Final

1999 annual fish and shellfish report

Massachusetts Water Resources Authority

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FINAL

1999 ANNUAL

FISH AND SHELLFISH REPORT

submitted to

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF TABLES

TABLE OF CONTENTS (continued)

LIST OF FIGURES

TABLE OF CONTENTS (continued)

APPENDICES

EXECUTIVE SUMMARY

The Massachusetts Water Resources Authority (MWRA) continued to conduct its biomonitoring program for fish and shellfish in 1999. The 1999 activities represent the latest year in a continuing biomonitoring program that supports evaluation of the MWRA effluent discharged into Massachusetts Bay. The goal of the biomonitoring program is to obtain baseline data that may be used to assess the potential environmental impact of the effluent discharge on Massachusetts Bay, and to evaluate the facility's compliance against the NPDES effluent discharge permit.

The specific objective of the 1999 fish and shellfish monitoring program was to further define the baseline condition of three indicator species: winter flounder (*Pleuronectes americanus*), lobster (*Homarus americanus*), and blue mussel (*Mytilus edulis*). Flounder and lobster specimens were collected from three core sites in Boston Harbor and the Bays: Deer Island Flats (DIF), the Outfall Site (OS) and East Cape Cod Bay (ECCB). Flounder were collected also at two ancillary sites, Broad Sound (BS) and off Nantasket Beach (NB), to provide information on flounder in the general area of the existing Deer Island outfall. Caged mussels, collected from Gloucester and Sandwich, were deployed at four sites in Boston Harbor and the Bays to evaluate bioaccumulation potential. All collection and deployment sites are discussed in the 1999 Fish and Shellfish Report in terms of chemical contaminants and histological parameters in flounder.

Baseline conditions of the species collected were characterized in terms of biological parameters (*e.g.* length, weight, biological condition); external condition; and concentrations of organic and inorganic compounds in both edible and liver/hepatopancreas tissue. Flounder livers were examined for the extent and severity of lesions. The monitored parameters were examined for spatial distribution among stations in 1999 and inter-annual variations from previous monitoring data. In addition, body burdens of certain pesticides, PCBs, lead and mercury were compared to FDA Action Limits and monitoring program caution and warning levels to evaluate potential risk or trends.

Flounder

Winter flounder were collected at the five established monitoring locations in 1999. The mean length of fish collected at DIF was significantly higher than the other stations. Although this is unlikely to be biologically significant, it is consistent with findings from previous years. The external condition of fish indicated few abnormalities. Fin erosion at Deer Island was not significantly different than at the other stations and was extremely low at all stations.

Flounder liver histology results indicated that the prevalence of tubular and centrotubular hydropic vacuolation (CHV) was highest at BS and lowest at ECCB. Inter-annual comparison showed that CHV prevalence has not changed substantially at any of the stations since 1991. However, CHV prevalence at DIF has shown a decrease over the period 1987-1999 and in 1999 had the lowest recorded prevalence measured during the program. Neoplasia was absent from all fish collected in 1999. Neoplasm prevalence at DIF has fallen from elevated levels in the 1980's to undetectable levels during the period 1992-1999.

Fifteen winter flounder were collected at each of the five monitoring locations for chemical analysis of edible and liver tissues. The spatial patterns of tissue contaminant levels in winter flounder were examined. Mean 1999 concentrations of organic compounds in fillets were generally highest at NB and OS and lowest at ECCB. Mean 1999 concentrations of organic compounds in liver tissue were generally highest at DIF and lowest at ECCB. Mercury was slightly higher at OS in fillet tissue and higher at NB in liver tissue than at other sites. Other metals (Ag, Cd, Cr, Cu, Ni, Pb and Zn) measured in liver tissue showed station-to-station variation with no consistent spatial trend.

Tissue organic contaminant levels for 1999 were consistently similar or lower than those measured in the period 1992-1998 at all stations. The highest concentrations are historically found at DIF and the lowest in ECCB. This trend continued in 1999 for liver tissue, but not for fillet tissue, where levels at OS were similar or higher than at DIF. Chlorinated pesticides show relatively stable concentrations (DDT, chlordane, and hexachlorobenzene) or a slight increase (dieldrin in fillets), since 1992. Mercury concentrations measured in edible tissue and liver were within the measured range of previous years. Concentrations of other metals were variable over the period from 1992-1999. Spatially, overall levels of most metals appeared to be slightly higher at OS, rather than DIF.

As in previous years, organic contaminant body burdens appeared to be predictive of liver histopathology. Although 1999 body burdens are on the low end of the contaminant burdens measured since 1992, a general relationship between body burden and prevalence of centrotubular hydropic vacuolation was still observed.

Comparison was made between flounder edible tissue contaminant levels, MWRA Caution and Warning Levels, based on the 1992-1998 data, and FDA Action Limits. The 1999 levels (determined on a wet weight basis), like those detected in previous monitoring years (1992-1998), were well below the federal action limits. Dieldrin at OS in 1999, however, exceeded the MWRA Caution Level, based on the 1992-1998 baseline period.

Lobster

Fifteen lobsters were collected at the three core monitoring stations for the 1999 study (DIF, OS, and ECCB). All lobsters were obtained from commercial traps located within the vicinity of the designated sampling stations. The size, sex and external appearance (*i.e*. black gill disease, shell erosion, external tumors, etc.) were determined for the collected lobsters. Little difference in length and weight were noted between stations. The ratio of males and females, however, differed greatly between stations, with mostly males found at DIF and ECCB and mostly females collected at OS. No deleterious external conditions were noted.

