 50 |
| DIF | FL0211C3 | 08/02/02 | 7.0 | 740 | 0.28 | 0.39 | 2,100 | 84 | 130 | 1,900 | 1,900 | 2,000 | 390 | 58 |
| DIF | FL0311C1 | 08/19/03 | 8.9 | 600 | 0.30 | 0.35 | 5,100 | 75 | 120 | 2,500 | 2,500 | 2,600 | 950 | 74 |
| DIF | FL0311C2 | 08/19/03 | 16 | 410 | 0.37 | 0.33 | 4,100 | 57 | 95 | 1,600 | 1,600 | 1,700 | 850 | 59 |
| DIF | FL0311C3 | 08/19/03 | 9.8 | 670 | 0.22 | 0.44 | 6,500 | 76 | 110 | 1,700 | 1,800 | 1,800 | 1,000 | 68 |
| DIF | FL06110C1 | 07/25/06 | 5.6 | 670 | 0.29 | 0.14 | 1,400 | 310 | 500 | 3,600 | 3,900 | 4,100 | 1,100 | 85 |
| DIF | FL06110C2 | 07/25/06 | 5.4 | 550 | 0.24 | 0.18 | 3,300 | 1,100 | 1,300 | 10,000 | 11,000 | 11,000 | 1,600 | 150 |
| DIF | FL06110C3 | 07/25/06 | 6.7 | 380 | 0.42 | 0.14 | 2,800 | 490 | 740 | 5,100 | 5,600 | 5,800 | 1,400 | 110 |
| ECCB | L95115000C1 | 07/18/95 | 8.2 | 170 | 0.036 | 0.40 | 1,300 | 200 | | 1,100 | 1,300 | | 680 | 37 |
| ECCB | L95115000C2 | 07/18/95 | 8.1 | 150 | 0.031 | 0.23 | 960 | 240 | | 2,700 | 2,900 | | 530 | 48 |
| ECCB | L95115000C3 | 07/18/95 | 7.5 | 59 | 0.061 | 0.18 | 1,600 | 280 | | 1,700 | 2,000 | | 760 | 110 |
| ECCB | L96115000C1 | 08/06/96 | 15 | 230 | 0.12 | 0.28 | 920 | 140 | | 570 | 710 | | 480 | 77 |
| ECCB | L96115000C2 | 08/06/96 | 15 | 180 | 0.039 | 0.20 | 1,100 | 350 | | 550 | 890 | | 540 | 47 |
| ECCB | L96115000C3 | 08/06/96 | 14 | 85 | 0.048 | 0.25 | 1,400 | 660 | | 1,200 | 1,800 | | 780 | 120 |
| ECCB | L97115000C1 | 07/23/97 | 15 | 310 | 0.068 | 0.40 | 1,300 | | | | | | 1,000 | 44 |
| ECCB | L97115000C2 | 07/23/97 | 14 | 360 | 0.048 | 0.42 | 1,100 | | | | | | 650 | 28 |
| ECCB | L97115000C3 | 07/23/97 | 12 | 220 | 0.024 *U* | 0.38 | 920 | | | | | | 540 | 52 |
| ECCB | VZST91 | 09/24/98 | 6.9 | 670 | 0.30 | 0.23 | 1,600 | 58 | 82 | | | | 650 | 38 |
| ECCB | VZST92 | 09/24/98 | 8.0 | 570 | 0.30 | 0.28 | 1,900 | 63 | 91 | | | | 730 | 39 |

**Table A-3. (cont.)**

| Station | Sample ID | Date | Cadmium | Copper | Lead | Mercury | PCBs | LMW(7)-PAH | LMW(12)-PAH | HMW-PAH | Total(19)-PAH | Total(24)-PAH | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ECCB | VZST93 | 09/24/98 | 7.8 | 480 | 0.32 | 0.22 | 1,700 | 62 | 91 | | | | 670 | 46 |
| ECCB | FL9915C1 | 09/09/99 | 15 | 340 | 0.31 | 0.29 | 1,500 | 84 | 120 | 650 | 740 | 770 | 470 | 24 |
| ECCB | FL9915C2 | 09/09/99 | 11 | 560 | 0.23 | 0.35 | 1,500 | 94 | 130 | 750 | 840 | 880 | 550 | 34 |
| ECCB | FL9915C3 | 09/09/99 | 11 | 540 | 0.21 | 0.31 | 1,800 | 87 | 120 | 580 | 670 | 700 | 570 | 25 |
| ECCB | FL0015C1 | 07/19/00 | 6.9 | 380 | 0.45 | 0.20 | 700 | 76 | | 790 | 870 | | 300 | 24 |
| ECCB | FL0015C2 | 07/19/00 | 8.1 | 250 | 0.31 | 0.20 | 560 | 67 | | 610 | 680 | | 210 | 31 |
| ECCB | FL0015C3 | 07/19/00 | 13 | 630 | 0.34 | 0.30 | 1,500 | 70 | | 550 | 620 | | 630 | 28 |
| ECCB | FL0115-C1 | 09/07/01 | 13 | 760 | 0.39 | 0.28 | 900 | 58 | 84 | | | | 320 | 20 |
| ECCB | FL0115-C2 | 09/07/01 | 13 | 320 | 0.35 | 0.22 | 1,100 | 66 | 94 | | | | 410 | 16 |
| ECCB | FL0115-C3 | 09/07/01 | 12 | 480 | 0.38 | 0.23 | 1,100 | 54 | 74 | 630 | 680 | 700 | 420 | 22 |
| ECCB | FL0215C1 | 08/14/02 | 12 | 370 | 0.47 | 0.21 | 630 | 52 | 68 | 600 | 650 | 670 | 220 | 26 |
| ECCB | FL0215C2 | 08/14/02 | 13 | 580 | 0.41 | 0.26 | 530 | 33 | 45 | 480 | 520 | 530 | 160 | 15 |
| ECCB | FL0215C3 | 08/14/02 | 14 | 430 | 0.38 | 0.23 | 690 | 34 | 47 | 540 | 580 | 590 | 200 | 14 |
| ECCB | FL0315C1 | 10/06/03 | 13 | 390 | 0.31 | 0.20 | 930 | 35 | 50 | 390 | 430 | 440 | 250 | 17 |
| ECCB | FL0315C2 | 10/06/03 | 10 | 350 | 0.15 | 0.20 | 840 | 38 | 56 | 350 | 390 | 410 | 360 | 17 |
| ECCB | FL0315C3 | 10/06/03 | 9.0 | 320 | 0.17 | 0.21 | 950 | 44 | 60 | 480 | 530 | 540 | 320 | 24 |
| ECCB | FL06150C1 | 09/07/06 | 7.2 | 560 | 0.11 | 0.17 | 1,300 | 190 | 310 | 750 | 930 | 1,100 | 860 | 130 |
| ECCB | FL06150C2 | 09/07/06 | 16 | 300 | 0.040 | 0.16 | 860 | 88 | 160 | 500 | 590 | 660 | 690 | 54 |
| ECCB | FL06150C3 | 09/07/06 | 8.5 | 380 | 0.087 | 0.12 | 1,400 | 140 | 200 | 1,100 | 1,200 | 1,300 | 790 | 48 |
| OS | L95114000C1 | 07/25/95 | 4.4 | 380 | 0.22 | 0.24 | 2,400 | 180 | | 2,100 | 2,300 | | 800 | 120 |
| OS | L95114000C2 | 07/25/95 | 5.1 | 300 | 0.38 | 0.41 | 2,300 | 180 | | 2,100 | 2,300 | | 780 | 1.2 *U* |
| OS | L95114000C3 | 07/25/95 | 6.4 | 260 | 0.30 | 0.36 | 1,800 | 190 | | 2,700 | 2,900 | | 710 | 100 |
| OS | L96114000C1 | 08/26/96 | 11 | 510 | 0.28 | 0.22 | 2,000 | 250 | | 3,100 | 3,300 | | 690 | 180 |
| OS | L96114000C2 | 08/26/96 | 9.5 | 300 | 0.65 | 0.33 | 2,300 | 290 | | 4,900 | 5,200 | | 870 | 180 |
| OS | L96114000C3 | 08/26/96 | 7.2 | 300 | 0.30 | 0.23 | 2,100 | 110 | | 1,700 | 1,900 | | 770 | 110 |
| OS | L97114000C1 | 08/01/97 | 8.2 | 110 | 0.20 | 0.35 | 1,400 | 86 | | 750 | 840 | | 530 | 35 |
| OS | L97114000C2 | 08/01/97 | 13 | 690 | 0.36 | 0.48 | 2,400 | 190 | | 1,700 | 1,900 | | 1,700 | 65 |
| OS | L97114000C3 | 08/01/97 | 15 | 740 | 0.34 | 0.48 | 1,500 | 65 | | 980 | 1,000 | | 820 | 73 |
| OS | VZST41 | 09/07/98 | 24 | 790 | 0.56 | 0.39 | 2,700 | 260 | 300 | | | | 780 | 100 |
| OS | VZST42 | 09/07/98 | 15 | 530 | 0.55 | 0.34 | 3,100 | 93 | 130 | | | | 1,000 | 81 |
| OS | VZST43 | 09/07/98 | 13 | 510 | 0.78 | 0.36 | 2,900 | 71 | 110 | | | | 940 | 86 |
| OS | FL9914C1 | 11/12/99 | 21 | 950 | 0.44 | 0.68 | 3,200 | 81 | 97 | 620 | 710 | 720 | 700 | 40 |
| OS | FL9914C2 | 11/12/99 | 8.1 | 920 | 0.27 | 0.42 | 3,000 | 99 | 130 | 820 | 920 | 950 | 820 | 63 |
| OS | FL9914C3 | 11/12/99 | 17 | 630 | 0.55 | 0.49 | 2,300 | 96 | 120 | 680 | 780 | 800 | 610 | 56 |
| OS | FL0014C1 | 08/24/00 | 13 | 880 | 0.33 | 0.35 | 1,100 | 58 | 83 | 890 | 950 | 970 | 290 | 26 |
| OS | FL0014C2 | 08/24/00 | 10 | 590 | 0.34 | 0.73 | 2,100 | 520 | 590 | 2,300 | 2,800 | 2,900 | 530 | 64 |
| OS | FL0014C3 | 08/24/00 | 10 | 610 | 0.28 | 0.32 | 730 | 77 | 130 | 670 | 750 | 800 | 120 | 16 |
| OS | FL0114-C1 | 08/22/01 | 15 | 650 | 0.34 | 0.26 | 1,100 | 68 | 120 | 550 | 620 | 670 | 250 | 23 |
| OS | FL0114-C2 | 08/22/01 | 16 | 850 | 0.46 | 0.36 | 1,900 | 83 | 150 | | | | 490 | 39 |
| OS | FL0114-C3 | 08/22/01 | 15 | 830 | 0.45 | 0.33 | 2,000 | 74 | 140 | 910 | 990 | 1,100 | 480 | 36 |
| OS | FL0214C1 | 10/04/02 | 10 | 690 | 0.22 | 0.28 | 1,200 | 100 | 140 | 770 | 870 | 910 | 240 | 43 |

**Table A-3. (cont.)**

| Station | Sample ID | Date | Cadmium | Copper | Lead | Mercury | PCBs | LMW(7)-PAH | LMW(12)-PAH | HMW-PAH | Total(19)-PAH | Total(24)-PAH | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OS | FL0214C2 | 10/04/02 | 24 | 980 | 0.55 | 0.50 | 1,800 | 48 | 84 | 1,900 | 1,900 | 2,000 | 370 | 45 |
| OS | FL0214C3 | 10/04/02 | 14 | 940 | 0.21 | 0.31 | 950 | 86 | 150 | 2,900 | 3,000 | 3,000 | 230 | 34 |
| OS | FL0314C1 | 09/10/03 | 12 | 830 | 0.41 | 0.32 | 1,600 | 91 | 140 | 1,400 | 1,500 | 1,500 | 330 | 41 |
| OS | FL0314C2 | 09/10/03 | 15 | 520 | 0.21 | 0.36 | 1,400 | 110 | 160 | 1,600 | 1,700 | 1,700 | 330 | 40 |
| OS | FL0314C3 | 09/10/03 | 9.6 | 720 | 0.50 | 0.33 | 7,300 | 76 | 130 | 1,300 | 1,400 | 1,500 | 420 | 5.8 |
| OS | FL06140C1 | 10/09/06 | 19 | 830 | 0.57 | 0.25 | 1,900 | 120 | 180 | 1,100 | 1,200 | 1,300 | 710 | 56 |
| OS | FL06140C2 | 10/09/06 | 11 | 830 | 0.39 | 0.24 | 1,600 | 110 | 160 | 1,100 | 1,200 | 1,300 | 960 | 53 |
| OS | FL06140C3 | 10/09/06 | 16 | 660 | 0.34 | 0.30 | 1,100 | 110 | 220 | 1,100 | 1,200 | 1,300 | 500 | 41 |

**Note:** Concentrations reported as pg/g for metals and ng/g for all other compounds, rounded to two significant figures

CCB - Cape Cod Bay
DIF - Deer Island Flats
OS - outfall location

PCB: Sum of congeners 138 and 153
LMW PAH (7): Sum of 7 low molecular weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene)
LMW PAH (12): Sum of 12 low molecular weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene, 1-methylnaphthalene, 1-methylphenanthrene, 2,3,5-triethylnaphthalene, 2,6-dimethylnaphthalene, and 2-methylnaphthalene)
HMW PAH: Sum of 12 high molecular weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)
Total PAH (19): Sum of LMW PAH (7) and HMW PAH
Total PAH (24): Sum of LMW PAH (12) and HMW PAH
Chlordane: Sum of *cis*- chlordane and *trans*- nonachlor

**Table A-4. Concentrations measured in flouder fillet**

| Station | Sample ID | Date | Mercury | PCBs | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|
| DIF | P95111000C1 | 04/10/95 | 0.37 | 230 | 24 | 13 |
| DIF | P95111000C2 | 04/10/95 | 0.42 | 130 | 18 | 11 |
| DIF | P95111000C3 | 04/10/95 | 0.42 | 370 | 63 | 22 |
| DIF | P96111000C1 | 04/15/96 | 0.42 | 130 | 24 | 11 |
| DIF | P96111000C2 | 04/15/96 | 0.59 | 170 | 32 | 12 |
| DIF | P96111000C3 | 04/15/96 | 0.36 | 110 | 24 | 12 |
| DIF | P97111000C1 | 04/07/97 | 0.59 | 130 | 40 | 15 |
| DIF | P97111000C2 | 04/07/97 | 0.33 | 180 | 46 | 15 |
| DIF | P97111000C3 | 04/07/97 | 0.60 | 120 | 36 | 11 |
| DIF | VQST11 | 04/21/98 | 0.26 | 140 | 22 | 15 |
| DIF | VQST12 | 04/21/98 | 0.22 | 100 | 19 | 11 |
| DIF | VQST13 | 04/21/98 | 0.23 | 120 | 25 | 15 |
| DIF | FF99110C1 | 05/10/99 | 0.36 | 61 | 16 | 9.9 |
| DIF | FF99110C2 | 05/10/99 | 0.33 | 57 | 20 | 10 |
| DIF | FF99110C3 | 05/10/99 | 0.37 | 48 | 16 | 9.1 |
| DIF | FF00110C1 | 04/11/00 | 0.35 | 79 | 13 | 8.3 |
| DIF | FF00110C2 | 04/11/00 | 0.55 | 120 | 21 | 14 |
| DIF | FF00110C3 | 04/11/00 | 0.28 | 88 | 17 | 7.8 |
| DIF | FF01110C1 | 04/25/01 | 0.44 | 140 | 28 | 9.9 |
| DIF | FF01110C2 | 04/25/01 | 0.32 | 110 | 22 | 9.2 |
| DIF | FF01110C3 | 04/25/01 | 0.31 | 140 | 27 | 12 |
| DIF | FF02110C1 | 04/23/02 | 0.42 | 88 | 16 | 6.1 |
| DIF | FF02110C2 | 04/23/02 | 0.29 | 76 | 13 | 5.7 |
| DIF | FF02110C3 | 04/23/02 | 0.38 | 91 | 12 | 6.3 |
| DIF | FF03110C1 | 04/28/03 | 0.37 | 160 | 26 | 7.5 |
| DIF | FF03110C2 | 04/28/03 | 0.42 | 180 | 29 | 12 |
| DIF | FF03110C3 | 04/28/03 | 0.39 | 160 | 24 | 7.9 |
| DIF | FF04110C1 | 04/28/04 | 0.35 | | | |
| DIF | FF04110C2 | 04/28/04 | 0.33 | | | |
| DIF | FF04110C3 | 04/28/04 | 0.43 | | | |
| DIF | FF06110C1 | 04/25/06 | 0.38 | 160 | 33 | 6.0 |
| DIF | FF06110C2 | 04/25/06 | 0.33 | 120 | 22 | 4.3 |
| DIF | FF06110C3 | 04/25/06 | 0.26 | 130 | 21 | 5.9 |
| ECCB | P95115000C1 | 04/12/95 | 0.092 | 51 | 28 | 5.0 |
| ECCB | P95115000C2 | 04/12/95 | 0.092 | 59 | 26 | 4.4 |
| ECCB | P95115000C3 | 04/12/95 | 0.13 | 47 | 23 | 4.5 |
| ECCB | P96115000C1 | 04/29/96 | 0.44 | 41 | 13 | 1.9 |
| ECCB | P96115000C2 | 04/29/96 | 0.41 | 27 | 7.7 | 1.8 |
| ECCB | P96115000C3 | 04/29/96 | 0.35 | 26 | 7.9 | 1.0 *U* |
| ECCB | P97115000C1 | 05/13/97 | 0.23 | 24 | 6.1 | 1.8 |
| ECCB | P97115000C2 | 05/13/97 | 0.18 | 34 | 17 | 2.5 |
| ECCB | P97115000C3 | 05/13/97 | 0.17 | 31 | 11 | 1.7 |
| ECCB | VQST51 | 04/29/98 | 0.14 | 19 | 6.1 | 1.3 |
| ECCB | VQST52 | 04/29/98 | 0.093 | 16 | 5.0 | 1.2 |
| ECCB | VQST53 | 04/29/98 | 0.17 | 19 | 5.6 | 1.1 |
| ECCB | FF99150C1 | 04/19/99 | 0.22 | 32 | 12 | 3.3 |
| ECCB | FF99150C2 | 04/19/99 | 0.21 | 23 | 8.6 | 1.6 |
| ECCB | FF99150C3 | 04/19/99 | 0.25 | 29 | 10 | 2.1 |
| ECCB | FF00150C1 | 04/14/00 | 0.24 | 20 | 6.8 | 1.9 |
| ECCB | FF00150C2 | 04/14/00 | 0.19 | 20 | 7.1 | 2.0 |

**Table A-4. (cont.)**

| Station | Sample ID | Date | Mercury | PCBs | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|
| ECCB | FF00150C3 | 04/14/00 | 0.18 | 17 | 5.5 | 1.9 |
| ECCB | FF01150C1 | 04/29/01 | 0.13 | 22 | 7.4 | 1.7 |
| ECCB | FF01150C2 | 04/29/01 | 0.26 | 25 | 7.3 | 1.6 |
| ECCB | FF01150C3 | 04/29/01 | 0.15 | 25 | 8.1 | 1.9 |
| ECCB | FF02150C1 | 05/08/02 | 0.24 | 16 | 4.7 | 1.4 |
| ECCB | FF02150C2 | 05/08/02 | 0.18 | 12 | 3.1 | 1.2 |
| ECCB | FF02150C3 | 05/08/02 | 0.17 | 19 | 6.4 | 1.3 |
| ECCB | FF03150C1 | 04/30/03 | 0.34 | 23 | 5.9 | 1.1 |
| ECCB | FF03150C2 | 04/30/03 | 0.29 | 13 | 3.4 | 0.97 |
| ECCB | FF03150C3 | 04/30/03 | 0.21 | 36 | 11 | 2.7 |
| ECCB | FF04150C1 | 05/02/04 | 0.24 | | | |
| ECCB | FF04150C2 | 05/02/04 | 0.16 | | | |
| ECCB | FF04150C3 | 05/02/04 | 0.18 | | | |
| ECCB | FF06150C1 | 04/27/06 | 0.24 | 31 | 7.0 | 1.1 |
| ECCB | FF06150C2 | 04/27/06 | 0.21 | 32 | 5.6 | 0.84 |
| ECCB | FF06150C3 | 04/27/06 | 0.22 | 27 | 6.0 | 1.7 |
| OS | P95114000C1 | 04/11/95 | 0.39 | 100 | 18 | 5.3 |
| OS | P95114000C2 | 04/11/95 | 0.31 | 92 | 16 | 5.3 |
| OS | P95114000C3 | 04/11/95 | 0.24 | 100 | 25 | 6.7 |
| OS | P96114000C1 | 04/18/96 | 0.81 | 79 | 16 | 4.4 |
| OS | P96114000C2 | 04/18/96 | 0.53 | 130 | 26 | 4.3 |
| OS | P96114000C3 | 04/18/96 | 0.30 | 61 | 11 | 3.3 |
| OS | P97114000C1 | 04/07/97 | 0.66 | 100 | 25 | 7.0 |
| OS | P97114000C2 | 04/07/97 | 0.17 | 63 | 12 | 5.0 |
| OS | P97114000C3 | 04/07/97 | 0.0080 *U* | 110 | 22 | 4.8 |
| OS | VQST41 | 04/21/98 | 0.25 | 25 | 4.2 | 2.8 |
| OS | VQST42 | 04/21/98 | 0.38 | 89 | 15 | 9.1 |
| OS | VQST43 | 04/21/98 | 0.35 | 45 | 8.5 | 4.3 |
| OS | FF99140C1 | 04/15/99 | 0.46 | 51 | 17 | 5.7 |
| OS | FF99140C2 | 04/15/99 | 0.60 | 110 | 26 | 12 |
| OS | FF99140C3 | 04/15/99 | 0.57 | 63 | 14 | 3.1 |
| OS | FF00140C1 | 04/11/00 | 0.38 | 67 | 9.9 | 4.2 |
| OS | FF00140C2 | 04/11/00 | 0.31 | 51 | 8.6 | 2.6 |
| OS | FF00140C3 | 04/11/00 | 0.76 | 55 | 9.1 | 3.0 |
| OS | FF01140C1 | 04/26/01 | 0.49 | 51 | 8.5 | 2.0 |
| OS | FF01140C2 | 04/26/01 | 0.53 | 65 | 10 | 3.2 |
| OS | FF01140C3 | 04/26/01 | 0.43 | 71 | 13 | 3.5 |
| OS | FF02140C1 | 04/24/02 | 0.25 | 36 | 6.5 | 3.4 |
| OS | FF02140C2 | 04/24/02 | 0.42 | 47 | 8.6 | 3.0 |
| OS | FF02140C3 | 04/24/02 | 0.47 | 87 | 13 | 3.4 |
| OS | FF03140C1 | 04/28/03 | 0.77 | 76 | 9.3 | 2.4 |
| OS | FF03140C2 | 04/28/03 | 0.53 | 79 | 9.6 | 3.1 |
| OS | FF03140C3 | 04/28/03 | 0.69 | 120 | 15 | 4.3 |
| OS | FF04140C1 | 04/27/04 | 0.47 | | | |
| OS | FF04140C2 | 04/27/04 | 0.53 | | | |
| OS | FF04140C3 | 04/27/04 | 0.72 | | | |
| OS | FF06140C1 | 04/25/06 | 0.49 | 95 | 9.0 | 1.6 |
| OS | FF06140C2 | 04/25/06 | 0.37 | 61 | 12 | 2.3 |
| OS | FF06140C3 | 04/25/06 | 0.49 | 84 | 11 | 1.5 |

*Notes on following page.*

**Table A-4. (cont.)**

**Note:** Concentrations reported as pg/g for metals and ng/g for all other compounds, rounded to two significant figures.

DIF - Deer Island Flats
ECCB - East Cape Cod Bay
OS - outfall location

PCB: Sum of congeners 138 and 153
Chlordane: Sum of *cis*- chlordane and *trans*- nonachlor

**Table A-5. Concentrations measured in flouder liver**

| Station | Sample ID | Date | Cadmium | Copper | Lead | Mercury | PCBs | LMW(7)-PAH | LMW(12)-PAH | HMW-PAH | Total(19)-PAH | Total(24)-PAH | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DIF | P95111000C1 | 04/10/95 | 0.45 | 22 | 0.62 | 0.22 | 3,900 | 160 | | 10 *U* | 220 | | 570 | 310 |
| DIF | P95111000C2 | 04/10/95 | 0.55 | 98 | 0.75 | 0.18 | 3,300 | 130 | | 56 | 190 | | 860 | 200 |
| DIF | P95111000C3 | 04/10/95 | 0.32 | 48 | 1.2 | 0.34 | 4,100 | 120 | | 53 | 170 | | 700 | 340 |
| DIF | P96111000C1 | 04/15/96 | 0.33 | 28 | 1.8 | 0.42 | 2,300 | 130 | | 60 | 190 | | 470 | 240 |
| DIF | P96111000C2 | 04/15/96 | 1.0 | 81 | 2.4 | 0.70 | 1,600 | 190 | | 70 | 260 | | 340 | 130 |
| DIF | P96111000C3 | 04/15/96 | 1.3 | 18 | 2.2 | 0.47 | 1,200 | 190 | | 62 | 250 | | 240 | 130 |
| DIF | P97111000C1 | 04/07/97 | 1.0 | 58 | 1.8 | 0.43 | 1,700 | 87 | | 66 | 150 | | 410 | 210 |
| DIF | P97111000C2 | 04/07/97 | 0.49 | 53 | 3.6 | 0.24 | 2,900 | 100 | | 57 | 160 | | 660 | 350 |
| DIF | P97111000C3 | 04/07/97 | 5.2 | 53 | 3.8 | 0.36 | 1,600 | 80 | | 55 | 130 | | 340 | 170 |
| DIF | VQST11 | 04/21/98 | 0.48 | 26 | 2.1 | 0.20 | 2,200 | 43 | 67 | 22 | 65 | 89 | 440 | 280 |
| DIF | VQST12 | 04/21/98 | 0.83 | 43 | 2.6 | 0.29 | 1,300 | 36 | 59 | 19 | 55 | 78 | 220 | 120 |
| DIF | VQST13 | 04/21/98 | 0.66 | 59 | 2.8 | 0.32 | 1,200 | 37 | 55 | 20 | 58 | 76 | 200 | 120 |
| DIF | FF99110C1 | 05/10/99 | 0.48 | 38 | 3.0 | 0.22 | 1,300 | 95 | 120 | 20 | 110 | 140 | 350 | 200 |
| DIF | FF99110C2 | 05/10/99 | 0.45 | 28 | 2.0 | 0.22 | 1,100 | 55 | 74 | 24 | 79 | 98 | 410 | 210 |
| DIF | FF99110C3 | 05/10/99 | 0.84 | 35 | 2.3 | 0.23 | 1,100 | 89 | 110 | 6.7 *U* | 110 | 130 | 420 | 240 |
| DIF | FF00110C1 | 04/11/00 | 1.2 | 120 | 2.9 | 0.35 | 980 | 77 | 110 | 20 | 97 | 130 | 150 | 120 |
| DIF | FF00110C2 | 04/11/00 | 2.9 | 120 | 3.3 | 0.61 | 1,000 | 64 | 90 | 22 | 86 | 110 | 170 | 130 |
| DIF | FF00110C3 | 04/11/00 | 0.82 | 120 | 4.8 | 0.32 | 490 | 65 | 89 | 20 | 86 | 110 | 91 | 45 |
| DIF | FF01110C1 | 04/25/01 | 1.4 | 38 | 3.6 | 0.34 | 1,400 | 77 | 98 | 42 | 120 | 140 | 220 | 90 |
| DIF | FF01110C2 | 04/25/01 | 0.85 | 59 | 2.2 | 0.30 | 1,600 | 72 | 93 | 34 | 110 | 130 | 240 | 100 |
| DIF | FF01110C3 | 04/25/01 | 2.4 | 59 | 3.0 | 0.42 | 1,200 | 67 | 86 | 32 | 99 | 120 | 170 | 82 |
| DIF | FF02110C1 | 04/23/02 | 2.2 | 80 | 1.9 | 0.30 | 1,400 | 33 | 49 | 7.5 | 40 | 57 | 240 | 85 |
| DIF | FF02110C2 | 04/23/02 | 0.80 | 39 | 2.8 | 0.24 | 770 | 28 | 42 | 13 | 41 | 55 | 120 | 49 |
| DIF | FF02110C3 | 04/23/02 | 3.0 | 64 | 1.4 | 0.35 | 1,700 | 37 | 56 | 12 | 48 | 68 | 220 | 98 |
| DIF | FF03110C1 | 04/28/03 | 1.3 | 60 | 3.4 | 0.36 | 2,900 | 26 | 46 | 18 | 44 | 64 | 300 | 87 |
| DIF | FF03110C2 | 04/28/03 | 1.6 | 41 | 2.9 | 0.50 | 1,700 | 33 | 48 | 21 | 54 | 69 | 220 | 80 |
| DIF | FF03110C3 | 04/28/03 | 1.4 | 33 | 2.5 | 0.42 | 2,800 | 28 | 49 | 21 | 49 | 70 | 270 | 87 |
| DIF | FF04110C1 | 04/28/04 | | | | 0.30 | | | | | | | | |
| DIF | FF04110C2 | 04/28/04 | | | | 0.25 | | | | | | | | |
| DIF | FF04110C3 | 04/28/04 | | | | 0.35 | | | | | | | | |
| DIF | FF06110C1 | 04/25/06 | 1.3 | 49 | 1.5 | 0.22 | 1,400 | 96 | 160 | 150 | 250 | 320 | | |
| DIF | FF06110C2 | 04/25/06 | 2.2 | 75 | 1.5 | 0.17 | 1,300 | 71 *U* | 220 | 200 | 330 | 420 | | |
| DIF | FF06110C3 | 04/25/06 | 0.48 | 52 | 1.4 | 0.072 | 1,500 | 92 | 150 | 26 *U* | 250 | 310 | | |
| ECCB | P95115000C1 | 04/12/95 | 0.68 | 65 | 7.5 | 0.25 | 870 | 73 | | 10 *U* | 130 | | 120 | 73 |
| ECCB | P95115000C2 | 04/12/95 | 0.64 | 72 | 3.8 | 0.40 | 360 | 67 | | 10 *U* | 130 | | 180 | 26 |
| ECCB | P95115000C3 | 04/12/95 | 0.67 | 57 | 4.3 | 0.25 | 330 | 65 | | 10 *U* | 130 | | 130 | 20 |
| ECCB | P96115000C1 | 04/29/96 | 1.4 | 74 | 0.66 | 0.35 | 410 | 200 | | 74 | 270 | | 92 | 26 |
| ECCB | P96115000C2 | 04/29/96 | 1.2 | 50 | 1.4 | 0.48 | 360 | 160 | | 65 | 230 | | 94 | 15 |
| ECCB | P96115000C3 | 04/29/96 | 0.71 | 72 | 5.7 | 0.48 | 360 | 140 | | 71 | 210 | | 110 | 21 |
| ECCB | P97115000C1 | 05/13/97 | 2.4 | 110 | 0.88 | 0.24 | 300 | 45 | | 49 | 95 | | 100 | 24 |
| ECCB | P97115000C2 | 05/13/97 | 2.2 | 95 | 0.66 | 0.19 | 430 | 45 | | 51 | 97 | | 170 | 34 |

**Table A-5. (cont.)**

| Station | Sample ID | Date | Cadmium | Copper | Lead | Mercury | PCBs | LMW(7)-PAH | LMW(12)-PAH | HMW-PAH | Total(19)-PAH | Total(24)-PAH | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ECCB | P97115000C3 | 05/13/97 | 0.85 | 53 | 1.7 | 0.17 | 570 | 66 | | 49 | 110 | | 360 | 40 |
| ECCB | VQST51 | 04/29/98 | 1.8 | 130 | 2.7 | 0.31 | 320 | 31 | 44 | 4.2 *U* | 47 | 61 | 91 | 16 |
| ECCB | VQST52 | 04/29/98 | 0.72 | 93 | 1.3 | 0.19 | 210 | 20 | 32 | 18 | 38 | 50 | 54 | 13 |
| ECCB | VQST53 | 04/29/98 | 2.5 | 190 | 2.9 | 0.30 | 110 | 13 | 20 | | | | 24 | 5 |
| ECCB | FF99150C1 | 04/19/99 | 1.4 | 64 | 1.3 | 0.33 | 320 | 200 | 230 | 6.7 *U* | 220 | 250 | 120 | 28 |
| ECCB | FF99150C2 | 04/19/99 | 1.0 | 47 | 2.5 | 0.23 | 120 | 34 | 44 | 6.7 *U* | 51 | 61 | 42 | 8 |
| ECCB | FF99150C3 | 04/19/99 | 2.6 | 100 | 2.3 | 0.37 | 160 | 92 | 110 | 20 | 110 | 130 | 53 | 11 |
| ECCB | FF00150C1 | 04/14/00 | 1.4 | 98 | 1.5 | 0.27 | 110 | 47 | 60 | 6.7 *U* | 64 | 78 | 38 | 10 |
| ECCB | FF00150C2 | 04/14/00 | 1.8 | 150 | 1.9 | 0.30 | 130 | 40 | 54 | 6.7 *U* | 58 | 72 | 42 | 12 |
| ECCB | FF00150C3 | 04/14/00 | 0.57 | 51 | 1.5 | 0.40 | 140 | 50 | 60 | 59 | 110 | 120 | 41 | 15 |
| ECCB | FF01150C1 | 04/29/01 | 1.5 | 140 | 3.3 | 0.13 | 190 | 34 | 44 | 12 | 45 | 55 | 61 | 14 |
| ECCB | FF01150C2 | 04/29/01 | 2.3 | 66 | 2.4 | 0.26 | 190 | 40 | 52 | 16 | 56 | 68 | 52 | 11 |
| ECCB | FF01150C3 | 04/29/01 | 0.92 | 41 | 3.8 | 0.13 | 230 | 35 | 45 | 9.9 | 45 | 55 | 65 | 16 |
| ECCB | FF02150C1 | 05/08/02 | 1.4 | 27 | 1.5 | 0.22 | 350 | 59 | 93 | 60 | 120 | 150 | 100 | 19 |
| ECCB | FF02150C2 | 05/08/02 | 0.80 | 28 | 0.70 | 0.20 | 180 | 47 | 74 | 38 | 85 | 110 | 51 | 14 |
| ECCB | FF02150C3 | 05/08/02 | 2.9 | 76 | 2.8 | 0.23 | 230 | 24 | 35 | 6.4 | 31 | 42 | 77 | 13 |
| ECCB | FF03150C1 | 04/30/03 | 2.6 | 78 | 4.3 | 0.41 | 130 | 19 | 37 | 3.5 *U* | 32 | 49 | 37 | 6.7 |
| ECCB | FF03150C2 | 04/30/03 | 1.9 | 39 | 1.7 | 0.31 | 130 | 22 | 42 | 3.5 *U* | 34 | 54 | 34 | 9.4 |
| ECCB | FF03150C3 | 04/30/03 | 11 | 86 | 5.7 | 0.27 | 260 | 15 | 29 | 3.5 *U* | 27 | 41 | 83 | 15 |
| ECCB | FF04150C1 | 05/02/04 | | | | 0.23 | | | | | | | | |
| ECCB | FF04150C2 | 05/02/04 | | | | 0.14 | | | | | | | | |
| ECCB | FF04150C3 | 05/02/04 | | | | 0.26 | | | | | | | | |
| ECCB | FF06150C1 | 04/27/06 | 2.2 | 40 | 2.0 | 0.12 | 220 | 93 | 160 | 27 *U* | 250 | 320 | | |
| ECCB | FF06150C2 | 04/27/06 | 1.5 | 38 | 2.4 | 0.18 | 180 | 98 | 160 | 28 *U* | 270 | 330 | | |
| ECCB | FF06150C3 | 04/27/06 | 1.4 | 27 | 1.1 | 0.15 | 150 | 56 *U* | 170 | 28 *U* | 56 *U* | 340 | | |
| OS | P95114000C1 | 04/11/95 | 1.5 | 97 | 7.9 | 0.43 | 4,200 | 60 | | 53 | 110 | | 620 | 120 |
| OS | P95114000C2 | 04/11/95 | 1.2 | 130 | 2.6 | 0.37 | 2,300 | 62 | | 56 | 120 | | 290 | 66 |
| OS | P95114000C3 | 04/11/95 | 1.5 | 140 | 7.3 | 0.36 | 2,000 | 63 | | 10 *U* | 120 | | 350 | 100 |
| OS | P96114000C1 | 04/18/96 | 4.9 | 170 | 5.0 | 0.61 | 960 | 170 | | 84 | 250 | | 170 | 68 |
| OS | P96114000C2 | 04/18/96 | 2.8 | 59 | 5.2 | 0.51 | 1,600 | 120 | | 58 | 180 | | 400 | 110 |
| OS | P96114000C3 | 04/18/96 | 2.3 | 150 | 2.5 | 0.54 | 1,100 | 280 | | 77 | 360 | | 160 | 85 |
| OS | P97114000C1 | 04/07/97 | 1.0 | 53 | 4.9 | 0.48 | 930 | 54 | | 59 | 110 | | 260 | 72 |
| OS | P97114000C2 | 04/07/97 | 0.89 | 93 | 5.2 | 0.29 | 750 | 65 | | 56 | 120 | | 200 | 55 |
| OS | P97114000C3 | 04/07/97 | 1.2 | 79 | 3.1 | 0.26 | 2,000 | 69 | | 57 | 130 | | 340 | 110 |
| OS | VQST41 | 04/21/98 | 0.67 | 72 | 4.5 | 0.31 | 940 | 40 | 59 | 18 | 58 | 78 | 130 | 62 |
| OS | VQST42 | 04/21/98 | 1.6 | 130 | 3.8 | 0.42 | 520 | 24 | 37 | 18 | 43 | 56 | 80 | 49 |
| OS | VQST43 | 04/21/98 | 1.3 | 72 | 3.2 | 0.43 | 550 | 20 | 35 | 17 | 37 | 52 | 97 | 39 |
| OS | FF99140C1 | 04/15/99 | 2.3 | 96 | 3.5 | 0.43 | 550 | 85 | 100 | 20 | 100 | 120 | 140 | 48 |
| OS | FF99140C2 | 04/15/99 | 1.9 | 130 | 3.6 | 0.66 | 370 | 33 | 49 | 21 | 54 | 69 | 96 | 21 |
| OS | FF99140C3 | 04/15/99 | 5.3 | 160 | 13 | 0.84 | 800 | 100 | 120 | 6.7 *U* | 120 | 140 | 230 | 74 |
| OS | FF00140C1 | 04/11/00 | 2.7 | 140 | 8.8 | 0.44 | 610 | 42 | 56 | 18 | 60 | 74 | 89 | 36 |

**Table A-5. (cont.)**

| Station | Sample ID | Date | Cadmium | Copper | Lead | Mercury | PCBs | LMW(7)-PAH | LMW(12)-PAH | HMW-PAH | Total(19)-PAH | Total(24)-PAH | 4,4'-DDE | Chlordane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OS | FF00140C2 | 04/11/00 | 1.4 | 140 | 7.6 | 0.27 | 590 | 84 | 100 | 22 | 110 | 120 | 99 | 32 |
| OS | FF00140C3 | 04/11/00 | 3.9 | 270 | 8.0 | 1.2 | 450 | 210 | | 20 | 230 | | 74 | 24 |
| OS | FF01140C1 | 04/26/01 | 1.9 | 62 | 8.2 | 0.57 | 1,100 | 58 | 69 | 33 | 91 | 100 | 150 | 34 |
| OS | FF01140C2 | 04/26/01 | 2.1 | 160 | 7.3 | 0.50 | 1,000 | 59 | 70 | 31 | 90 | 100 | 140 | 38 |
| OS | FF01140C3 | 04/26/01 | 7.4 | 84 | 6.8 | 0.35 | 1,100 | 40 | 52 | 30 | 69 | 82 | 190 | 52 |
| OS | FF02140C1 | 04/24/02 | 1.6 | 69 | 4.5 | 0.36 | 990 | 29 | 42 | 7.1 | 36 | 49 | 120 | 34 |
| OS | FF02140C2 | 04/24/02 | 3.1 | 94 | 4.5 | 0.41 | 670 | 33 | 45 | 7.8 | 40 | 53 | 100 | 37 |
| OS | FF02140C3 | 04/24/02 | 1.9 | 80 | 5.9 | 0.43 | 1,100 | 24 | 33 | 6.6 | 30 | 40 | 140 | 33 |
| OS | FF03140C1 | 04/28/03 | 3.6 | 150 | 3.0 | 0.70 | 1,200 | 12 | 18 | 14 | 25 | 32 | 120 | 24 |
| OS | FF03140C2 | 04/28/03 | 1.8 | 130 | 4.9 | 0.62 | 1,400 | 19 | 39 | 3.5 *U* | 31 | 51 | 110 | 30 |
| OS | FF03140C3 | 04/28/03 | 2.8 | 120 | 7.3 | 0.62 | 1,800 | 13 | 16 | 3.5 *U* | 25 | 28 | 170 | 35 |
| OS | FF04140C1 | 04/27/04 | | | | 0.37 | | | | | | | | |
| OS | FF04140C2 | 04/27/04 | | | | 0.57 | | | | | | | | |
| OS | FF04140C3 | 04/27/04 | | | | 0.54 | | | | | | | | |
| OS | FF06140C1 | 04/25/06 | 2.7 | 110 | 4.9 | 0.32 | 440 | 110 | 180 | 180 | 300 | 360 | | |
| OS | FF06140C2 | 04/25/06 | 0.97 | 42 | 3.5 | 0.25 | 880 | 88 | 150 | 150 | 230 | 290 | | |
| OS | FF06140C3 | 04/25/06 | 2.7 | 69 | 9.5 | 0.40 | 570 | 110 | 180 | 170 | 280 | 350 | | |

**Note:** Concentrations reported as pg/g for metals and ng/g for all other compounds, rounded to two significant figures

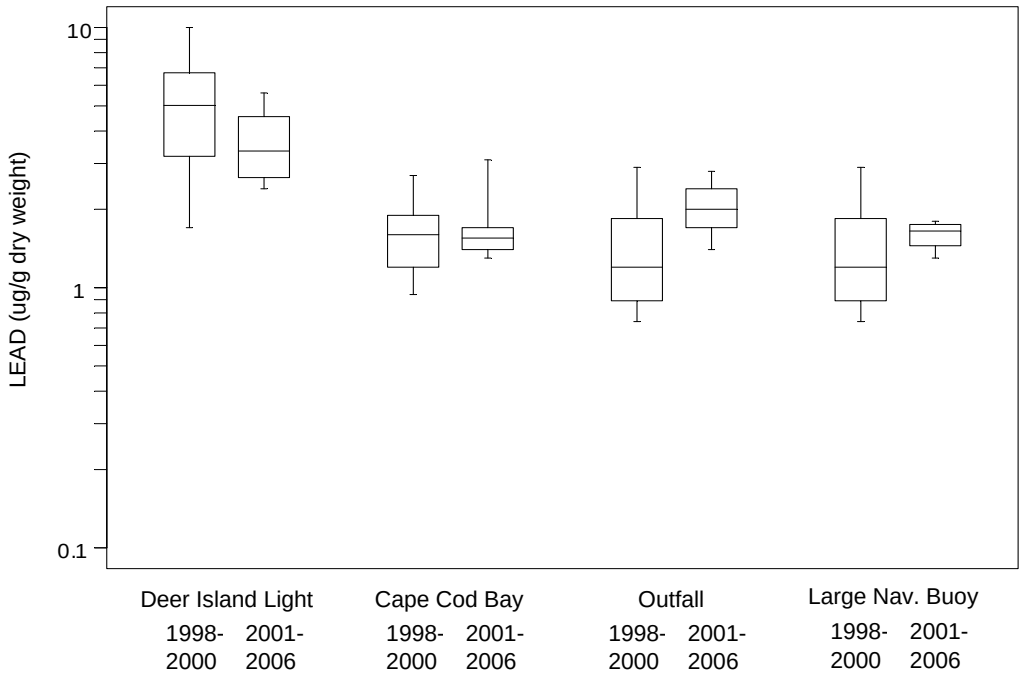
DIF - Deer Island Flats
ECCB - East Cape Cod Bay
OS - outfall location

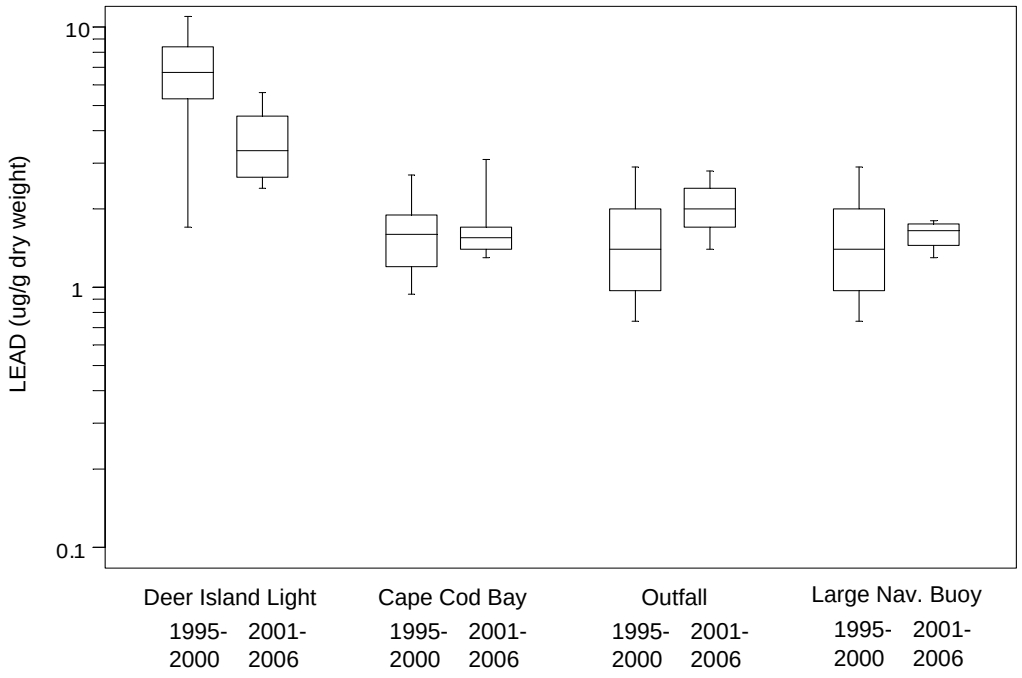
PCB: Sum of congeners 138 and 153
LMW PAH (7): Sum of 7 low molecular weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene)
LMW PAH (12): Sum of 12 low molecular weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene, 1-methylnaphthalene, 1-methylphenanthrene, 2,3,5-triethylnaphthalene, 2,6-dimethylnaphthalene, and 2-methylnaphthalene)
HMW PAH: Sum of 12 high molecular weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)
Total PAH (19): Sum of LMW PAH (7) and HMW PAH
Total PAH (24): Sum of LMW PAH (12) and HMW PAH
Chlordane: Sum of *cis*- chlordane and *trans*- nonachlor

# Appendix B

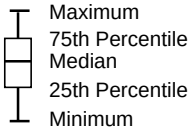
## Statistical Analyses

## Figures



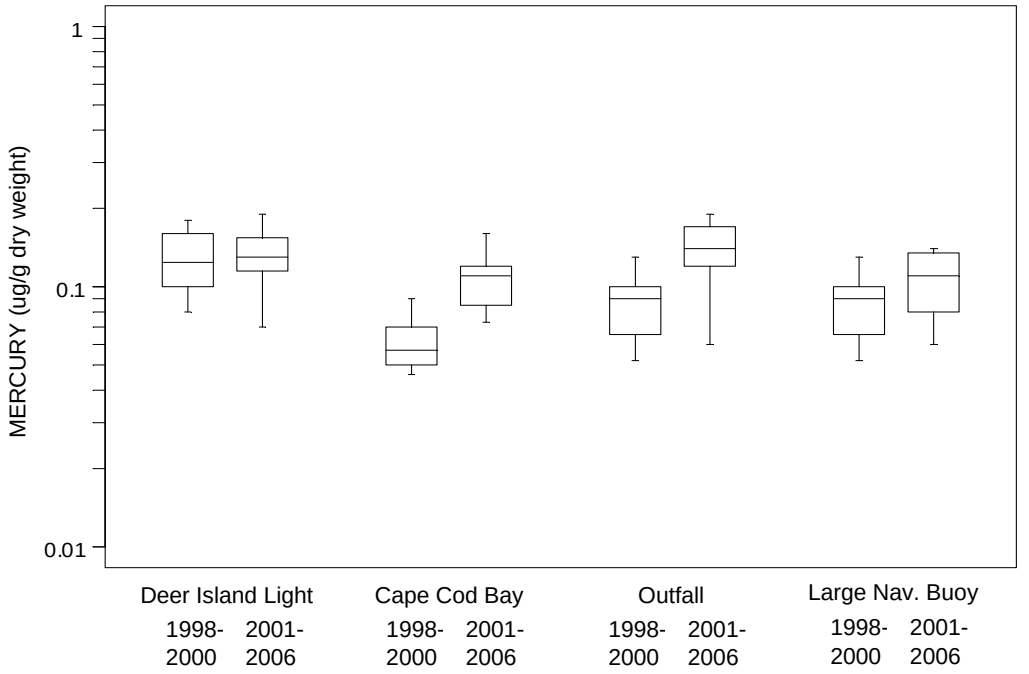



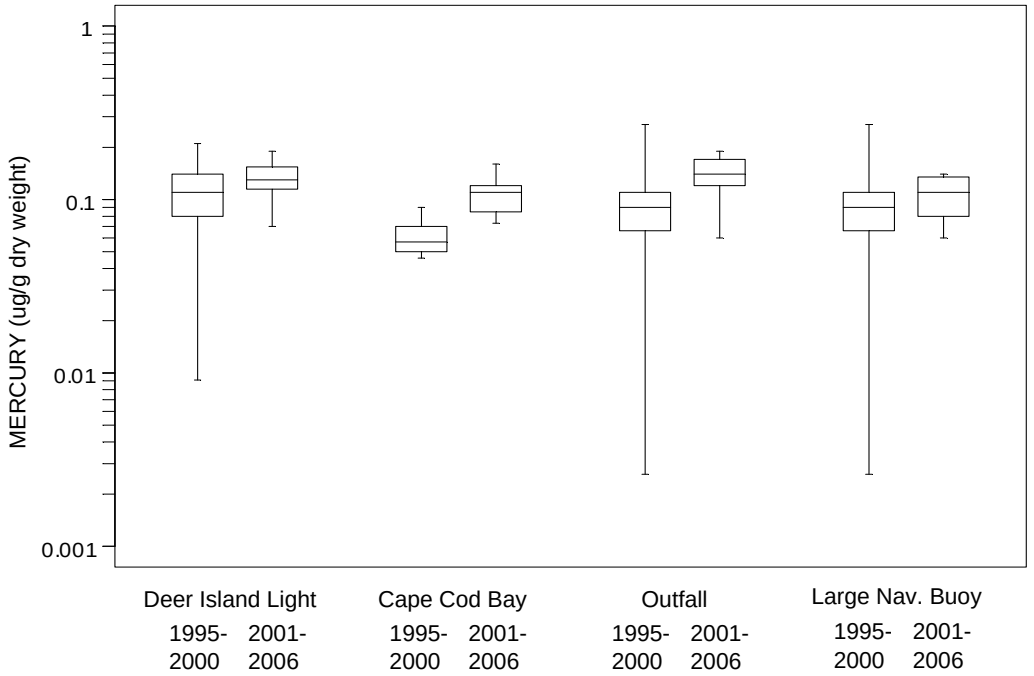

***LEGEND***



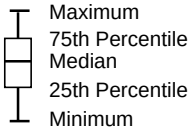

Control - Cape Cod Bay (CCB)
Impact - Deer Island Light (DIL), Outfall (OSM, OS-M1 - OS-M6), or Large Navigation Buoy (LNB)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