Mean 1999 concentrations of organic compounds in edible tail meat tissue and the hepatopancreas were generally highest at DIF and lowest in ECCB. Mean mercury concentrations in the meat and hepatopancreas were highest at DIF and OS. Comparison of 1999 data with previous years (1992-1998) indicates that most spatial distributions were similar. Concentrations of total PCB, silver and copper in lobster hepatopancreas continued to show an upward trend in 1999 at OS and DIF.

Comparison was made between contaminant levels in lobster edible tissue, MWRA Caution and Warning levels, based on the 1992-1998 data, and FDA Action Limits for pesticides, PCBs and mercury. The 1999 levels, like other monitoring years, were well below the federal action limits and indicate no risk for human consumption. However, concentrations of PCBs in hepatopancreas have slightly exceeded the FDA Action Limits in lobsters collected from the Deer Island location since 1996 and concentrations of PCBs at the OS have approached the FDA limits since 1995. This is consistent with the current Massachusetts State Advisory regarding consumption of lobster tomalley for lobsters caught in Massachusetts' waters.

Mussels

Mussels were collected at two reference sites (Gloucester, Sandwich) and deployed for up to 60 days in arrays at Deer Island (DI), OS and Cape Cod Bay (CCB), as well as BIH. Gloucester mussels were used to assess organic bioaccumulation, and Sandwich mussels were used to assess inorganic bioaccumulation. A full set of arrays was successfully retrieved at sixty-days from BIH, OS, and CCB. No arrays were obtained from DI. Mussel survival within the deployed arrays upon recovery was high (≥86%).

The 1999 data were similar to previous years with the highest body burdens of contaminants observed in mussels deployed in BIH. Contaminant levels overall were among the lowest measured since 1991. The lowest concentrations overall were found in mussels deployed at OS and CCB. CCB was added in 1998 as an outer harbor reference site.

Comparison was made between mussel tissue contaminant levels and MWRA Caution and Warning levels, based on the 1992-1998 data, and FDA Action Limits for mercury and lead. The 1999 levels, like other monitoring years, were well below the federal action limits and indicate no risk for human consumption.

Evaluation of Monitoring Thresholds

MWRA has set Caution and Warning Levels to ensure the protection of human health. Caution Levels are set at two times the baseline arithmetic averages of annual means (of composite samples) for organisms collected or deployed at OS during the baseline period to date (1992 through 1999). The significant increase value is the 95th percentile upper confidence limit (based on the "t" distribution) of the arithmetic mean of the annual means of the baseline period. Warning Levels have been set at 80% of the FDA Action Limit.

Caution Levels are statistically different from the baseline means, and significant increases can be detected prior to reaching Caution Levels. In addition, current tissue concentrations are generally an order of magnitude or more below Warning Levels and FDA Action Limits. Similarly, the monitoring hypothesis regarding future increases of the prevalence of flounder liver centrotubular hydropic vacuolation at OS relative to baseline levels measured in outer Boston Harbor is sufficiently sensitive to detect trends based on current data.

1.0 INTRODUCTION

The Massachusetts Water Resources Authority (MWRA) has implemented a long-term Harbor and Outfall Monitoring (HOM) Program for Massachusetts and Cape Cod Bays. The objectives of the HOM Program are to test whether the environmental impacts of the MWRA discharge are consistent with SEIS projections and do not exceed any Contingency Plan thresholds. A detailed description of the monitoring and its rationale is provided in the Effluent Outfall Monitoring Plan developed for the baseline period and the post discharge monitoring plan (MWRA 1997, 1999).

One aspect of the MWRA HOM program is a long-term biomonitoring program for fish and shellfish (MWRA, 1991). The goal of the biomonitoring is to provide data that may be used to assess potential environmental impact of effluent discharge into Massachusetts Bay. This data will be used to ensure that discharge from the new outfall does not result in adverse impacts to fish and shellfish by comparing values with established thresholds (MWRA 1997a).

The objective of the fish and shellfish monitoring is to define the condition of three indicator species: winter flounder (*Pleuronectes americanus),* lobster (*Homarus americanus),* and blue mussel *(Mytilus edulis*). Measured parameters include length, weight, biological condition, the presence of external or internal disease, and inorganic and organic contaminant tissue concentrations. This baseline characterization of the health of winter flounder, lobster and mussel in Boston Harbor, Massachusetts Bay, and Cape Cod Bay (hereafter: Boston Harbor and the Bays) forms the basis for assessing potential changes resulting from the relocation of the outfall discharge (Figure 1-1).

The scope of the 1999 fish and shellfish report is focused primarily towards providing a compilation of the biomonitoring data collected during 1999 and a comparison of the 1999 data with data collected from 1992 through 1998. The report first provides a summary of the survey and laboratory methods (Section 2). Section 3 presents the results of biomonitoring data from surveys conducted during 1999, as well as selected data from previous studies, and Section 4 presents the conclusions drawn from the 1999 survey results and historical trends. Finally, recommendations for future sampling and analyses are summarized in Section 5.