**Figure B-1. Comparison of lead concentrations measured in mussel soft tissue between control and impact locations before and after relocation of the outfall**



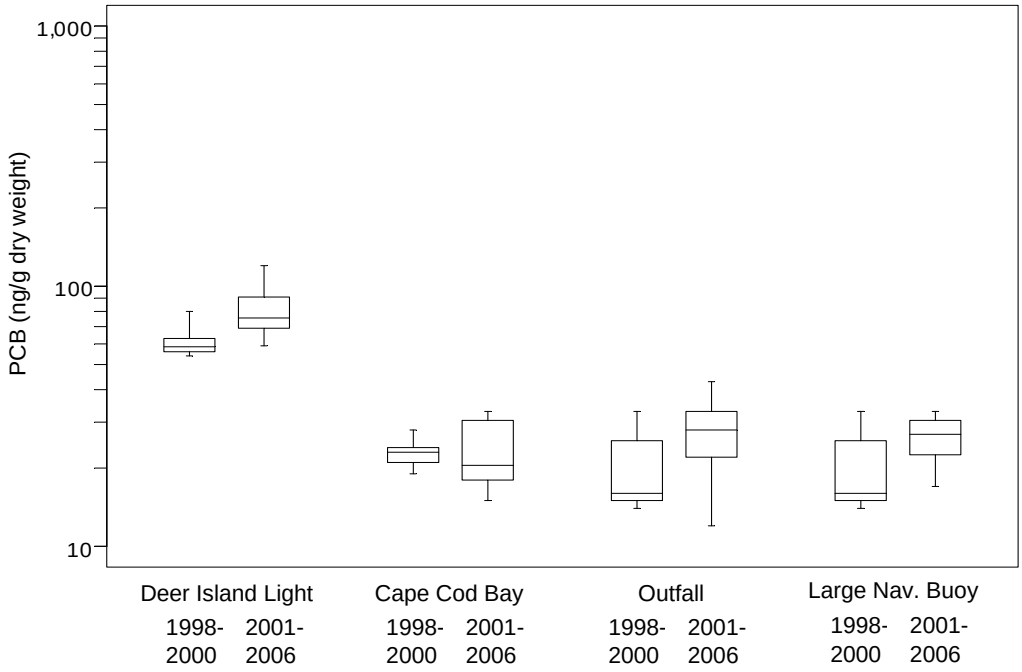



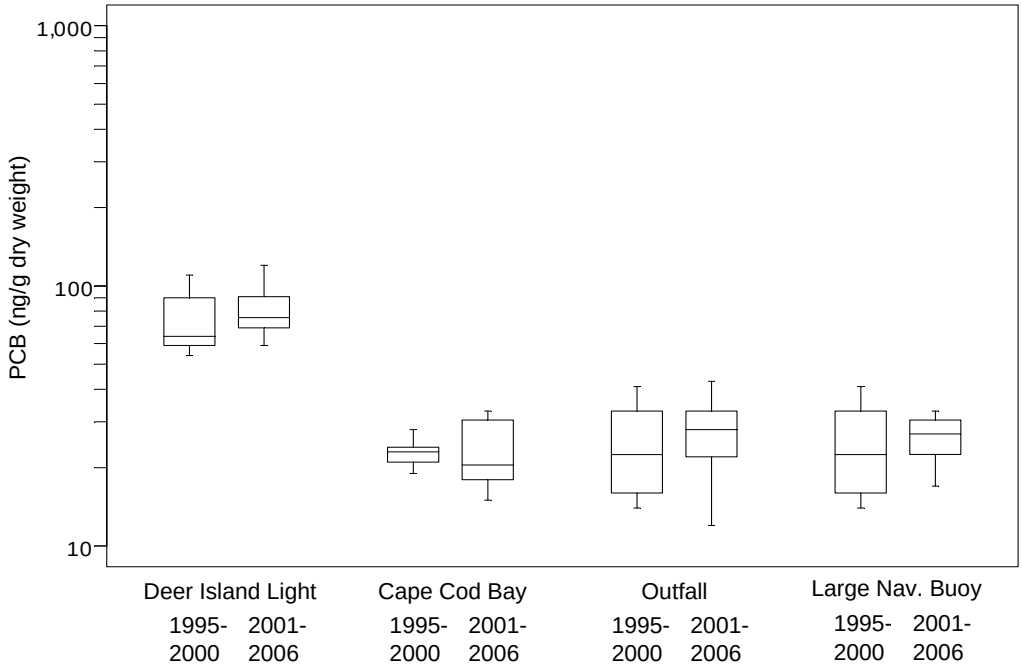

***LEGEND***




Control - Cape Cod Bay (CCB)
Impact - Deer Island Light (DIL), Outfall (OSM, OS-M1 - OS-M6), or Large Navigation Buoy (LNB)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

**Figure B-2. Comparison of mercury concentrations measured in mussel soft tissue between control and impact locations before and after relocation of the outfall**



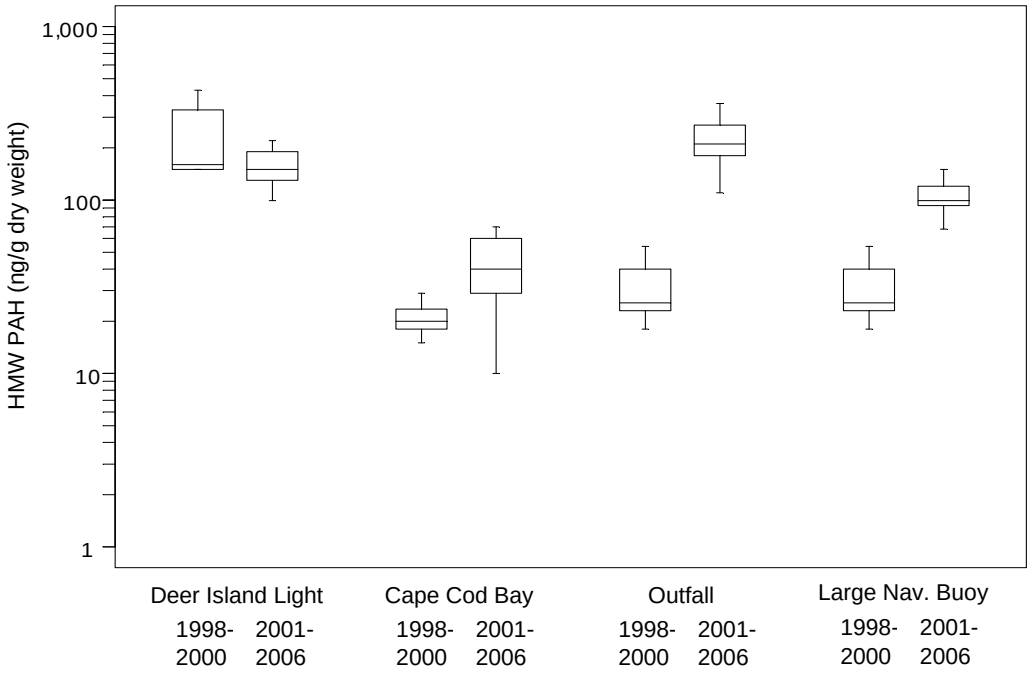

***LEGEND***

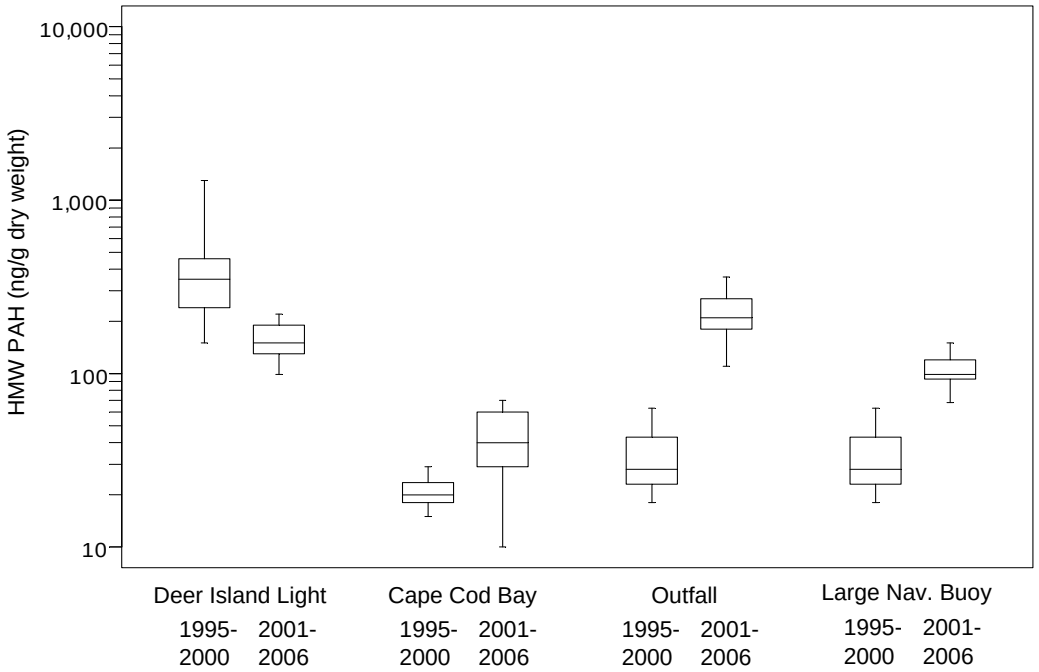
Maximum
75th Percentile
Median
25th Percentile
Minimum

Control - Cape Cod Bay (CCB)
Impact - Deer Island Light (DIL), Outfall (OSM, OS-M1 - OS-M6), or Large Navigation Buoy (LNB)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

PCB is the sum of congeners 138 and 153

**Figure B-3. Comparison of PCB concentrations measured in mussel soft tissue between control and impact locations before and after relocation of the outfall**



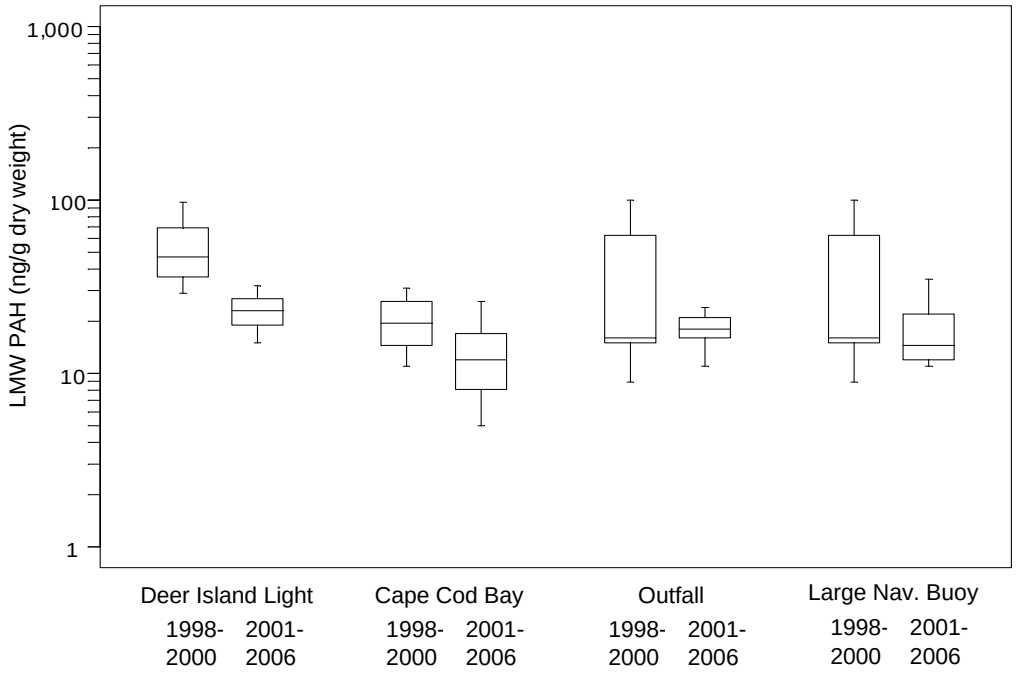

***LEGEND***

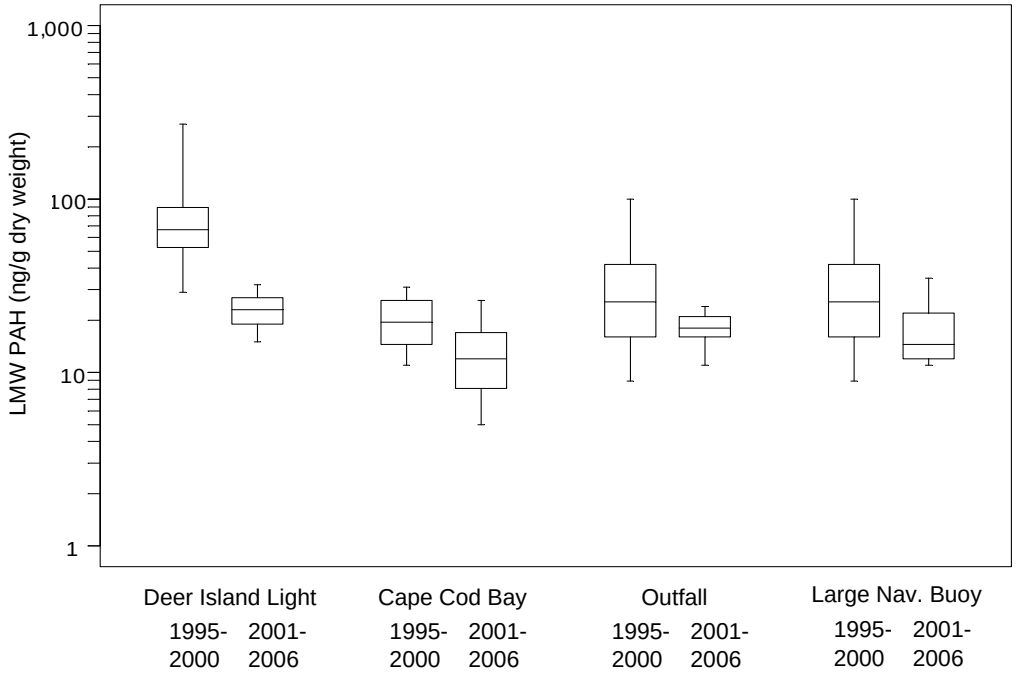
Maximum
75th Percentile
Median
25th Percentile
Minimum

Control - Cape Cod Bay (CCB)
Impact - Deer Island Light (DIL), Outfall (OSM, OS-M1 - OS-M6), or Large Navigation Buoy (LNB)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

HMW PAH is the sum of the 12 HMW analytes on the historical NOAA list

**Figure B-4. Comparison of high molecular weight (HMW) PAH concentrations measured in mussel soft tissue between control and impact locations before and after relocation of the outfall**



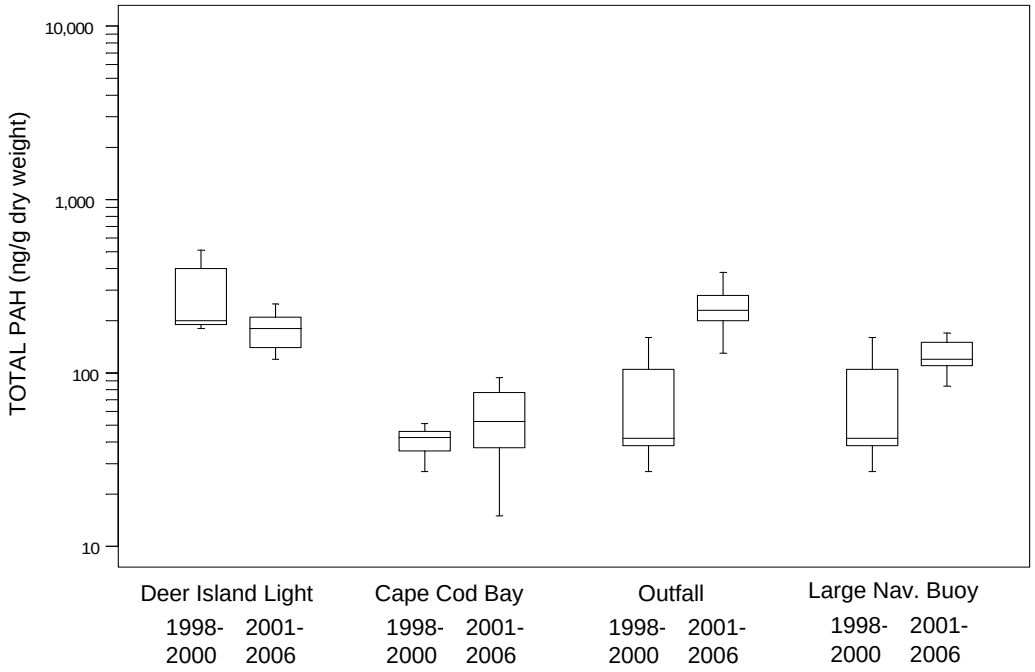

***LEGEND***

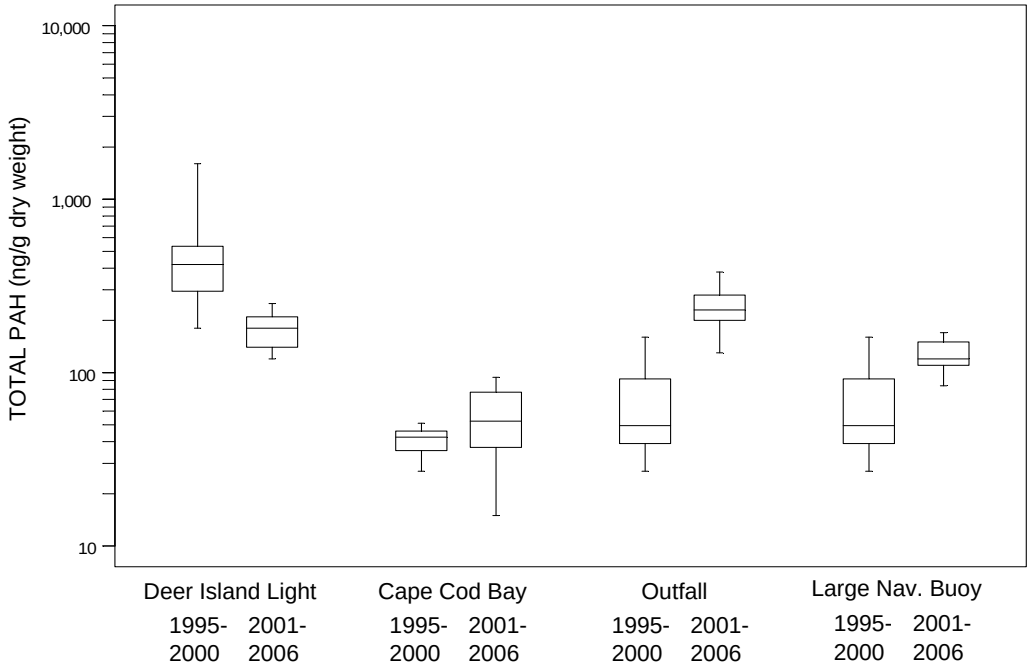
Maximum
75th Percentile
Median
25th Percentile
Minimum

Control - Cape Cod Bay (CCB)
Impact - Deer Island Light (DIL), Outfall (OSM, OS-M1 - OS-M6), or Large Navigation Buoy (LNB)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

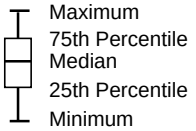
LMW PAH is the sum of 7 LMW analytes on the historical NOAA list (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, and phenanthrene)

**Figure B-5. Comparison of low molecular weight (LMW) PAH concentrations measured in mussel soft tissue between control and impact locations before and after relocation of the outfall**



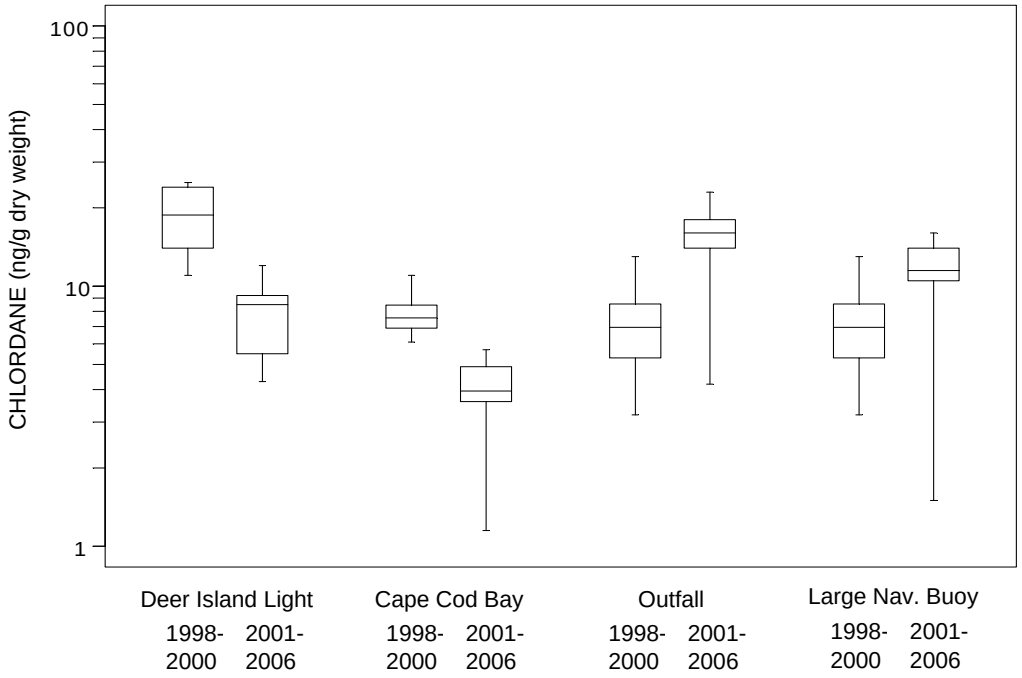

***LEGEND***

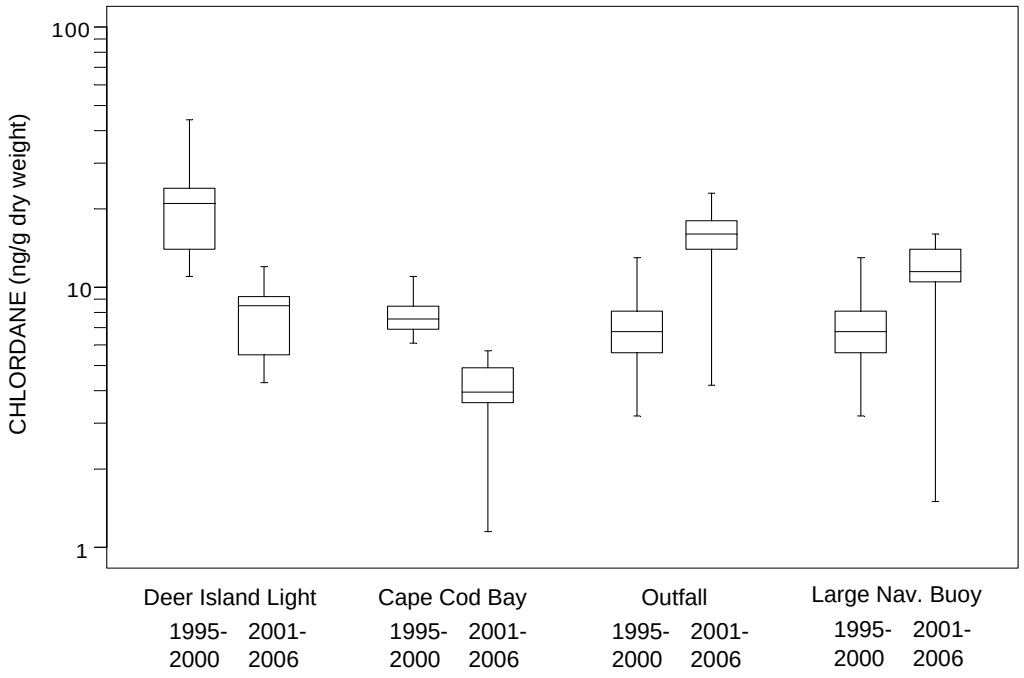



Control - Cape Cod Bay (CCB)
Impact - Deer Island Light (DIL), Outfall (OSM, OS-M1 - OS-M6), or Large Navigation Buoy (LNB)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

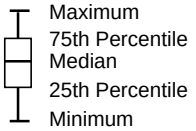
Total PAH is the sum of 19 analytes on the historical NOAA list (7 LMW analytes as identified on Figure B-5 and 12 HMW analytes)

**Figure B-6. Comparison of total PAH concentrations measured in mussel soft tissue between control and impact locations before and after relocation of the outfall**



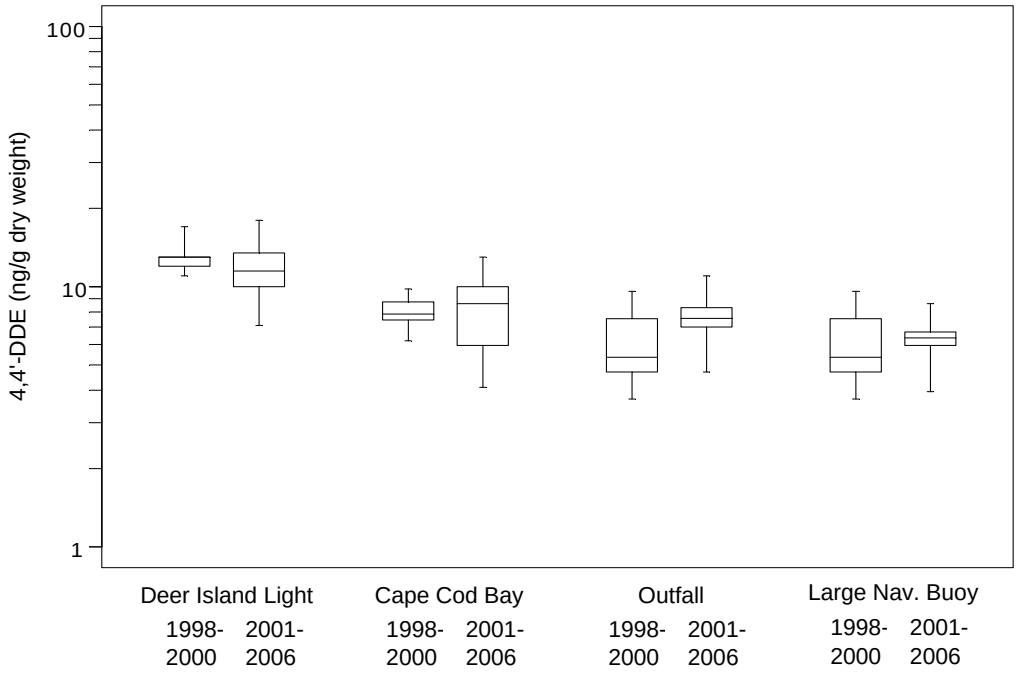

***LEGEND***

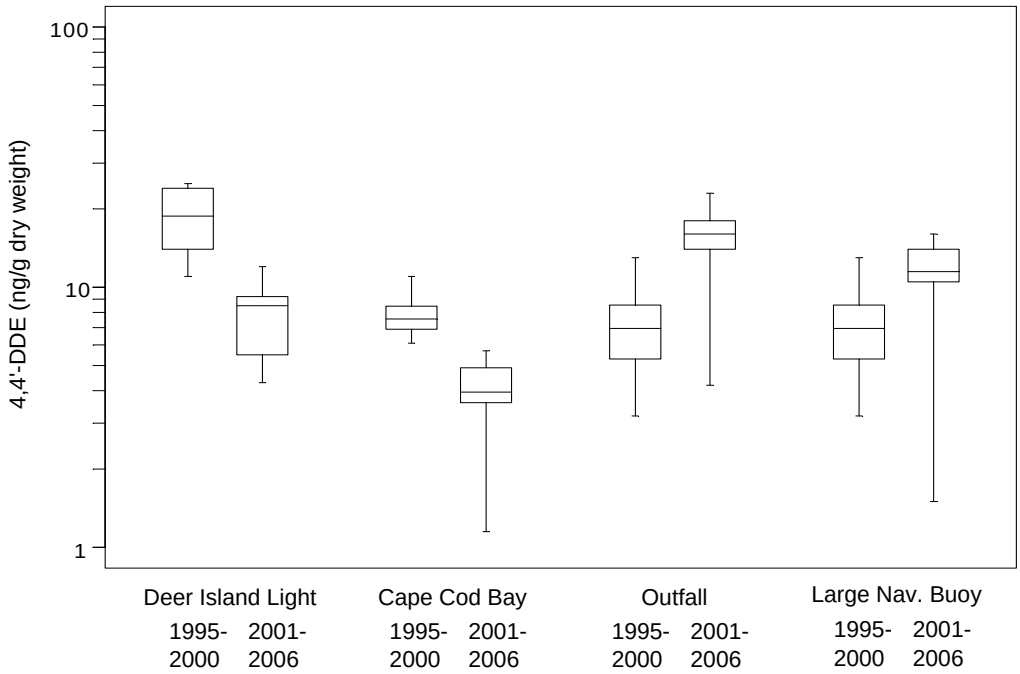



Control - Cape Cod Bay (CCB)
Impact - Deer Island Light (DIL), Outfall (OSM, OS-M1 - OS-M6), or Large Navigation Buoy (LNB)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

Chlordane is the sum of *cis*-chlordane and *trans*-nonachlor

**Figure B-7. Comparison of chlordane concentrations measured in mussel soft tissue between control and impact locations before and after relocation of the outfall**




***LEGEND***

Maximum
75th Percentile
Median
25th Percentile
Minimum

Control - Cape Cod Bay (CCB)
Impact - Deer Island Light (DIL), Outfall (OSM, OS-M1 - OS-M6), or Large Navigation Buoy (LNB)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

**Figure B-8. Comparison of 4,4'-DDE concentrations measured in mussel soft tissue between control and impact locations before and after relocation of the outfall**

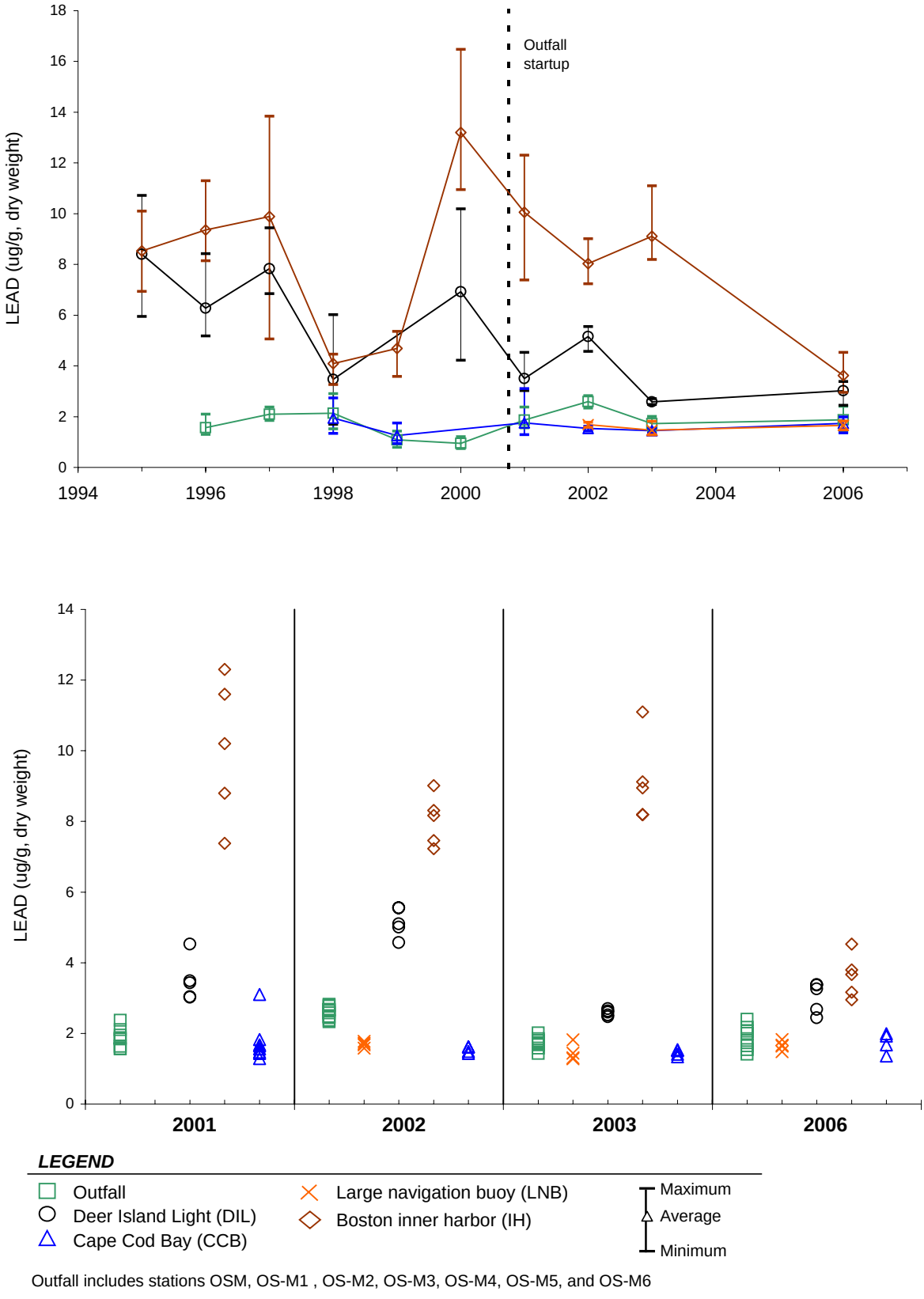



**Figure B-9. Lead concentrations in mussel soft tissue over time**

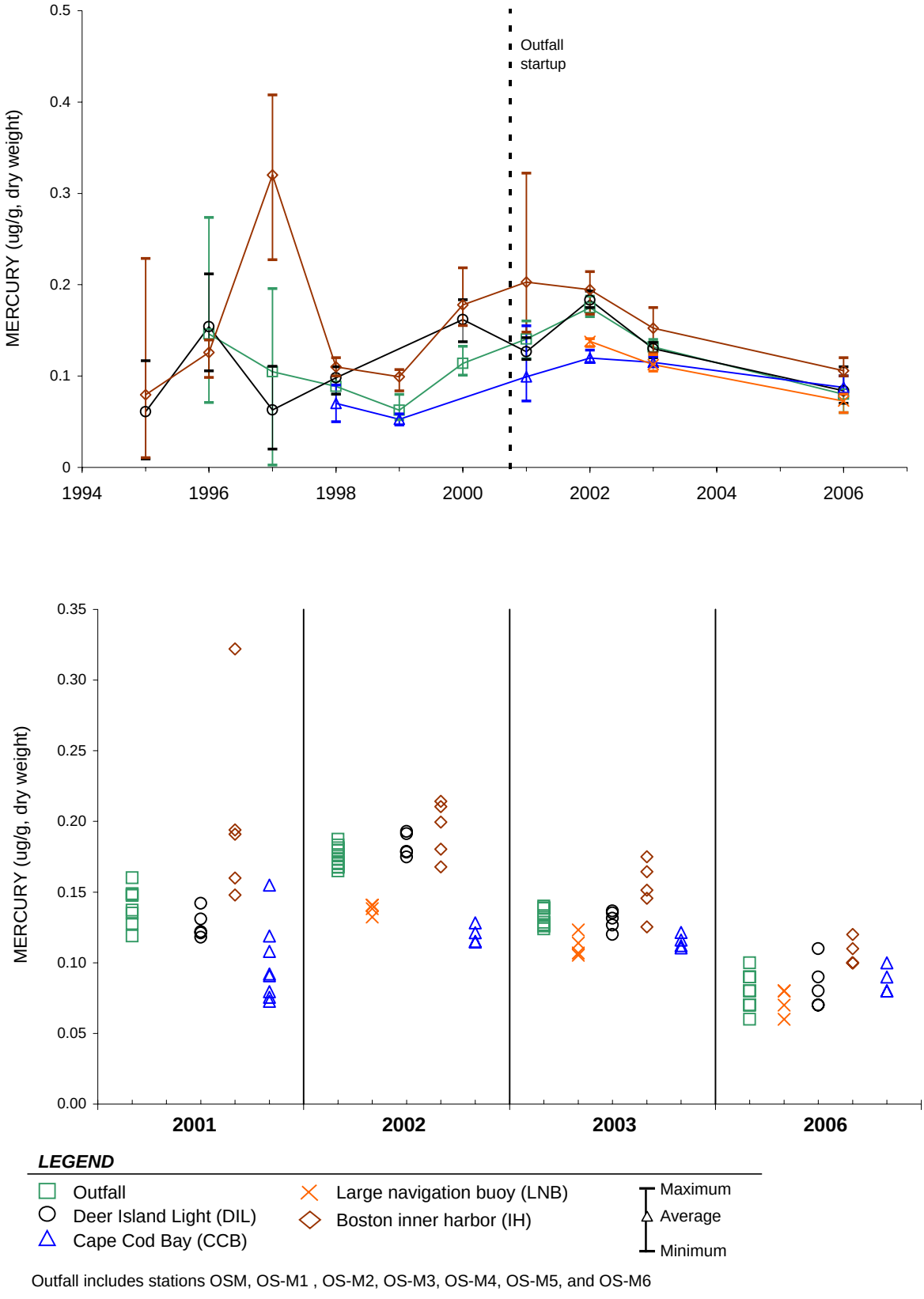



**Figure B-10. Mercury concentrations in mussel soft tissue over time**

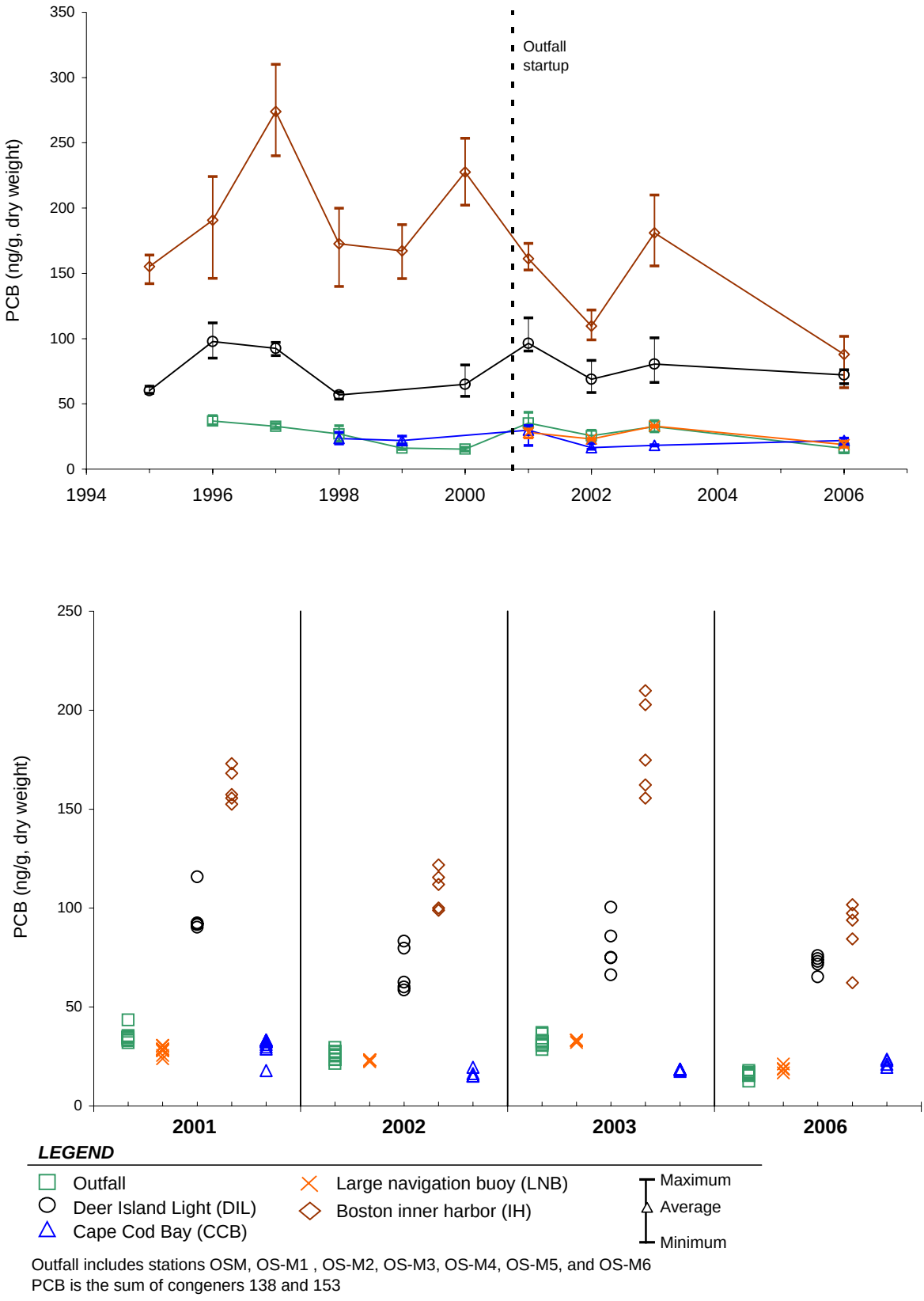



**Figure B-11. PCB concentrations in mussel soft tissue over time**

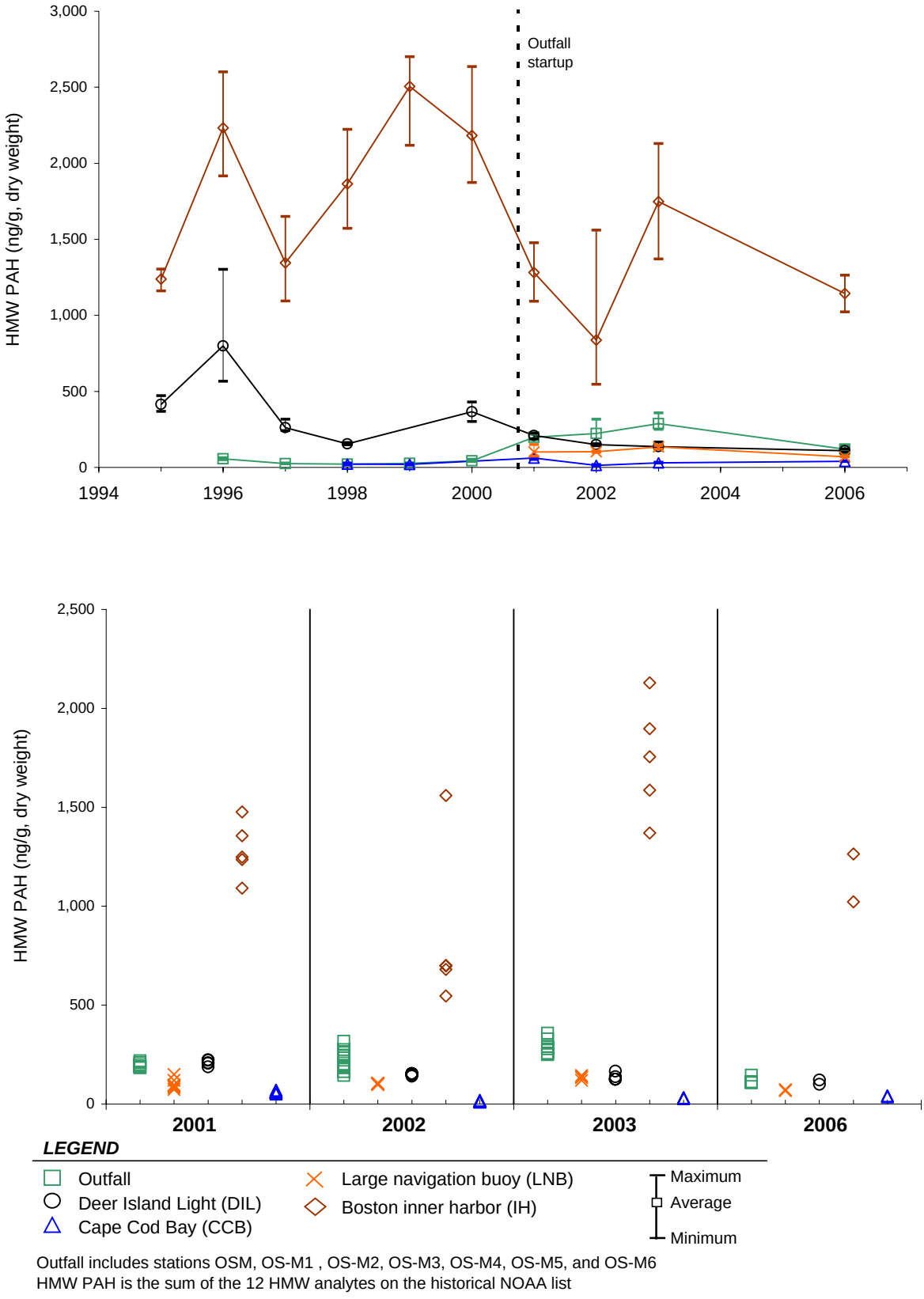



**Figure B-12. High molecular weight (HMW) PAH concentrations in mussel soft tissue over time**

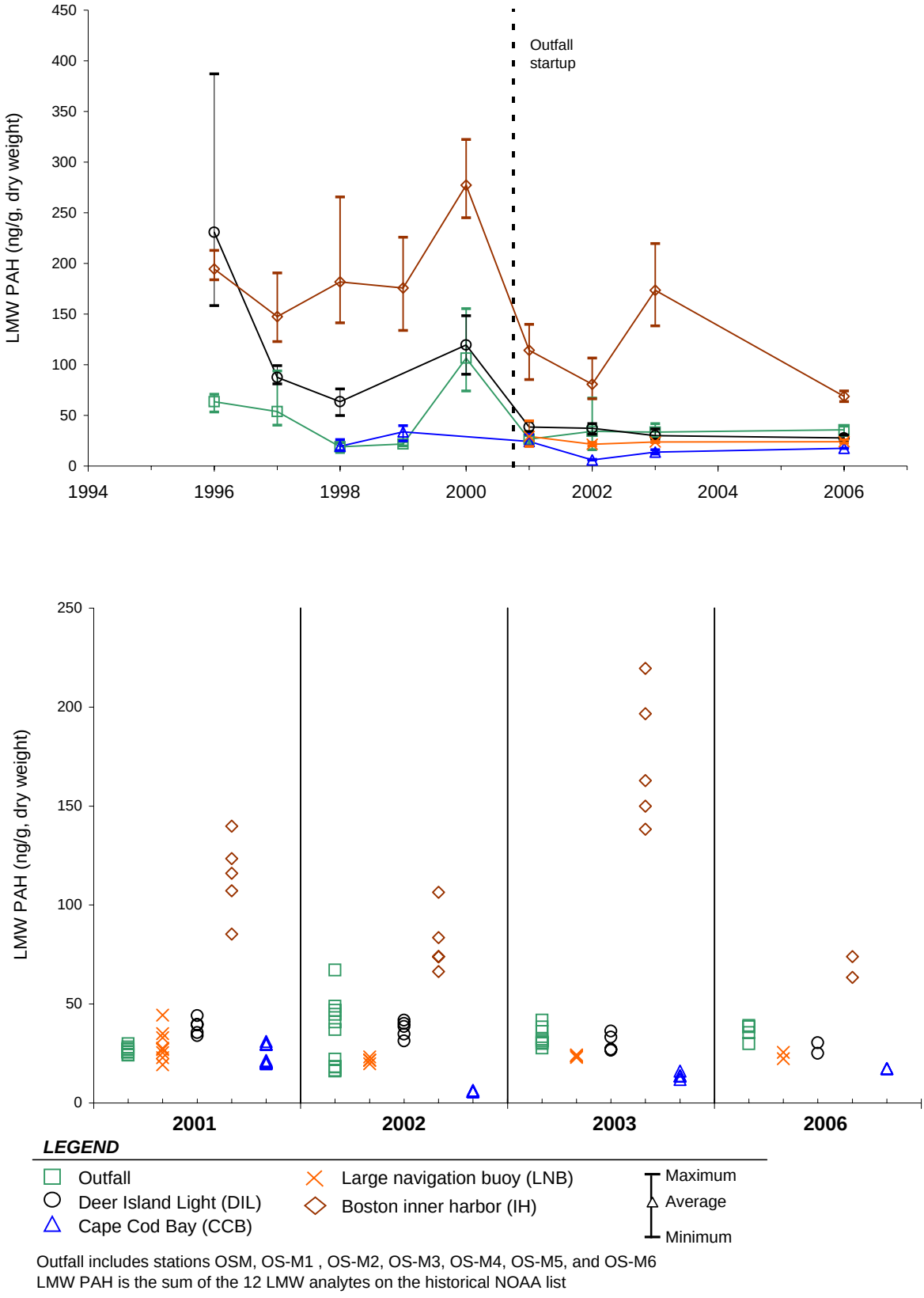
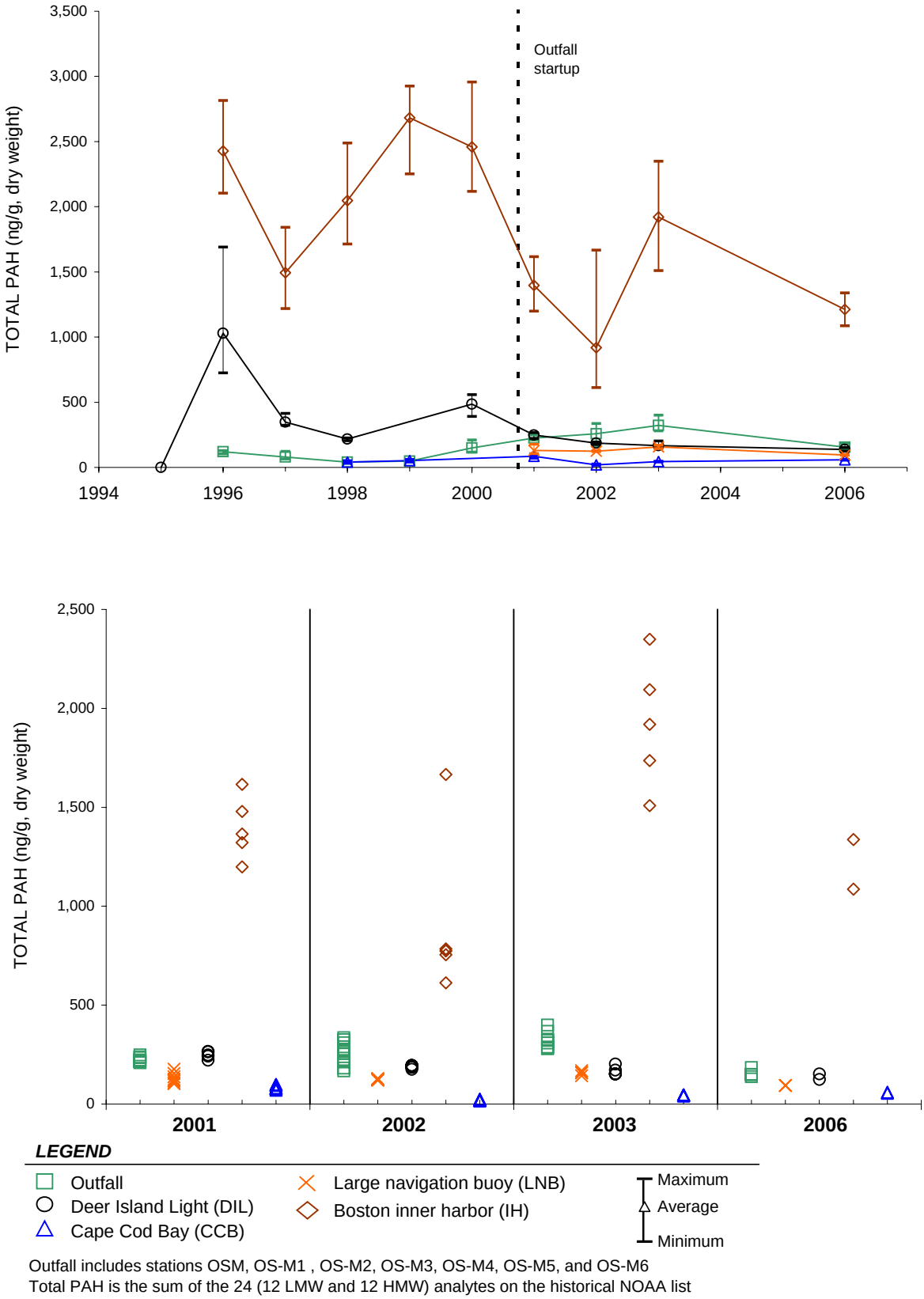



**Figure B-13. Low molecular weight (LMW) PAH concentrations in mussel soft tissue over time**




Outfall includes stations OSM, OS-M1 , OS-M2, OS-M3, OS-M4, OS-M5, and OS-M6
Total PAH is the sum of the 24 (12 LMW and 12 HMW) analytes on the historical NOAA list

**Figure B-14. Total PAH concentrations in mussel soft tissue over time**

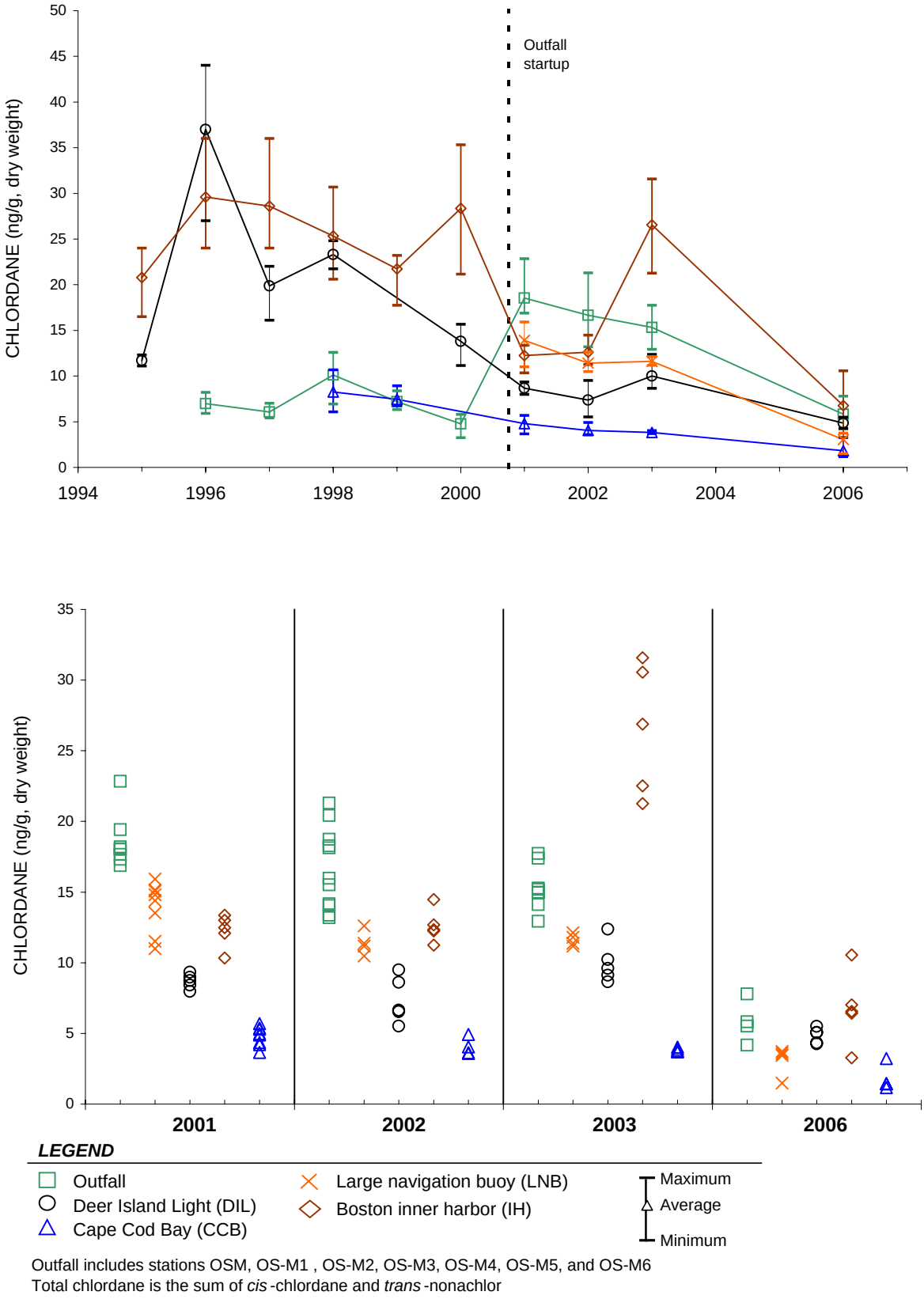



**Figure B-15. Chlordane concentrations in mussel soft tissue over time**

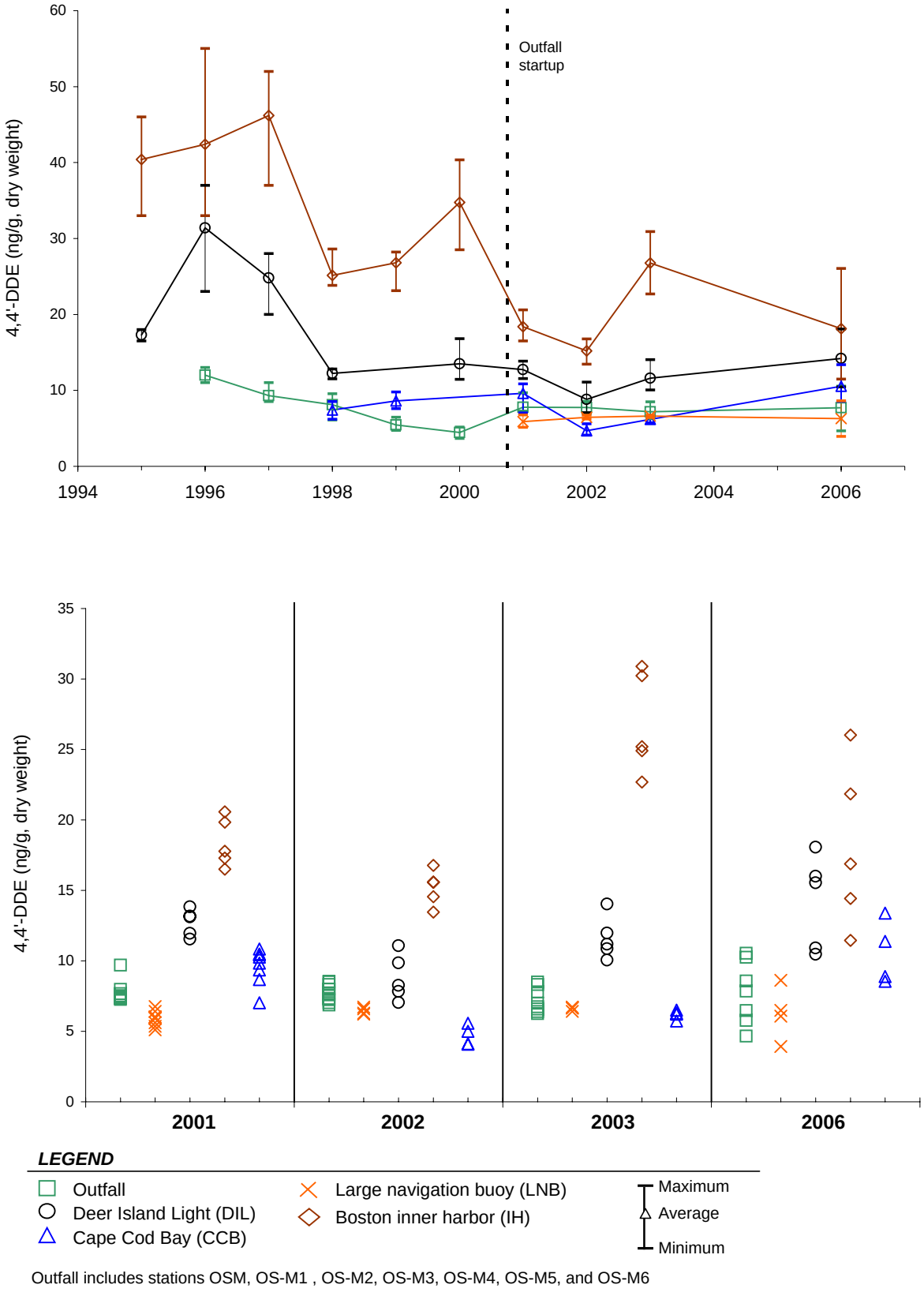
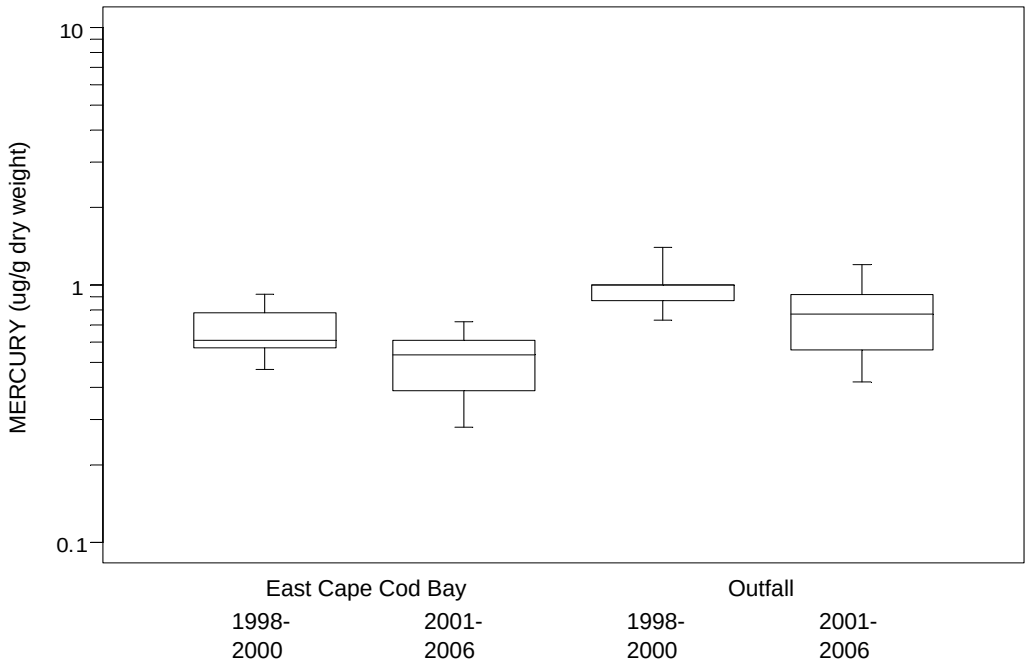
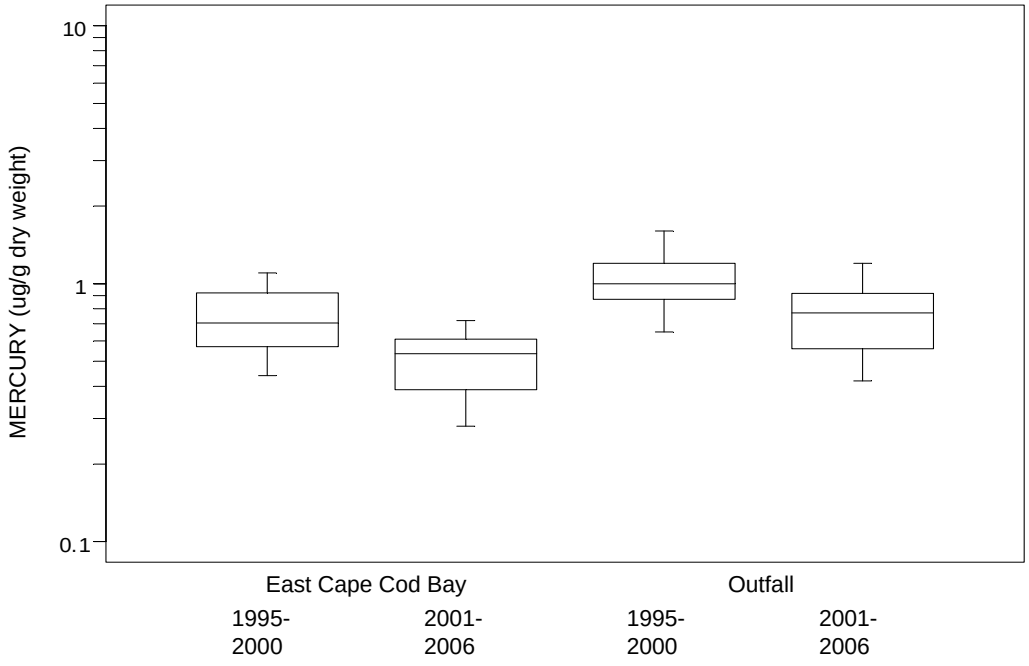
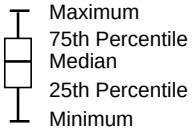



**Figure B-16. 4,4'-DDE concentrations in mussel soft tissue over time**



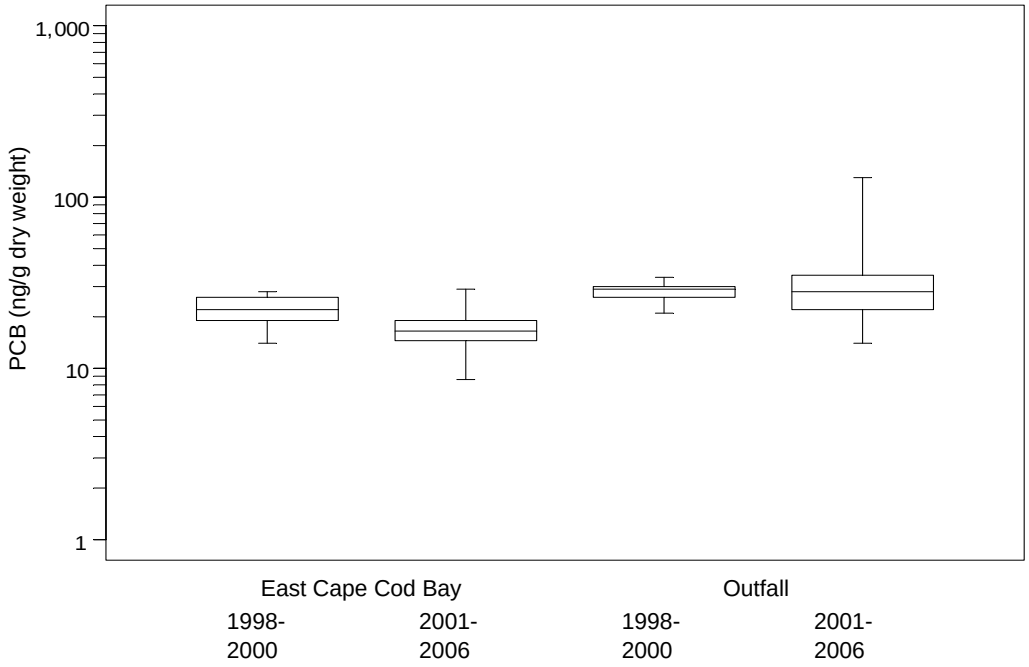



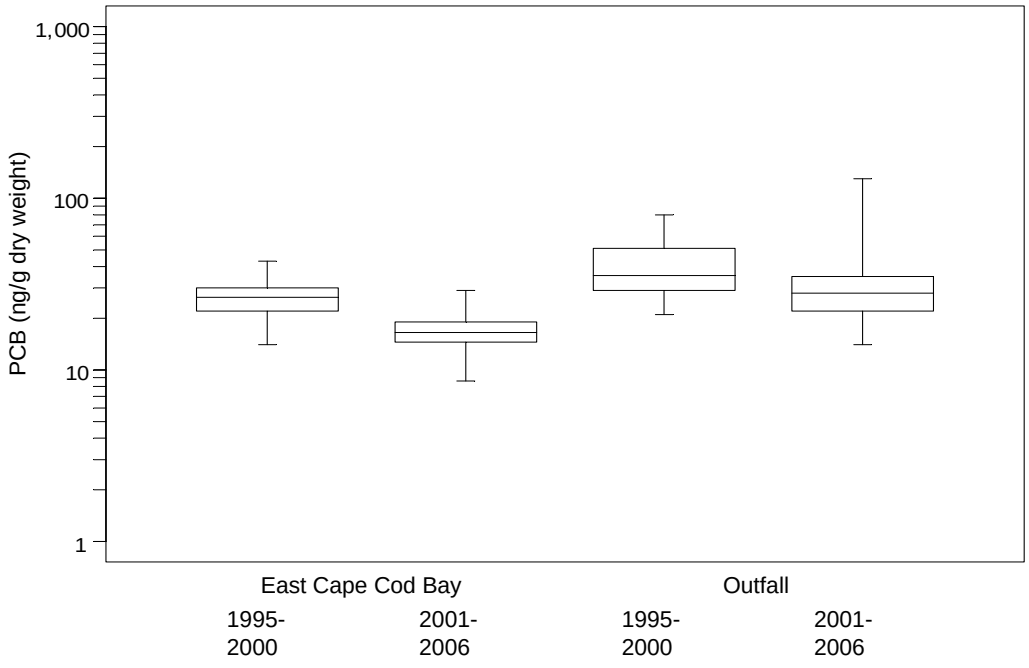

***LEGEND***




Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

**Figure B-17. Comparison of mercury concentrations measured in edible lobster meat between control and impact locations before and after relocation of the outfall**



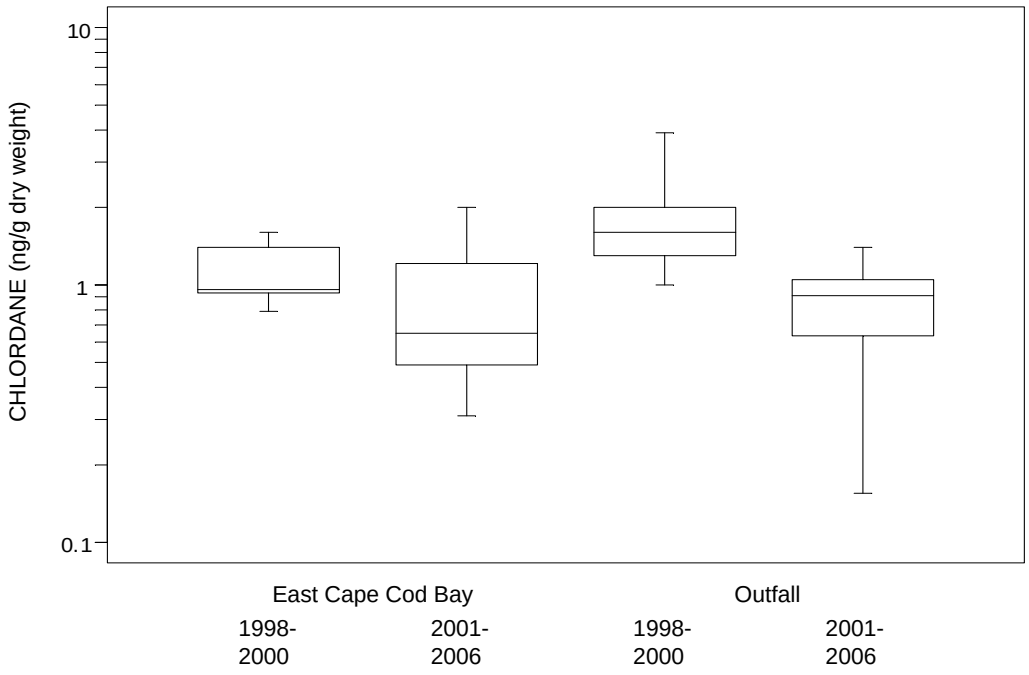

***LEGEND***

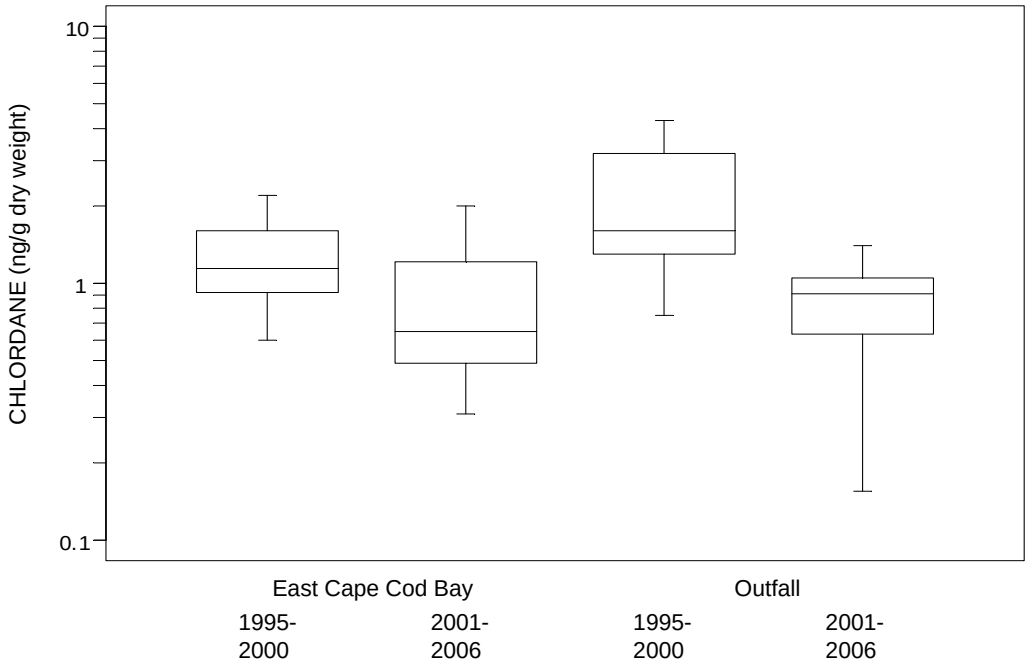
Maximum
75th Percentile
Median
25th Percentile
Minimum

Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

PCB is the sum of congeners 138 and 153

**Figure B-18. Comparison of PCB concentrations measured in edible lobster meat between control and impact locations before and after relocation of the outfall**



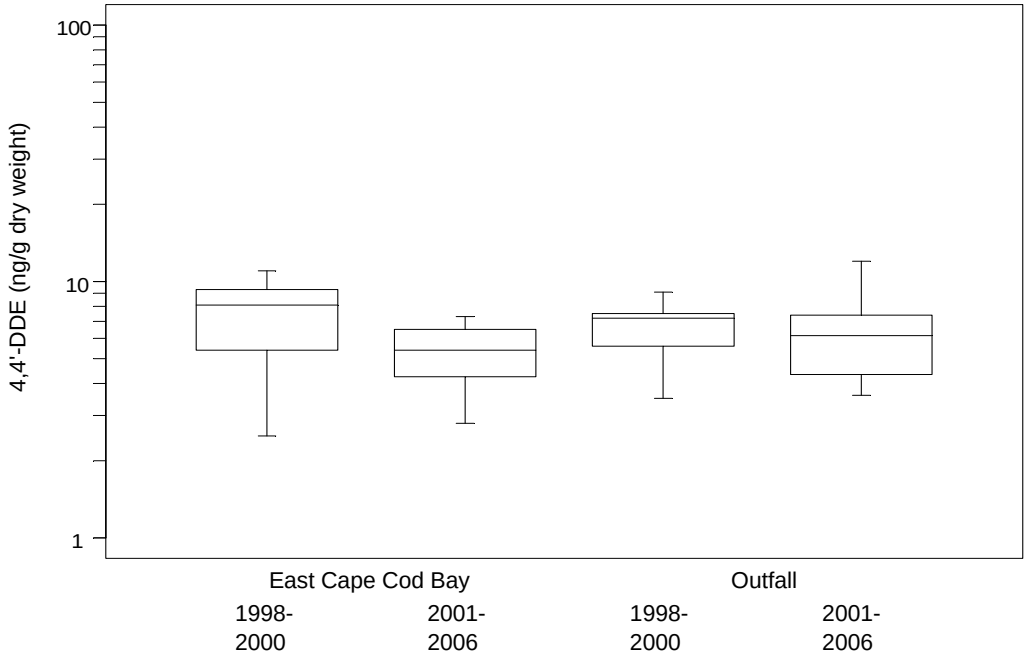

***LEGEND***

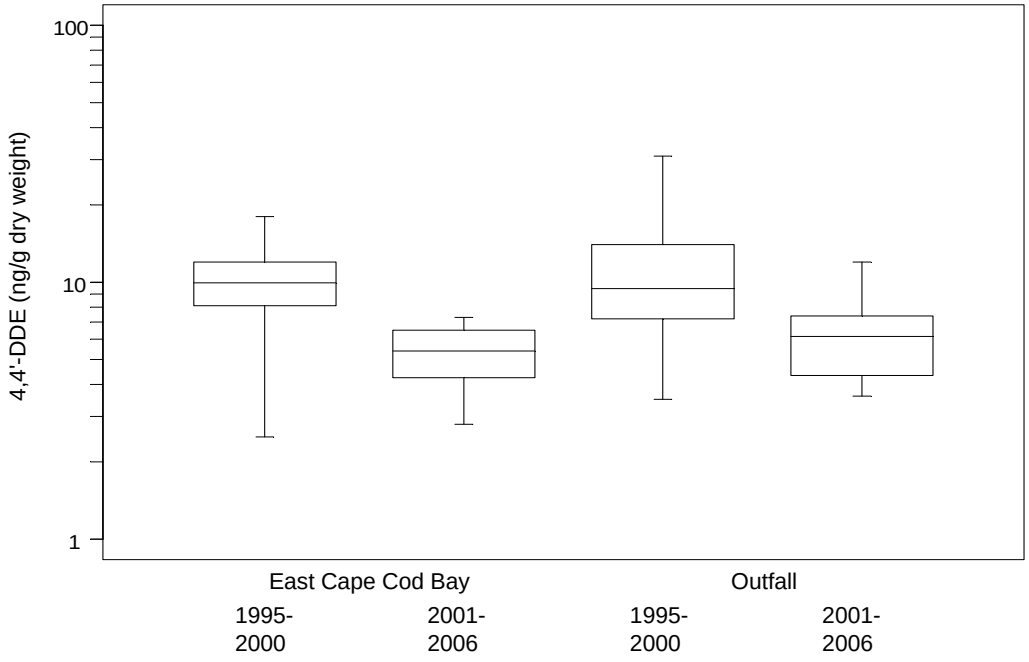
Maximum
75th Percentile
Median
25th Percentile
Minimum

Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

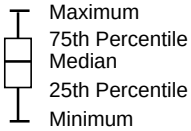
Chlordane is the sum of *cis* - chlordane and *trans* -nonachlor

**Figure B-19. Comparison of chlordane concentrations measured in edible lobster meat between control and impact locations before and after relocation of the outfall**



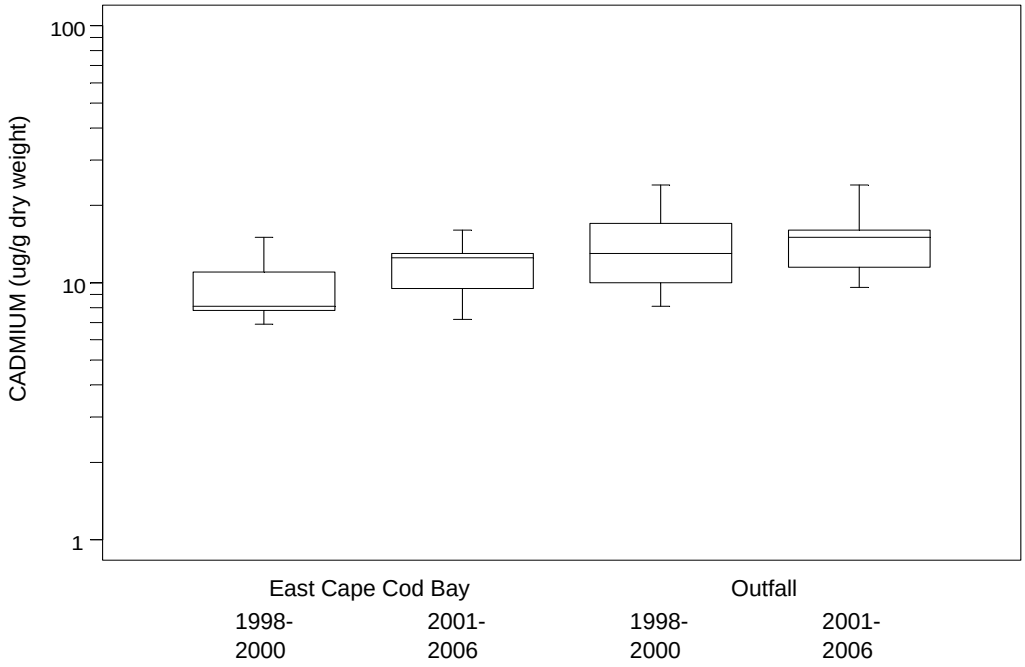



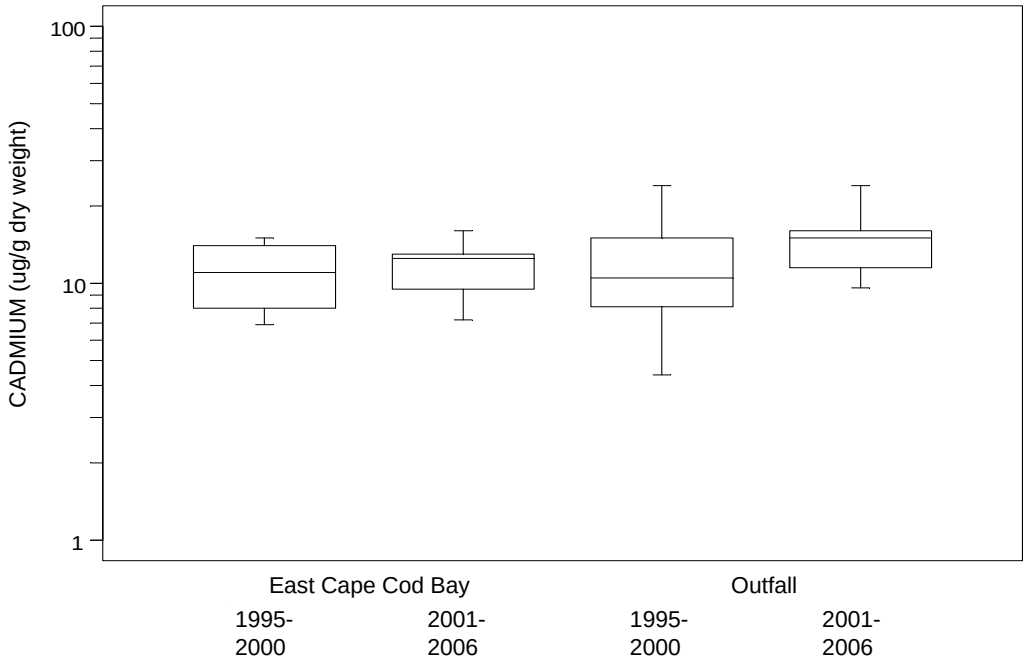

***LEGEND***



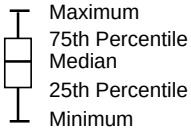

Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

**Figure B-20. Comparison of 4,4'-DDE concentrations measured in edible lobster meat between control and impact locations before and after relocation of the outfall**



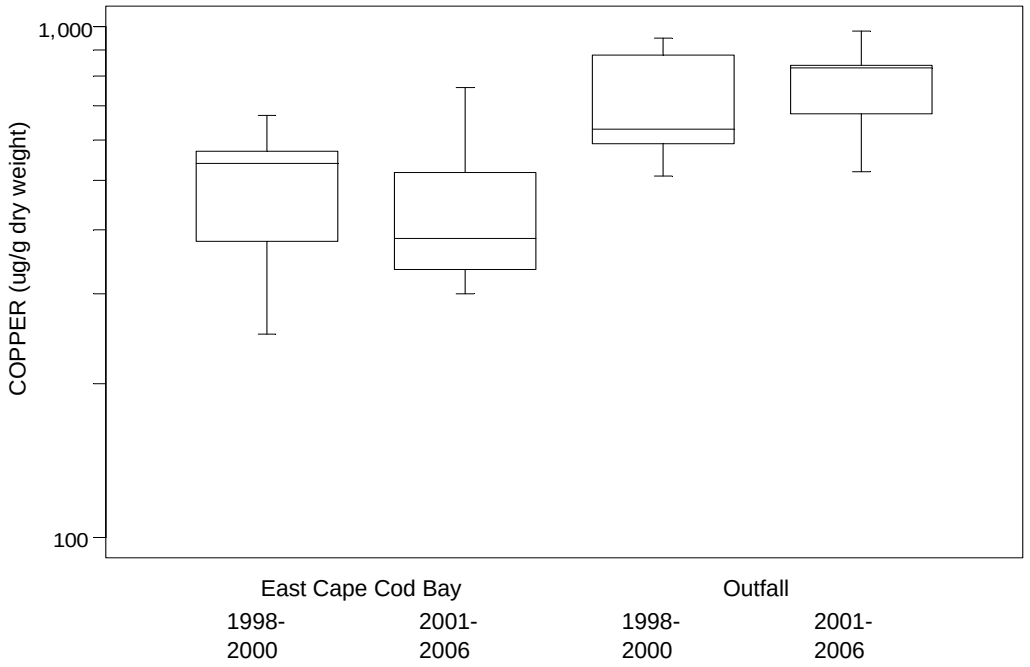



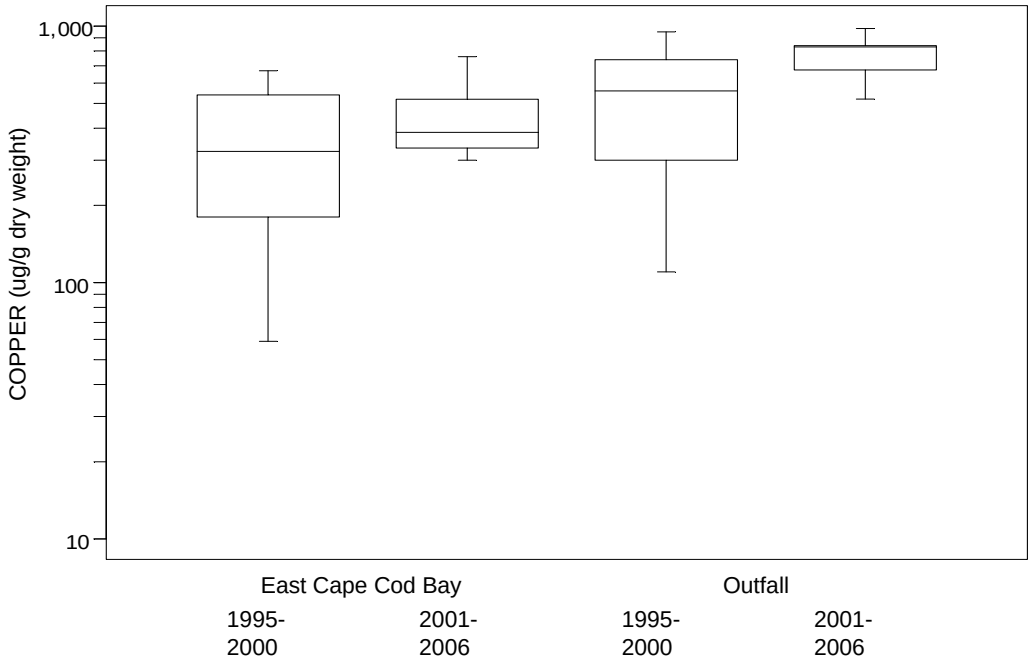

***LEGEND***



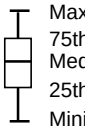

Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

**Figure B-21. Comparison of cadmium concentrations measured in lobster hepatopancreas between control and impact locations before and after relocation of the outfall**



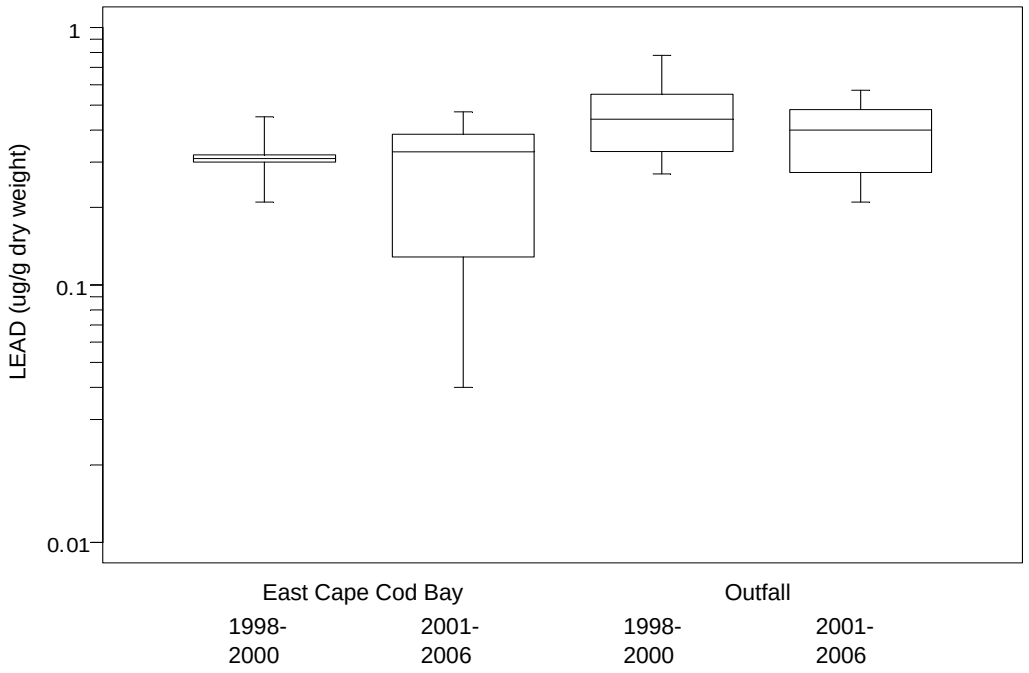



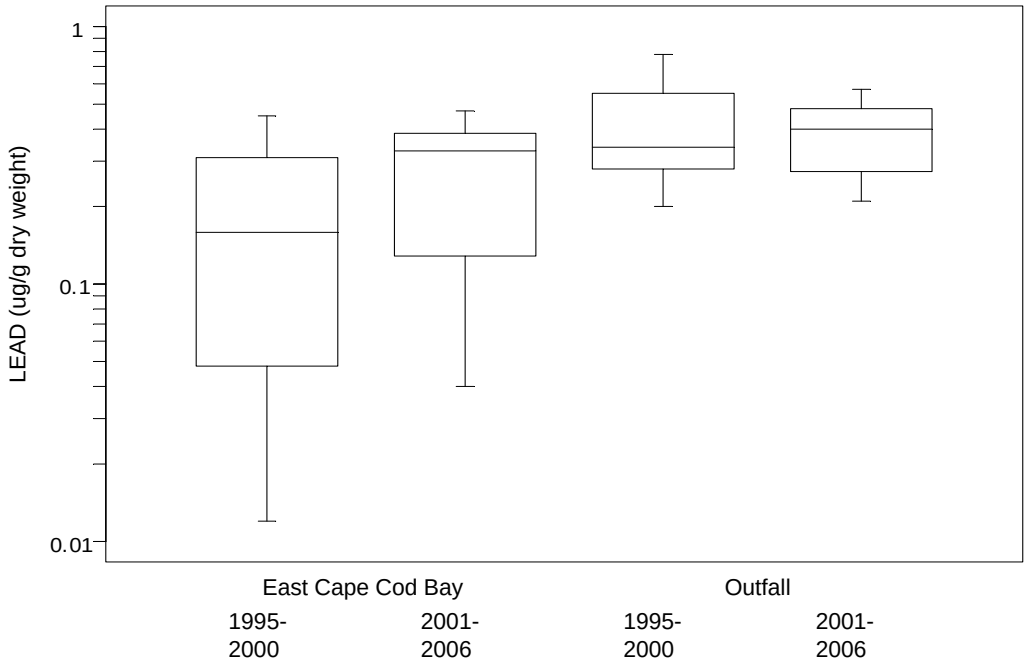

***LEGEND***



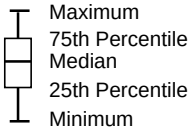

Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

**Figure B-22. Comparison of copper concentrations measured in lobster hepatopancreas between control and impact locations before and after relocation of the outfall**



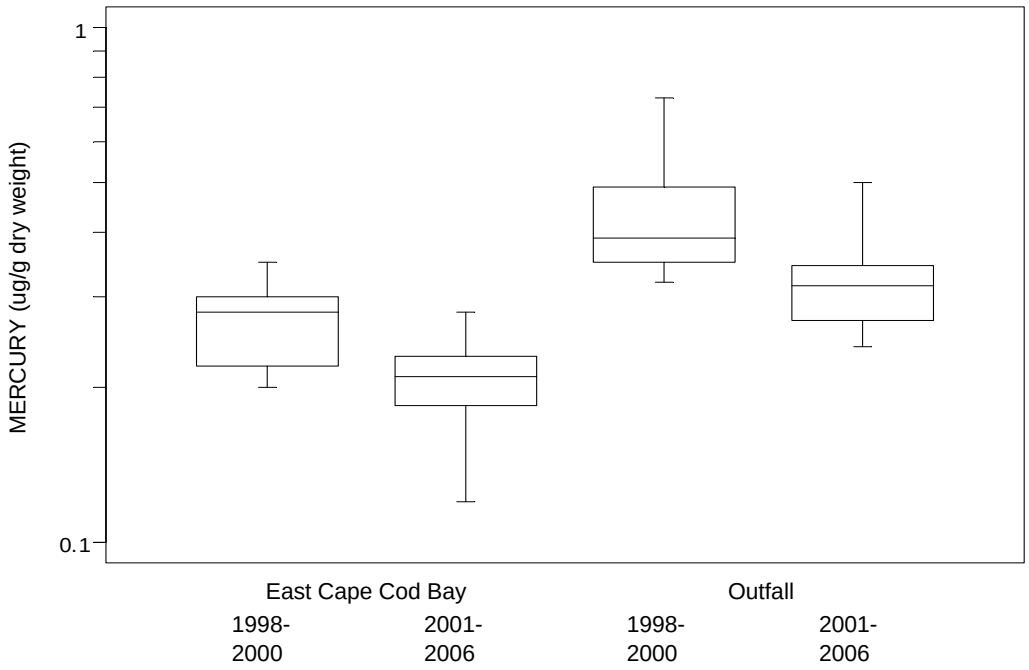



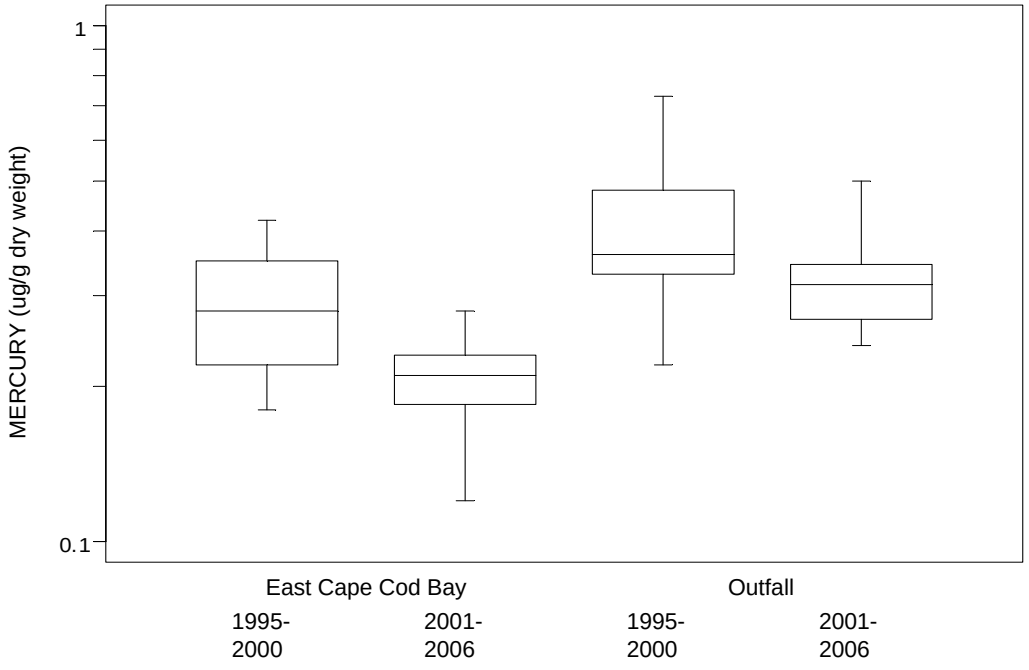

***LEGEND***



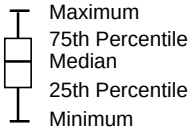

Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

**Figure B-23. Comparison of lead concentrations measured in lobster hepatopancreas between control and impact locations before and after relocation of the outfall**