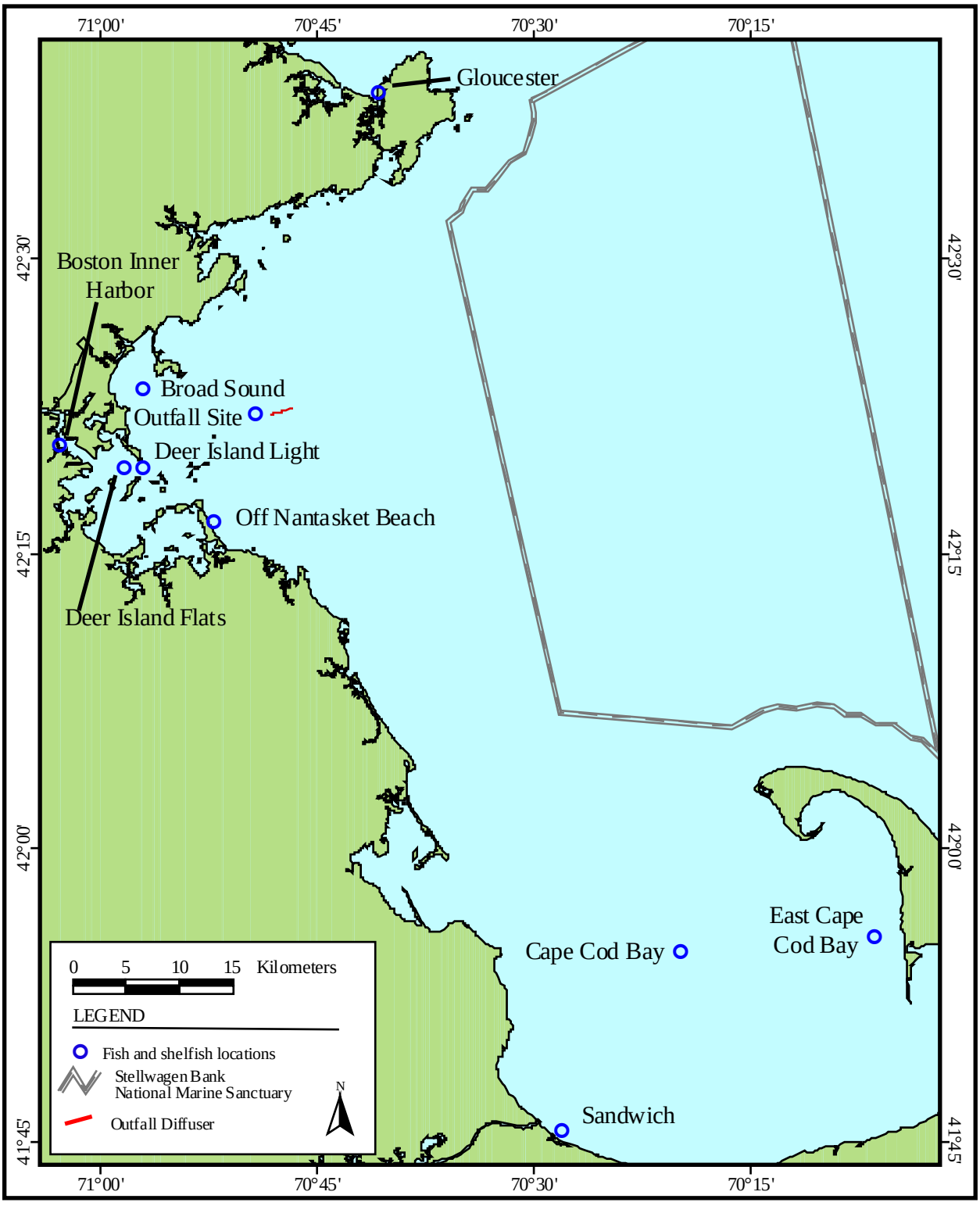


Figure 1-1. Boston Harbor and the Bays with Outfall Site.

2.0 METHODS

This section provides an overview of the methods and protocols used in the three surveys conducted to collect biological specimens. More detailed descriptions of the methods are contained in *Combined Work/Quality Assurance Project Plan (CW/QAPP) for the Fish and Shellfish Monitoring: 1998 ((Fish and Shellfish Monitoring CW/QAPP)* Lefkovitz *et al.* 1998).

2.1 Winter Flounder Monitoring

Winter flounder *(Pleuronectes americanus)* were collected from 5 locations in Boston Harbor and the Bays to obtain specimens for age, weight, and length determination, gross examination of health, histology of livers, and chemical analyses of tissues to determine contaminant exposure. Chemical data were used to determine whether contaminant tissue burdens approach human health consumption limits.

2.1.1 Stations and Sampling

The 1999 flounder survey was conducted between April 14, 1999 and May 10, 1999. Five sites were sampled to collect winter flounder for histological and chemical analyses:

- Deer Island Flats (DIF)
- Off Nantasket Beach (NB)
- Broad Sound (BS)
- Outfall Site (OS)
- East Cape Cod Bay (ECCB).

Table 2-1 provides the planned and actual sampling sites and locations for the 1999 flounder sampling. Adjustments in location and time were made to ensure that the required 50 flounder per site were captured. Figure 2-1 shows the monitoring locations.

At each of the five designated sampling sites, otter-trawl tows were conducted from the F/V *Odessa* (captained by Captain William Crossen) to collect 50 sexually mature (4-5 years old) winter flounder. Thirty-five fish were assigned unique identification numbers to indicate date, time, and site of collection. These fish were killed at sea by cervical section and used for histological processing. They were examined externally and their external condition noted prior to histological processing. The gonads of each flounder were examined to determine sexual maturity. All specimens were weighed, and standard and total fork length was determined. Scales were then taken from each specimen for age determination.