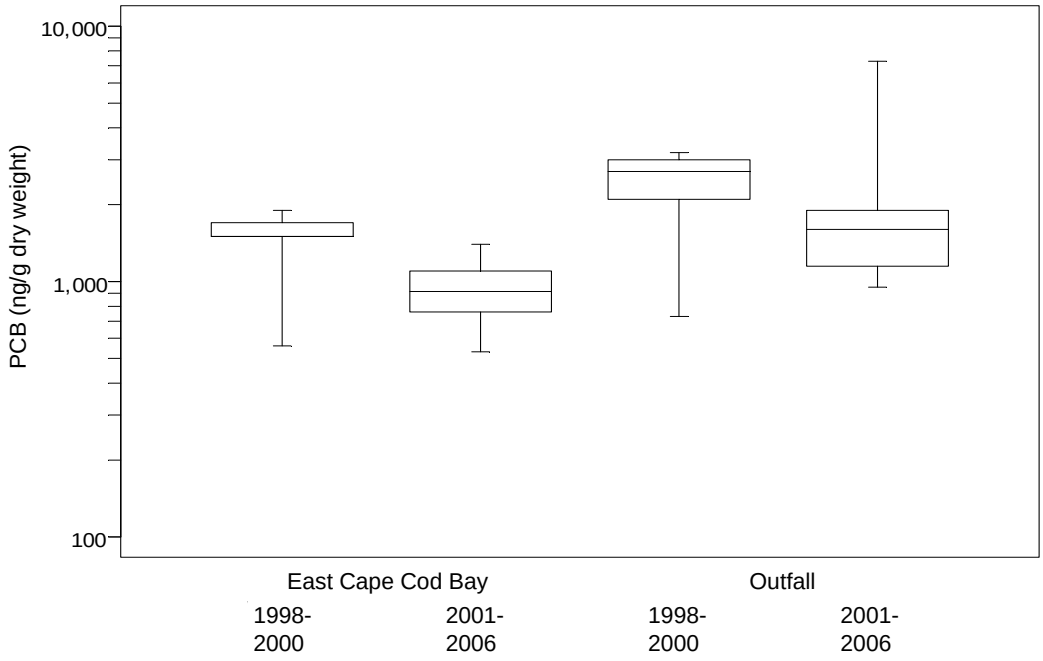



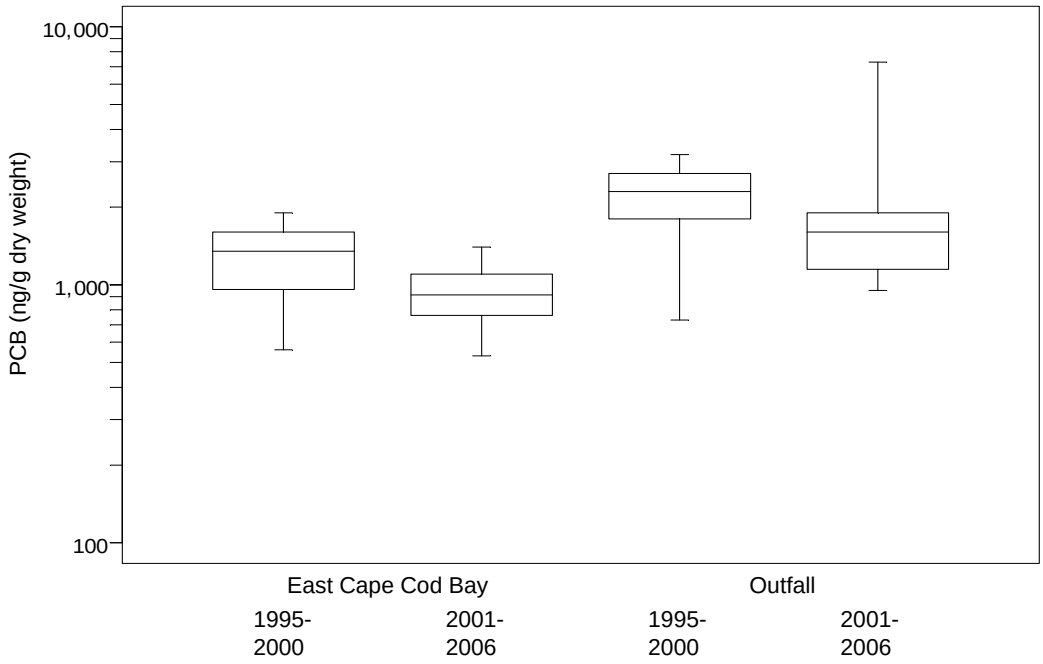

***LEGEND***



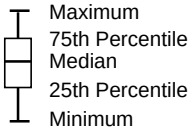

Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

**Figure B-24. Comparison of mercury concentrations measured in lobster hepatopancreas between control and impact locations before and after relocation of the outfall**



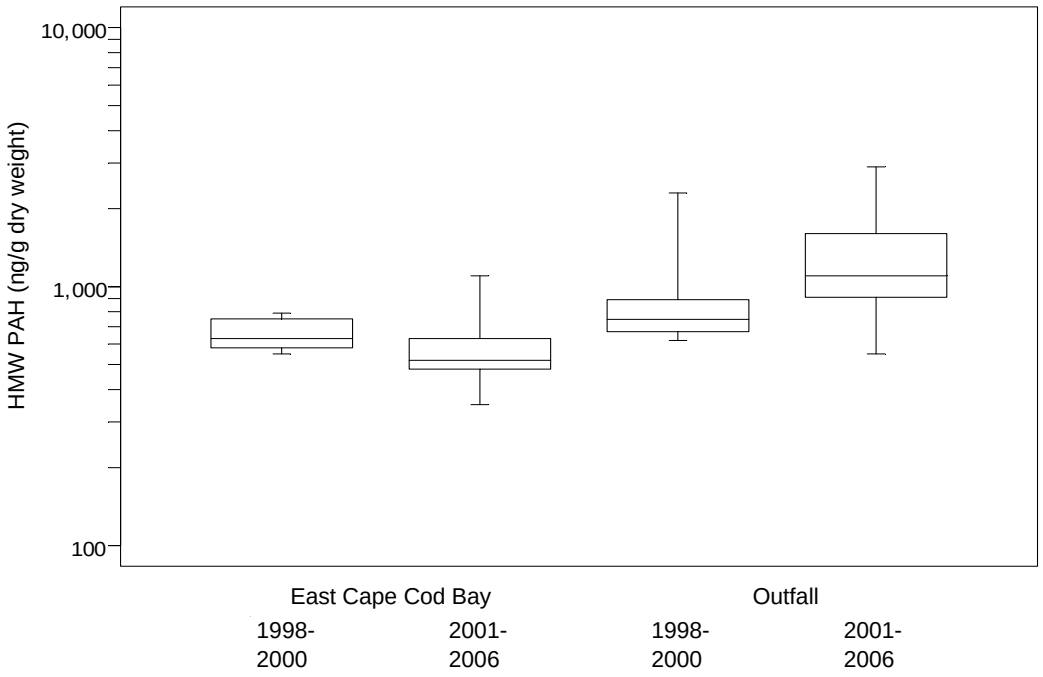

***LEGEND***

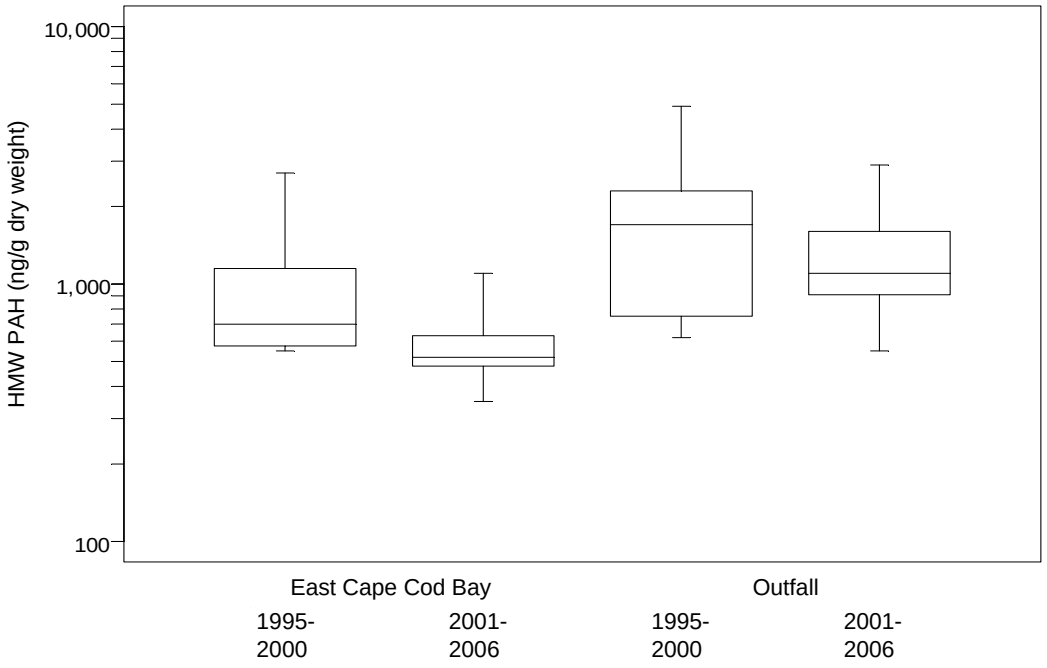



Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

PCB is the sum of congeners 138 and 153

**Figure B-25. Comparison of PCB concentrations measured in lobster hepatopancreas between control and impact locations before and after relocation of the outfall**



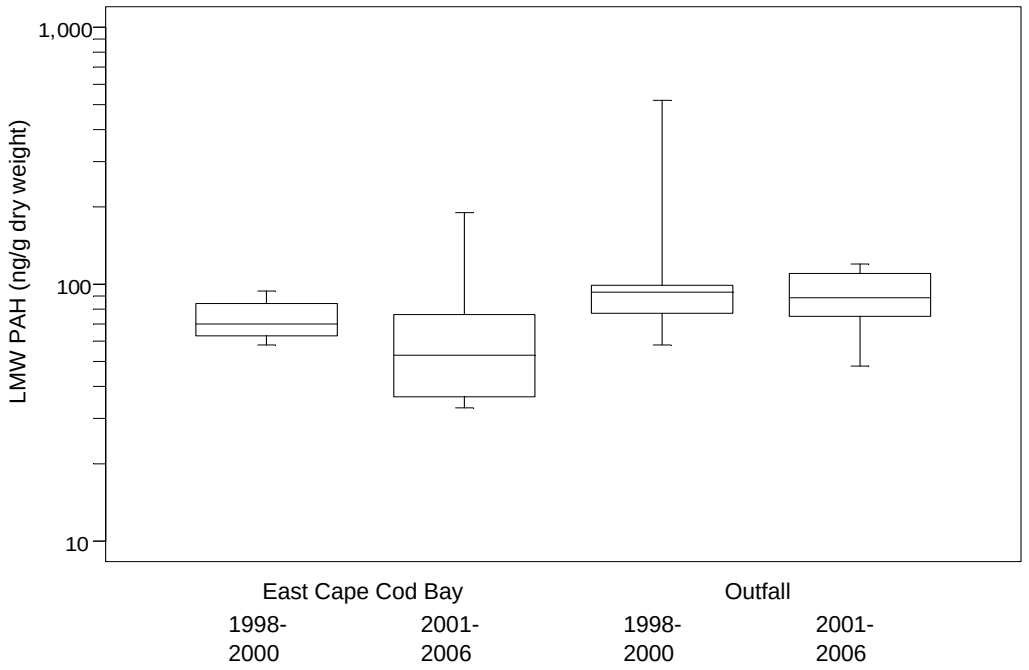

***LEGEND***

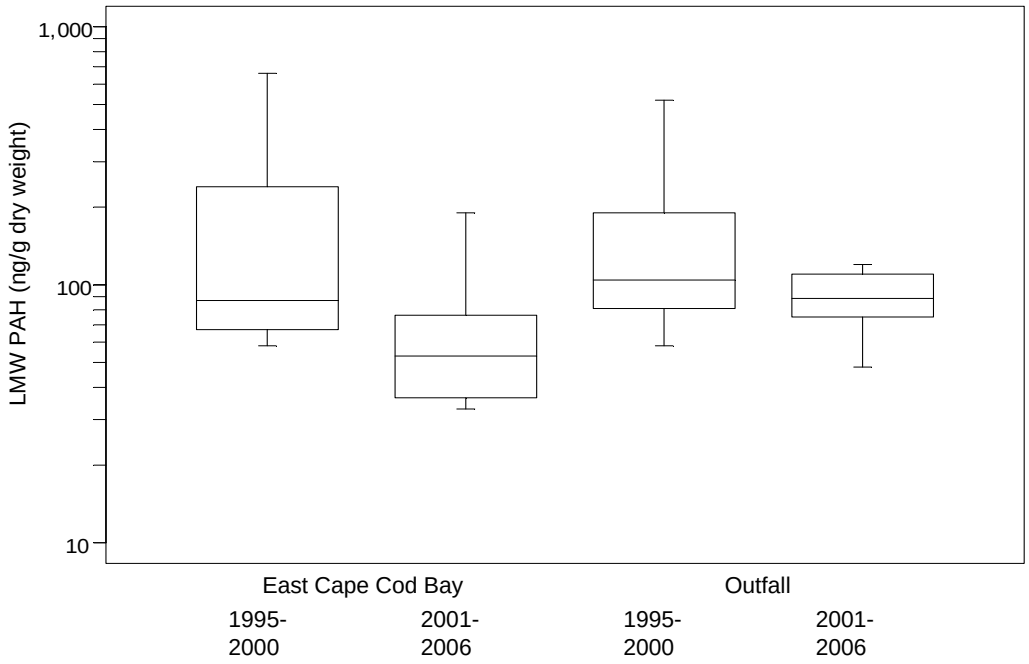
Maximum
75th Percentile
Median
25th Percentile
Minimum

Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

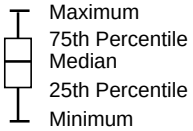
HMW PAH is the sum of the 12 HMW analytes on the historical NOAA list

**Figure B-26. Comparison of high molecular weight (HMW) PAH concentrations measured in lobster hepatopancreas between control and impact locations before and after relocation of the outfall**



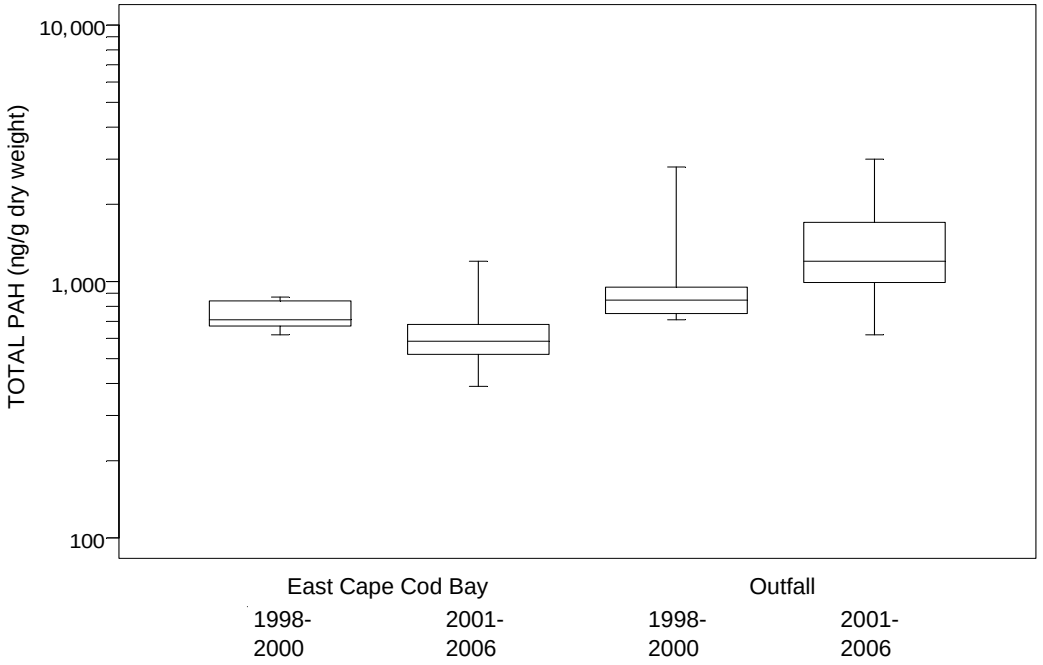

***LEGEND***

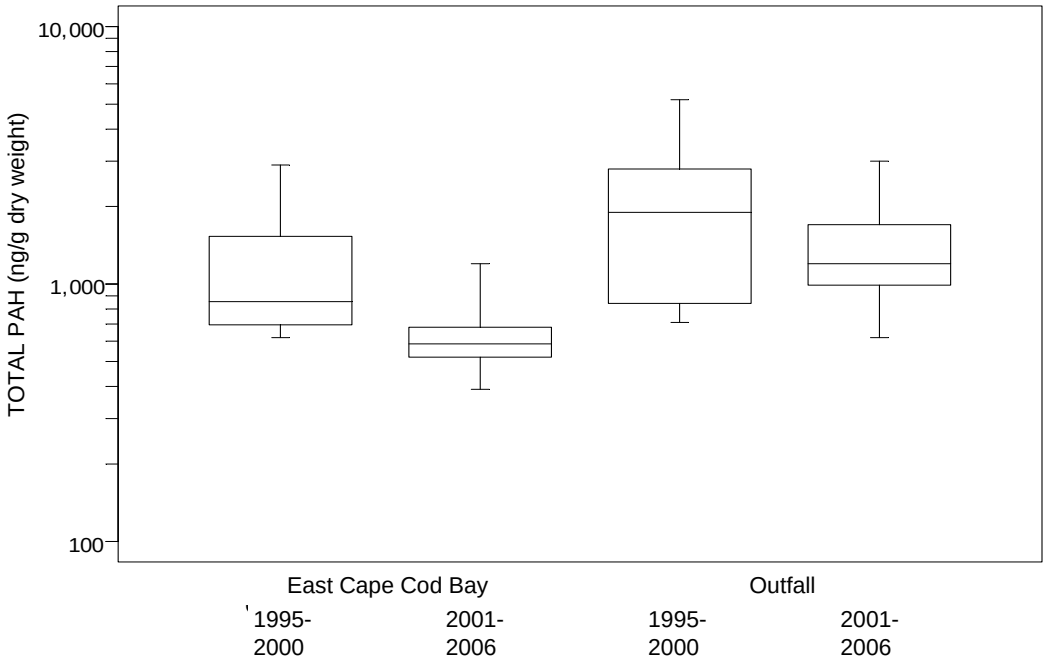



Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

LMW PAH is the sum of 7 LMW analytes on the historical NOAA list (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, and phenanthrene)

**Figure B-27. Comparison of low molecular weight (LMW) PAH concentrations measured in lobster hepatopancreas between control and impact locations before and after relocation of the outfall**



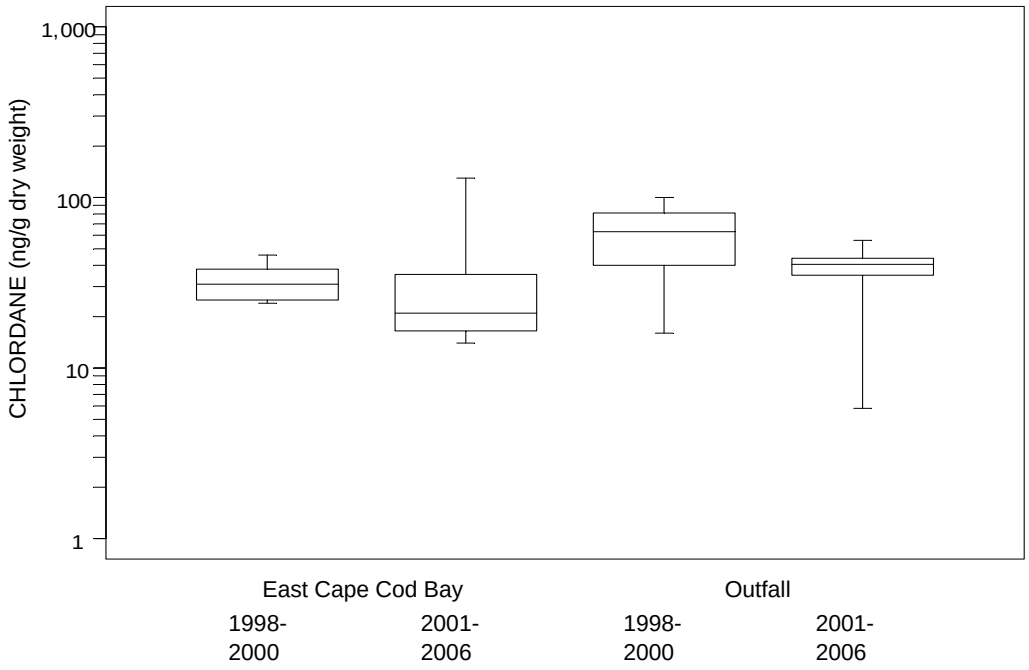

***LEGEND***

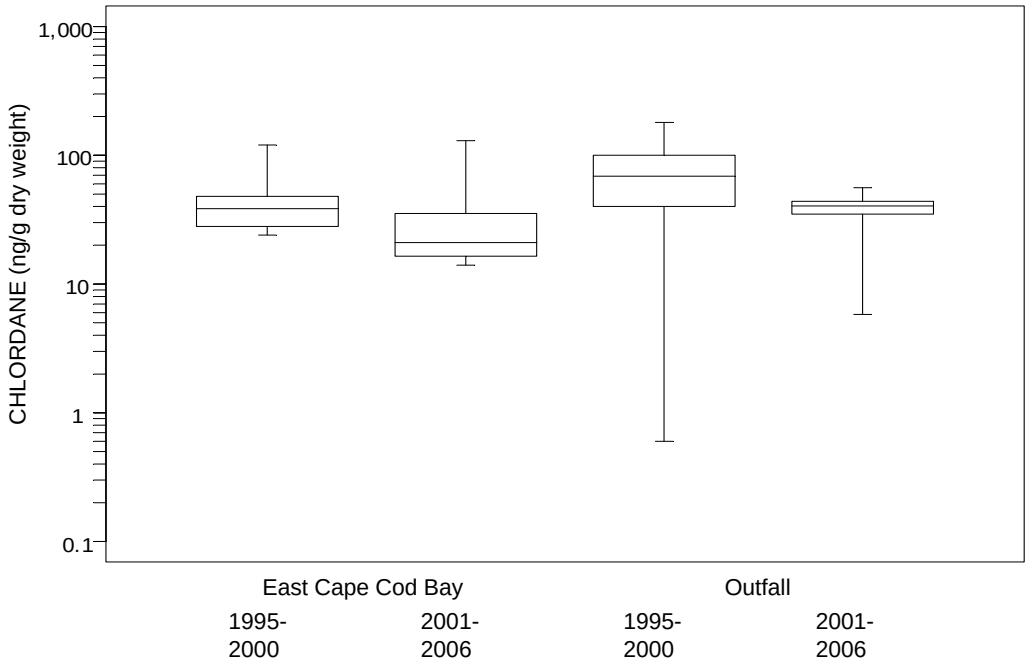
Maximum
75th Percentile
Median
25th Percentile
Minimum

Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

Total PAH is the sum of 19 analytes on the historical NOAA list (7 LMW analytes as identified on Figure BX6 and 12 HMW analytes)

**Figure B-28. Comparison of total PAH concentrations measured in lobster hepatopancreas between control and impact locations before and after relocation of the outfall**



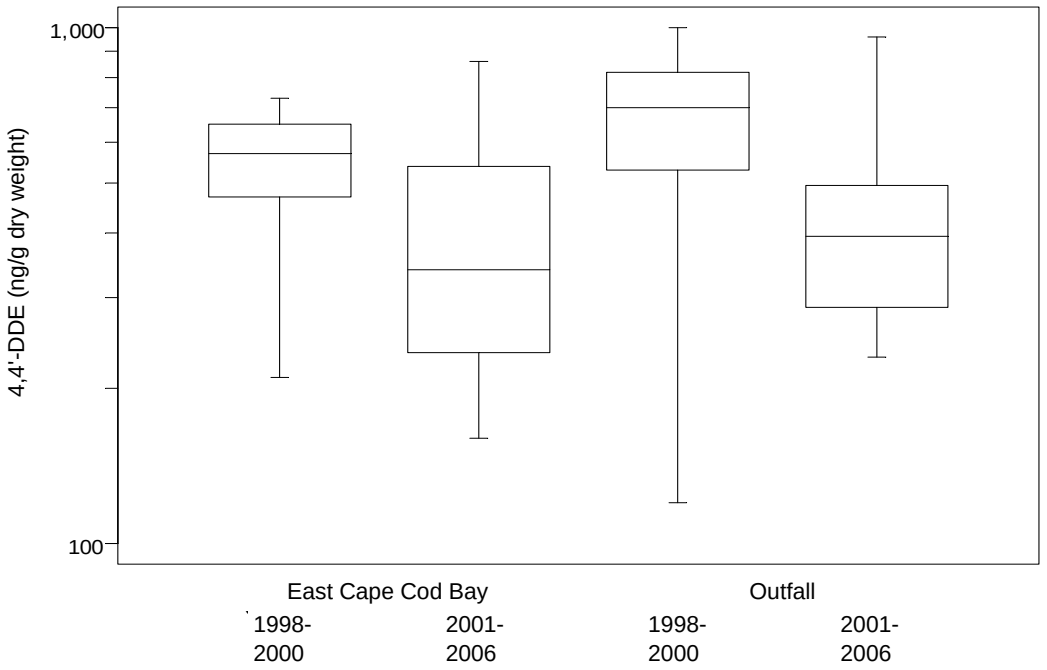

***LEGEND***

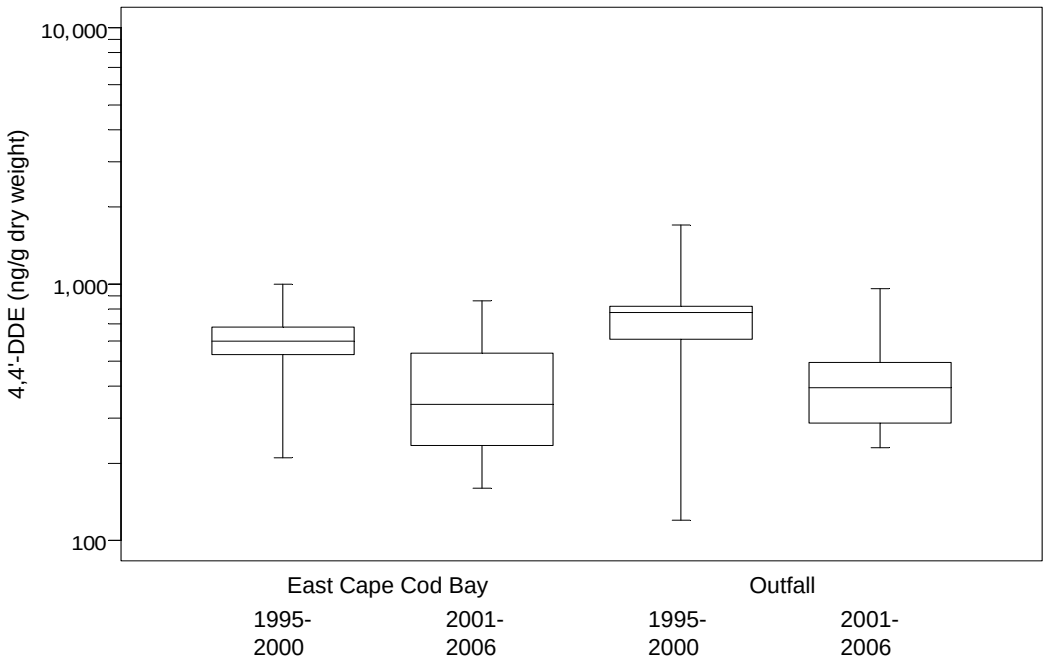
Maximum
75th Percentile
Median
25th Percentile
Minimum

Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

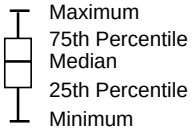
Chlordane is the sum of *cis*-chlordane and *trans*-nonachlor

**Figure B-29. Comparison of chlordane concentrations measured in lobster hepatopancreas between control and impact locations before and after relocation of the outfall**




***LEGEND***




Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

**Figure B-30. Comparison of 4,4'-DDE concentrations measured in lobster hepatopancreas between control and impact locations before and after relocation of the outfall**

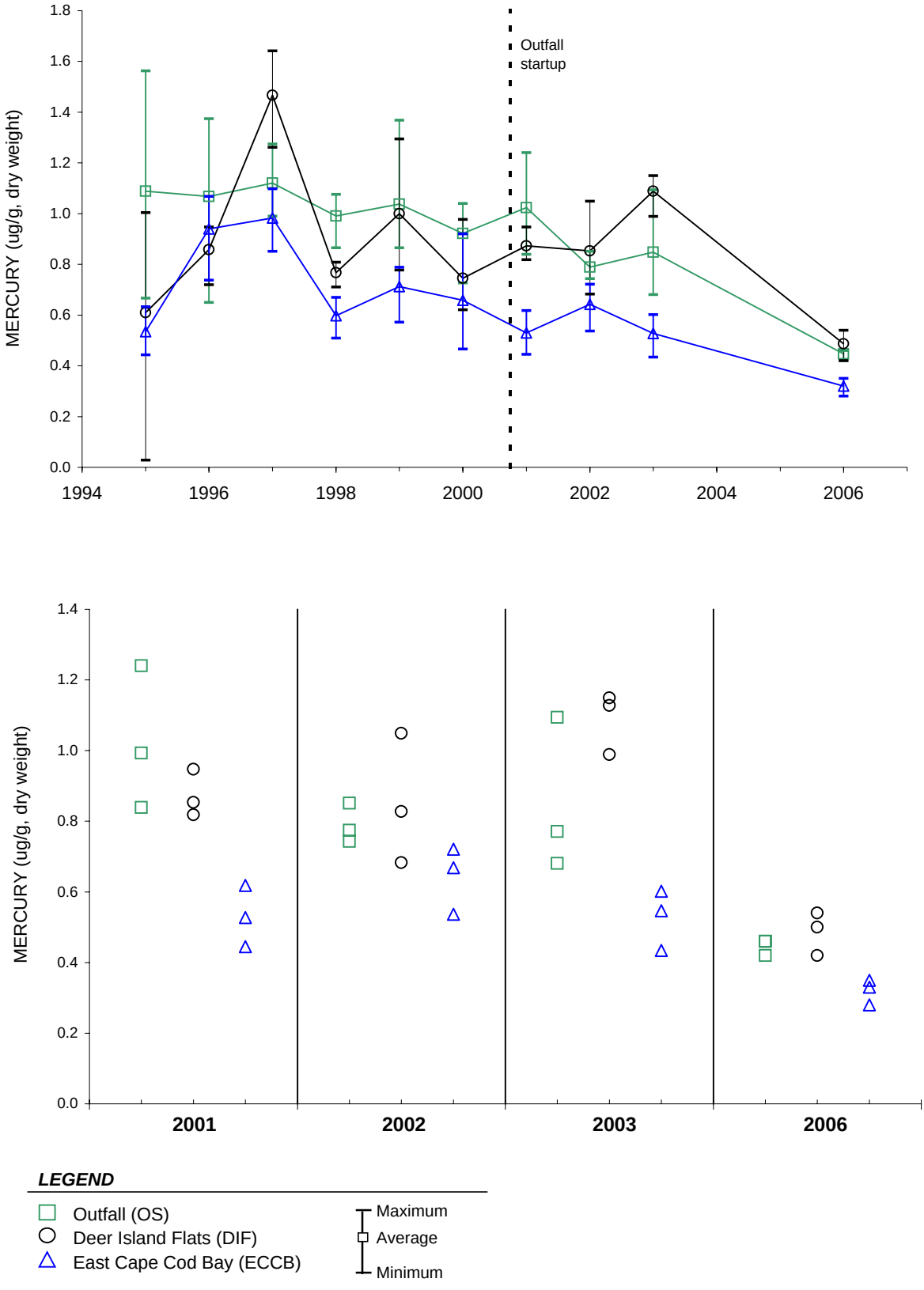



**Figure B-31. Mercury concentrations in edible lobster meat over time**

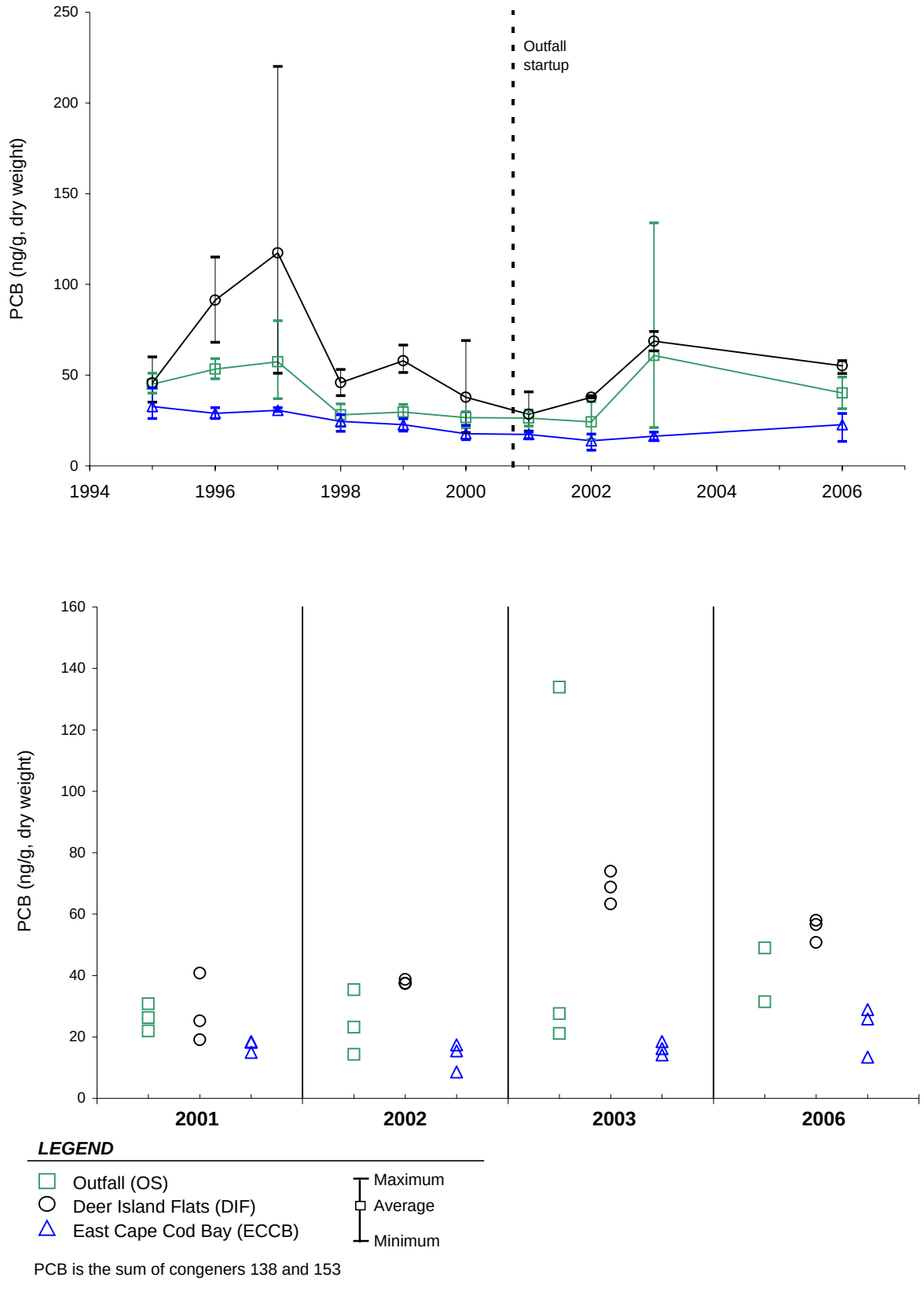



**Figure B-32. PCB concentrations in edible lobster meat over time**

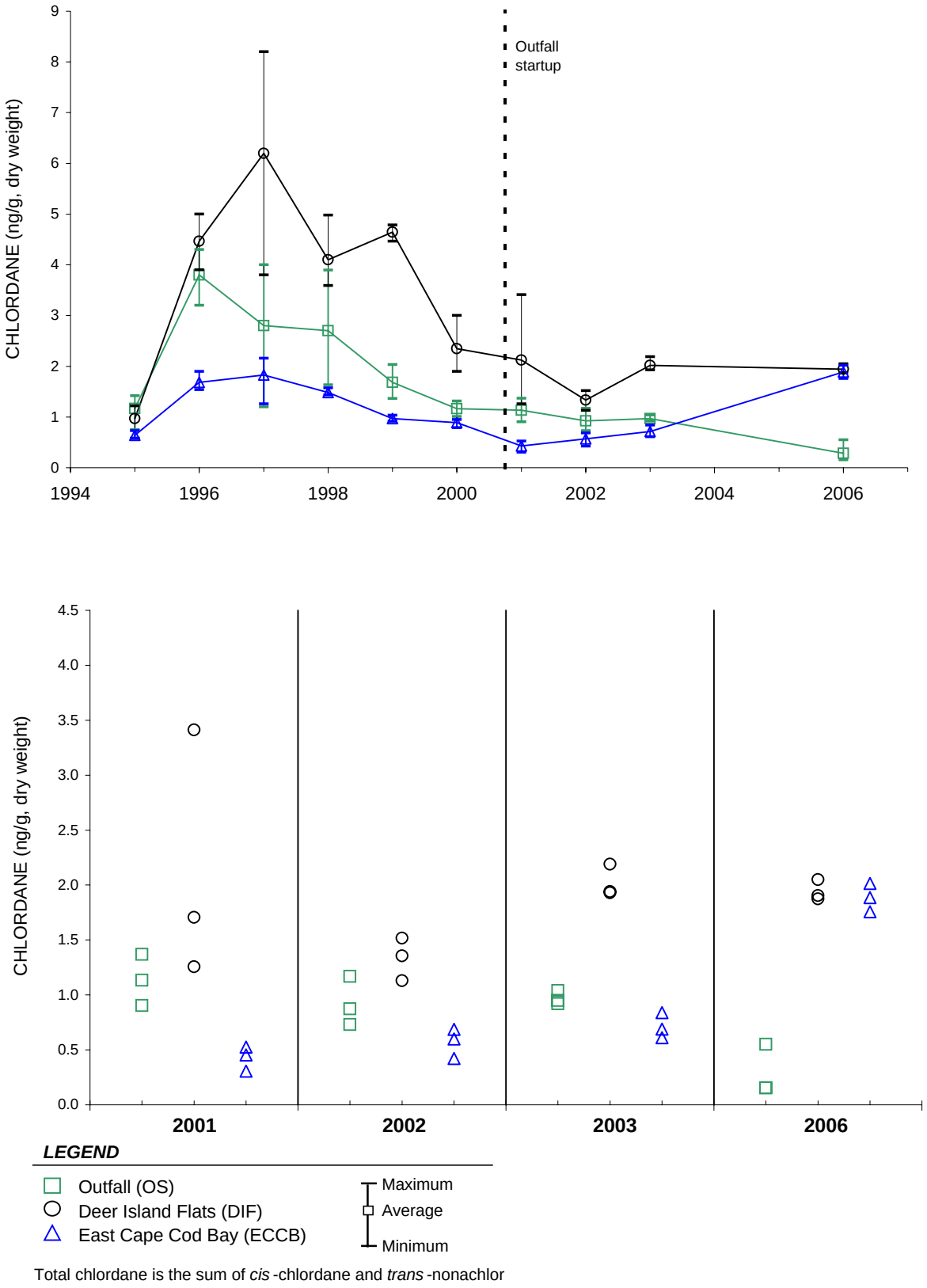



**Figure B-33. Chlordane concentrations in edible lobster meat over time**

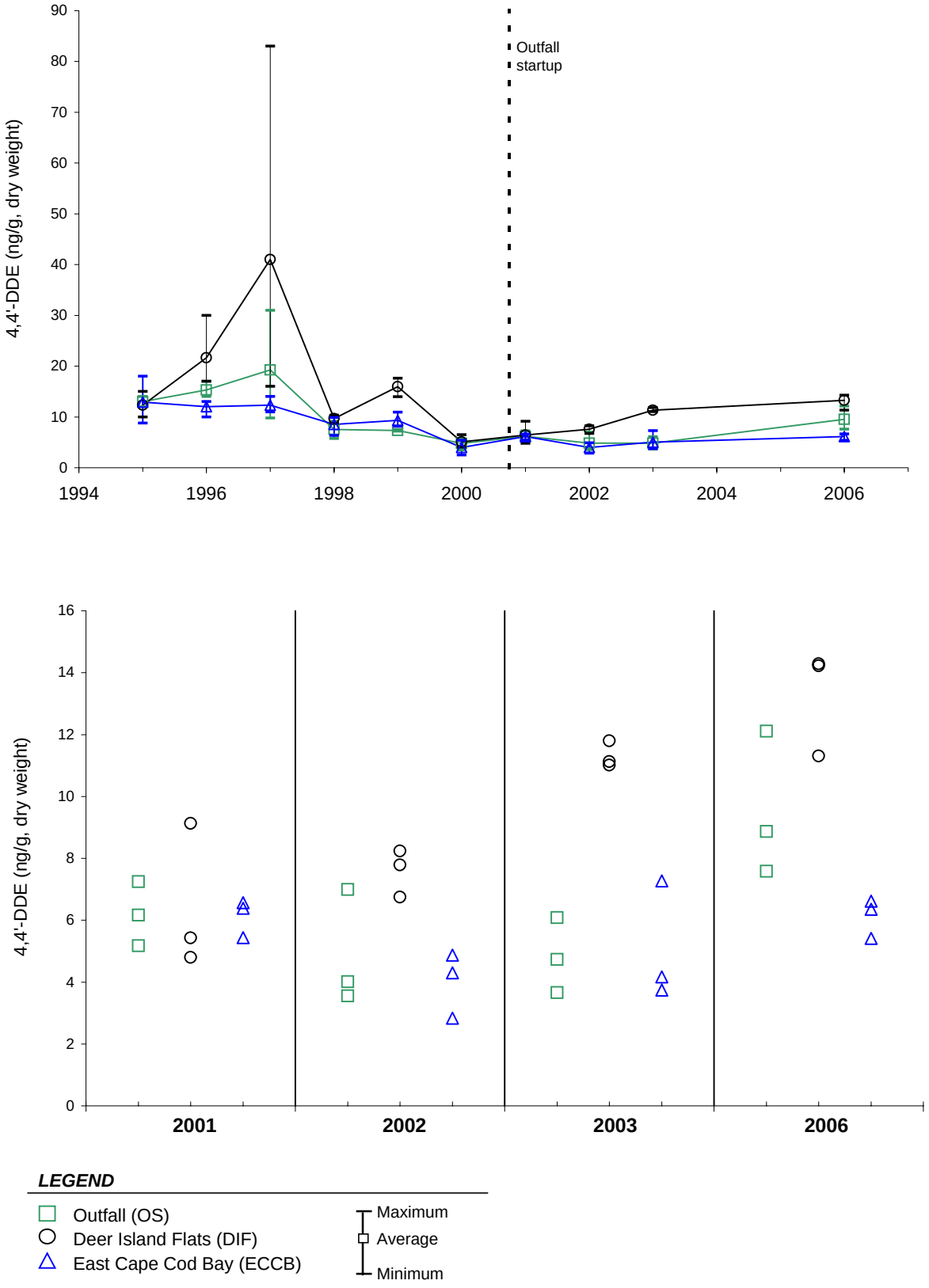



**Figure B-34. 4,4'-DDE concentrations in edible lobster meat over time**

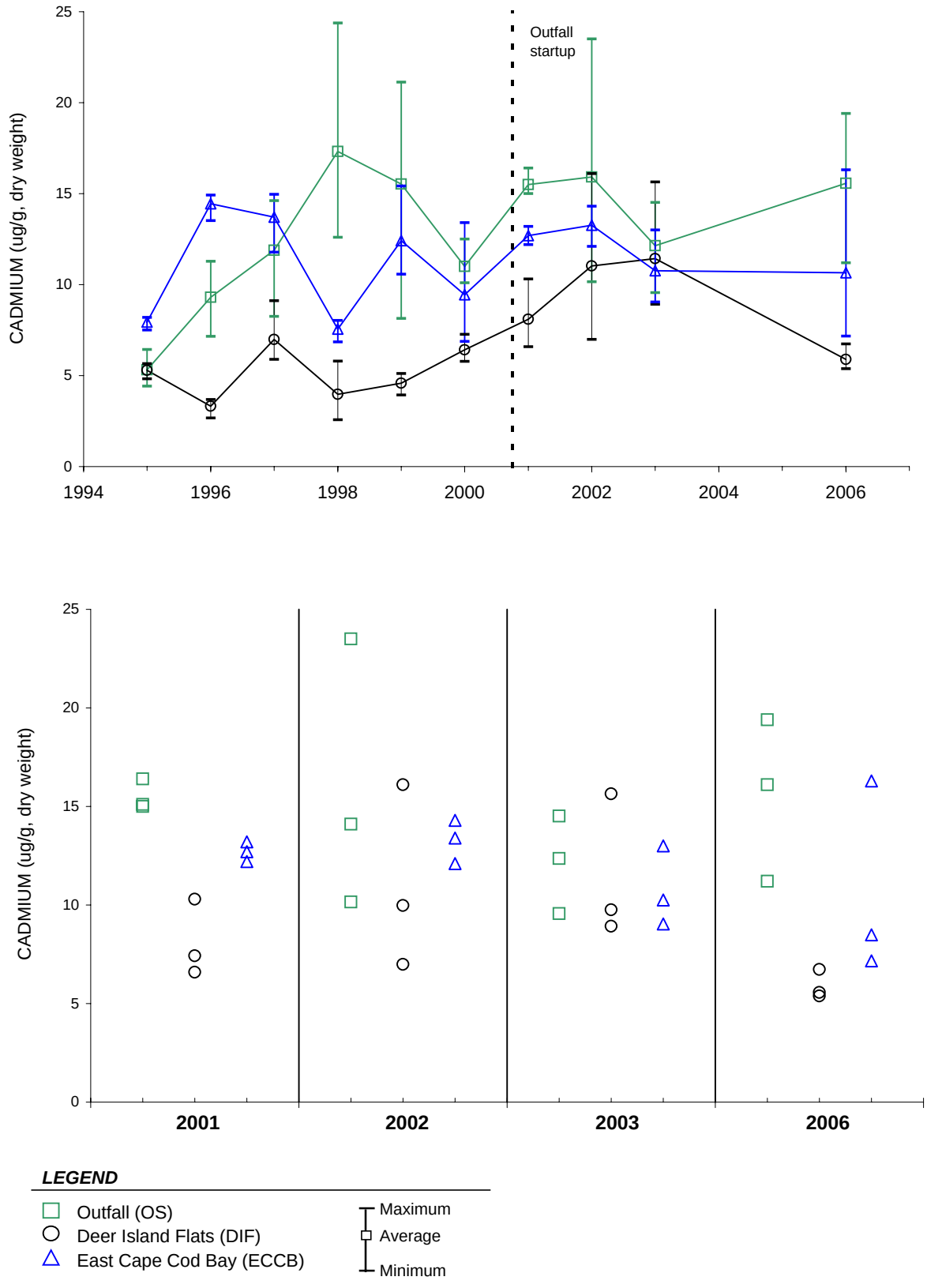



**Figure B-35. Cadmium concentrations in lobster hepatopancreas tissue over time**

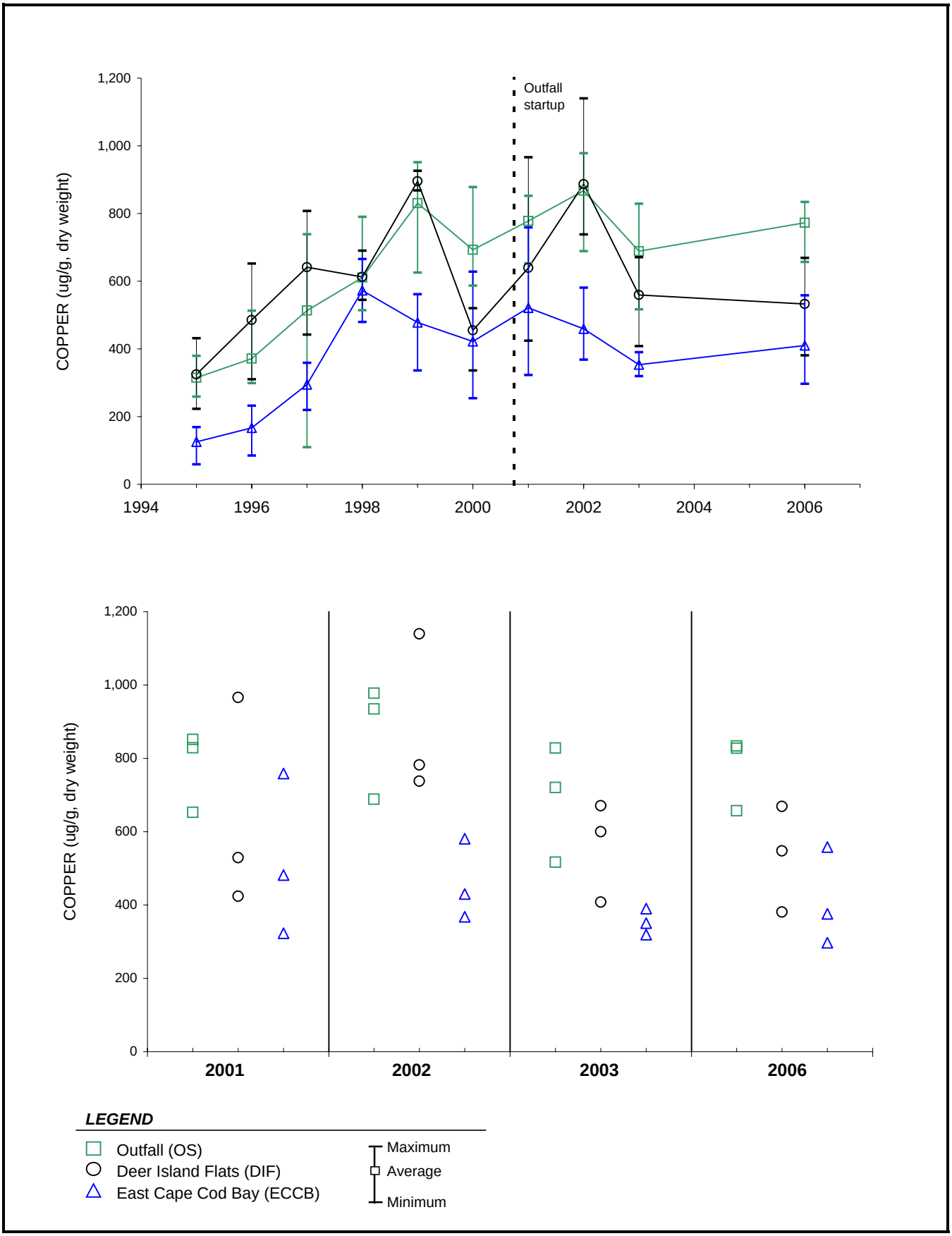



**Figure B-36. Copper concentrations in lobster hepatopancreas tissue over time**

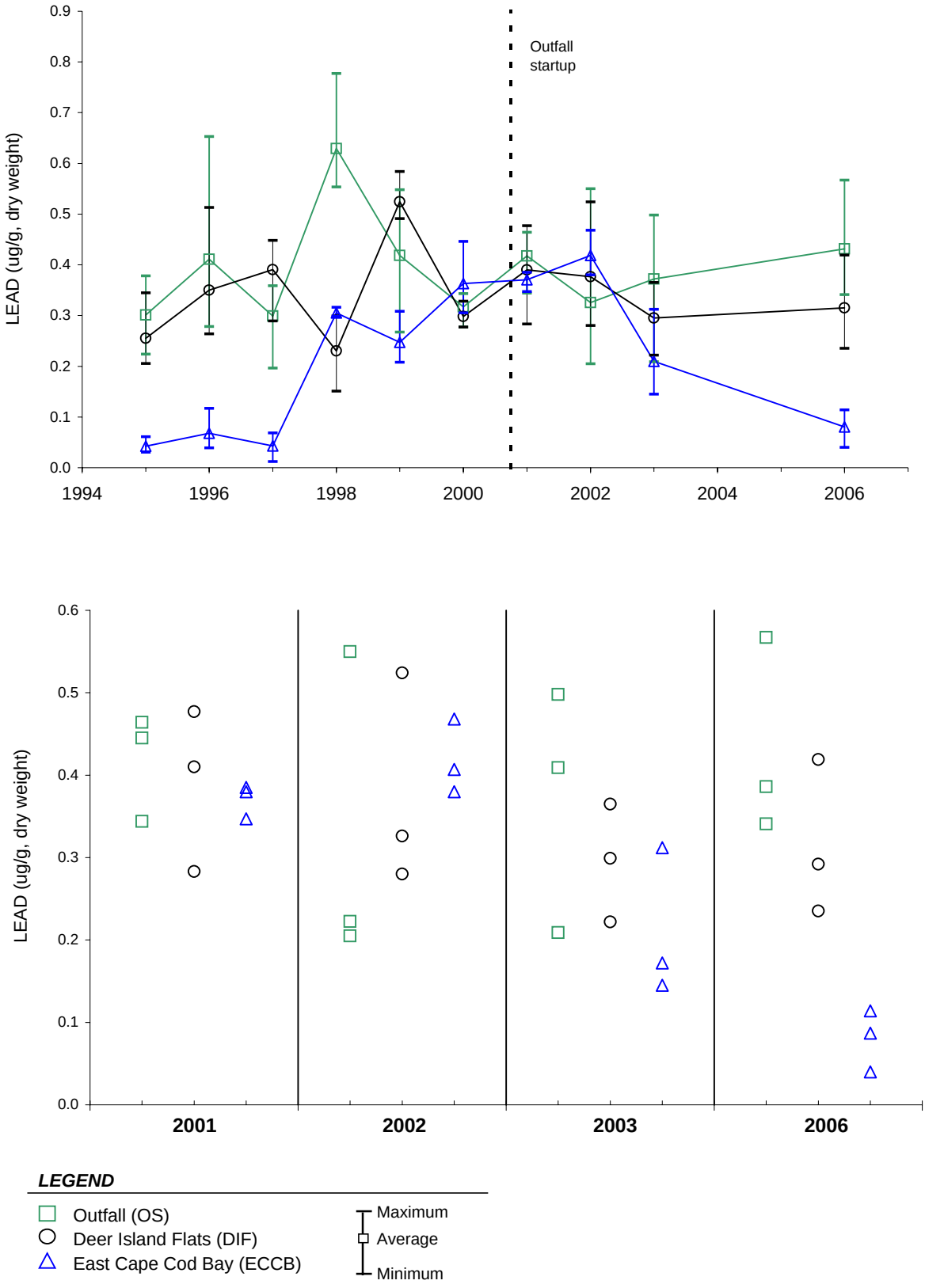



**Figure B-37. Lead concentrations in lobster hepatopancreas tissue over time**

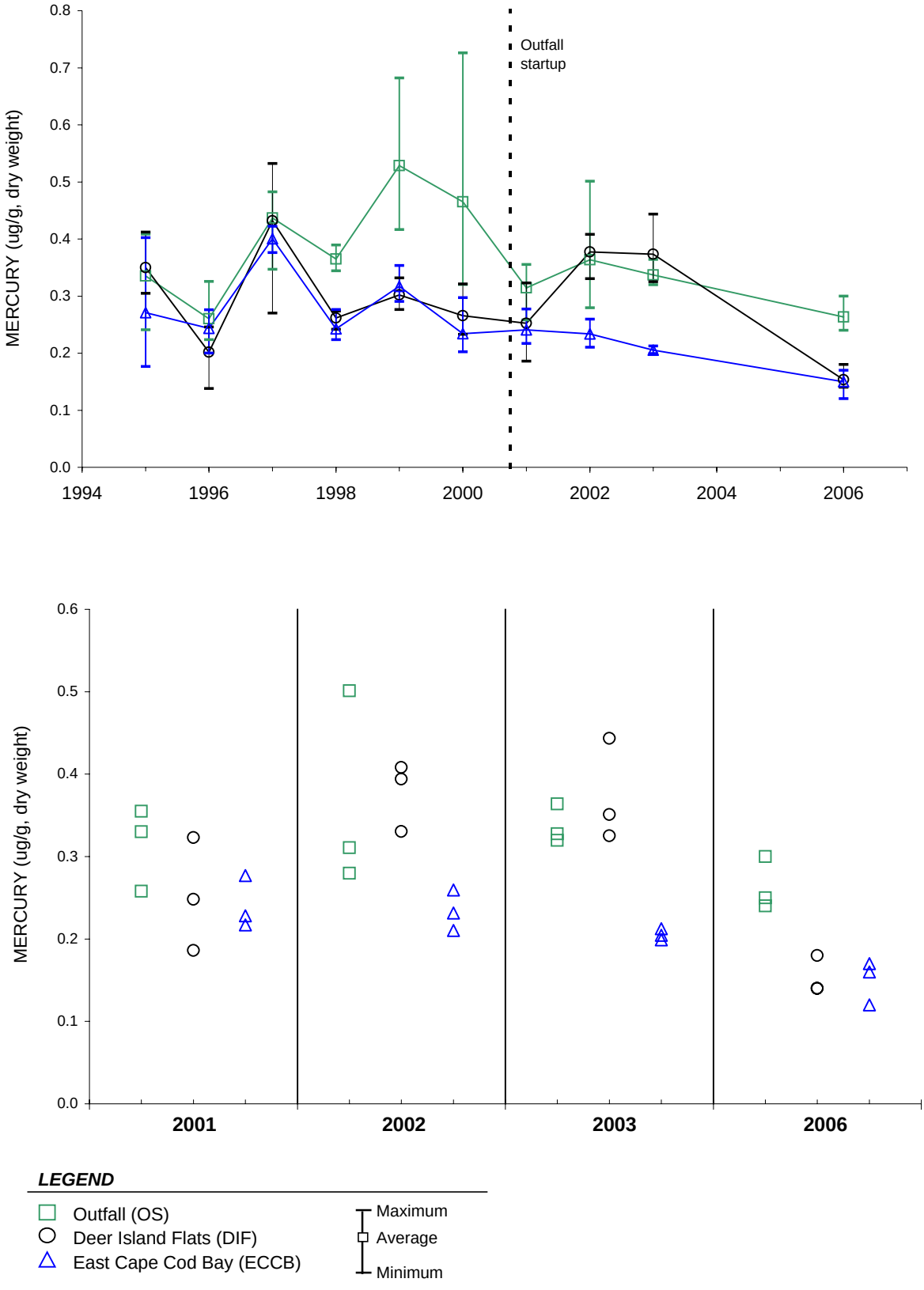



**Figure B-38. Mercury concentrations in lobster hepatopancreas tissue over time**

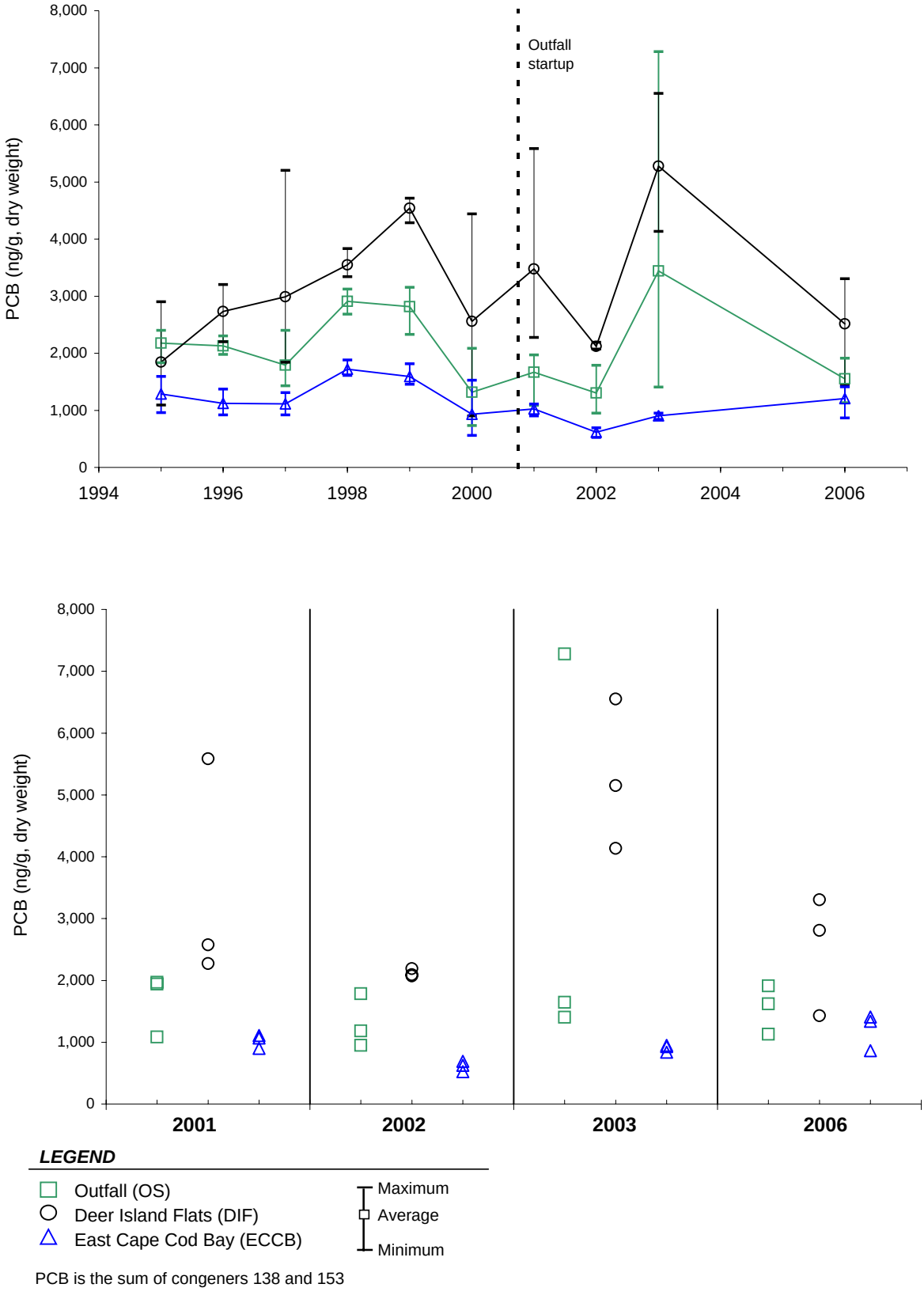
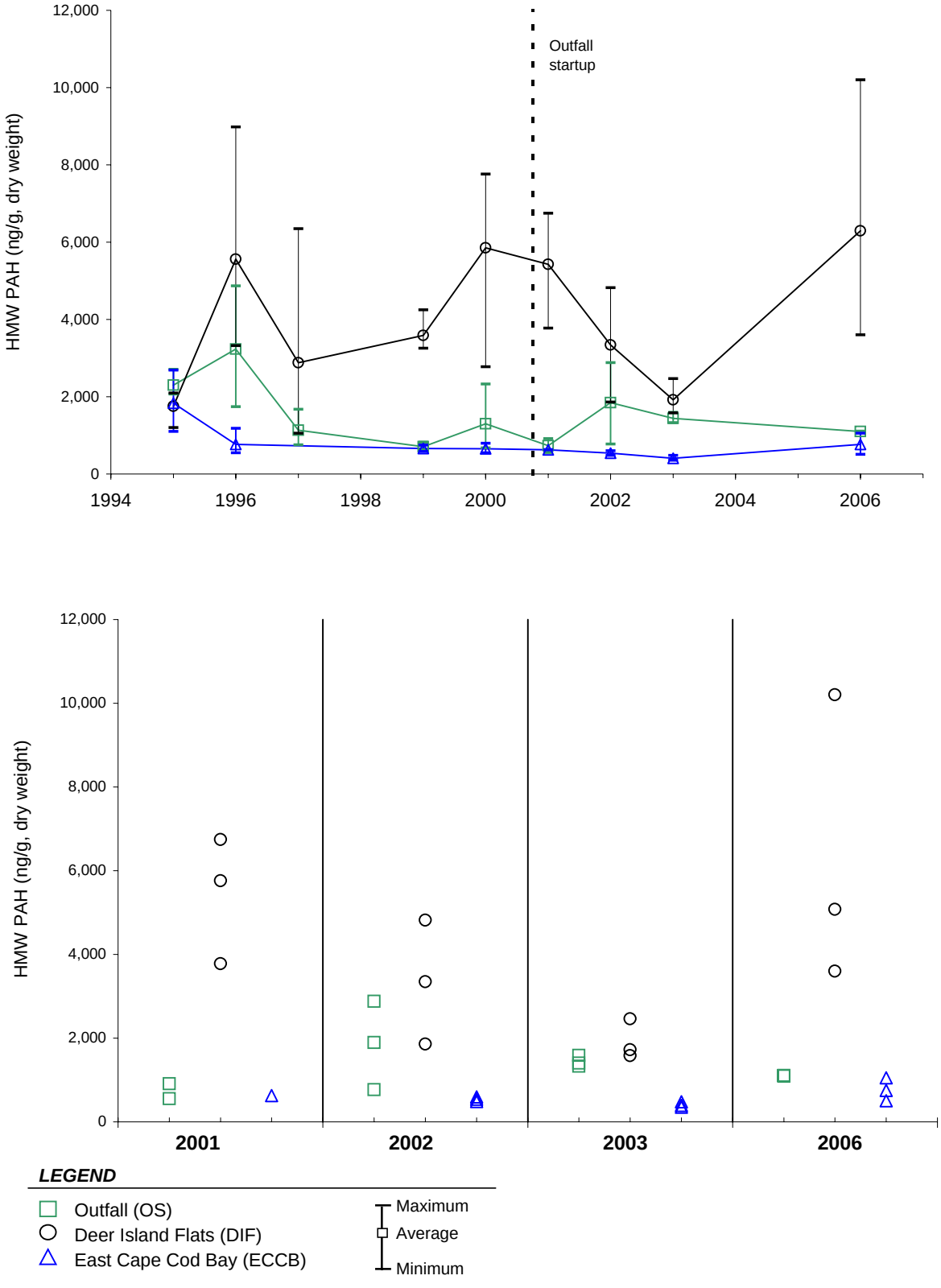
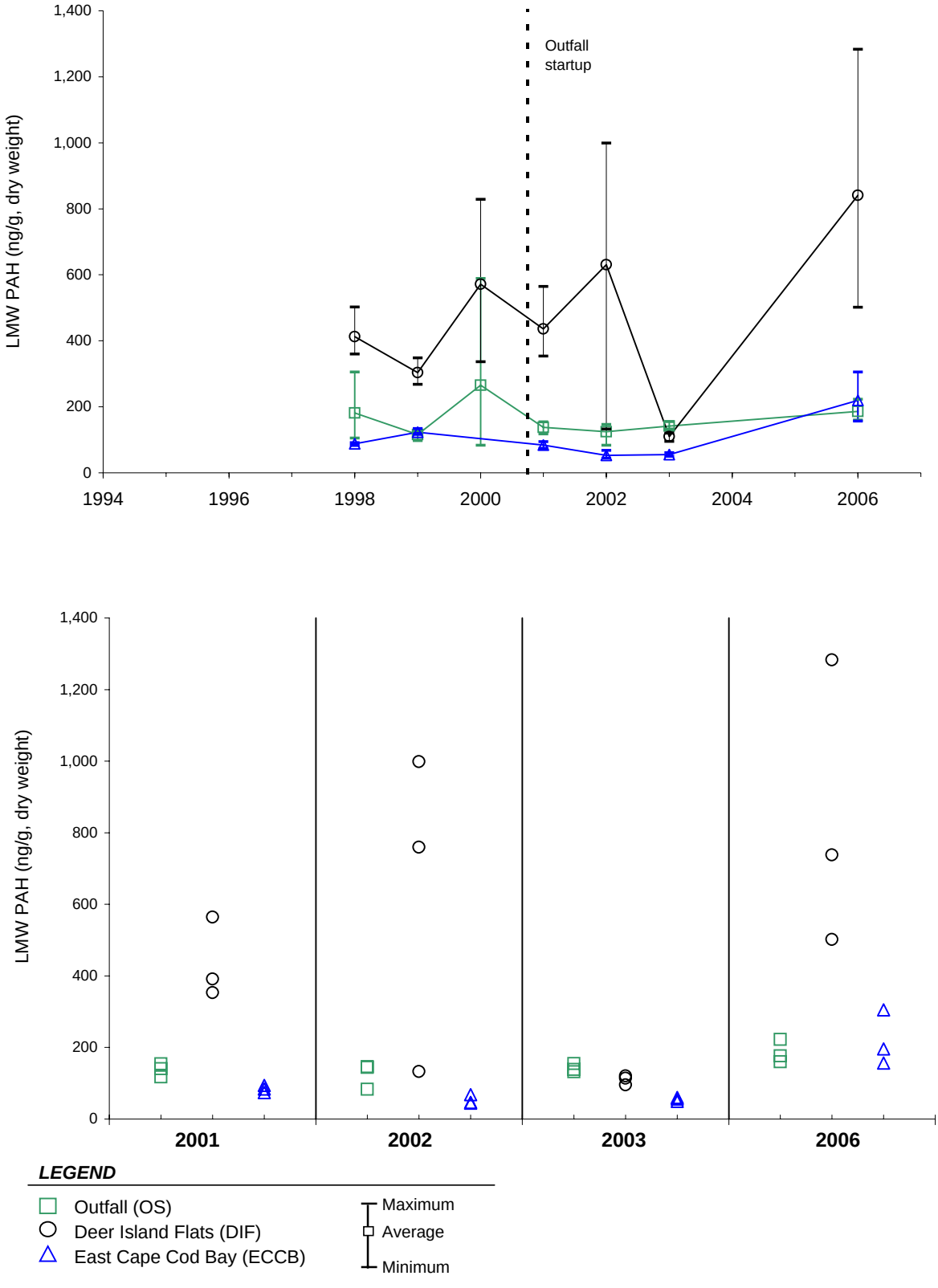



**Figure B-39. PCB concentrations in lobster hepatopancreas tissue over time**



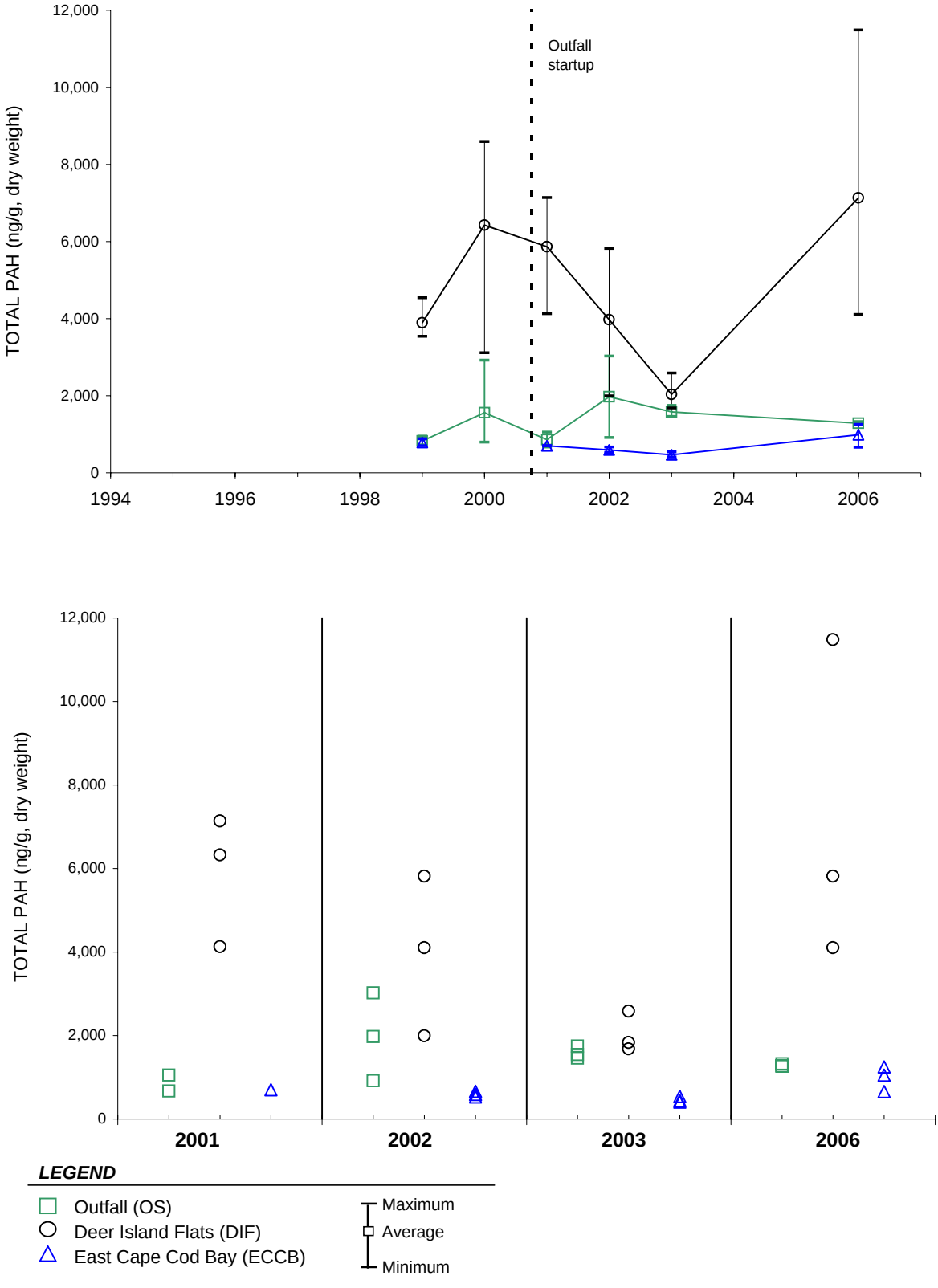

HMW PAH is the sum of the 12 HMW analytes on the historical NOAA list

**Figure B-40. High molecular weight (HMW) PAH concentrations in lobster hepatopancreas tissue over time**




LMW PAH is the sum of the 12 LMW analytes on the historical NOAA list

**Figure B-41. Low molecular weight (LMW) PAH concentrations in lobster hepatopancreas tissue over time**




Total PAH is the sum of the 24 (12 LMW and 12 HMW) analytes on the historical NOAA list

**Figure B-42. Total PAH concentrations in lobster hepatopancreas tissue over time**

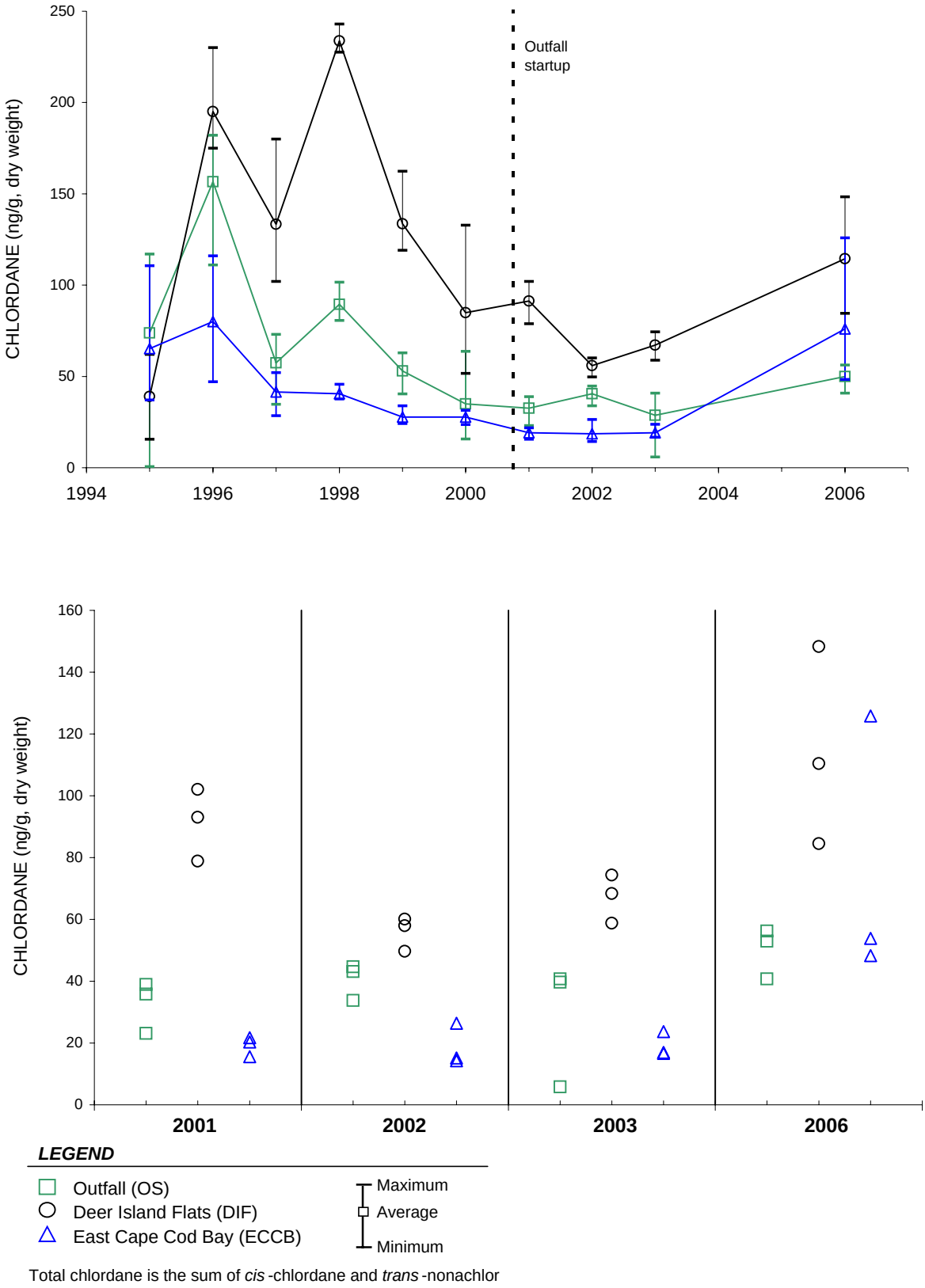



**Figure B-43. Chlordane concentrations in lobster hepatopancreas tissue over time**

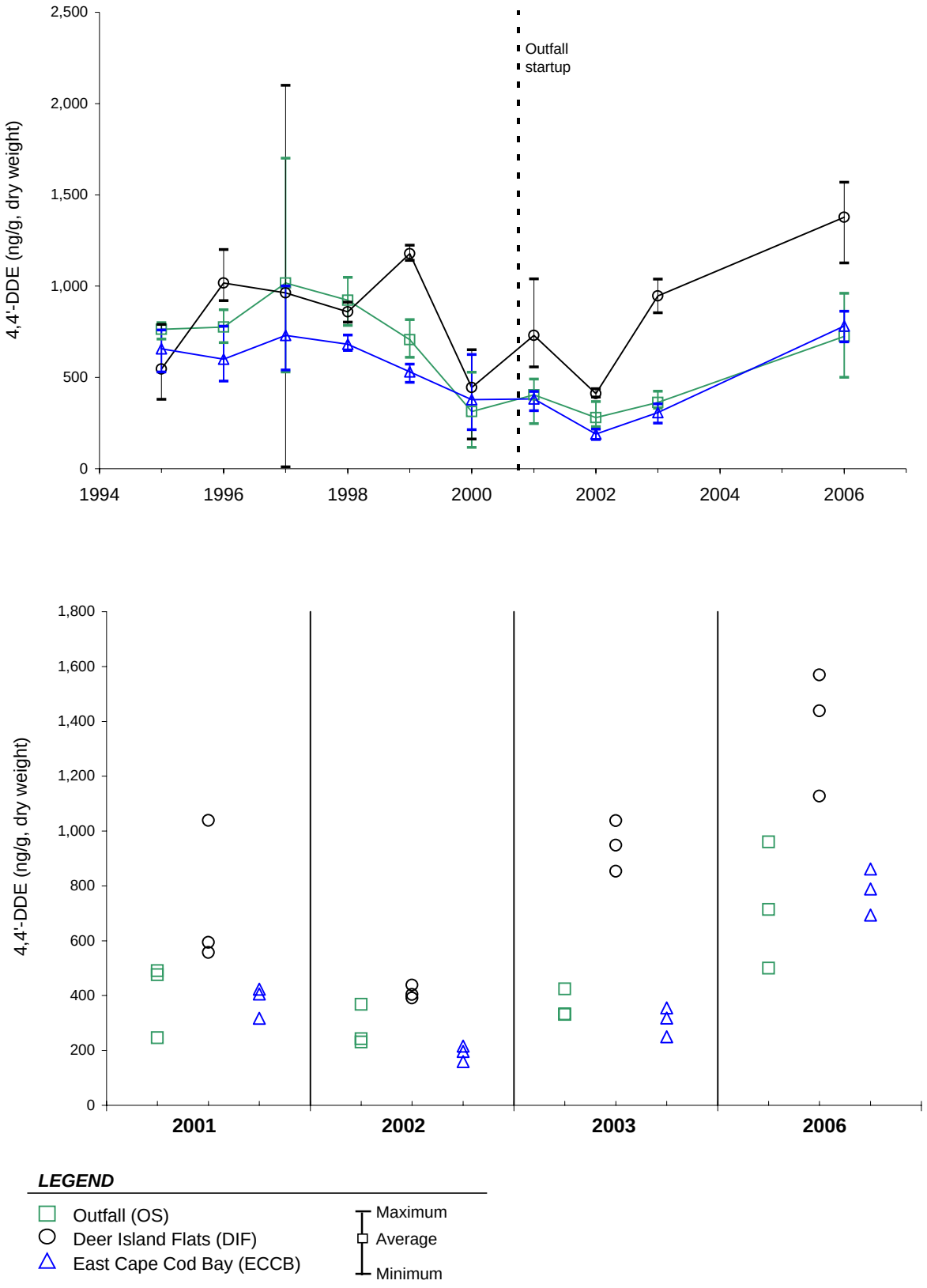
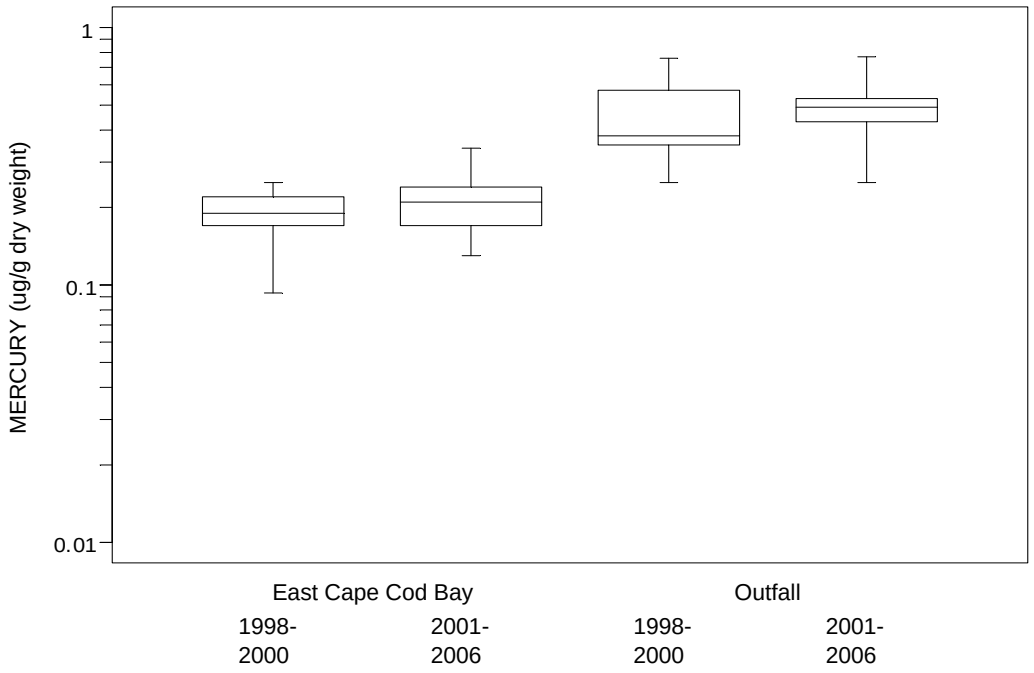
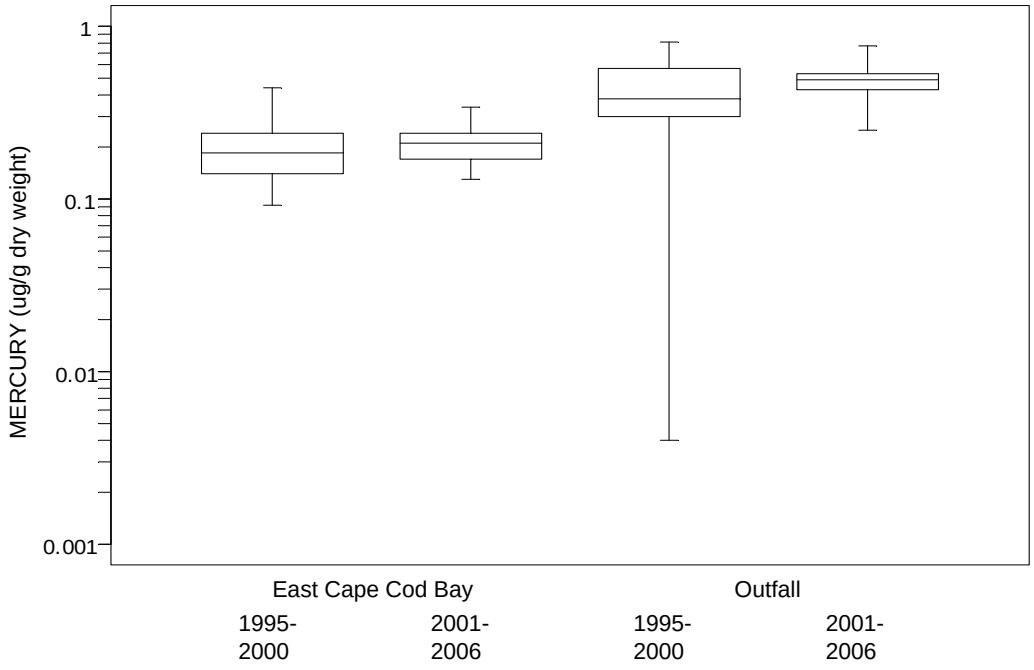
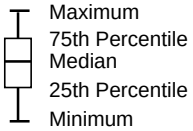



**Figure B-44. 4,4'-DDE concentrations in lobster hepatopancreas tissue over time**



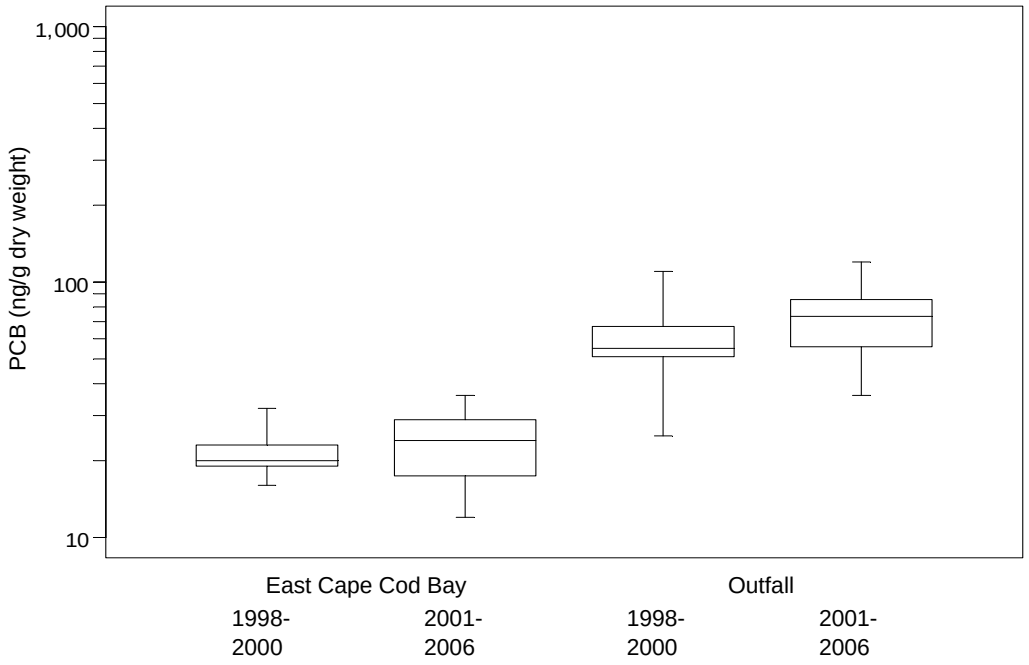



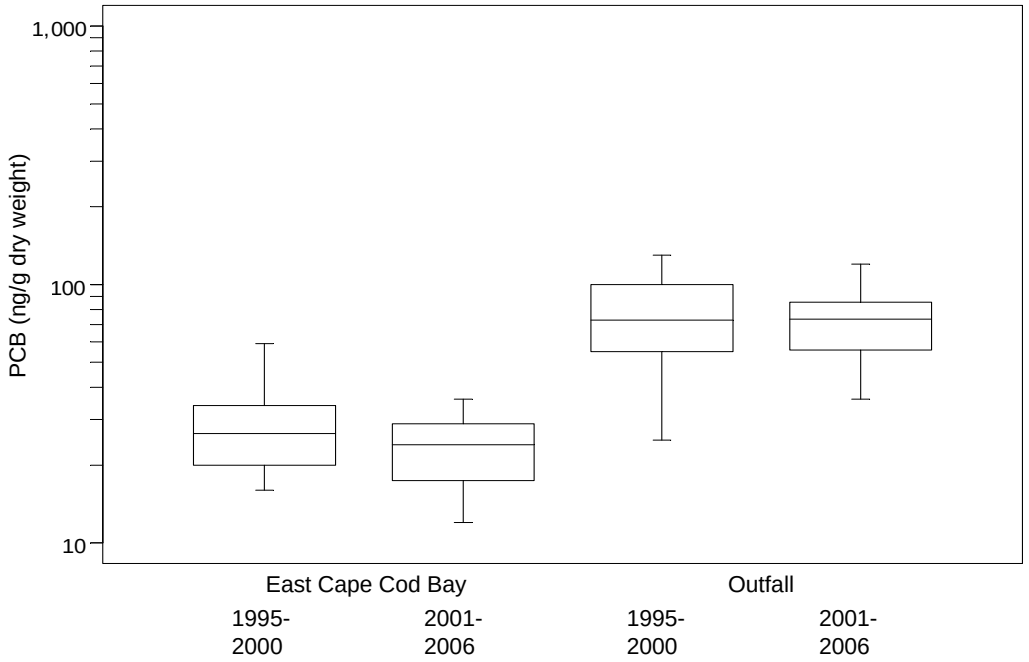

***LEGEND***



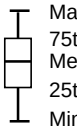

Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

**Figure B-45. Comparison of mercury concentrations measured in flounder fillet between control and impact locations before and after relocation of the outfall**



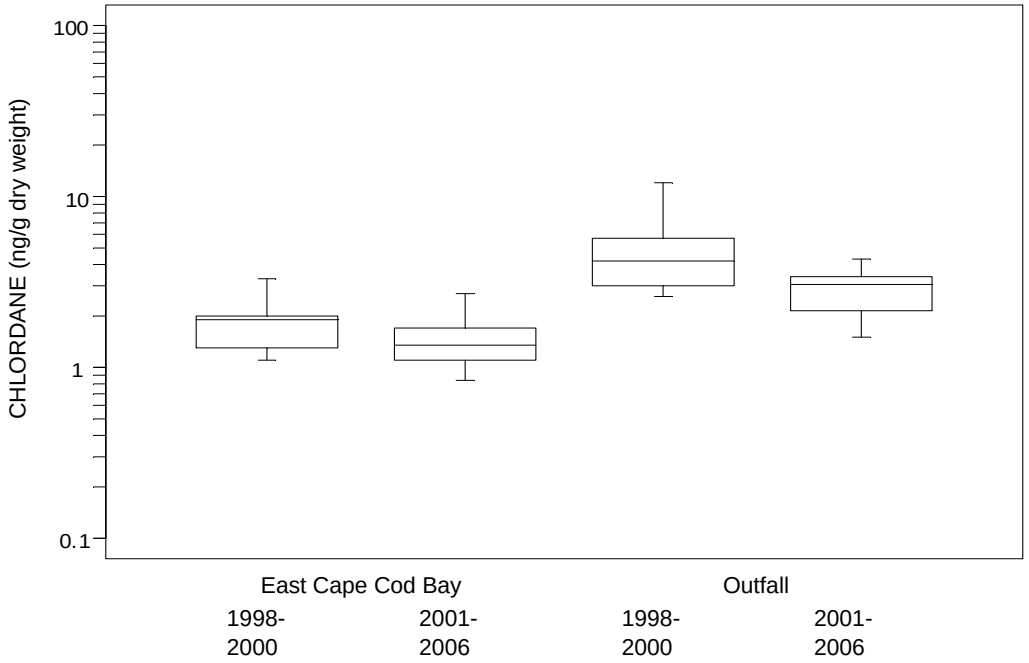

***LEGEND***

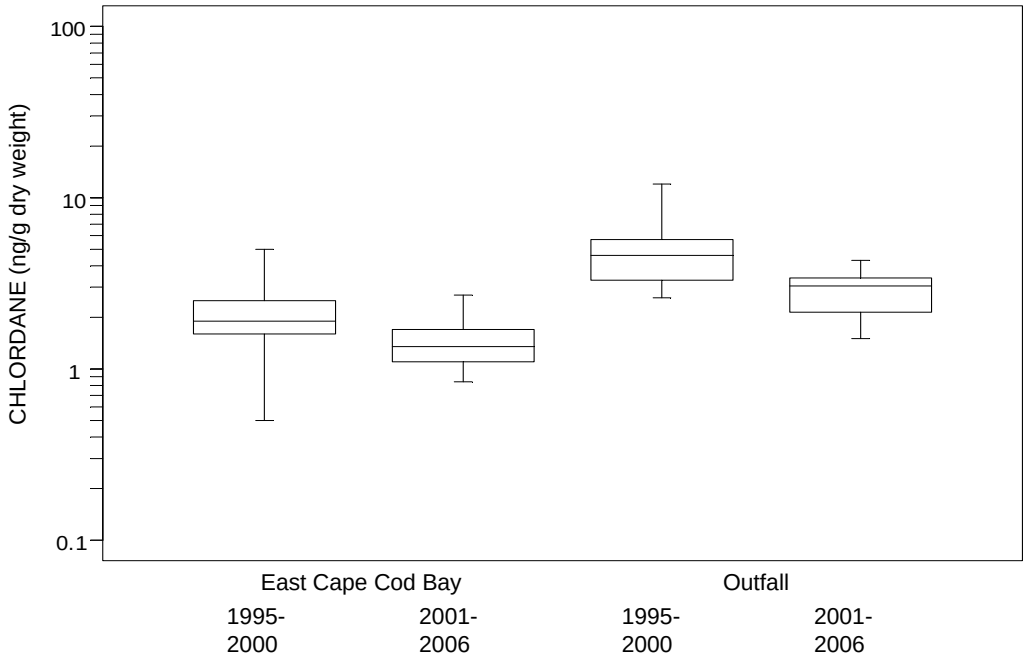



Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

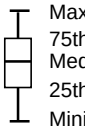
PCB is the sum of congeners 138 and 153

**Figure B-46. Comparison of PCB concentrations measured in flounder fillet between control and impact locations before and after relocation of the outfall**



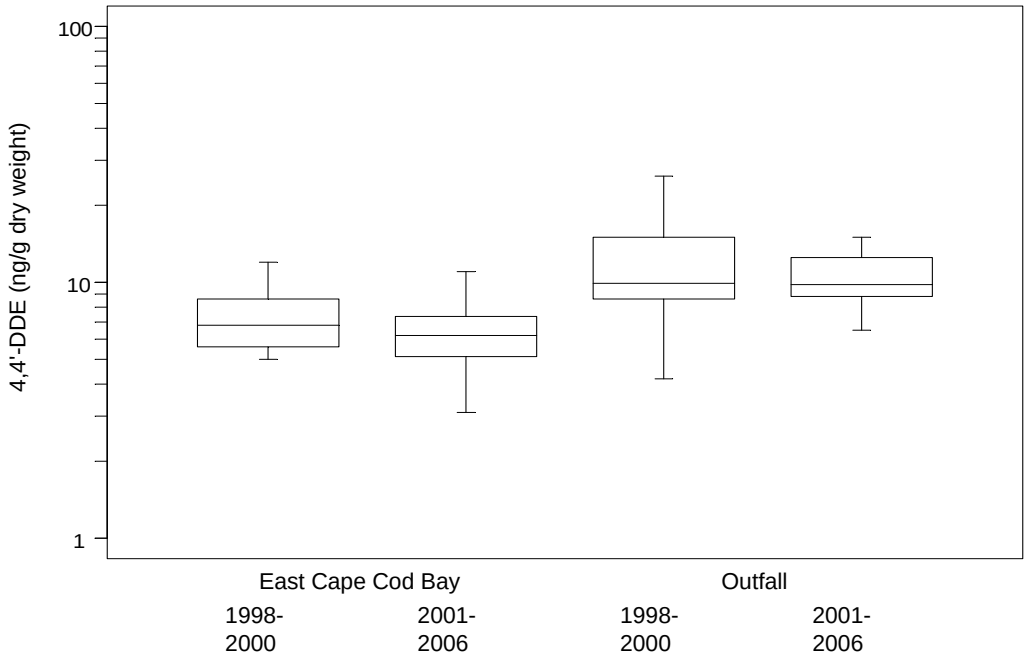

***LEGEND***

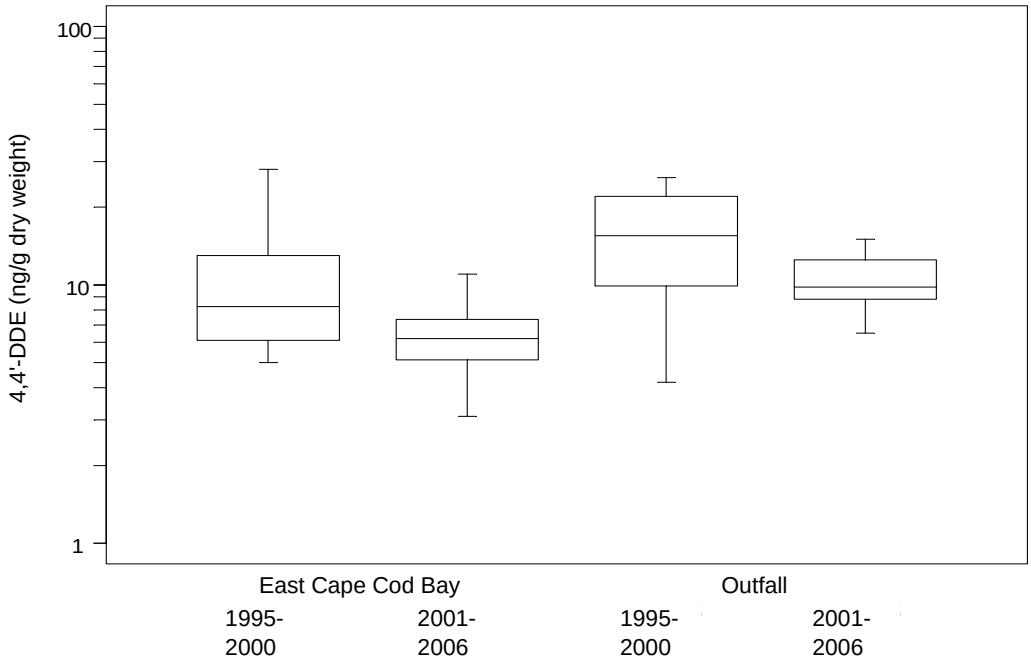



Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

Chlordane is the sum of *cis* -chlordane and *trans* -nonachlor

**Figure B-47. Comparison of chlordane concentrations measured in flounder fillet between control and impact locations before and after relocation of the outfall**