Of the 50 flounder collected from each site, 15 were designated for tissue chemical analysis. Because contaminant-free conditions were not available on board the vessel, the fish used for chemical analysis were returned to the laboratory for organ dissection. These fish were maintained alive on-board and transported to Battelle, Duxbury for histological and chemical analysis. These fish were also examined for external condition in the laboratory. Fifteen additional unique sample identification numbers were generated at sea at the time of fish collection, however, actual assignment of IDs to individual fish did not occur until the fish were sacrificed at the laboratory.

2.1.2 Age Determination

Scales from each specimen were collected for age determination. Scales were removed after first removing any mucus, debris, and epidermis from the dorsum of the caudal peduncle by wiping in the direction of the tail with a blunt-edged table knife. Scales were then collected from the cleaned area by

applying quick, firm, scraping motions in the direction of the head. The loosened scales were placed in the labeled age-sample envelope by inserting the knife between the liner of the sample envelope and scraping off the scales. The age of each flounder was determined by scientists at the National Marine Fisheries Services (NMFS) in Woods Hole, Massachusetts through analysis of growth rings (annuli).

2.1.3 Dissection of Fish

The flounder tissues were removed in the laboratory under contaminant-free conditions. Tissue processing was conducted in a Class-100 clean room. The fillets (muscle) were removed from the flounder and the skin was removed from the fillet, using a pre-cleaned (*i.e.*, rinsed with 10% HCL, Milli-Q (18 megohm) water, acetone, DCM, and hexane) stainless steel knife.

From each site, three composites were prepared; each composed of approximately equal masses of top and bottom tissue from five randomly chosen fish. Homogenization was performed using a stainless steel TEKMAR® tissuemizer. Each composite was placed in a sample container clearly identified with the unique sample identifier.

Livers from the 15 fish selected for chemical analyses were removed using a titanium knife and analyzed for chemical parameters, after sectioning for histopathology analysis. (Livers from the remaining 35 fish not used for chemical analyses were removed shipboard and processed as described below). Following the processing for histology analysis, the livers were individually homogenized by finely chopping with the titanium knife and divided into three separate composites to correspond to the composites made for the fillets (*e.g.*, the livers of the same five specimens used for each edible tissue composite were combined). This was done to ensure comparability between fillet and liver chemical analyses. Each composite was placed in a sample container clearly identified with the unique sample identifier. This resulted in 30 pooled samples for analysis in 1999 (15 pooled fillets and 15 pooled livers). The homogenized tissue and liver samples were frozen and stored. Any remaining tissue from each specimen was archived frozen in case additional analysis was required.

At least one homogenization blank was carried out for each batch of 20 fish to monitor for sample contamination during the homogenization process. For the blank sample, a known quantity (about 100 ml) of Milli-Q water was transferred to a clear glass jar and "tissuemized" for two minutes. The blank was held for analysis of both PCB/Pesticides and Hg (fillet measurements only).

2.1.4 Histological Processing

After the fish were completely examined and scales removed, the livers were removed (either on-board the ship or in the lab, as described above) and examined for visible gross abnormalities. The livers were then preserved in 10% neutral buffered formalin for histological analysis. Liver samples from each fish were placed in a separate clearly labeled sample container.

2.1.5 Histological Analysis

Livers of 50 flounder from each site were prepared for histological analysis by Experimental Pathology Laboratories in Herndon, VA. Transverse sections of flounder livers fixed as part of tissue sample processing were removed from the buffered formalin after at least 24 hours, rinsed in running tap water, dehydrated through a series of ethanols, cleared in xylene, and embedded in paraffin. Paraffin-embedded material was sectioned on a rotary microtome at a thickness of 5 μm. Each block contained three liver slices, resulting in one slide with three slices per slide per fish and a total of 250 slides (50 fish X 5 sites). The sections were stained in hematoxylin and eosin.

Each slide was examined under bright-field illumination at 25x, 100x, and 200x to quantify the presence and extent of:

- Three types of vacuolation (centrotubular, tubular, and focal)
- Macrophage aggregation
- Biliary duct proliferation
- Neoplasia

The severity of each lesion was rated on a scale of 0 to 4, where: 0 = absent; 1 = minor; 2 = moderate; 3 = severe; and 4 = extreme. For each lesion and each fish, a histopathological index was then calculated as a mean of scores from three slices on one slide.

2.1.6 Tissue Processing and Chemical Analyses

Chemical analyses were performed on composite samples of flounder from DIF, NB, BS, OS, and ECCB. Two tissue types (fillet, liver) were analyzed. Flounder fillet and livers were analyzed for PCBs/Pesticides, lipids, and mercury. In addition, flounder livers were analyzed for PAHs, lead, silver, cadmium, chromium, copper, nickel, and zinc. The individual steps involved in the tissue processing and chemical analyses of these samples are detailed in Section 2.4 Chemical Analysis of Tissues.

2.1.7 Data Reduction and Statistical Analyses

Data reduction was conducted as described in the Fish and Shellfish Monitoring CW/QAPP (Lefkovitz *et al.*, 1998) and in Section 2.5 of this report. Histopathological indices and prevalence of lesions were compared between classes of flounder by differences in station, age, sex and length. Chemical constituents were presented graphically and compared among stations using ANOVA analysis.