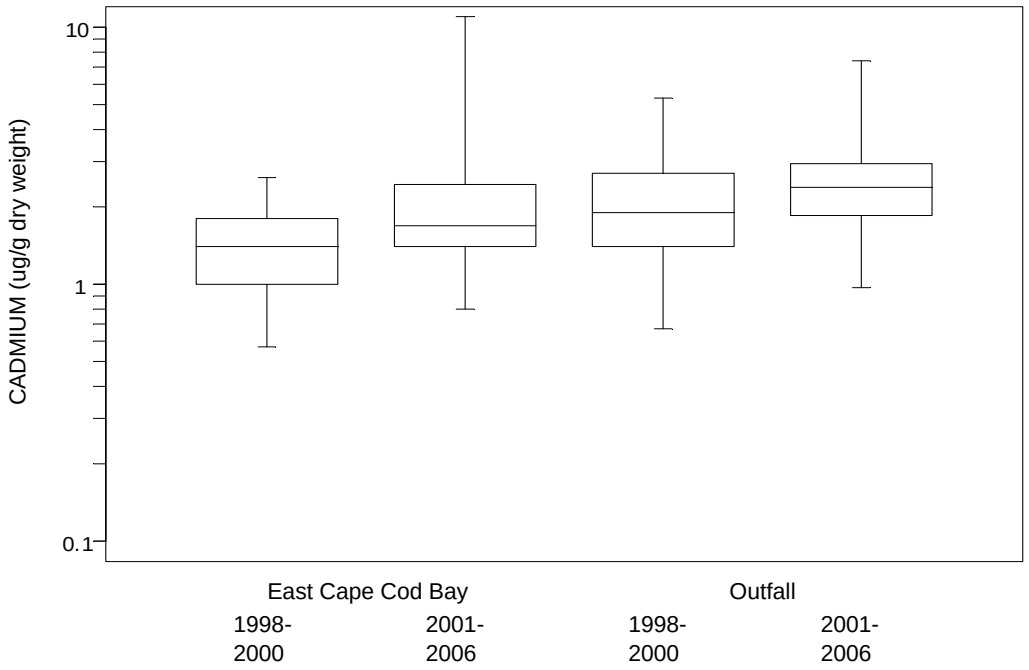



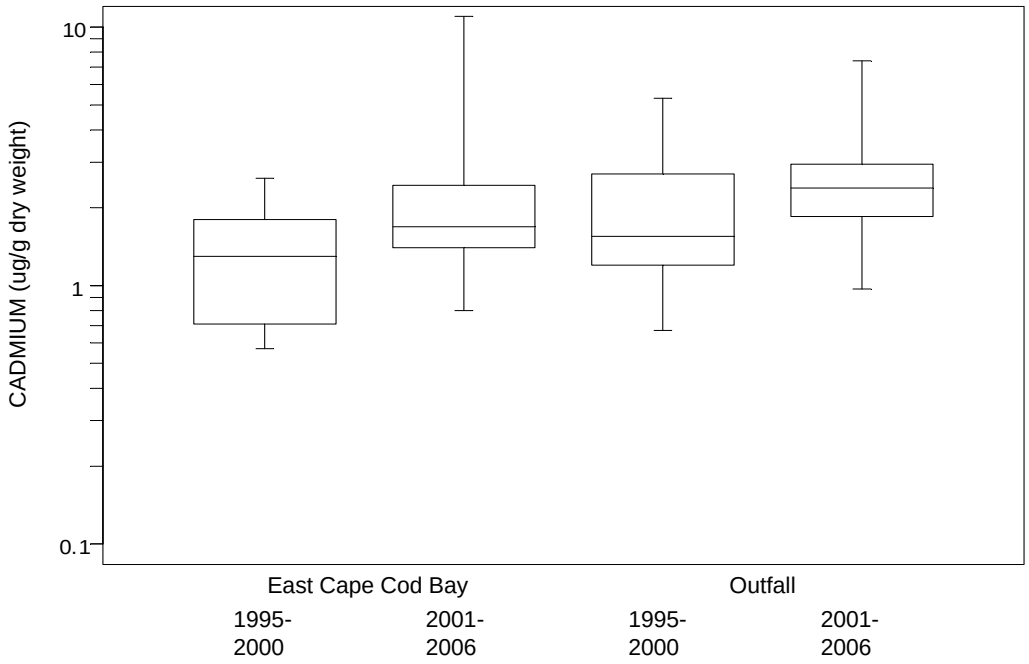

***LEGEND***

Maximum
75th Percentile
Median
25th Percentile
Minimum

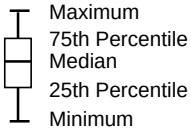
Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

**Figure B-48. Comparison of 4,4'-DDE concentrations measured in flounder fillet between control and impact locations before and after relocation of the outfall**



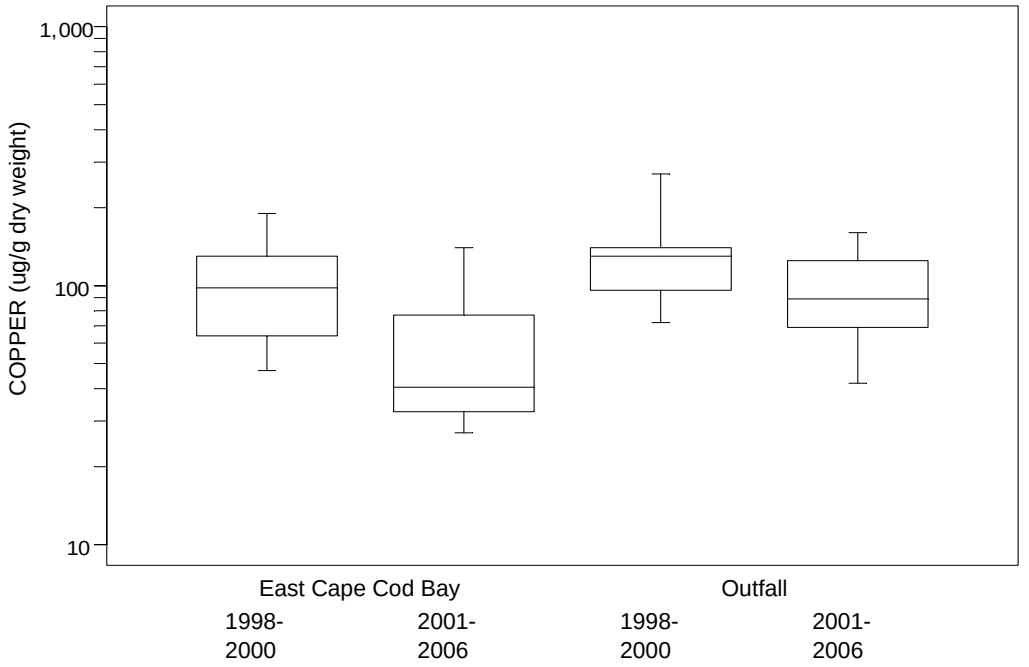



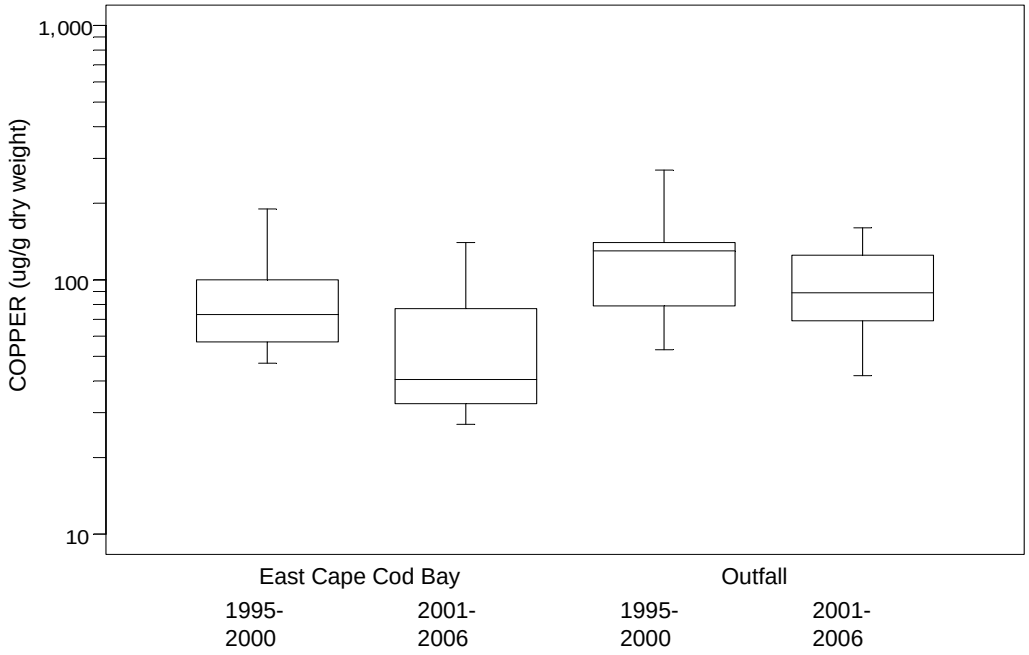

***LEGEND***



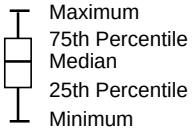

Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

**Figure B-49. Comparison of cadmium concentrations measured in flounder liver between control and impact locations before and after relocation of the outfall**



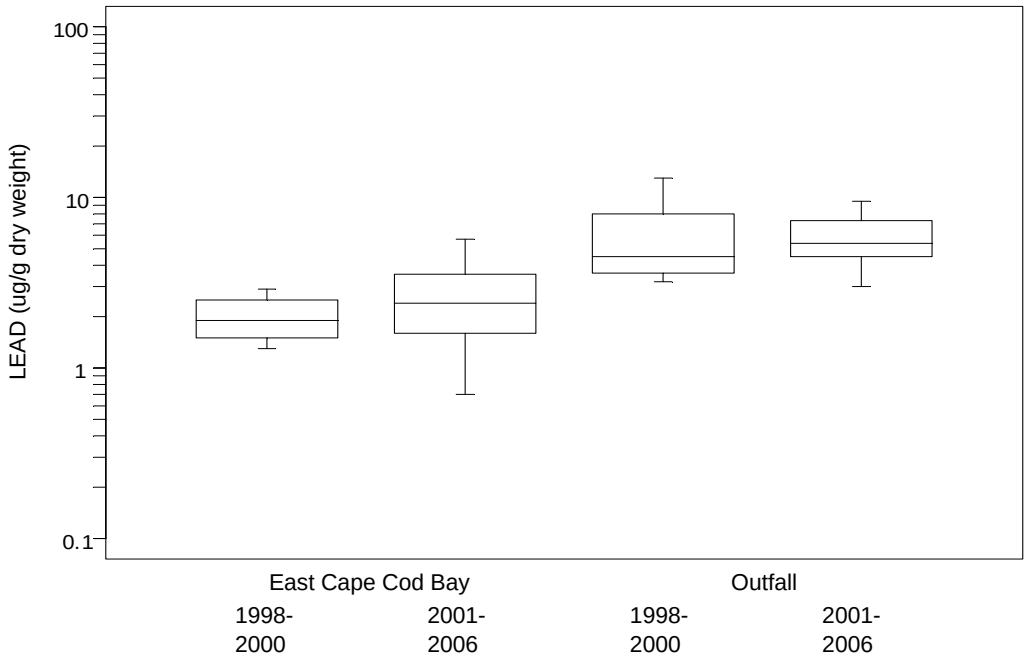



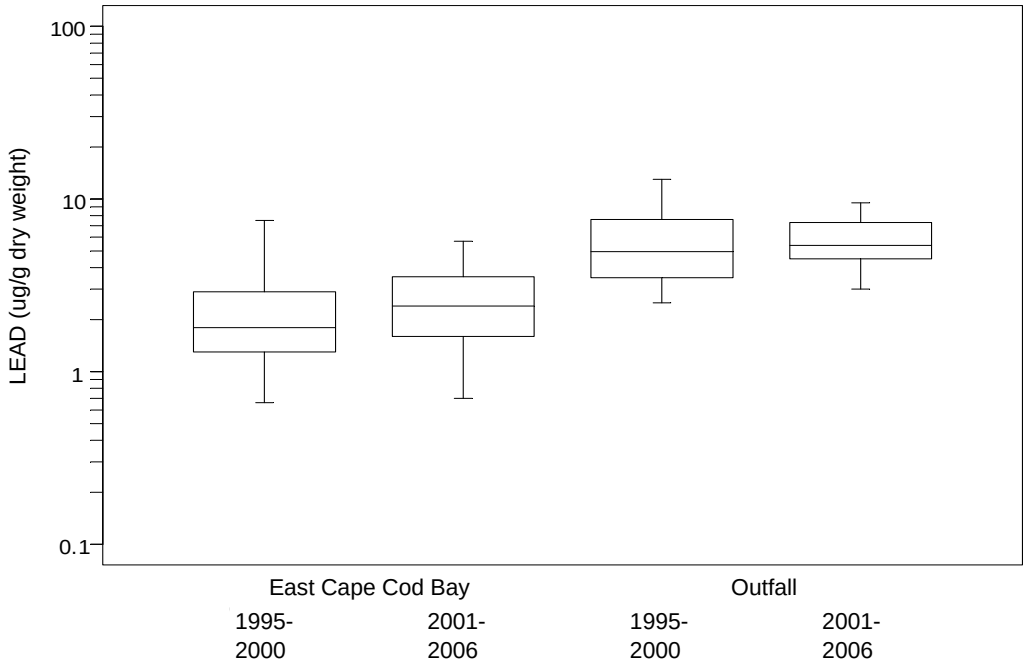

***LEGEND***



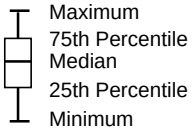

Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

**Figure B-50. Comparison of copper concentrations measured in flounder liver between control and impact locations before and after relocation of the outfall**



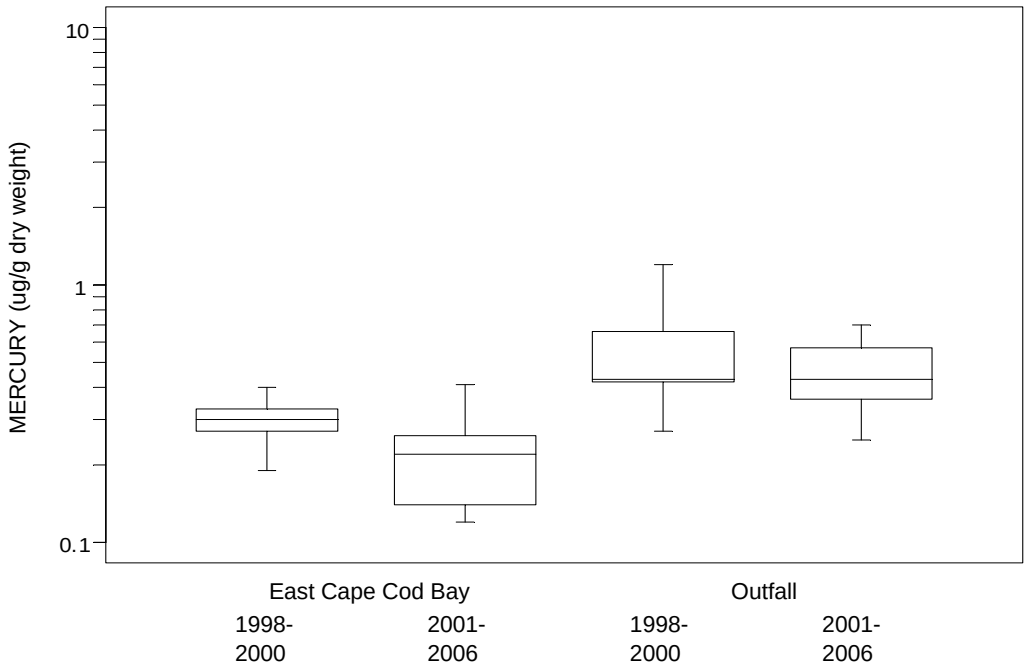



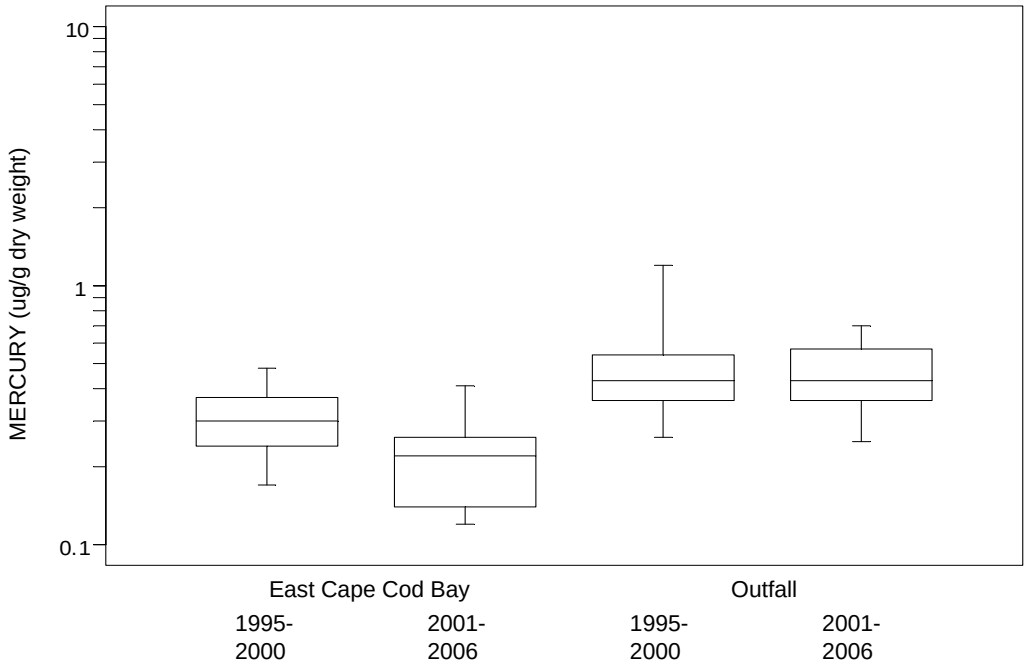

***LEGEND***




Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

**Figure B-51. Comparison of lead concentrations measured in flounder liver between control and impact locations before and after relocation of the outfall**



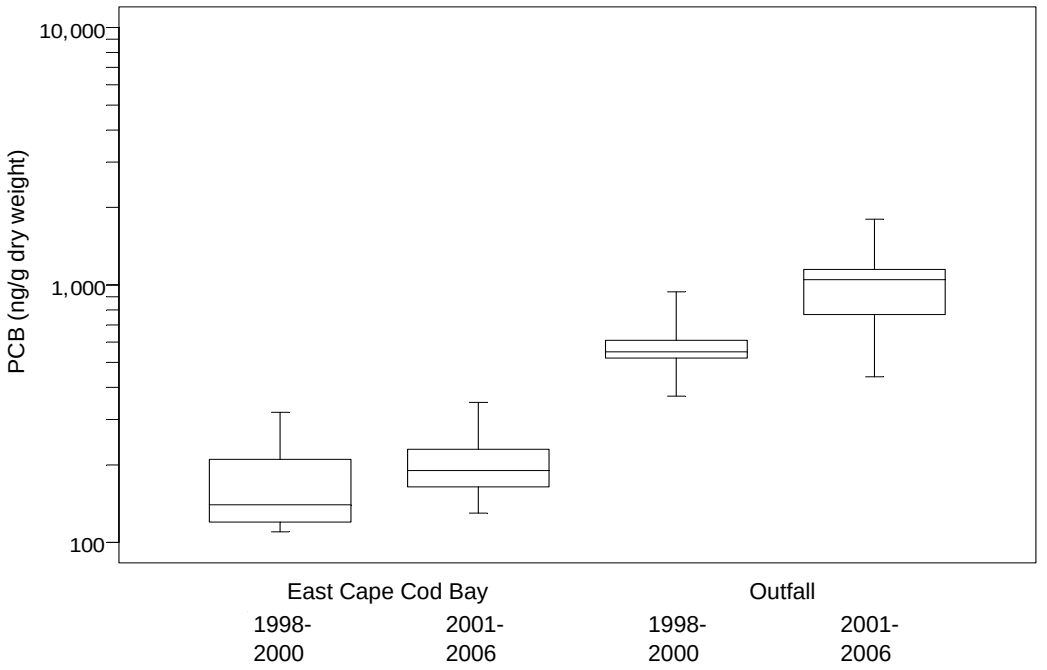



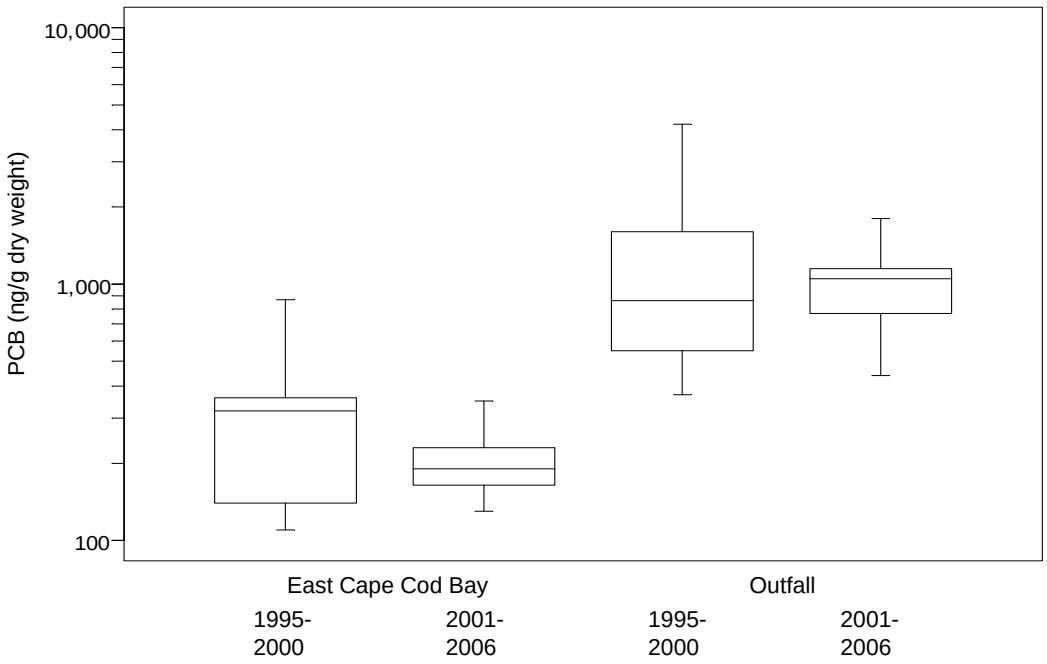

***LEGEND***

Maximum
75th Percentile
Median
25th Percentile
Minimum

Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

**Figure B-52. Comparison of mercury concentrations measured in flounder liver between control and impact locations before and after relocation of the outfall**



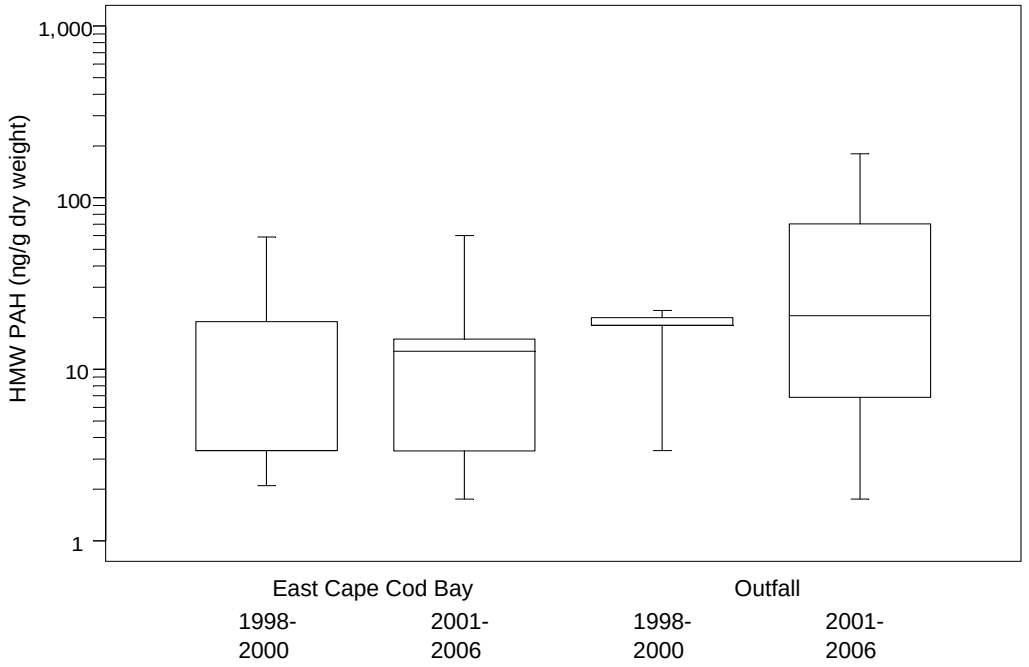

***LEGEND***

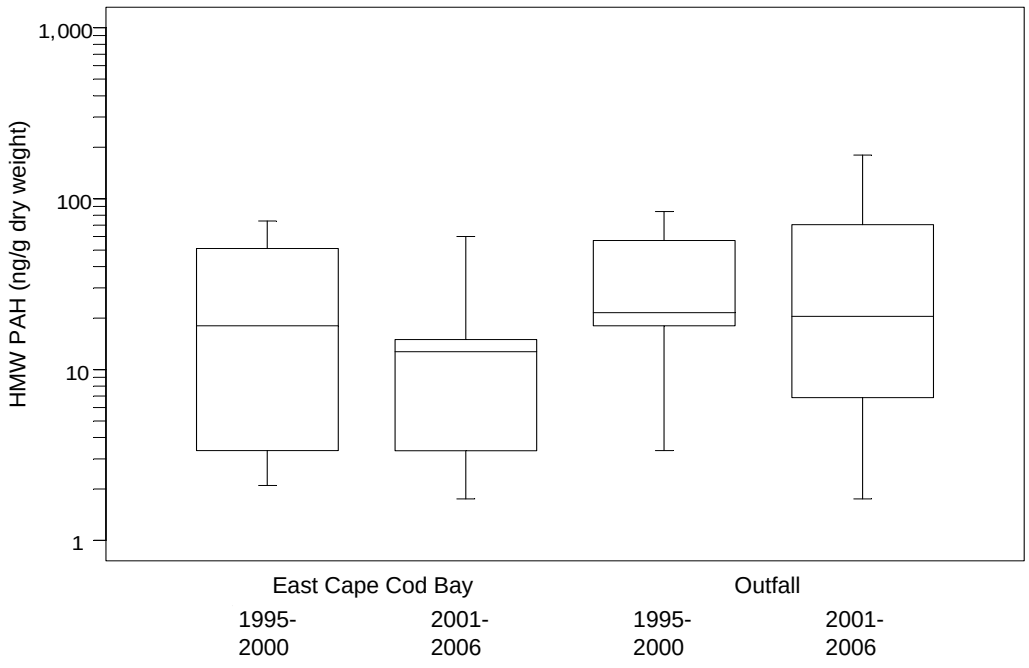
Maximum
75th Percentile
Median
25th Percentile
Minimum

Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

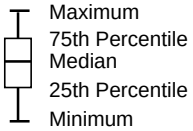
PCB is the sum of congeners 138 and 153

**Figure B-53. Comparison of PCB concentrations measured in flounder liver between control and impact locations before and after relocation of the outfall**



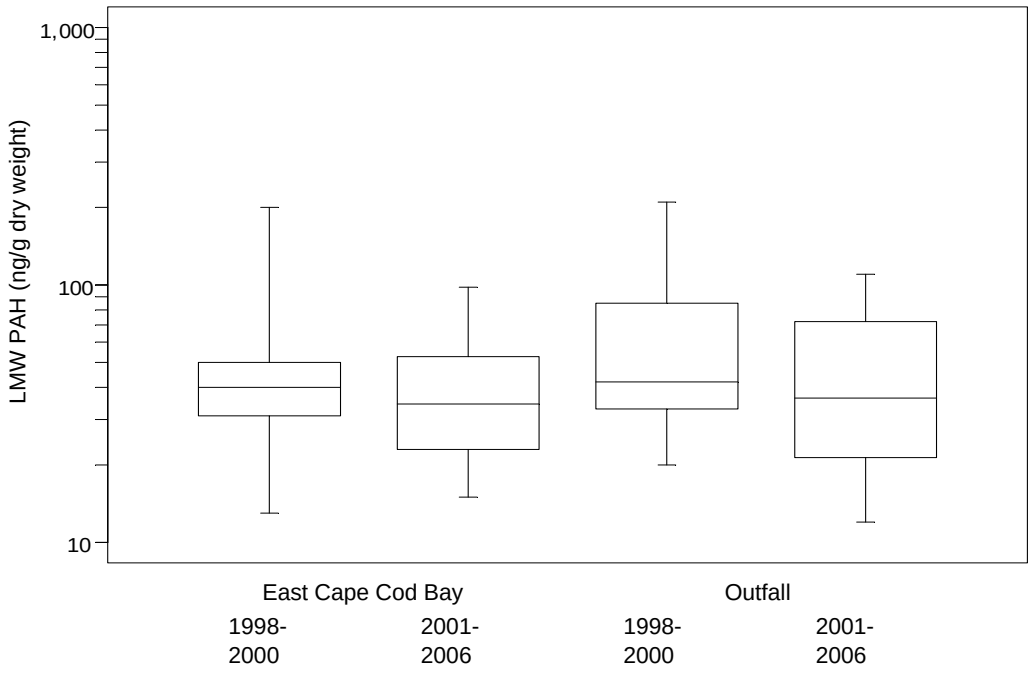

***LEGEND***

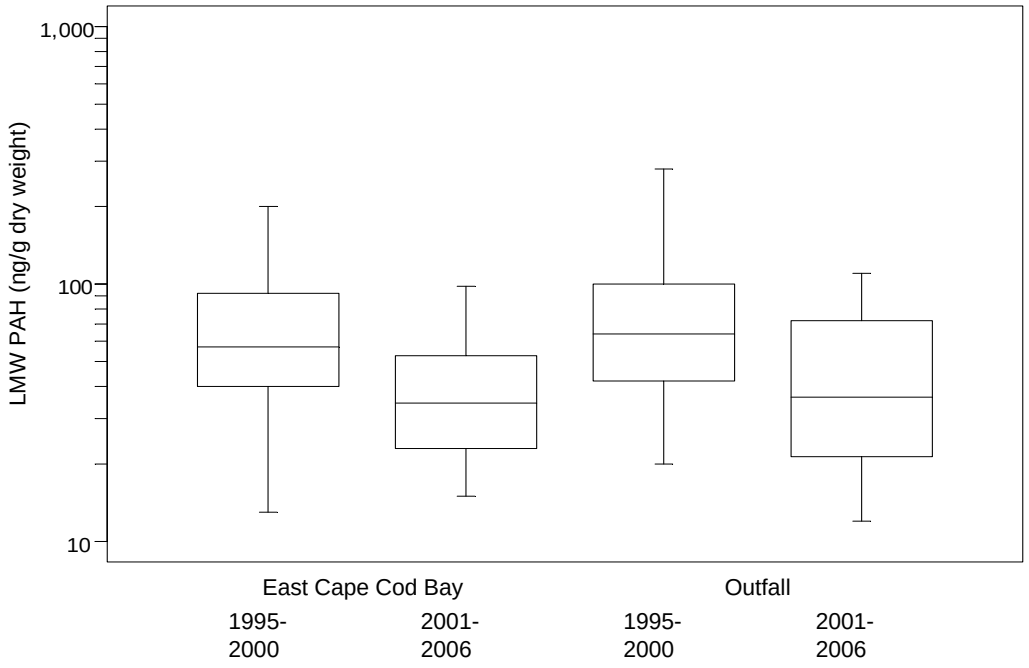



Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

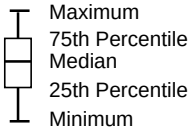
HMW PAH is the sum of the 12 HMW analytes on the historical NOAA list

**Figure B-54. Comparison of high molecular weight (HMW) PAH concentrations measured in flounder liver between control and impact locations before and after relocation of the outfall**



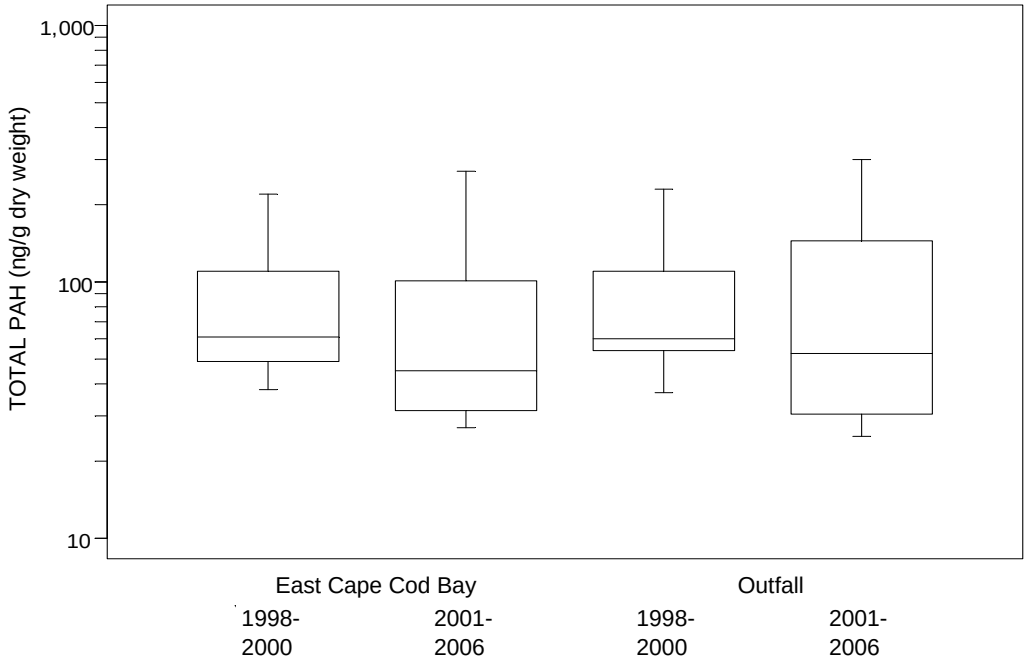

***LEGEND***

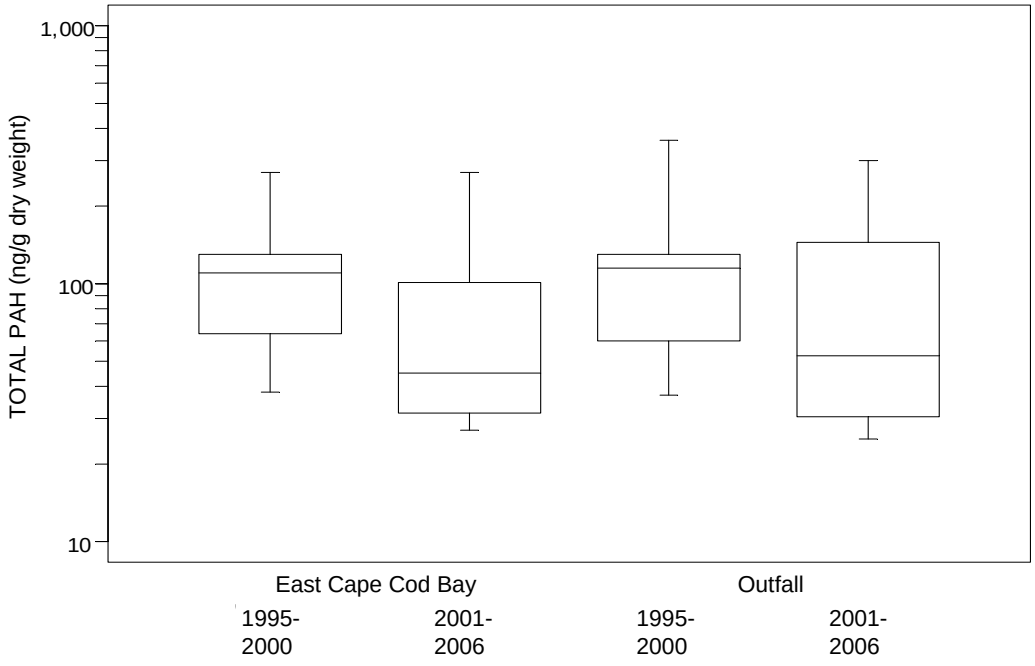



Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

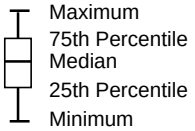
LMW PAH is the sum of 7 LMW analytes on the historical NOAA list (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, and phenanthrene)

**Figure B-55. Comparison of low molecular weight (LMW) PAH concentrations measured in flounder liver between control and impact locations before and after relocation of the outfall**



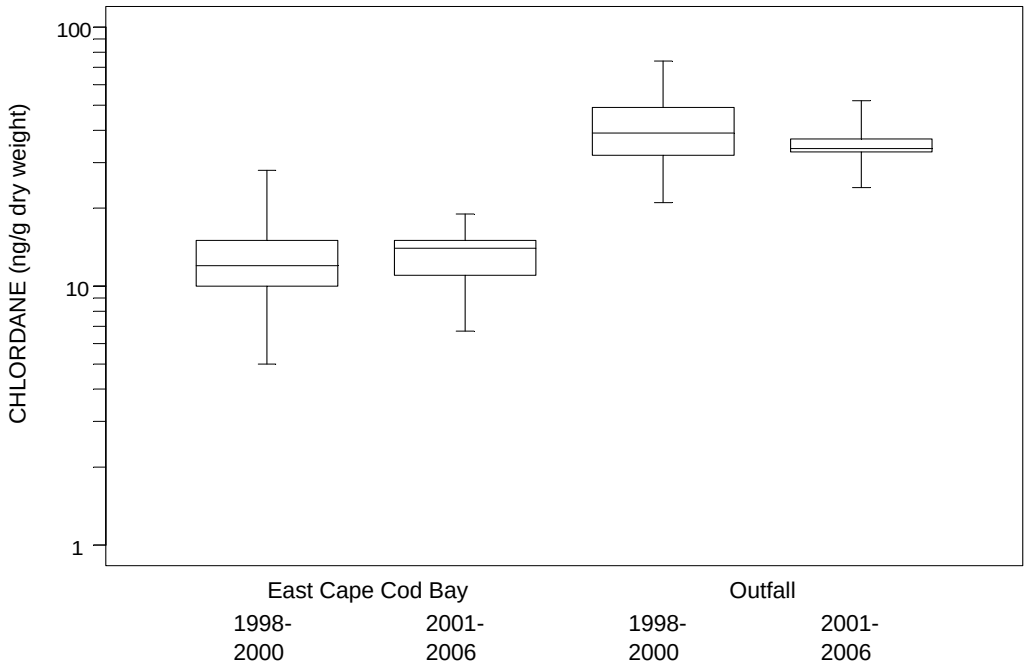

***LEGEND***

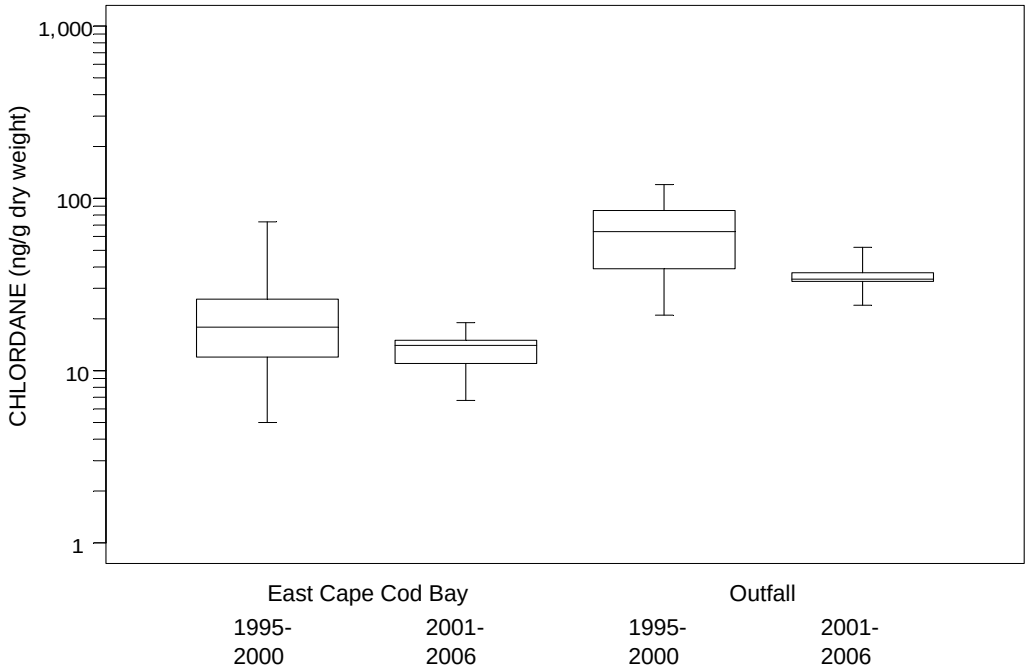



Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

Total PAH is the sum of 19 analytes on the historical NOAA list (7 LMW analytes as identified on Figure 3-29 and 12 HMW analytes)

**Figure B-56. Comparison of total PAH concentrations measured in flounder liver between control and impact locations before and after relocation of the outfall**



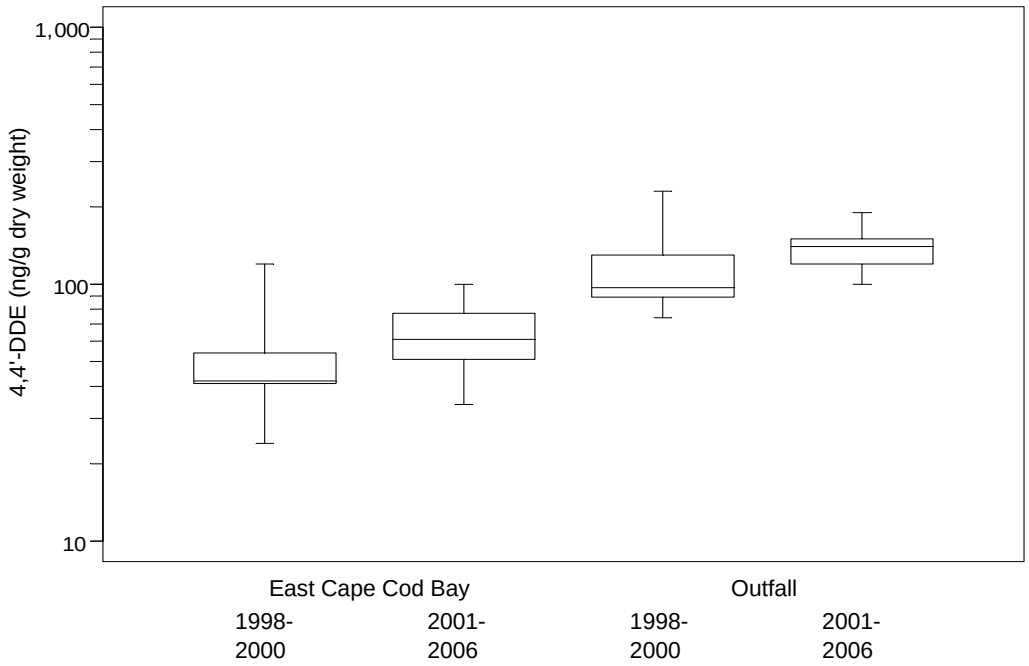

***LEGEND***

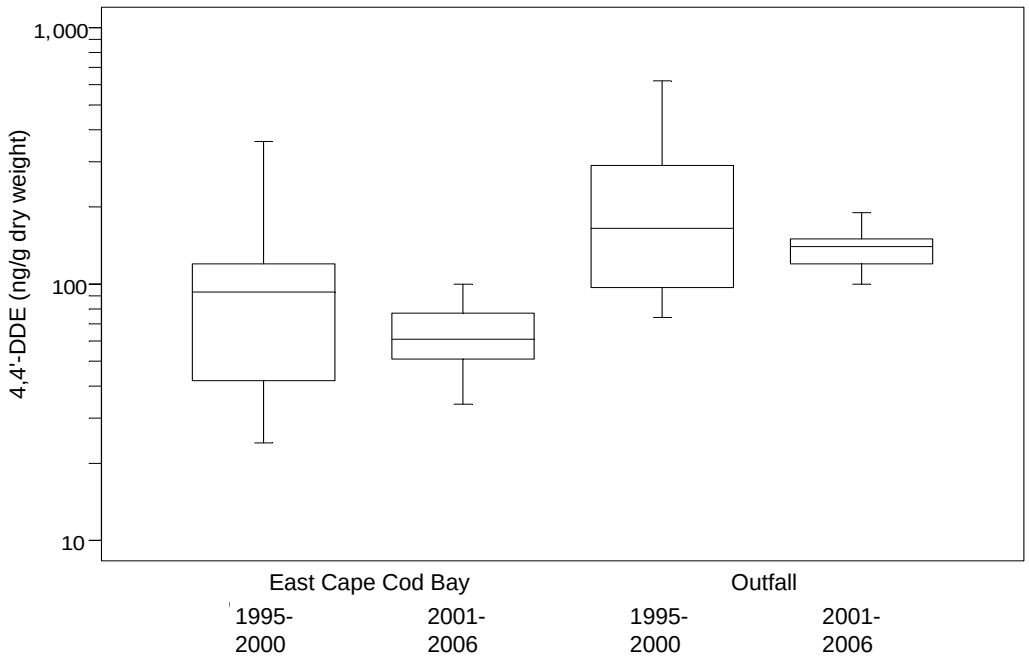
Maximum
75th Percentile
Median
25th Percentile
Minimum

Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

Chlordane is the sum of *cis*-chlordane and *trans*-nonachlor

**Figure B-57. Comparison of chlordane concentrations measured in flounder liver between control and impact locations before and after relocation of the outfall**




***LEGEND***

Maximum
75th Percentile
Median
25th Percentile
Minimum

Control - East Cape Cod Bay (ECCB)
Impact - Outfall (OS)
Before - 1995 - 2000 or 1998 - 2000
After - 2001 - 2006

**Figure B-58. Comparison of 4,4'-DDE concentrations measured in flounder liver between control and impact locations before and after relocation of the outfall**