Histopathological observations of the livers of the winter flounder from all sites were conducted and, where possible, comparisons of the results with those of previous years were made. Possible relationships between observed lesions and contaminant body burdens were also investigated.

In addition to reporting the prevalence and lesion index of hydropic vacuolation, historical data has included several other lesions, including macrophage aggregates, biliary proliferation, neoplasia, and a lesion unreported before 1993, referred to as “balloon hepatocytes” (Hillman & Peven, 1995).

The levels of contaminants measured in edible tissues were compared to Food and Drug Administration (FDA) Action Levels (U.S. EPA 1989) for those contaminants.

2.1.8 Deviations From the CW/QAPP

Only four fish were caught from Deer Island on April 14th. Sampling of this site on May 5th proved to be successful and a more than adequate number of fish were captured for analyses. The four fish from the April collection were processed for histology but were not included in the histology or chemistry analysis. Those samples were labeled F99 1001 through 1004. The first four of 50 fish sampled from Deer Island on May 5th were labeled F99 1001a through 1004a and were used in the analysis. The balance used aboard the vessel began to malfunction on May 5th. Due to questions relating to the collection of weight data in the field (balance performance and units/conversions used), the weights of only the 15 fish per station used for chemical analyses are presented in this report. Age data for two flounder (FF913017 and FF9914002) were inadvertently not collected during the survey.

2.2 Lobster Monitoring

Lobster *(Homarus americanus)* were collected from three sampling sites for gross examination (to determine specimen health) and chemical analyses to determine tissue burden of contaminants.

2.2.1 Stations and Sampling

Lobster surveys were conducted on July 29, 1999 (DIF), September 09, 1999 (ECCB) and November 12, 1999 (OS). Lobster surveys originally scheduled to take place in July were postponed to September and November, when lobsters were more abundant in the sampling locations.

Table 2-2 provides the planned and actual sampling sites and locations for the lobster surveys. Figure 2-2 illustrates the sampling locations in Boston Harbor and the Bays.

Lobsters were purchased from commercial lobstermen. The location was verified by placing a Battelle staff member on board during collection operations. Individual lobsters retained for analyses were assigned a unique identification number to indicate date, time, and site of collection. Lobsters were measured for carapace length and width and the gender was determined. Lobster specimens were visually examined and the condition noted. Processing of the hepatopancreas and edible tissue samples were conducted in the laboratory.

2.2.2 Size and Sex Determination

Carapace length was determined with calipers by measuring the distance from the tip of the rostrum to the posterior edge of the median uropod. Measurements were recorded to the nearest millimeter. Specimen weight was recorded to the nearest gram. Specimens were visually examined for the presence and severity of gross external abnormalities, such as black gill disease, shell erosion, and parasites. Data for each specimen were recorded on a lobster sample collection log.

2.2.3 Dissection of Lobster

The hepatopancreas was removed and frozen for chemical analysis. The tail and claw meat (edible tissue) was stored frozen in the shells until processed in the laboratory. Samples were placed in sample containers that were clearly identified with a bar-coded or conventional label containing the pertinent sample information.

The 15 lobsters collected at each site were randomly divided into three groups of five lobsters each. Within each of the three groups, edible meat (tail and claw) and hepatopancreas from the five lobsters were pooled by tissue type. Homogenization of lobster meat was performed using a stainless steel TEKMAR® tissuemizer. Hepatopancreas samples were homogenized using a titanium knife to avoid metals contamination. Each composite was placed in a sample container clearly identified with the unique sample identifier. This resulted in 18 pooled samples for analysis in 1999.

2.2.4 Tissue Processing and Chemical Analyses

Chemical analyses were performed on the composite samples of lobster (hepatopancreas and edible meat). Edible lobster meat and hepatopancreas were analyzed for PCBs/Pesticides, lipids, and mercury. In addition, hepatopancreas samples were analyzed for PAHs, lead, silver, cadmium, chromium, copper, nickel, and zinc. The individual steps involved in the tissue processing and chemical analyses of these samples are detailed in Section 2.4 Chemical Analysis of Tissues.

2.2.5 Data Reduction and Statistical Analyses

Data reduction was conducted as described in the Fish and Shellfish Monitoring CW/QAPP (Lefkovitz *et al.*, 1998) and Section 2.5 of this report. Temporal patterns of contaminants in edible lobster tissue and hepatopancreas tissue were evaluated through available data from 1992 through 1998. Spatial distributions were analyzed among stations using ANOVA analysis. Comparisons were made to the FDA Action Limits and other appropriate levels of regulatory concern.

2.2.6 Deviations from the CW/QAPP

There were no deviations from the CW/QAPP, other than the extended sampling period due to lack of lobster at the collection sites.

2.3 Mussel Bioaccumulation Monitoring

Blue mussels *(Mytilus edulis)* were collected from two reference locations and deployed in suspended cages at four sites in Boston Harbor and the Bays. Mussels were recovered for determination of short-term accumulation of anthropogenic contaminants in soft tissues.

2.3.1 Stations and Reference Area

During the 1999 surveys, mussels were collected from reference sites in Gloucester and Sandwich and deployed at four sites:

- Off Deer Island Light (DI) (~2 m above bottom)
- In vicinity of the Outfall Site (OS)
- Reference Station in Boston's Inner Harbor (BIH)
- New offshore Reference Station (Cape Cod Bay- CCB).