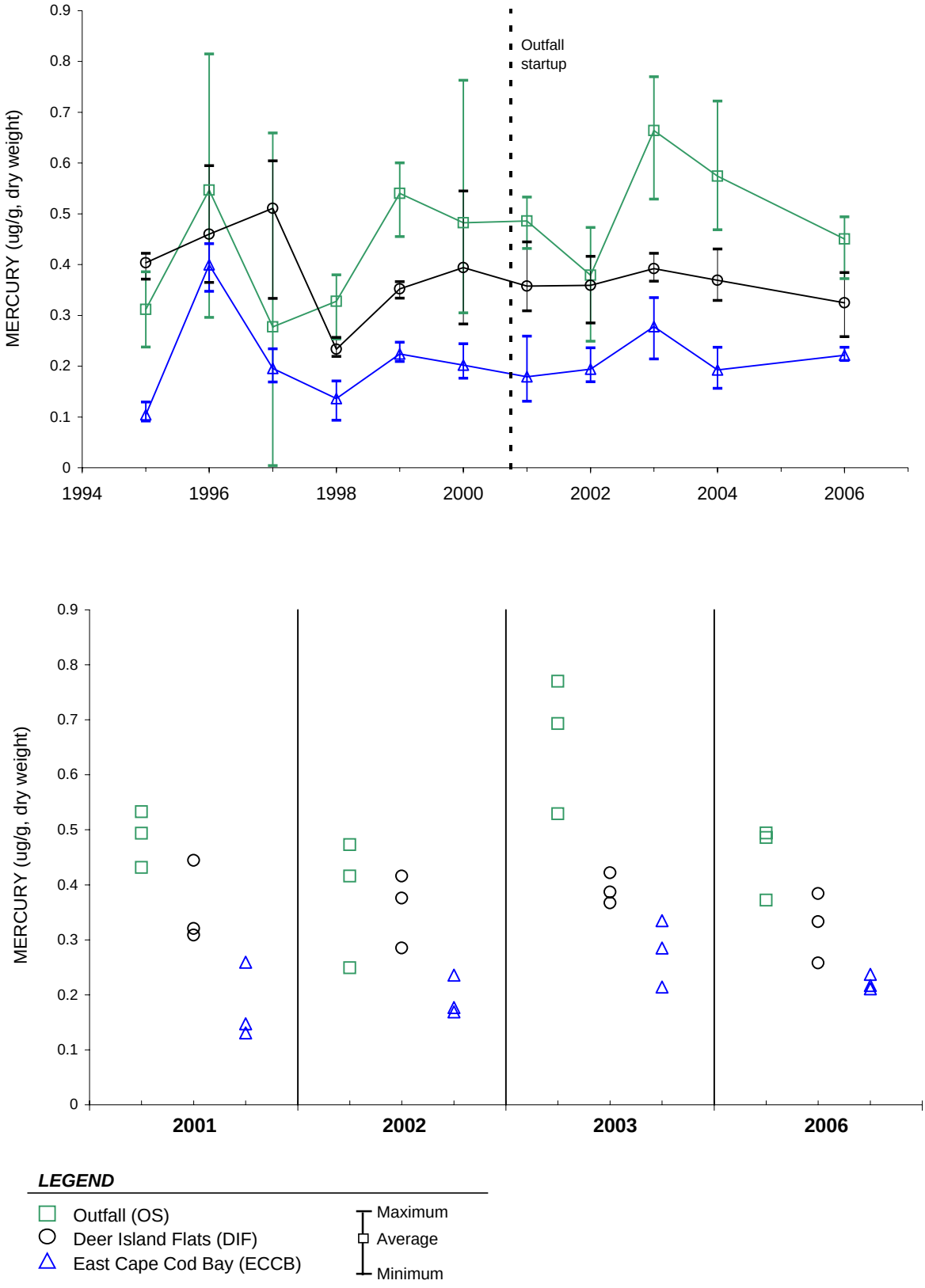



**Figure B-59. Mercury concentrations in flounder fillet tissue over time**

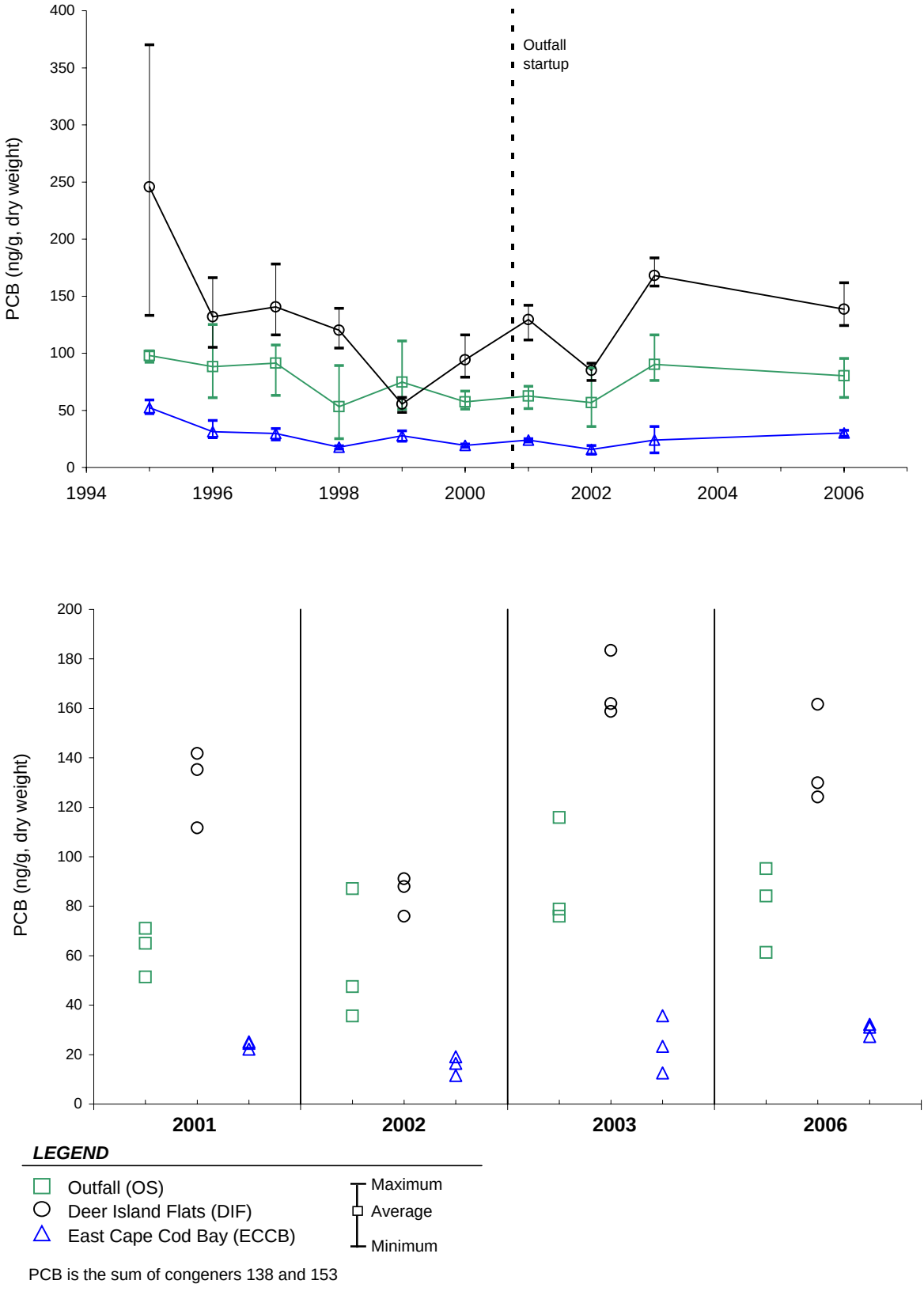



**Figure B-60. PCB concentrations in flounder fillet tissue over time**

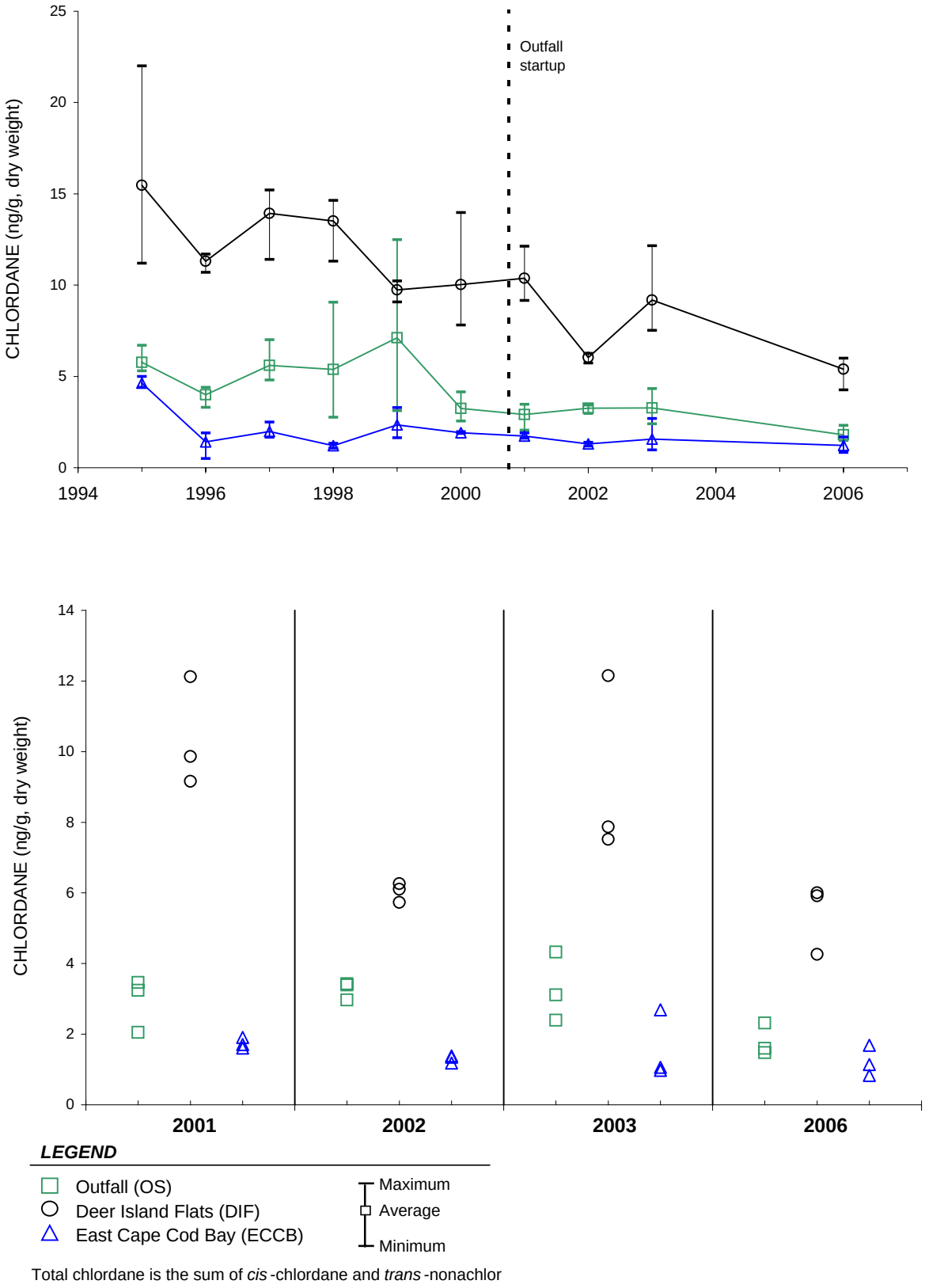



**Figure B-61. Chlordane concentrations in flounder fillet tissue over time**

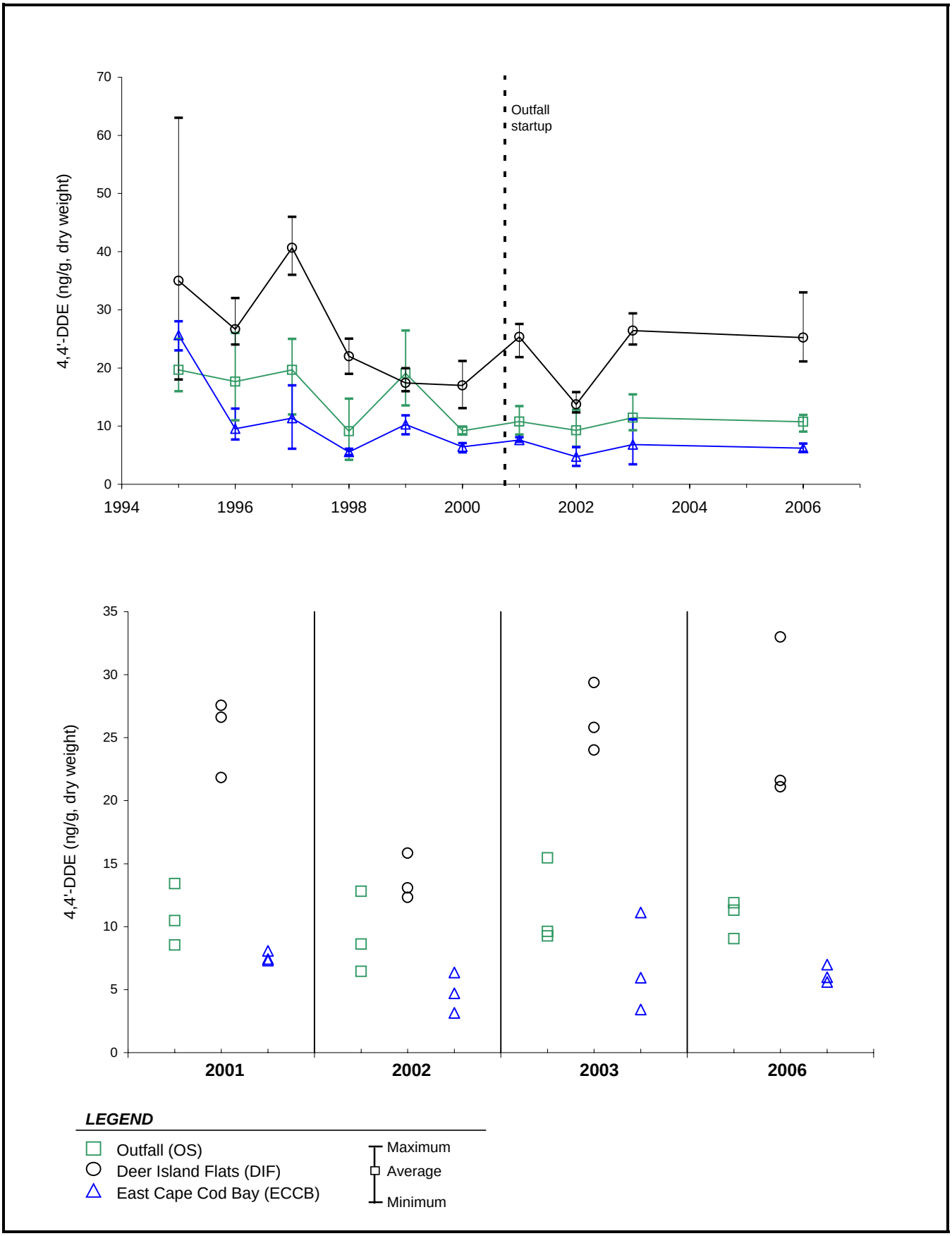
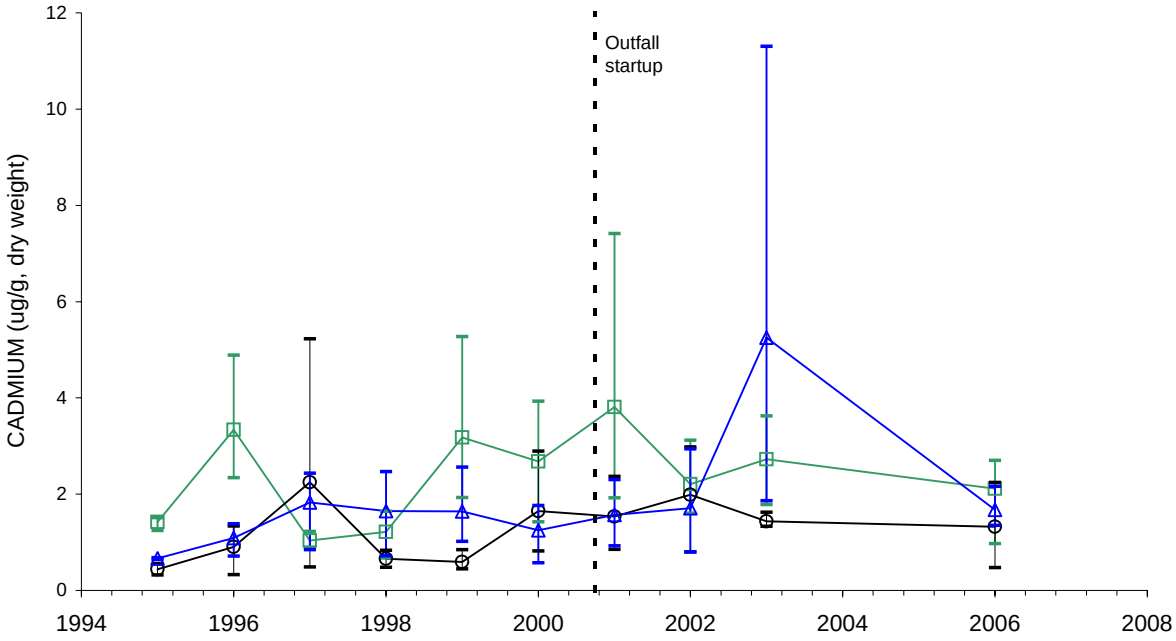



**Figure B-62. 4,4'-DDE concentrations in flounder fillet tissue over time**



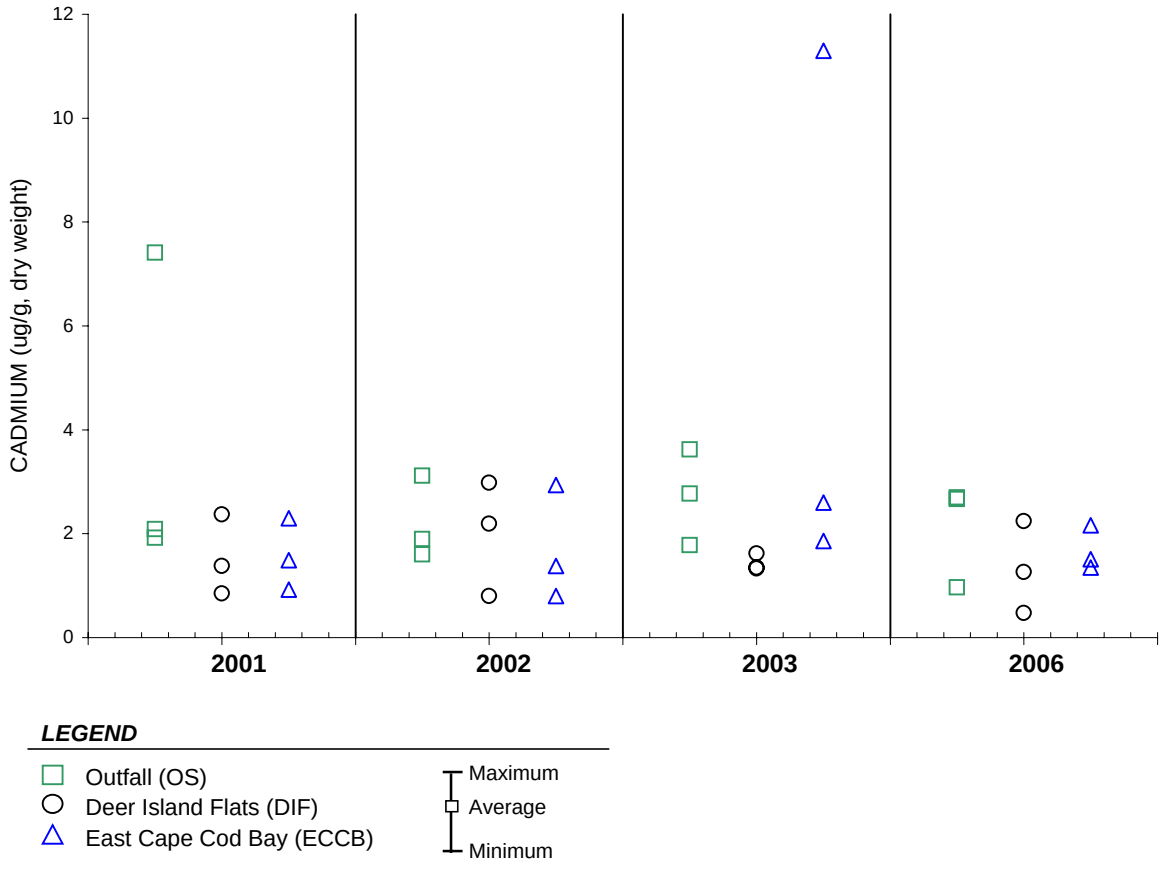




**Figure B-63. Cadmium concentrations in flounder liver tissue over time**

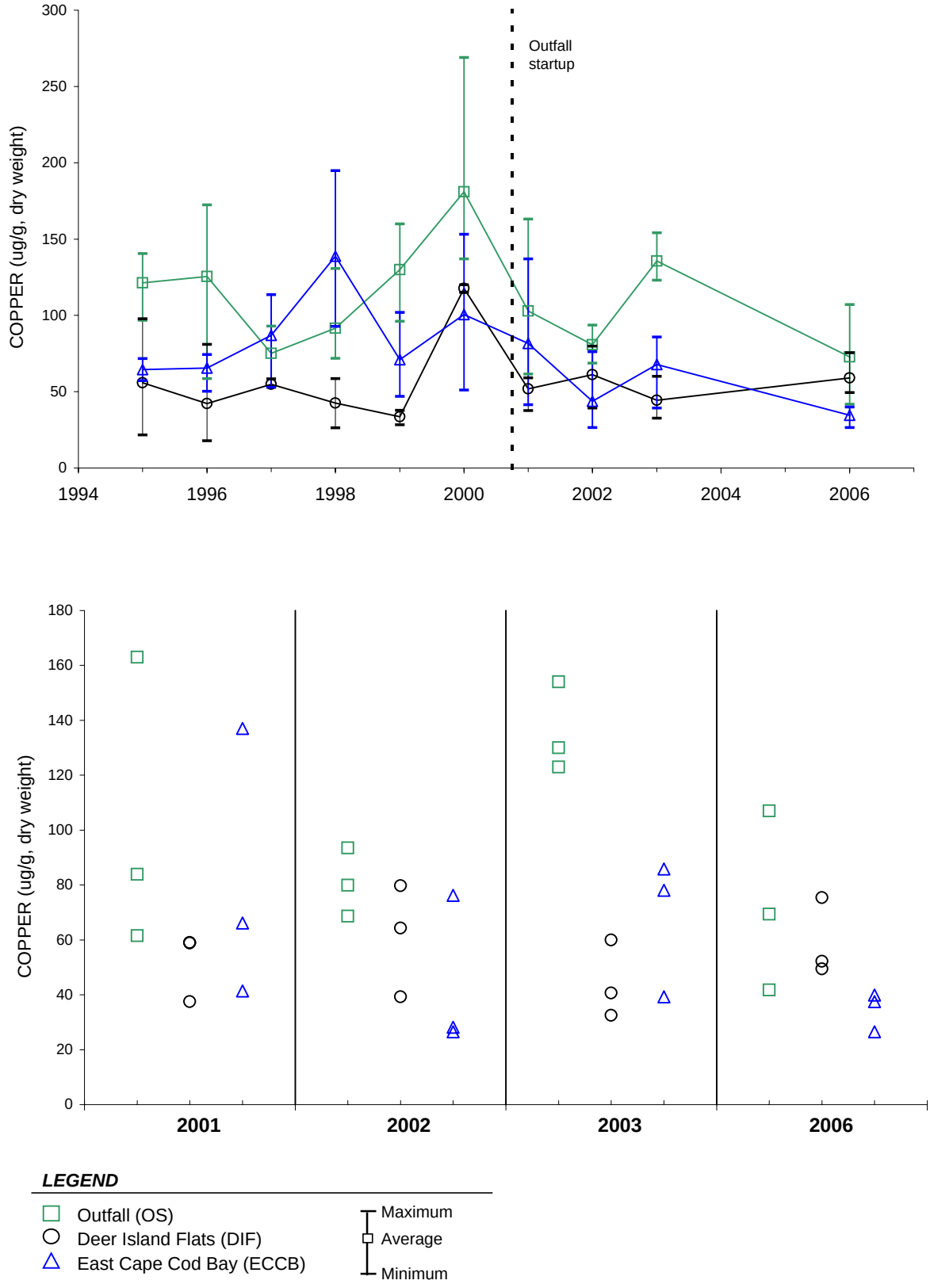



**Figure B-64. Copper concentrations in flounder liver tissue over time**

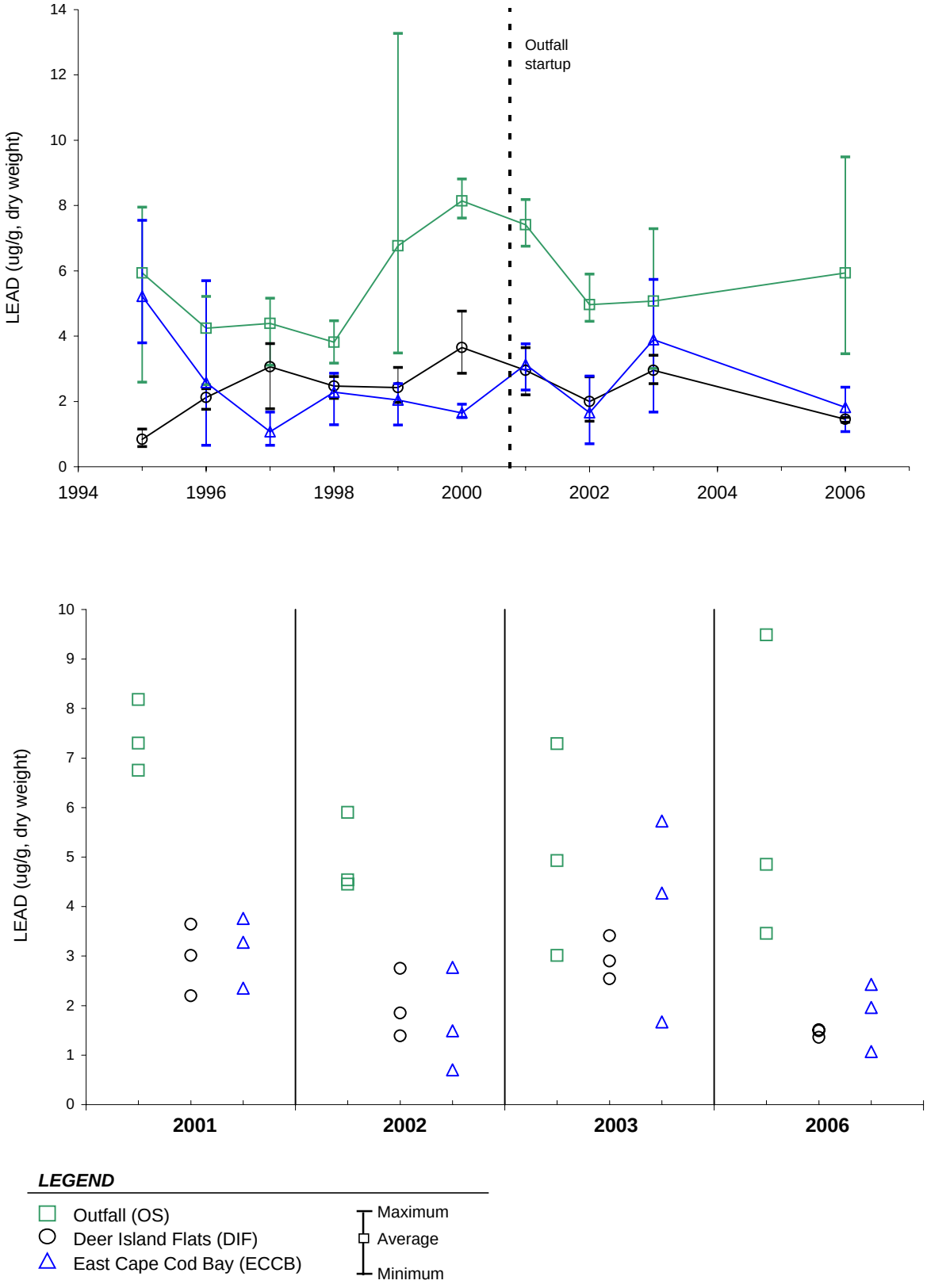



**Figure B-65. Lead concentrations in flounder liver tissue over time**

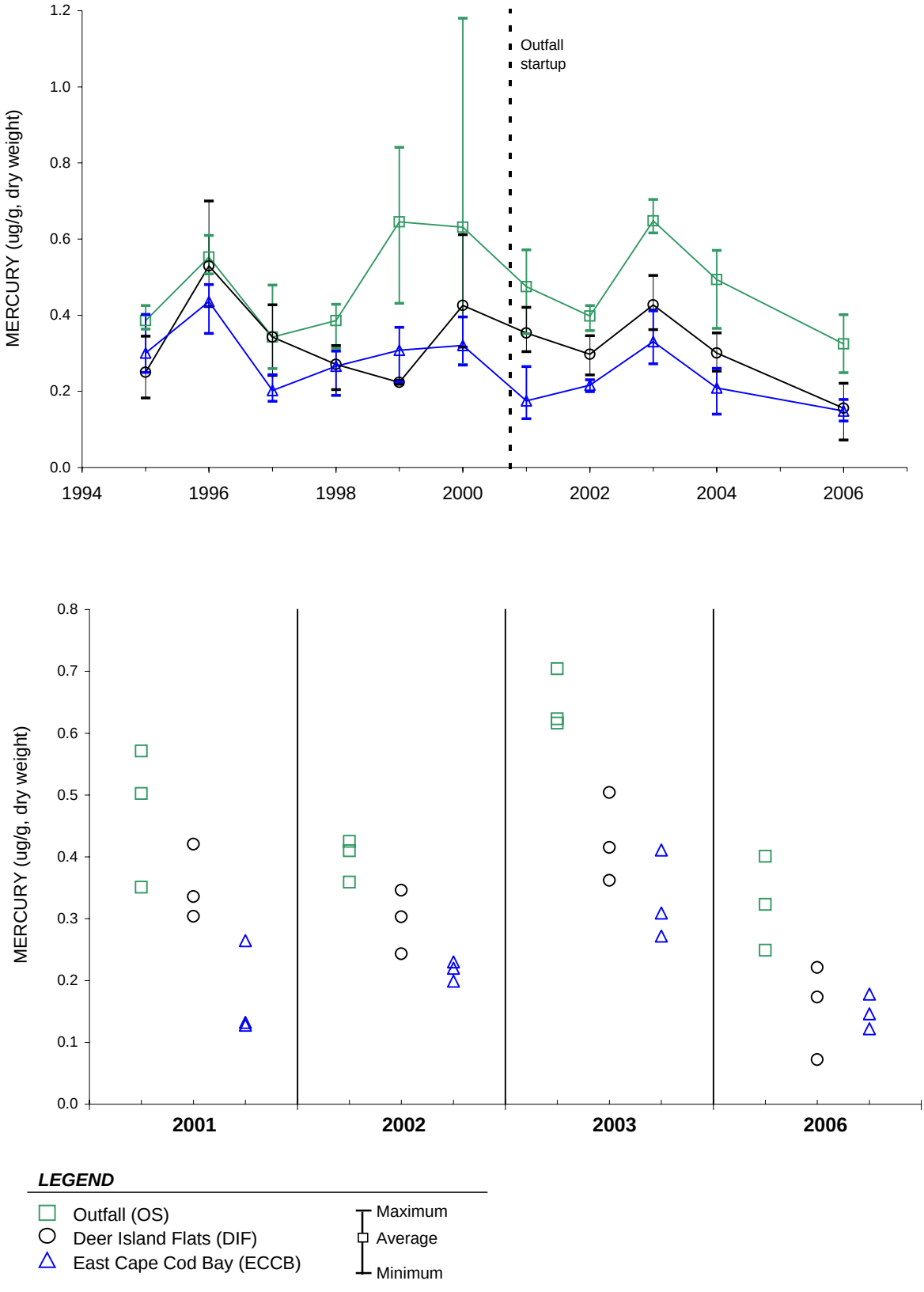



**Figure B-66. Mercury concentrations in flounder liver tissue over time**

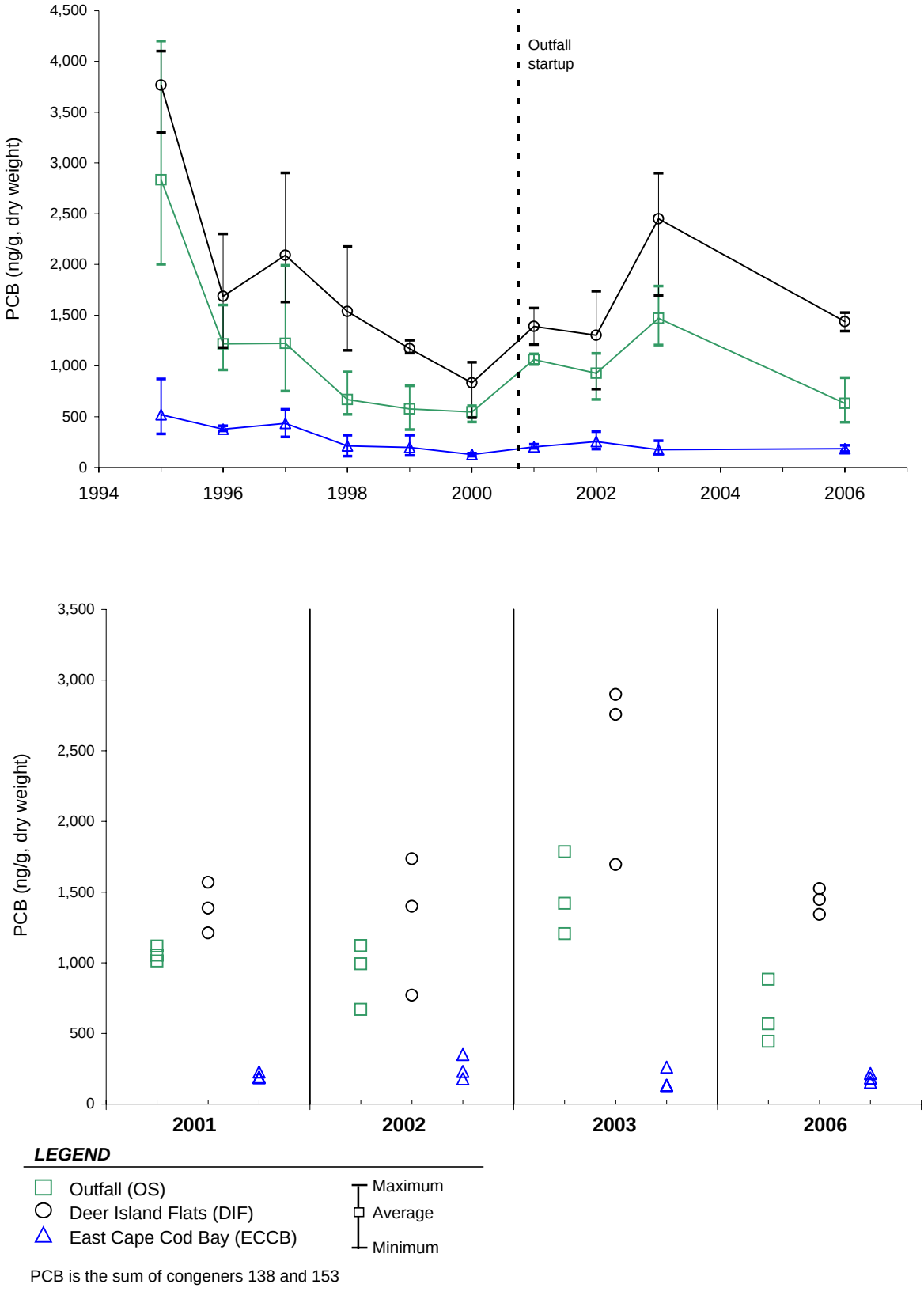
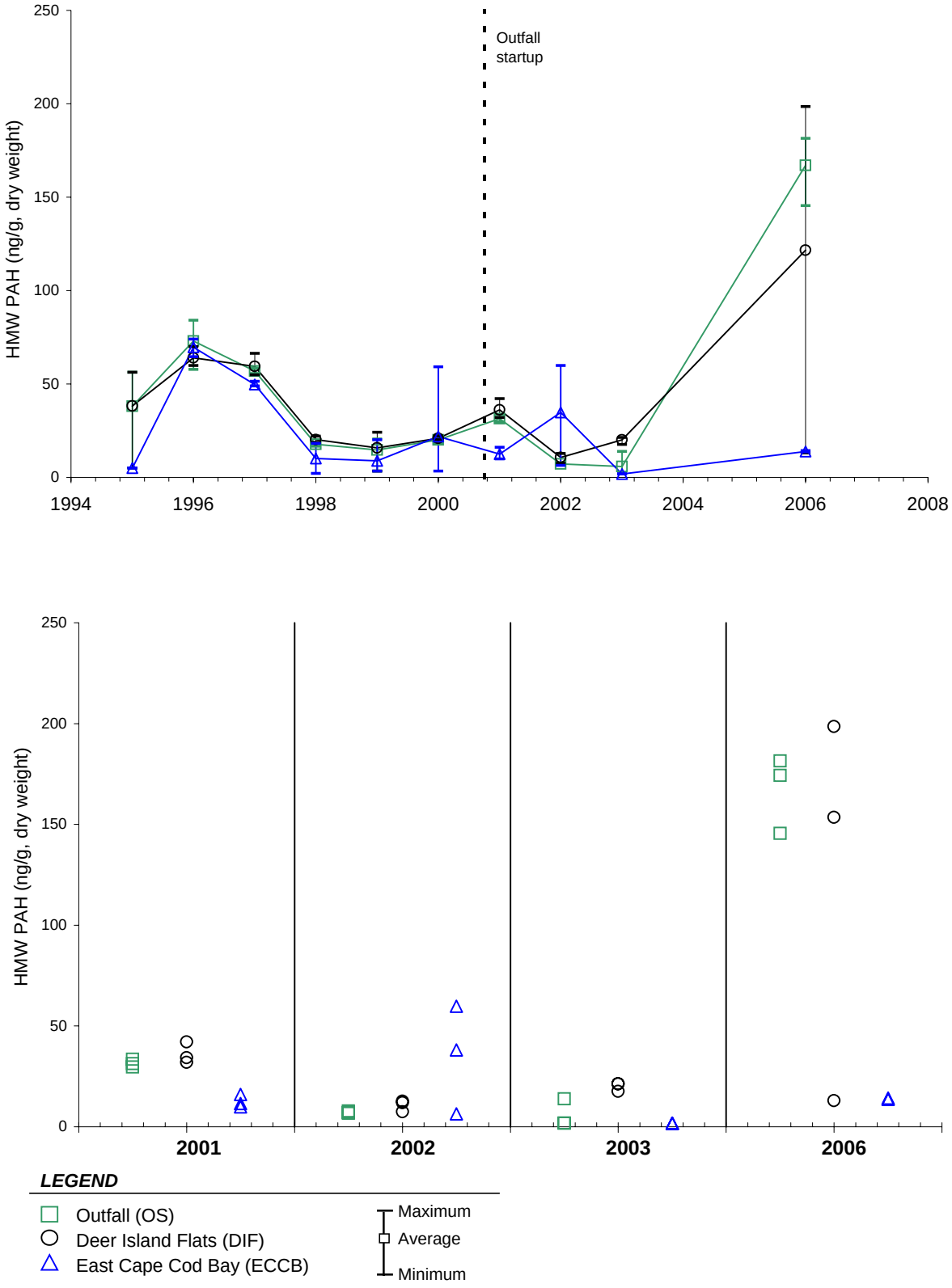
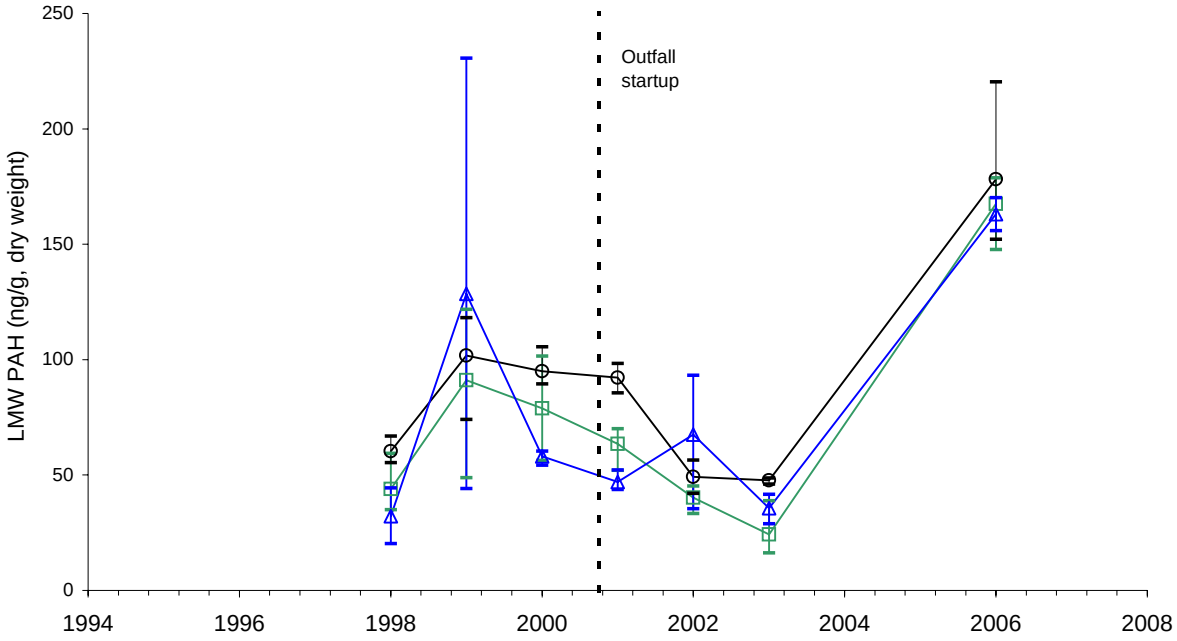


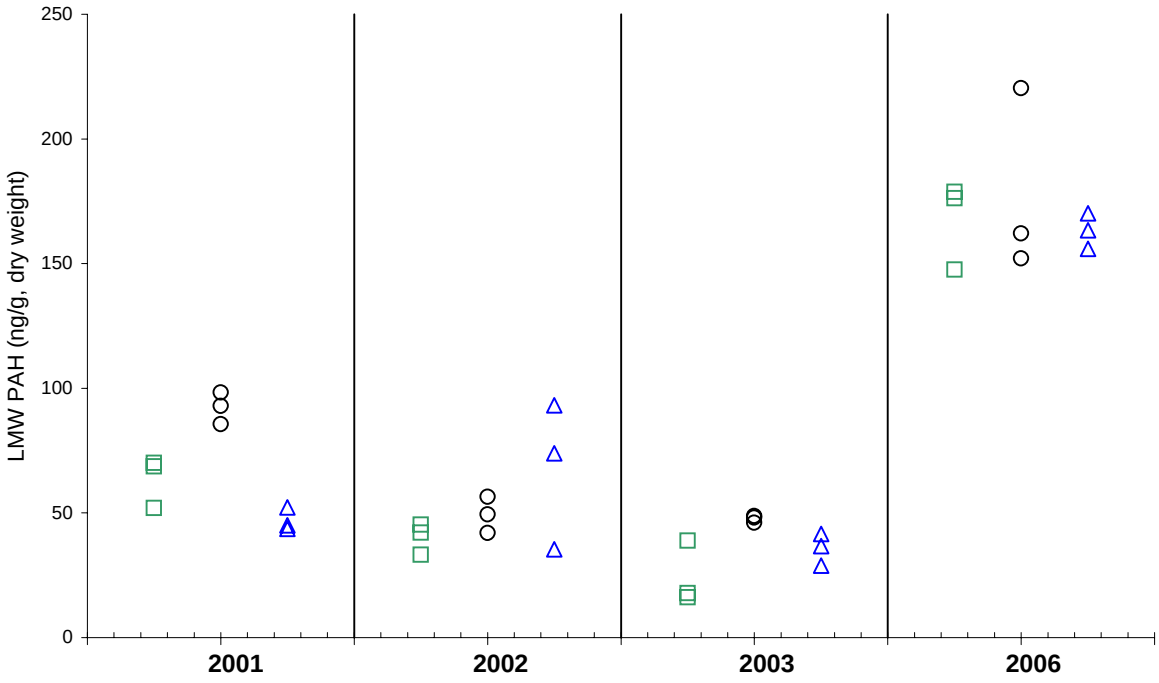

**Figure B-67. PCB concentrations in flounder liver tissue over time**




HMW PAH is the sum of the 12 HMW analytes on the historical NOAA list

**Figure B-68. High molecular weight (HMW) PAH concentrations in flounder liver tissue over time**



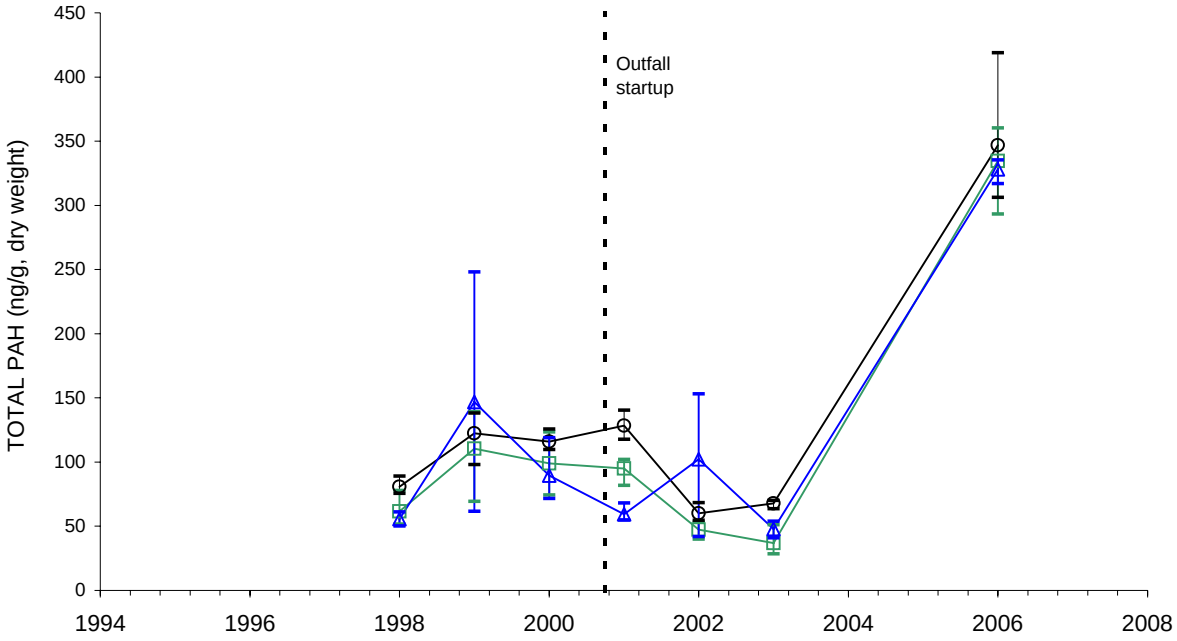



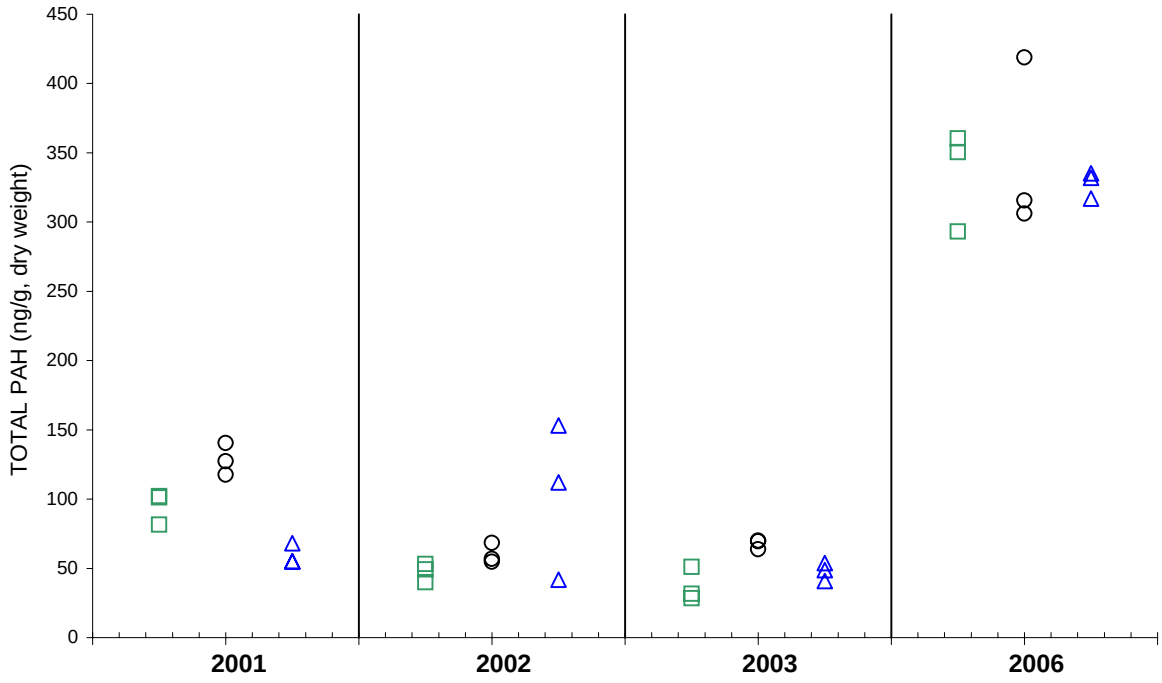

***LEGEND***

- Outfall (OS)
- Deer Island Flats (DIF)
- East Cape Cod Bay (ECCB)
- Maximum
- Average
- Minimum

LMW PAH is the sum of the 12 LMW analytes on the historical NOAA list

**Figure B-69. Low molecular weight (LMW) PAH concentrations in flounder liver tissue over time**



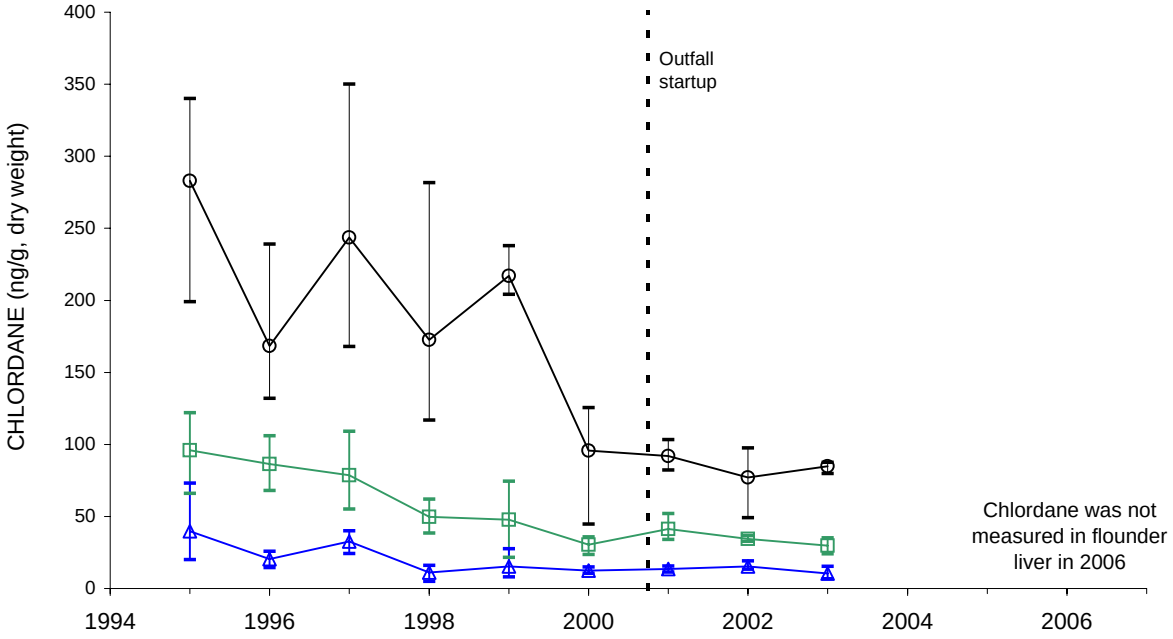




***LEGEND***

- Outfall (OS)
- Deer Island Flats (DIF)
- East Cape Cod Bay (ECCB)
- Maximum
- Average
- Minimum

Total PAH is the sum of the 24 (12 LMW and 12 HMW) analytes on the historical NOAA list