Table 2-3 provides the planned and actual sampling sites and locations. Figure 2-3 illustrates the sampling locations in Boston Harbor and Massachusetts Bay.

2.3.2 Mussel Collection

In late June, approximately 1200 mussels were collected from Gloucester, MA to be used for organic contaminant analysis and 700 from Sandwich, MA for inorganic analysis. Control mussels were collected from two sites because historical data have shown Sandwich mussels to have high body burdens of pesticides and Gloucester mussels to have high body burdens of metals. Mussels were harvested during low tide and individually checked for length. Only mussels measuring between 55-65 mm were used for this study. A sub-sample of 80 Gloucester and 40 Sandwich mussels were randomly selected and set aside for pre-deployment biological and chemical analyses.

2.3.3 Mussel Deployment

After collection, the mussels were randomly distributed to plastic cages for deployment as an array (*i.e.*, set of cages) in sufficient number to provide the necessary biological material. At least 10% additional mussels were included to account for potential mortality. Mussels were deployed on June 30 and July 1 in replicate arrays at the four sites (Table 2-3 and Figure 2-3). Table 2-4 lists the minimum numbers of mussels and the number of cages and corresponding arrays that were deployed at each location.

At each location, a minimum of three arrays was deployed except for the offshore locations (OS and CCB), where four arrays were deployed. Each array was deployed on a separate mooring and each with enough mussels to provide sufficient tissue to complete the study. The locations of the arrays were recorded using Differential Global Positioning System (DGPS).

2.3.4 Mussel Retrieval

Mussel retrieval was planned for two occasions with collection of up to one half of the mussels at 40-days to provide tissue in the event of failure of the 60-day collection. At BIH, OS, and CCB, 60-day mussels were retrieved. No arrays, thus no samples, were recovered at Deer Island at either 40 or 60 days, even after

search and recovery efforts with a side scan sonar and hard hat divers. Actual mussel recovery is discussed in Section 3.3. The amount of biofouling of the arrays was also assessed at 40 days.

2.3.5 Tissue Processing and Chemical Analyses

Individual mussels were pooled for organic and inorganic analyses separately. For organic analysis, composite groups of 10 mussels were pooled from the 50 Gloucester mussels deployed and collected to create five pooled samples per site. At the OS and Cape Cod sites, eight pooled samples were created from 80 Gloucester mussels. For inorganic analysis composites (Hg and Pb), groups of five mussels were pooled from 25 Sandwich mussels deployed and collected to create five pooled samples per site. At the OS and Cape Cod Bay site, eight pooled samples were created from 40 Sandwich mussels. Gloucester and Sandwich pre-deployment mussels were also analyzed for organic and inorganic parameters, respectively. Details of actual mussel retrievals are discussed in Section 3.3.

Mussel composites were prepared from individual mussels by cleaning of attached material, removing all byssal threads and placing all soft tissue including fluids directly into the appropriate container (500-ml I-Chem clean bottle for organics and a pre-cleaned 4 ounce plastic jar for metals). Mussel composite samples were prepared for organic chemical analyses by homogenization using a stainless steel Tekmar "tissumizer" rinsed with methanol and de-ionized water prior to use. Mussel composite samples for metal analyses were prepared by freeze drying and subsequent ball milling, to achieve homogenization.

Chemical analyses were performed on composite samples of mussel tissue. The Gloucester mussel tissue was analyzed for PCBs/Pesticides, PAHs, and lipids. The Sandwich mussel tissue was analyzed for mercury and lead. The individual steps involved in the tissue processing and chemical analyses of these samples are detailed in Section 2.4 Chemical Analysis of Tissue Samples.

2.3.6 Data Reduction and Statistical Analyses

The extent of bioaccumulation of contaminants in the mussels was evaluated. Data reduction was conducted as described in the Fish and Shellfish Monitoring CW/QAPP (Lefkovitz *et al.*, 1998) and in Section 2.5 of this report. The 1999 results were compared statistically to initial contaminant levels in the control mussels using two-sample t-tests. Further evaluation focused on spatial and temporal patterns in contaminant accumulation by ANOVA analysis.

2.3.7 Deviations from the CW/QAPP

Retrieval of mussels was limited due to loss of part or all of some arrays. Deviations from the original CW/QAPP are as follows:

- Deer Island (DI) – No arrays and no samples could be recovered. Therefore, there are no data for this station.

2.4 Chemical Analyses of Tissue Samples

Table 2-5 summarizes the analyses performed on each type of tissue sample. Table 2-6 lists the analysis methods, units of measurement and method reference. The chemical analytes of interest are listed in Table 2-7. The same analytical methods were used for all tissues.

2.4.1 Organic Tissue Extraction

Tissues were extracted and cleaned following the procedures of Peven and Uhler (1993) as described in Battelle SOP 5-190. Approximately 30-g of tissue homogenate was weighed into a Teflon extraction jar, spiked with the appropriate surrogate internal standard (SIS), combined with 75 mL dichloromethane (DCM) and sodium sulfate, macerated with a Tissumizer and centrifuged. An aliquot of the original

sample was also taken for dry weight determination. The extract was decanted into an Erlenmeyer flask. This process was repeated once using 75 mL DCM. After each maceration, the centrifuged solvent extracts were combined in the Erlenmeyer flask. An additional extraction was performed using 50 mL DCM and shaking techniques, the sample centrifuged a third time, and the extract combined with the other two. A 10-mL aliquot of the combined extracts was removed for lipid weight determination. Lipid results were gravimetrically measured by evaporating the aliquot of organic extract and weighing the remaining residue. Results were reported in percent dry weight.

The combined extract was dried over sodium sulfate, processed through an alumina cleanup column, and concentrated to approximately 900-µL for additional HPLC cleanup. Raw extracts (post-alumina) were fractionated by HPLC (BOS SOP 5-191). The post-HPLC extract was concentrated under nitrogen to approximately 0.5 mL, and spiked with recovery internal standard (RIS). Dry weight determinations were performed by oven drying a portion of each composite sample.

Extracts requiring both PCB/Pesticide and PAH analyses were split for analysis, one half remaining in DCM for PAH analysis, and the other half solvent-exchanged with isooctane for PCB and pesticide analysis.

2.4.2 Metals Tissue Digestion

Flounder Liver and Fillet; Lobster Hepatopancreas and Edible Tissue - To prepare tissue samples for metals analysis, samples were freeze-dried and homogenized in a ball-mill. A 200- to 300-mg aliquot of each dried, homogeneous sample was digested using aqua regia (nitric and hydrochloric acids at a ratio of 5.0 mL: 3.5 mL) according to Battelle SOP MSL-I-006 *Aqua Regia Sediment and Tissue Digestion*. The freeze-dried tissue and digestion acids were combined in a Teflon bomb and heated in an oven at 130 ºC (±10 ºC) overnight. After heating and cooling, deionized water was added to the acid-digested tissue and the digestates were submitted for analysis.

Mussel Tissue - To prepare tissue samples for metals analysis, samples were freeze-dried and homogenized in a ball-mill. An approximately 300-mg aliquot of each dried, homogeneous sample was digested using nitric acid according to Battelle SOP MSL-I-005 *Hot Nitric Acid Digestion of Sediments and Tissues*. The freeze-dried tissue and digestion acid were combined in a glass vial. The vials were loosely capped and heated on a hot plate at a temperature just high enough to boil the acid, without boiling over or evaporating the sample to dryness. After heating and cooling, deionized water was added to the acid-digested tissue and the digestates were submitted for analysis.

2.4.3 Organic Analyses

Organic analyses performed on the flounder, lobster, and mussel tissues included PAHs and PCB/Pesticides as summarized in Table 2-5.

PAH Analysis - Trace level organic compounds (PAH) were identified using electron impact gas chromatography/mass spectrometry (GC/MS). Target compounds were separated using an HP 5890 Series II gas chromatograph, equipped with a 60-m x 0.25-mm-inner diameter (0.25-um film thickness) DB-5 column (J&W Scientific), and measured using a HP 5972a mass selective detector operated in the selective ion monitoring (SIM) mode following Battelle SOP 5-157. Concentrations for all target analytes were determined by the method of internal standard, using SISs for quantification. All PAH results were reported in ng/g dry wt.

PCB/Pesticide Analysis - Pesticides and PCB congeners were analyzed and quantified using gas chromatography/electron capture detection (GC/ECD) (Hewlett Packard 5890 Series 2 GC) using a 60-m DBS column and hydrogen as the carrier gas following Battelle SOP 5-128, including a second column

for confirmation. Concentrations for all target analytes were determined by the method of internal standard, using SISs for quantification. All PCB and pesticide results were reported in ng/g dry wt.

2.4.4 Metals Analyses

Analysis of Hg - Sample digestates were analyzed for Hg using cold-vapor atomic absorption spectroscopy (CVAA) according to Battelle SOP MSL-I-016 *Total Mercury in Tissues and Sediments by Cold Vapor Atomic Absorption*, which is based on EPA Method 245.6 *Determination of Mercury in Tissues by Cold Vapor Atomic Absorption Spectrometry* (EPA 1991a). Results were reported in units of µg/g on a dry-weight basis.

Analysis of As, Cd, Cr, Cu, Ni, Pb, and Zn - For analysis of multiple metals simultaneously, sample digestates were analyzed for As, Cd, Cr, Cu, Ni, Pb, and Zn using inductively coupled plasma - mass spectrometry (ICP-MS) according to Battelle SOP ML-I-022 *Determination of Elements in Aqueous and Digestate Samples by ICP/MS*. This procedure is based on two methods modified and adapted for analysis of solid sample digestates, EPA Method 1638 *Determination of Trace Elements in Ambient Waters by Inductively Coupled Plasma - Mass Spectrometry* (EPA 1996) and EPA Method 1640 *Determination of Trace Elements in Water by Preconcentration and Inductively Coupled Plasma - Mass Spectrometry* (EPA 1997). Results were reported in units of µg/g on a dry-weight basis.

Sample digestates were also analyzed by graphite furnace atomic absorption (GFAA) when analysis of a single element was required. GFAA analysis was conducted according to Battelle SOP MSL-I-029 *Determination of Metals in Aqueous and Digestate Samples by GFAA*. This procedure is based on EPA Method 200.9 *Determination of Trace Elements by Stabilized Temperature Graphite Furnace Atomic Absorption Spectrometry* (EPA 1991b).