**Figure B-70. Total PAH concentrations in flounder liver tissue over time**



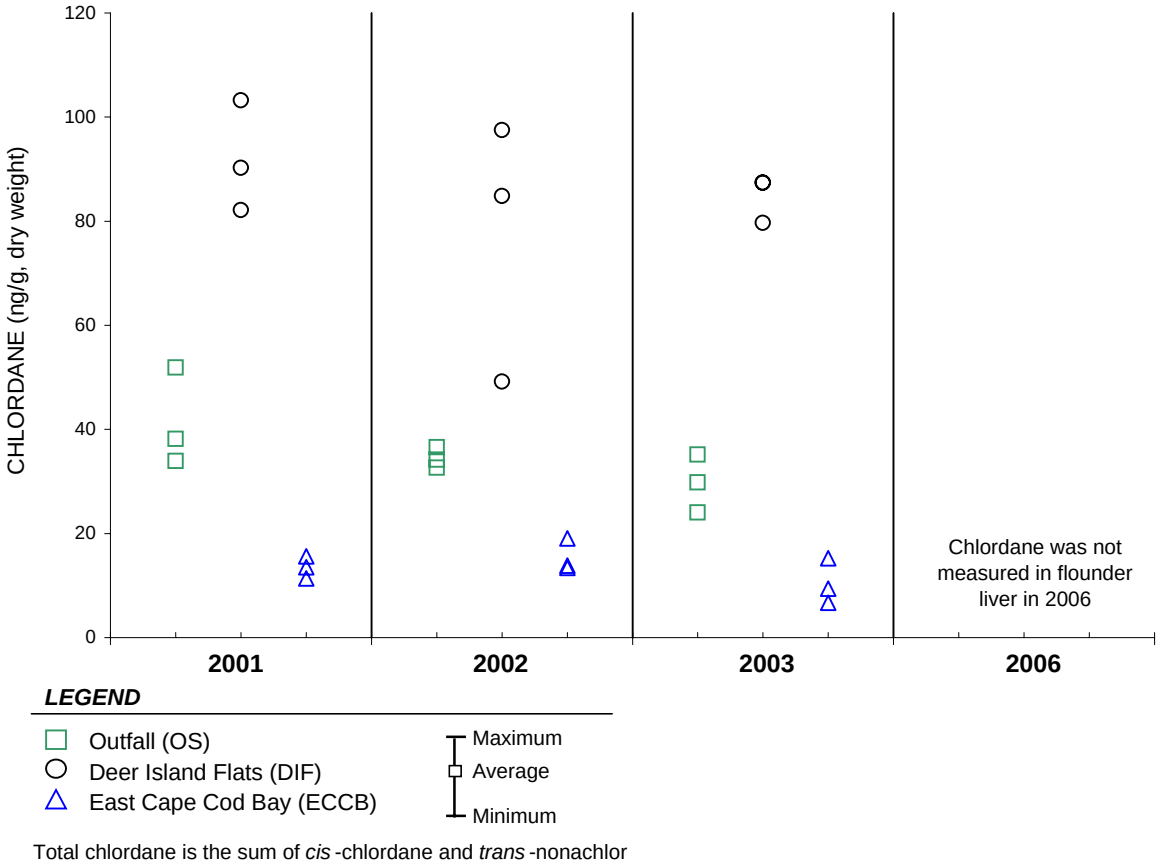
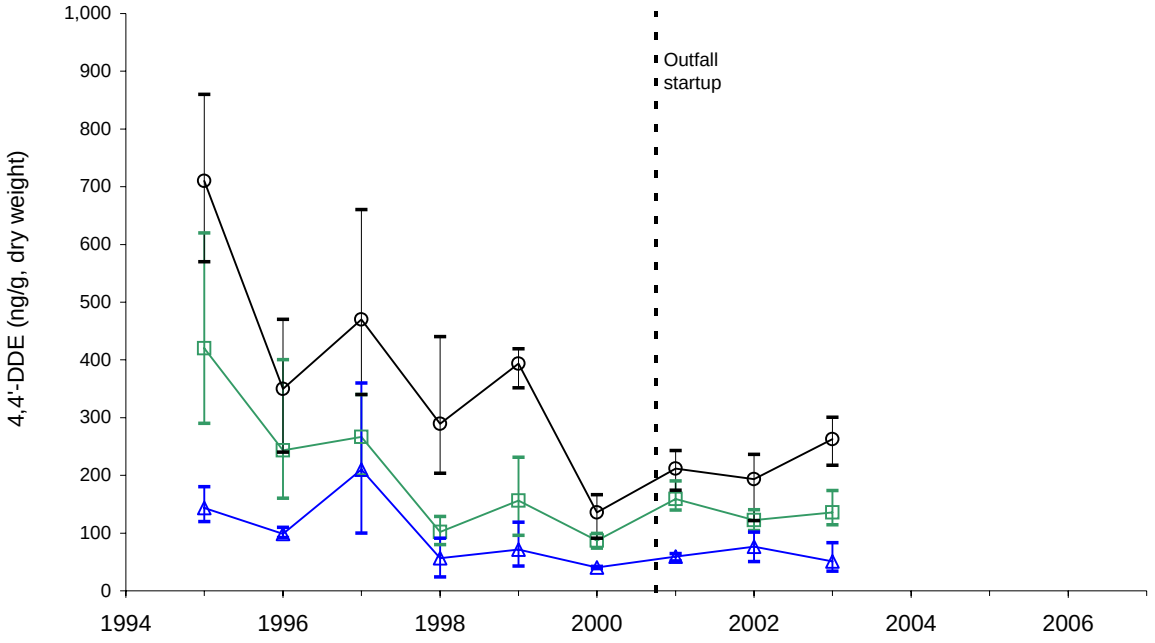
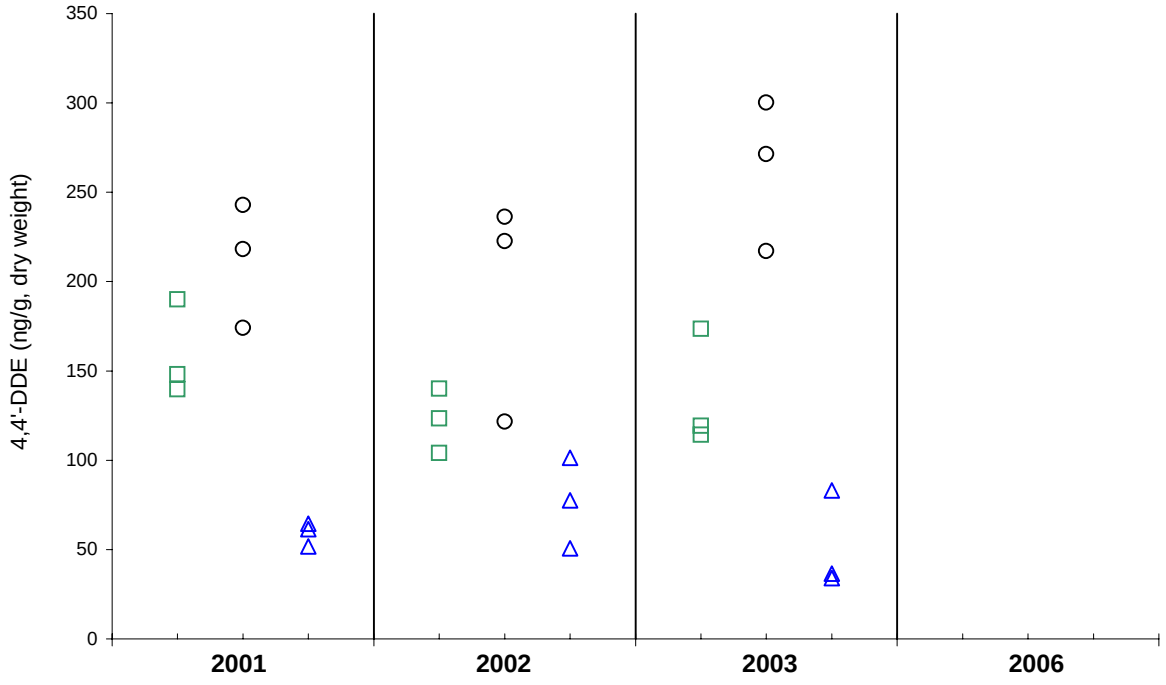




**Figure B-71. Chlordane concentrations in flounder liver tissue over time**




***LEGEND***

- Outfall (OS)
- Deer Island Flats (DIF)
- East Cape Cod Bay (ECCB)
- Maximum
- Average
- Minimum

Note: 2006 data not available due to analytical interference

**Figure B-72. 4,4'-DDE concentrations in flounder liver tissue over time**

# Tables

**Table B-1. Summary of BACI analysis of mussel soft tissue from the outfall and Cape Cod Bay locations**

**Before = 1998-2000**

| | | | | PAHs | | | | |
|---|---|---|---|---|---|---|---|---|
| | Lead | Mercury | PCBs | HMW | LMW (7) | Total (19) | Chlordane | 4,4'-DDE |
| ***P*-values for components of ANOVA model** | | | | | | | | |
| Before/After | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.6583 | 0.0002 |
| Control/Impact | 0.0486 | <0.0001 | 0.0948 | <0.0001 | 0.0383 | <0.0001 | <0.0001 | 0.0798 |
| Interaction term | 0.0054 | -- | 0.0004 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.0207 |
| Year within period | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **Conclusions from multiple comparison test** | | | | | | | | |
| Before/After | | | | | | | | |
| Main effect | NE | Aft > Bef | NE | NE | NE | NE | NE | NE |
| OS | Aft > Bef | NE | Aft > Bef | Aft > Bef | Bef > Aft | Aft > Bef | Aft > Bef | Aft > Bef |
| CCB | Aft > Bef | NE | -- | -- | Bef > Aft | Bef > Aft | Bef > Aft | -- |
| Control/Impact | | | | | | | | |
| Main effect | NE | OS > CCB | NE | NE | NE | NE | NE | NE |
| Before | -- | NE | -- | -- | CCB > OS | -- | -- | CCB > OS |
| After | OS > CCB | NE | OS > CCB | OS > CCB | OS > CCB | OS > CCB | OS > CCB | -- |
| OS-Before v. CCB-After | CCB > OS | NE | -- | -- | OS > CCB | OS > CCB | OS > CCB | CCB > OS |
| CCB-Before v. OS-After | OS > CCB | NE | OS > CCB | OS > CCB | CCB > OS | OS > CCB | OS > CCB | -- |

**Before = 1995-2000**

| | | | | PAHs | | | | |
|---|---|---|---|---|---|---|---|---|
| | Lead | Mercury | PCBs | HMW | LMW (7) | Total (19) | Chlordane | 4,4'-DDE |
| ***P*-values for components of ANOVA model** | | | | | | | | |
| Before/After | 0.0001 | <0.0001 | 0.1514 | <0.0001 | <0.0001 | <0.0001 | 0.8316 | 0.1556 |
| Control/Impact | 0.0448 | -- | 0.0825 | <0.0001 | 0.0330 | <0.0001 | <0.0001 | 0.0697 |
| Interaction term | 0.0046 | -- | 0.0002 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.0166 |
| Year within period | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **Conclusions from multiple comparison test** | | | | | | | | |
| Before/After | | | | | | | | |
| Main effect | NE | Aft > Bef | NE | NE | NE | NE | NE | NE |
| OS | Aft > Bef | NE | -- | Aft > Bef | Bef > Aft | Aft > Bef | Aft > Bef | -- |
| CCB | -- | NE | Bef > Aft | -- | Bef > Aft | Bef > Aft | Bef > Aft | -- |
| Control/Impact | | | | | | | | |
| Main effect | NE | -- | NE | NE | NE | NE | NE | NE |
| Before | -- | NE | -- | -- | CCB > OS | -- | -- | CCB > OS |
| After | OS > CCB | NE | OS > CCB | OS > CCB | OS > CCB | OS > CCB | OS > CCB | -- |
| OS-Before v. CCB-After | -- | NE | -- | -- | OS > CCB | OS > CCB | OS > CCB | -- |
| CCB-Before v. OS-After | OS > CCB | NE | -- | OS > CCB | CCB > OS | OS > CCB | OS > CCB | -- |

**Note:** Conclusions based on ANOVA followed by multiple comparison test at an overall 95 percent confidence level.
If the interaction term is significant, conclusions are based on the interaction comparisons rather than the main effects
*P*-values reported from the final ANOVA model.
-- - indicates no significant difference
NE - not evaluated due to significance of interaction term

BACI - Before-After-Control-Impact model
OS - Outfall location (includes stations OSM, OS-M1, OS-M2, OS-M3, OS-M4, OS-M5, and OS-M6)
CCB - Cape Cod Bay

PCB - Sum of congeners 138 and 153
Chlordane - Sum of *cis*-chlordane and *trans*-nonachlor
LMW PAH (7) - Sum of 7 low molecular weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene)
HMW PAH - Sum of 12 high molecular weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)
Total PAH (19) - Sum of LMW PAH and HMW PAH

**Table B-2. Summary of BACI analysis of mussel soft tissue from Deer Island Light and Cape Cod Bay locations**

**Before = 1998-2000**

| | | | | PAHs | | | | |
|---|---|---|---|---|---|---|---|---|
| | Lead | Mercury | PCBs | HMW | LMW (7) | Total (19) | Chlordane | 4,4'-DDE |
| ***P*-values for components of ANOVA model** | | | | | | | | |
| Before/After | 0.0134 | <0.0001 | 0.0103 | 0.4646 | <0.0001 | 0.0001 | <0.0001 | 0.0073 |
| Control/Impact | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Interaction term | -- | -- | <0.0001 | 0.0324 | -- | -- | 0.0213 | -- |
| Year within period | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **Conclusions from multiple comparison test** | | | | | | | | |
| Before/After | | | | | | | | |
| Main effect | Bef > Aft | Aft > Bef | NE | NE | Bef > Aft | Bef > Aft | NE | Bef > Aft |
| DIL | NE | NE | Aft > Bef | -- | NE | NE | Bef > Aft | NE |
| CCB | NE | NE | -- | -- | NE | NE | Bef > Aft | NE |
| Control/Impact | | | | | | | | |
| Main effect | DIL > CCB | DIL > CCB | NE | NE | DIL > CCB | DIL > CCB | NE | DIL > CCB |
| Before | NE | NE | DIL > CCB | DIL > CCB | NE | NE | DIL > CCB | NE |
| After | NE | NE | DIL > CCB | DIL > CCB | NE | NE | DIL > CCB | NE |
| DIL-Before v. CCB-After | NE | NE | DIL > CCB | DIL > CCB | NE | NE | DIL > CCB | NE |
| CCB-Before v. DIL-After | NE | NE | DIL > CCB | DIL > CCB | NE | NE | -- | NE |

**Before = 1995-2000**

| | | | | PAHs | | | | |
|---|---|---|---|---|---|---|---|---|
| | Lead | Mercury | PCBs | HMW | LMW (7) | Total (19) | Chlordane | 4,4'-DDE |
| ***P*-values for components of ANOVA model** | | | | | | | | |
| Before/After | <0.0001 | <0.0001 | 0.0323 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Control/Impact | <0.0001 | 0.0177 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Interaction term | -- | -- | <0.0001 | 0.0262 | -- | -- | 0.0162 | -- |
| Year within period | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **Conclusions from multiple comparison test** | | | | | | | | |
| Before/After | | | | | | | | |
| Main effect | Bef > Aft | Aft > Bef | NE | NE | Bef > Aft | Bef > Aft | NE | Bef > Aft |
| DIL | NE | NE | Aft > Bef | Bef > Aft | NE | NE | Bef > Aft | NE |
| CCB | NE | NE | Bef > Aft | -- | NE | NE | Bef > Aft | NE |
| Control/Impact | | | | | | | | |
| Main effect | DIL > CCB | DIL > CCB | NE | NE | DIL > CCB | DIL > CCB | NE | DIL > CCB |
| Before | NE | NE | DIL > CCB | DIL > CCB | NE | NE | DIL > CCB | NE |
| After | NE | NE | DIL > CCB | DIL > CCB | NE | NE | DIL > CCB | NE |
| DIL-Before v. CCB-After | NE | NE | DIL > CCB | DIL > CCB | NE | NE | DIL > CCB | NE |
| CCB-Before v. DIL-After | NE | NE | DIL > CCB | DIL > CCB | NE | NE | -- | NE |

**Note:** Conclusions based on ANOVA followed by multiple comparison test at an overall 95 percent confidence level.
If the interaction term is significant, conclusions are based on the interaction comparisons rather than the main effects
*P*-values reported from the final ANOVA model.
-- - indicates no significant difference
NE - not evaluated due to significance of interaction term

BACI - Before-After-Control-Impact model
DIL - Deer Island Light
CCB - Cape Cod Bay

PCB - Sum of congeners 138 and 153
Chlordane - Sum of *cis*-chlordane and *trans*-nonachlor
LMW PAH (7) - Sum of 7 low molecular weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene)
HMW PAH - Sum of 12 high molecular weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)
Total PAH (19) - Sum of LMW PAH and HMW PAH

**Table B-3. Summary of BACI analysis of mussel soft tissue from the Large Navigation Buoy and Cape Cod Bay locations**

**Before = 1998-2000**

| | | | | PAHs | | | | |
|---|---|---|---|---|---|---|---|---|
| | Lead | Mercury | PCBs | HMW | LMW (7) | Total (19) | Chlordane | 4,4'-DDE |
| ***P*-values for components of ANOVA model** | | | | | | | | |
| Before/After | <0.0001 | <0.0001 | 0.0001 | <0.0001 | <0.0001 | 0.0029 | <0.0001 | 0.2421 |
| Control/Impact | -- | 0.0256 | 0.5128 | <0.0001 | 0.4490 | <0.0001 | <0.0001 | 0.0001 |
| Interaction term | -- | 0.0051 | 0.0082 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | -- |
| Year within period | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **Conclusions from multiple comparison test** | | | | | | | | |
| Before/After | | | | | | | | |
| Main effect | Aft>Bef | NE | NE | NE | NE | NE | NE | -- |
| LNB | NE | Aft>Bef | Aft>Bef | Aft>Bef | Bef>Aft | Aft>Bef | Aft>Bef | NE |
| CCB | NE | Aft>Bef | -- | -- | Bef>Aft | Bef>Aft | Bef>Aft | NE |
| Control/Impact | | | | | | | | |
| Main effect | -- | NE | NE | NE | NE | NE | NE | CCB>LNB |
| Before | NE | LNB>CCB | -- | -- | CCB>LNB | -- | -- | NE |
| After | NE | -- | -- | LNB>CCB | LNB>CCB | LNB>CCB | LNB>CCB | NE |
| LNB-Before v. CCB-After | NE | CCB>LNB | CCB>LNB | -- | LNB>CCB | LNB>CCB | LNB>CCB | NE |
| CCB-Before v. LNB-After | NE | LNB>CCB | LNB>CCB | LNB>CCB | CCB>LNB | LNB>CCB | LNB>CCB | NE |

**Before = 1995-2000**

| | | | | PAHs | | | | |
|---|---|---|---|---|---|---|---|---|
| | Lead | Mercury | PCBs | HMW | LMW (7) | Total (19) | Chlordane | 4,4'-DDE |
| ***P*-values for components of ANOVA model** | | | | | | | | |
| Before/After | -- | 0.0129 | 0.0422 | <0.0001 | <0.0001 | 0.1227 | 0.0002 | 0.0002 |
| Control/Impact | -- | -- | 0.4936 | <0.0001 | 0.4373 | <0.0001 | <0.0001 | <0.0001 |
| Interaction term | -- | -- | 0.0057 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | -- |
| Year within period | <0.0001 | 0.0024 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **Conclusions from multiple comparison test** | | | | | | | | |
| Before/After | | | | | | | | |
| Main effect | -- | Aft>Bef | NE | NE | NE | NE | NE | Bef>Aft |
| LNB | NE | NE | -- | Aft>Bef | Bef>Aft | Aft>Bef | Aft>Bef | NE |
| CCB | NE | NE | Bef>Aft | -- | Bef>Aft | Bef>Aft | Bef>Aft | NE |
| Control/Impact | | | | | | | | |
| Main effect | -- | -- | NE | NE | NE | NE | NE | CCB>LNB |
| Before | NE | NE | -- | -- | CCB>LNB | -- | -- | NE |
| After | NE | NE | LNB>CCB | LNB>CCB | LNB>CCB | LNB>CCB | LNB>CCB | NE |
| LNB-Before v. CCB-After | NE | NE | -- | -- | LNB>CCB | LNB>CCB | LNB>CCB | NE |
| CCB-Before v. LNB-After | NE | NE | -- | LNB>CCB | CCB>LNB | LNB>CCB | LNB>CCB | NE |

**Note:** Conclusions based on ANOVA followed by multiple comparison test at an overall 95 percent confidence level.
If the interaction term is significant, conclusions are based on the interaction comparisons rather than the main effects
*P*-values reported from the final ANOVA model.
-- - indicates no significant difference
NE - not evaluated due to significance of interaction term

BACI - Before-After-Control-Impact model
LNB - Large navigation buoy
CCB - Cape Cod Bay

PCB - Sum of congeners 138 and 153
Chlordane - Sum of *cis*- chlordane and *trans*- nonachlor
LMW PAH (7) - Sum of 7 low molecular weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene)
HMW PAH - Sum of 12 high molecular weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)
Total PAH (19) - Sum of LMW PAH and HMW PAH

**Table B-4. Summary of station comparisons by year for mussel soft tissue**

| | 2001 | | | | 2002 | | | | 2003 | | | | 2006 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OS | DIL | CCB | IH | OS | DIL | CCB | IH | OS | DIL | CCB | IH | OS | DIL | CCB | IH |
| **Lead** | | | | | | | | | | | | | | | | |
| | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | |
| DIL | DIL | | | | DIL | | | | DIL | | | | DIL | | | |
| CCB | -- | DIL | | | OS | DIL | | | -- | DIL | | | -- | DIL | | |
| IH | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | | IH | -- | IH | |
| LNB | nd | nd | nd | nd | OS | DIL | -- | IH | -- | DIL | -- | IH | -- | DIL | -- | IH |
| **Mercury** | | | | | | | | | | | | | | | | |
| | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | 0.0086 | |
| DIL | -- | | | | -- | | | | -- | | | | -- | | | |
| CCB | OS | -- | | | OS | DIL | | | OS | -- | | | -- | -- | | |
| IH | -- | IH | IH | | IH | -- | IH | | IH | IH | IH | | IH | -- | -- | |
| LNB | nd | nd | nd | nd | OS | DIL | LNB | IH | OS | DIL | -- | IH | -- | -- | -- | IH |
| **PCB** | | | | | | | | | | | | | | | | |
| | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | |
| DIL | DIL | | | | DIL | | | | DIL | | | | DIL | | | |
| CCB | -- | DIL | | | OS | DIL | | | OS | DIL | | | CCB | DIL | | |
| IH | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | | IH | -- | IH | |
| LNB | OS | DIL | -- | IH | -- | DIL | LNB | IH | -- | DIL | LNB | IH | -- | DIL | -- | IH |
| **HMW PAH** | | | | | | | | | | | | | | | | |
| | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | |
| DIL | -- | | | | -- | | | | OS | | | | -- | | | |
| CCB | OS | DIL | | | OS | DIL | | | OS | DIL | | | OS | DIL | | |
| IH | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | |
| LNB | OS | DIL | LNB | IH | OS | -- | LNB | IH | OS | -- | LNB | IH | OS | -- | LNB | IH |
| **LMW PAH (12)** | | | | | | | | | | | | | | | | |
| | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | 0.0001 | |
| DIL | DIL | | | | -- | | | | -- | | | | -- | | | |
| CCB | -- | DIL | | | OS | DIL | | | OS | DIL | | | OS | DIL | | |
| IH | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | |
| LNB | -- | DIL | -- | IH | -- | -- | LNB | IH | OS | -- | LNB | IH | OS | -- | -- | IH |
| **Total PAH (24)** | | | | | | | | | | | | | | | | |
| | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | |
| DIL | -- | | | | -- | | | | OS | | | | -- | | | |
| CCB | OS | DIL | | | OS | DIL | | | OS | DIL | | | OS | DIL | | |
| IH | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | |
| LNB | OS | DIL | LNB | IH | OS | -- | LNB | IH | OS | -- | LNB | IH | OS | -- | LNB | IH |
| **Chlordane** | | | | | | | | | | | | | | | | |
| | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | 0.0002 | |
| DIL | OS | | | | OS | | | | OS | | | | -- | | | |
| CCB | OS | DIL | | | OS | DIL | | | OS | DIL | | | OS | DIL | | |
| IH | OS | IH | IH | | OS | IH | IH | | IH | IH | IH | | -- | -- | IH | |
| LNB | OS | LNB | LNB | -- | OS | LNB | LNB | -- | OS | -- | LNB | IH | -- | -- | -- | IH |
| **4,4'-DDE** | | | | | | | | | | | | | | | | |
| | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | <0.0001 | | *P*-value = | | 0.0001 | |
| DIL | DIL | | | | -- | | | | DIL | | | | DIL | | | |
| CCB | CCB | DIL | | | OS | DIL | | | -- | DIL | | | -- | -- | | |
| IH | IH | IH | IH | | IH | IH | IH | | IH | IH | IH | | IH | -- | -- | |
| LNB | OS | DIL | CCB | IH | -- | DIL | LNB | IH | -- | DIL | -- | IH | -- | DIL | -- | IH |

*Notes on following page.*

**Table B-4. (cont.)**

**Note:** *P*-value is from the ANOVA model. Tukey's multiple comparison test was used to test for pariwise differences between locations at an overall 95 percent confidence level.
Location abreviation indicates location has significantly higher concentration.
-- - indicates no significant difference in concentration between locations
nd - no data available

OS - outfall location (includes stations OSM, OS-M1, OS-M2, OS-M3, OS-M4, OS-M5, and OS-M6)
DIL - Deer Island Light
CCB - Cape Cod Bay
IH - Boston inner harbor
LNB - Large navigation buoy

PCB - Sum of congeners 138 and 153
Chlordane - Sum of *cis*-chlordane and *trans*-nonachlor
LMW PAH (12) - Sum of 12 low molecular weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene, 1-methylnaphthalene, 1-methylphenanthrene, 2,3,5-triethylnaphthalene, 2,6-dimethylnaphthalene, and 2-methylnaphthalene)
HMW PAH - Sum of 12 high molecular weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)
Total PAH (24) - Sum of LMW PAH and HMW PAH

## Table B-5. Summary of BACI analysis of edible lobster meat from the outfall and East Cape Cod Bay locations

**Before = 1998-2000**

| | Mercury | PCBs | Chlordane | 4,4'-DDE |
|---|---|---|---|---|
| ***P*-values for components of ANOVA model** | | | | |
| Before/After | <0.0001 | -- | 0.0010 | 0.0512 |
| Control/Impact | <0.0001 | 0.0003 | -- | -- |
| Interaction term | -- | -- | -- | -- |
| Year within period | <0.0001 | -- | -- | <0.0001 |
| **Conclusions from multiple comparison test** | | | | |
| Before/After | | | | |
| Main effect | Bef > Aft | -- | Bef > Aft | -- |
| OS | NE | NE | NE | NE |
| ECCB | NE | NE | NE | NE |
| Control/Impact | | | | |
| Main effect | OS > ECCB | OS > ECCB | -- | -- |
| Before | NE | NE | NE | NE |
| After | NE | NE | NE | NE |
| OS-Before v. ECCB-After | NE | NE | NE | NE |
| ECCB-Before v. OS-After | NE | NE | NE | NE |

**Before = 1995-2000**

| | Mercury | PCBs | Chlordane | 4,4'-DDE |
|---|---|---|---|---|
| ***P*-values for components of ANOVA model** | | | | |
| Before/After | <0.0001 | 0.0009 | <0.0001 | <0.0001 |
| Control/Impact | <0.0001 | <0.0001 | 0.1104 | -- |
| Interaction term | -- | -- | 0.0329 | -- |
| Year within period | <0.0001 | 0.0014 | 0.0096 | <0.0001 |
| **Conclusions from multiple comparison test** | | | | |
| Before/After | | | | |
| Main effect | Bef > Aft | Bef > Aft | NE | Bef > Aft |
| OS | NE | NE | Bef > Aft | NE |
| ECCB | NE | NE | -- | NE |
| Control/Impact | | | | |
| Main effect | OS > ECCB | OS > ECCB | NE | -- |
| Before | NE | NE | OS > ECCB | NE |
| After | NE | NE | -- | NE |
| OS-Before v. ECCB-After | NE | NE | OS > ECCB | NE |
| ECCB-Before v. OS-After | NE | NE | ECCB > OS | NE |

**Note:** Conclusions based on ANOVA followed by multiple comparison test at an overall 95 percent confidence level.

If the interaction term is significant, conclusions are based on the interaction comparisons rather than the main effects

*P*-values reported from the final ANOVA model.

-- - indicates no significant difference

NE - not evaluated due to significance of interaction term

BACI - Before-After-Control-Impact model

OS - Outfall location

ECCB - East Cape Cod Bay

PCB - Sum of congeners 138 and 153

Chlordane - Sum of *cis*- chlordane and *trans*- nonachlor

**Table B-6. Summary of BACI analysis of lobster hepatopancreas from the outfall and East Cape Cod Bay locations**

**Before = 1998-2000**

| | | | | | | PAHs | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Cadmium | Copper | Lead | Mercury | PCBs | HMW | LMW (7) | Total (19) | Chlordane | 4,4'-DDE |
| ***P*-values for components of ANOVA model** | | | | | | | | | | |
| Before/After | -- | -- | 0.0972 | <0.0001 | 0.0079 | -- | 0.0784 | -- | 0.0350 | 0.0024 |
| Control/Impact | 0.0022 | <0.0001 | 0.0030 | <0.0001 | <0.0001 | 0.0001 | 0.0028 | 0.0001 | 0.0102 | -- |
| Interaction term | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Year within period | -- | -- | 0.0424 | 0.0027 | 0.0009 | -- | 0.0295 | -- | 0.0006 | <0.0001 |
| **Conclusions from multiple comparison test** | | | | | | | | | | |
| Before/After | | | | | | | | | | |
| Main effect | -- | -- | -- | Bef > Aft | Bef > Aft | -- | -- | -- | Bef > Aft | Bef > Aft |
| OS | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| ECCB | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| Control/Impact | | | | | | | | | | |
| Main effect | OS > ECCB | OS > ECCB | OS > ECCB | OS > ECCB | OS > ECCB | OS > ECCB | OS > ECCB | OS > ECCB | OS > ECCB | -- |
| Before | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| After | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| OS-Before v. ECCB-After | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| ECCB-Before v. OS-After | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |

**Before = 1995-2000**

| | | | | | | PAHs | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Cadmium | Copper | Lead | Mercury | PCBs | HMW | LMW (7) | Total (19) | Chlordane | 4,4'-DDE |
| ***P*-values for components of ANOVA model** | | | | | | | | | | |
| Before/After | 0.0201 | 0.0001 | 0.0461 | 0.0001 | 0.0026 | 0.0351 | 0.0001 | 0.0116 | 0.0296 | <0.0001 |
| Control/Impact | -- | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | -- | <0.0001 | -- | -- |
| Interaction term | -- | -- | 0.0405 | -- | -- | -- | -- | -- | -- | -- |
| Year within period | 0.0068 | <0.0001 | 0.0001 | 0.0004 | 0.0003 | 0.0020 | 0.0002 | 0.0007 | 0.0414 | <0.0001 |
| **Conclusions from multiple comparison test** | | | | | | | | | | |
| Before/After | | | | | | | | | | |
| Main effect | Aft > Bef | Aft > Bef | NE | Bef > Aft | Bef > Aft | Bef > Aft | Bef > Aft | Bef > Aft | Bef > Aft | Bef > Aft |
| OS | NE | NE | -- | NE | NE | NE | NE | NE | NE | NE |
| ECCB | NE | NE | Aft > Bef | NE | NE | NE | NE | NE | NE | NE |
| Control/Impact | | | | | | | | | | |
| Main effect | -- | OS > ECCB | NE | OS > ECCB | OS > ECCB | OS > ECCB | -- | OS > ECCB | -- | -- |
| Before | NE | NE | OS > ECCB | NE | NE | NE | NE | NE | NE | NE |
| After | NE | NE | -- | NE | NE | NE | NE | NE | NE | NE |
| OS-Before v. ECCB-After | NE | NE | -- | NE | NE | NE | NE | NE | NE | NE |
| ECCB-Before v. OS-After | NE | NE | OS > ECCB | NE | NE | NE | NE | NE | NE | NE |

*Notes on following page.*

**Table B-6. (cont.)**

**Note:** Conclusions based on ANOVA followed by multiple comparison test at an overall 95 percent confidence level.
If the interaction term is significant, conclusions are based on the interaction comparisons rather than the main effects
*P*-values reported from the final ANOVA model.
-- - indicates no significant difference
NE - not evaluated due to significance of interaction term

BACI - Before-After-Control-Impact model
OS - Outfall location
ECCB - East Cape Cod Bay

PCB - Sum of congeners 138 and 153
Chlordane - Sum of cis-chlordane and *trans*-nonachlor
LMW PAH (7) - Sum of 7 low molecular weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene)
HMW PAH - Sum of 12 high molecular weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)
Total PAH (19) - Sum of LMW PAH and HMW PAH

**Table B-7. Summary of station comparisons by year for edible lobster meat**

| | 2001 | | 2002 | | 2003 | | 2006 | |
|---|---|---|---|---|---|---|---|---|
| | OS | DIF | OS | DIF | OS | DIF | OS | DIF |
| **Mercury** | | | | | | | | |
| | *P*-value = 0.0040 | | *P*-value = 0.1545 | | *P*-value = 0.0076 | | *P*-value = 0.0060 | |
| DIF | -- | | -- | | -- | | -- | |
| ECCB | OS | DIF | -- | -- | OS | DIF | OS | DIF |
| **PCB** | | | | | | | | |
| | *P*-value = 0.1370 | | *P*-value = 0.0238 | | *P*-value = 0.0548 | | *P*-value = 0.0359 | |
| DIF | -- | | -- | | -- | | -- | |
| ECCB | -- | -- | -- | DIF | -- | -- | -- | DIF |
| **Chlordane** | | | | | | | | |
| | *P*-value = 0.0048 | | *P*-value = 0.0102 | | *P*-value = 0.0001 | | *P*-value = 0.0013 | |
| DIF | -- | | -- | | DIF | | DIF | |
| ECCB | OS | DIF | -- | DIF | OS | DIF | ECCB | -- |
| **4,4'-DDE** | | | | | | | | |
| | *P*-value = 0.9982 | | *P*-value = 0.0595 | | *P*-value = 0.0091 | | *P*-value = 0.0047 | |
| DIF | -- | | -- | | DIF | | -- | |
| ECCB | -- | -- | -- | -- | -- | DIF | OS | DIF |

**Note:** *P*-value is from the ANOVA model. Tukey's multiple comparison test was used to test for pariwise differences between locations at an overall 95 percent confidence level.
Location abreviation indicates location has significantly higher concentration.
-- - indicates no significant difference in concentration between locations

OS - outfall location
DIF - Deer Island Flats
ECCB - East Cape Cod Bay

PCB - Sum of congeners 138 and 153
Chlordane - Sum of *cis*- chlordane and *trans*- nonachlor

**Table B-8. Summary of station comparisons by year for lobster hepatopancreas**

| | 2001 | | 2002 | | 2003 | | 2006 | |
|---|---|---|---|---|---|---|---|---|
| | OS | DIF | OS | DIF | OS | DIF | OS | DIF |
| **Cadmium** | | | | | | | | |
| | *P*-value = 0.0019 | | *P*-value = 0.4837 | | *P*-value = 0.8189 | | *P*-value = 0.0244 | |
| DIF | OS | | -- | | -- | | OS | |
| ECCB | -- | ECCB | -- | -- | -- | -- | -- | -- |
| **Copper** | | | | | | | | |
| | *P*-value = 0.3682 | | *P*-value = 0.0150 | | *P*-value = 0.0233 | | *P*-value = 0.0550 | |
| DIF | -- | | -- | | -- | | -- | |
| ECCB | -- | -- | OS | DIF | OS | -- | OS | -- |
| **Lead** | | | | | | | | |
| | *P*-value = 0.7932 | | *P*-value = 0.5357 | | *P*-value = 0.2521 | | *P*-value = 0.0028 | |
| DIF | -- | | -- | | -- | | -- | |
| ECCB | -- | -- | -- | -- | -- | -- | OS | DIF |
| **Mercury** | | | | | | | | |
| | *P*-value = 0.2691 | | *P*-value = 0.0519 | | *P*-value = 0.0005 | | *P*-value = 0.0062 | |
| DIF | -- | | -- | | -- | | OS | |
| ECCB | -- | -- | -- | -- | OS | DIF | OS | -- |
| **PCB** | | | | | | | | |
| | *P*-value = 0.0184 | | *P*-value = 0.0009 | | *P*-value = 0.0224 | | *P*-value = 0.1116 | |
| DIF | -- | | DIF | | -- | | -- | |
| ECCB | -- | DIF | OS | DIF | -- | DIF | -- | -- |
| **HMW PAH** | | | | | | | | |
| | *P*-value = 0.0097 | | *P*-value = 0.0115 | | *P*-value = 0.0001 | | *P*-value = 0.0013 | |
| DIF | DIF | | -- | | -- | | DIF | |
| ECCB | -- | DIF | -- | DIF | OS | DIF | -- | DIF |
| **LMW PAH (12)** | | | | | | | | |
| | *P*-value = 0.0001 | | *P*-value = 0.0210 | | *P*-value = 0.0001 | | *P*-value = 0.0044 | |
| DIF | DIF | | -- | | OS | | DIF | |
| ECCB | OS | DIF | -- | DIF | OS | DIF | -- | DIF |
| **Total PAH (24)** | | | | | | | | |
| | *P*-value = 0.0104 | | *P*-value = 0.0098 | | *P*-value = 0.0001 | | *P*-value = 0.0013 | |
| DIF | DIF | | -- | | -- | | DIF | |
| ECCB | -- | DIF | -- | DIF | OS | DIF | -- | DIF |
| **Chlordane** | | | | | | | | |
| | *P*-value = 0.0002 | | *P*-value = 0.0018 | | *P*-value = 0.1075 | | *P*-value = 0.0888 | |
| DIF | DIF | | -- | | -- | | -- | |
| ECCB | OS | DIF | OS | DIF | -- | -- | -- | -- |
| **4,4'-DDE** | | | | | | | | |
| | *P*-value = 0.0861 | | *P*-value = 0.0066 | | *P*-value = 0.0001 | | *P*-value = 0.0249 | |
| DIF | -- | | -- | | DIF | | DIF | |
| ECCB | -- | -- | -- | DIF | -- | DIF | -- | -- |

*Notes on following page.*

**Table B-8. (cont.)**

**Note:** *P*-value is from the ANOVA model. Tukey's multiple comparison test was used to test for pariwise differences between locations at an overall 95 percent confidence level.
Location abreviation indicates location has significantly higher concentration.
-- - indicates no significant difference in concentration between locations

OS - outfall location
DIF - Deer Island Flats
ECCB - East Cape Cod Bay

PCB - Sum of congeners 138 and 153
Chlordane - Sum of *cis*-chlordane and *trans*-nonachlor
LMW PAH (12) - Sum of 12 low molecular weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene, 1-methylnaphthalene, 1-methylphenanthrene, 2,3,5-triethylnaphthalene, 2,6-dimethylnaphthalene, and 2-methylnaphthalene)
HMW PAH - Sum of 12 high molecular weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)
Total PAH (24) - Sum of LMW PAH and HMW PAH

## Table B-9. Summary of BACI analysis of flounder fillet from the outfall and East Cape Cod Bay locations

**Before = 1998-2000**

| | Mercury | PCBs | Chlordane | 4,4'-DDE |
|---|---|---|---|---|
| ***P*-values for components of ANOVA model** | | | | |
| Before/After | 0.0478 | 0.1973 | 0.0041 | 0.1622 |
| Control/Impact | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Interaction term | -- | -- | -- | -- |
| Year within period | 0.0006 | 0.0096 | -- | 0.0017 |
| **Conclusions from multiple comparison test** | | | | |
| Before/After | | | | |
| Main effect | Aft > Bef | -- | Bef > Aft | -- |
| OS | NE | NE | NE | NE |
| ECCB | NE | NE | NE | NE |
| Control/Impact | | | | |
| Main effect | OS > ECCB | OS > ECCB | OS > ECCB | OS > ECCB |
| Before | NE | NE | NE | NE |
| After | NE | NE | NE | NE |
| OS-Before v. ECCB-After | NE | NE | NE | NE |
| ECCB-Before v. OS-After | NE | NE | NE | NE |

**Before = 1995-2000**

| | Mercury | PCBs | Chlordane | 4,4'-DDE |
|---|---|---|---|---|
| ***P*-values for components of ANOVA model** | | | | |
| Before/After | 0.0850 | 0.0921 | <0.0001 | <0.0001 |
| Control/Impact | 0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Interaction term | -- | -- | -- | -- |
| Year within period | 0.0413 | <0.0001 | 0.0027 | <0.0001 |
| **Conclusions from multiple comparison test** | | | | |
| Before/After | | | | |
| Main effect | -- | -- | Bef > Aft | Bef > Aft |
| OS | NE | NE | NE | NE |
| ECCB | NE | NE | NE | NE |
| Control/Impact | | | | |
| Main effect | OS > ECCB | OS > ECCB | OS > ECCB | OS > ECCB |
| Before | NE | NE | NE | NE |
| After | NE | NE | NE | NE |
| OS-Before v. ECCB-After | NE | NE | NE | NE |
| ECCB-Before v. OS-After | NE | NE | NE | NE |

**Note:** Conclusions based on ANOVA followed by multiple comparison test at an overall 95 percent confidence level.

If the interaction term is significant, conclusions are based on the interaction comparisons rather than the main effects

*P*-values reported from the final ANOVA model.

-- - indicates no significant difference

NE - not evaluated due to significance of interaction term

BACI - Before-After-Control-Impact model

OS - Outfall location

ECCB - East Cape Cod Bay

PCB - Sum of congeners 138 and 153

Chlordane - Sum of *cis*-chlordane and *trans*-nonachlor

**Table B-10. Summary of BACI analysis of flounder liver from the outfall and East Cape Cod Bay locations**

**Before = 1998-2000**

| | | | | | | PAHs | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Cadmium | Copper | Lead | Mercury | PCBs | HMW | LMW (7) | Total (19) | Chlordane | 4,4'-DDE |
| ***P*-values for components of ANOVA model** | | | | | | | | | | |
| Before/After | -- | 0.0023 | -- | 0.0104 | 0.0041 | 0.4416 | 0.0918 | 0.4057 | -- | -- |
| Control/Impact | -- | 0.0021 | <0.0001 | <0.0001 | <0.0001 | 0.0137 | -- | -- | <0.0001 | <0.0001 |
| Interaction term | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Year within period | -- | -- | -- | 0.0028 | -- | 0.0002 | <0.0001 | <0.0001 | -- | -- |
| **Conclusions from multiple comparison test** | | | | | | | | | | |
| Before/After | | | | | | | | | | |
| Main effect | -- | Bef > Aft | -- | Bef > Aft | Aft > Bef | -- | -- | -- | -- | -- |
| OS | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| ECCB | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| Control/Impact | | | | | | | | | | |
| Main effect | -- | OS > ECCB | OS > ECCB | OS > ECCB | OS > ECCB | OS > ECCB | -- | -- | OS > ECCB | OS > ECCB |
| Before | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| After | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| OS-Before v. ECCB-After | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| ECCB-Before v. OS-After | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |

**Before = 1995-2000**

| | | | | | | PAHs | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Cadmium | Copper | Lead | Mercury | PCBs | HMW | LMW (7) | Total (19) | Chlordane | 4,4'-DDE |
| ***P*-values for components of ANOVA model** | | | | | | | | | | |
| Before/After | 0.0142 | 0.0041 | -- | 0.0067 | 0.1508 | 0.1103 | <0.0001 | 0.0001 | 0.0001 | 0.0054 |
| Control/Impact | 0.0257 | 0.0003 | <0.0001 | <0.0001 | <0.0001 | 0.0026 | -- | -- | <0.0001 | <0.0001 |
| Interaction term | -- | -- | -- | 0.0096 | -- | -- | -- | -- | -- | -- |
| Year within period | -- | -- | -- | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **Conclusions from multiple comparison test** | | | | | | | | | | |
| Before/After | | | | | | | | | | |
| Main effect | Aft > Bef | Bef > Aft | -- | NE | -- | -- | Bef > Aft | Bef > Aft | Bef > Aft | Bef > Aft |
| OS | NE | NE | NE | -- | NE | NE | NE | NE | NE | NE |
| ECCB | NE | NE | NE | Bef > Aft | NE | NE | NE | NE | NE | NE |
| Control/Impact | | | | | | | | | | |
| Main effect | OS > ECCB | OS > ECCB | OS > ECCB | NE | OS > ECCB | OS > ECCB | -- | -- | OS > ECCB | OS > ECCB |
| Before | NE | NE | NE | OS > ECCB | NE | NE | NE | NE | NE | NE |
| After | NE | NE | NE | OS > ECCB | NE | NE | NE | NE | NE | NE |
| OS-Before v. ECCB-After | NE | NE | NE | OS > ECCB | NE | NE | NE | NE | NE | NE |
| ECCB-Before v. OS-After | NE | NE | NE | OS > ECCB | NE | NE | NE | NE | NE | NE |

*Notes on following page.*

**Table B-10. (cont.)**

**Note:** Conclusions based on ANOVA followed by multiple comparison test at an overall 95 percent confidence level.
If the interaction term is significant, conclusions are based on the interaction comparisons rather than the main effects
*P* -values reported from the final ANOVA model.
-- - indicates no significant difference
NE - not evaluated due to significance of interaction term

BACI - Before-After-Control-Impact model
OS - Outfall location
ECCB - East Cape Cod Bay

PCB - Sum of congeners 138 and 153
Chlordane - Sum of *cis*- chlordane and *trans*- nonachlor
LMW PAH (7) - Sum of 7 low molecular weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene)
HMW PAH - Sum of 12 high molecular weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)
Total PAH (19) - Sum of LMW PAH and HMW PAH

**Table B-11. Summary of station comparisons by year for flounder fillet**

| | 2001 | | 2002 | | 2003 | | 2006 | |
|---|---|---|---|---|---|---|---|---|
| | OS | DIF | OS | DIF | OS | DIF | OS | DIF |
| **Mercury** | | | | | | | | |
| | *P*-value = 0.0057 | | *P*-value = 0.0330 | | *P*-value = 0.0034 | | *P*-value = 0.0039 | |
| DIF | -- | | -- | | OS | | -- | |
| ECCB | OS | DIF | OS | -- | OS | -- | OS | -- |
| **PCB** | | | | | | | | |
| | *P*-value = <0.0001 | | *P*-value = 0.0011 | | *P*-value = 0.0008 | | *P*-value = 0.0001 | |
| DIF | DIF | | -- | | -- | | DIF | |
| ECCB | OS | DIF | OS | DIF | OS | DIF | OS | DIF |
| **Chlordane** | | | | | | | | |
| | *P*-value = 0.0001 | | *P*-value = <0.0001 | | *P*-value = 0.0037 | | *P*-value = 0.0011 | |
| DIF | DIF | | DIF | | DIF | | DIF | |
| ECCB | -- | DIF | OS | DIF | -- | DIF | -- | DIF |
| **4,4'-DDE** | | | | | | | | |
| | *P*-value = 0.0001 | | *P*-value = 0.0123 | | *P*-value = 0.0088 | | *P*-value = 0.0002 | |
| DIF | DIF | | -- | | -- | | DIF | |
| ECCB | -- | DIF | -- | DIF | -- | DIF | OS | DIF |

**Note:** *P*-value is from the ANOVA model. Tukey's multiple comparison test was used to test for pariwise differences between locations at an overall 95 percent confidence level.
Location abreviation indicates location has significantly higher concentration.
-- - indicates no significant difference in concentration between locations

OS - Outfall location
DIF - Deer Island Flats
ECCB - East Cape Cod Bay

PCB - Sum of congeners 138 and 153
Chlordane - Sum of *cis*-chlordane and *trans*-nonachlor

**Table B-12. Summary of station comparisons by year for flounder liver**

| | 2001 | | 2002 | | 2003 | | 2006 | |
|---|---|---|---|---|---|---|---|---|
| | OS | DIF | OS | DIF | OS | DIF | OS | DIF |
| **Cadmium** | | | | | | | | |
| | *P*-value = 0.2683 | | *P*-value = 0.7645 | | *P*-value = 0.1964 | | *P*-value = 0.5250 | |
| DIF | -- | | -- | | -- | | -- | |
| ECCB | -- | -- | -- | -- | -- | -- | -- | -- |
| **Copper** | | | | | | | | |
| | *P*-value = 0.3518 | | *P*-value = 0.1699 | | *P*-value = 0.0122 | | *P*-value = 0.1009 | |
| DIF | -- | | -- | | OS | | -- | |
| ECCB | -- | -- | -- | -- | -- | -- | -- | -- |
| **Lead** | | | | | | | | |
| | *P*-value = 0.0023 | | *P*-value = 0.0380 | | *P*-value = 0.4579 | | *P*-value = 0.0103 | |
| DIF | OS | | -- | | -- | | OS | |
| ECCB | OS | -- | OS | -- | -- | -- | OS | -- |
| **Mercury** | | | | | | | | |
| | *P*-value = 0.0114 | | *P*-value = 0.0034 | | *P*-value = 0.0055 | | *P*-value = 0.0684 | |
| DIF | -- | | -- | | OS | | -- | |
| ECCB | OS | DIF | OS | -- | OS | -- | -- | -- |
| **PCB** | | | | | | | | |
| | *P*-value = <0.0001 | | *P*-value = 0.0026 | | *P*-value = 0.0001 | | *P*-value = 0.0001 | |
| DIF | -- | | -- | | -- | | DIF | |
| ECCB | OS | DIF | OS | DIF | OS | DIF | OS | DIF |
| **HMW PAH** | | | | | | | | |
| | *P*-value = 0.0004 | | *P*-value = 0.1736 | | *P*-value = 0.0130 | | *P*-value = 0.0328 | |
| DIF | -- | | -- | | -- | | -- | |
| ECCB | OS | DIF | -- | -- | -- | DIF | OS | -- |
| **LMW PAH (12)** | | | | | | | | |
| | *P*-value = 0.0012 | | *P*-value = 0.2996 | | *P*-value = 0.0565 | | *P*-value = 0.8452 | |
| DIF | DIF | | -- | | DIF | | -- | |
| ECCB | OS | DIF | -- | -- | -- | -- | -- | -- |
| **Total PAH (24)** | | | | | | | | |
| | *P*-value = 0.0031 | | *P*-value = 0.2247 | | *P*-value = 0.0228 | | *P*-value = 0.8596 | |
| DIF | DIF | | -- | | DIF | | -- | |
| ECCB | OS | DIF | -- | -- | -- | -- | -- | -- |
| **Chlordane** | | | | | | | | |
| | *P*-value = <0.0001 | | *P*-value = 0.0006 | | *P*-value = 0.0002 | | | |
| DIF | DIF | | DIF | | DIF | | nd | |
| ECCB | OS | DIF | OS | DIF | OS | DIF | nd | nd |
| **4,4'-DDE** | | | | | | | | |
| | *P*-value = 0.0001 | | *P*-value = 0.0290 | | *P*-value = 0.0020 | | | |
| DIF | -- | | -- | | -- | | nd | |
| ECCB | OS | DIF | -- | DIF | OS | DIF | nd | nd |

*Notes on following page.*

**Table B-12. (cont.)**

**Note:** *P*-value is from the ANOVA model. Tukey's multiple comparison test was used to test for pariwise differences between locations at an overall 95 percent confidence level.
Location abreviation indicates location has significantly higher concentration.
-- - indicates no significant difference in concentration between locations
nd - no data available

OS - Outfall location
DIF - Deer Island Flats
ECCB - East Cape Cod Bay

PCB - Sum of congeners 138 and 153
Chlordane - Sum of *cis*-chlordane and *trans*-nonachlor
LMW PAH (12) - Sum of 12 low molecular weight compounds (acenaphthene, acenaphthylene, anthracene, biphenyl, fluorene, naphthalene, phenanthrene, 1-methylnaphthalene, 1-methylphenanthrene,2,3,5-triethylnaphthalene, 2,6-dimethylnaphthalene, and 2-methylnaphthalene)
HMW PAH - Sum of 12 high molecular weight compounds (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, perylene, and pyrene)
Total PAH (24) - Sum of LMW PAH and HMW PAH


Massachusetts Water Resources Authority
Charlestown Navy Yard
100 First Avenue
Boston, MA 02129
(617) 242-6000
http://www.mwra.state.ma.us