2.4.5 Corrective Actions in Metals Analyses

In some instances, analytical results for certain metals, particularly the analysis of flounder liver tissue for Cr, initially did not meet data quality objectives. This condition was most likely due to chloride interferences in the ICP-MS analysis from the hydrochloric acid used in the sample digestion. In these cases, a portion of the nitric and hydrochloric acid digestates were evaporated to dryness then returned to volume using only nitric acid. The nitric acid digestates were reanalyzed by ICP-MS for Cr and acceptable results were achieved.

2.5 General Data Treatment and Reduction

This section describes the data reduction performed on 1999 Fish and Shellfish data, as well as historical data, as part of the 1999 MWRA Harbor and Outfall Monitoring Project.

Specifics of data handling are as follows:

- All 1999 chemical data were generated at Battelle and loaded directly into the HOM database. During the preparation of the 1998 Fish and Shellfish Annual Report, data issues and inconsistencies in the historical data were identified and corrections were made to the database.
- All fish and shellfish data (1999 and historical) were extracted directly from the HOM database and exported into Excel files, where graphical presentations and statistical analyses were preformed.
- All laboratory duplicates for pre-1998 data were averaged for reporting and calculating. No laboratory duplicate data were entered for 1999 data.

- Contaminant data were reported as mean, standard error and *n* by station and year.
- 1993 lobster selection consisted of two animals collected in June and one in August. Results were calculated by taking the average of these three animals (*n* = 3). The difference in sample collection times was footnoted.
- Total PCB was calculated as the sum of twenty PCB congeners (Table 2-7).
- Total DDT was calculated as the sum of six DDT-related compounds: 2,4'-DDD, 4,4'-DDD, 2,4'-DDE, 4,4'-DDE, 2,4'-DDT, and 4,4'-DDT (Table 2-7).
- Total chlordane was calculated as the sum of five compounds: heptachlor, heptachlorepoxide, alpha-chlordane, cis-chlordane, and trans-nonachlor (Table 2-7).
- For the temporal presentation and analysis of data, the "Historical NOAA List" was used to calculate Total PAHs (Table 3-17). For the spatial presentation and analysis of data, the "Total PAH List" was used to calculate Total PAHs.
- In 1995, the individual five alkylated PAHs on the "Historical NOAA List" were not measured in mussels. Instead, the C1, C2 and C3-napthalene homologue groups were quantified. To make 1995 results more comparable to the "Historical NOAA List", values for the individual naphthalene compounds were estimated using ratios of the individuals to their respective homologue groups from 1996 and 1997 data sets.
- The "f" qualifier was used to indicate compounds that were quantified but were below the detection limit. "f"-flagged data were included in the graphical presentation of results and the calculations of thresholds and baseline means.
- The "G" qualifier was used to indicate compounds that co-eluted with a second known/unknown compound. The values for "G"-flagged data are estimated values and were included in the graphical presentations of results and the calculations of thresholds and baseline means.
- The "s" qualifier was used to indicate suspect data. "s"-flagged data were not included in any calculations or graphs.
- All non-detects used in calculations and trend analyses in this report were treated as zero.
- All data entered into the database are in dry weight units.
- Wet weight tissue concentrations were calculated from the wet/dry ratio and used in comparison to MWRA thresholds and FDA action levels.

2.5.1 Statistical Analyses

Statistical analyses were conducted to evaluate whether the various contaminant concentrations in flounder tissue (fillet and liver), lobster tissue (edible meat and hepatopancreas), and mussel tissue were significantly different between sampling sites. Table 2-8 presents the various chemical contaminant analyses for a given tissue type. A Single Factor Analysis of Variance (ANOVA) was used to evaluate each particular contaminant-tissue type combination (*e.g.*, total PCBs in flounder liver; total DDTs in flounder fillet; mercury in lobster meat; etc.).

All ANOVAs were run in Microsoft Excel version 7.0. Data were tested for normality and equality of variances. Homogeneity of variance was checked prior to running each ANOVA. In the few cases where the variances were not equal, data were log transformed and the ANOVA run. The log transformed

ANOVA results were no different from non-transformed ANOVA results; therefore, the results presented in the report are based on non-transformed data. Following each ANOVA, individual comparisons between any two sites (for any particular tissue-contaminant combination) were conducted using simple two-sample t-tests. ANOVA results and individual site comparisons are presented by tissue type in Section 3.

Table 2-1. Planned and Actual Sampling and Locations for Flounder Surveys.

Station #	Station Abbrev.	Sampling Site	Number of Tows	Planned Locations		Actual Locations[1]	
				N Latitude	W Longitude	N Latitude	W Longitude
1	DIF	Deer Island Flats	4	42º20.4’	70º58.4’	42º20.8’	70º58.1’
2	NB	Off Nantasket Beach	4	42º17.6’	70º52.2’	42º17.5’	70º51.5’
3	BS	Broad Sound	2	42º24.4’	70º57.2’	42º24.3’	70º57.5’
4	OS	Outfall Site	3	42º23.1’	70º49.3’	42º23.3’	70º49.8’
5	ECCB	East Cape Cod Bay	1	41º56.2’	70º06.6’	41º58.1’	70º06.7’

[1]Based on an average of the Latitude and Longitude of several tows

Table 2-2. Planned and Actual Sampling and Locations for Lobster Surveys.

Station #	Station Abbrev.	Sampling Site	Planned Location		Actual Location	
			N Latitude	W Longitude	N Latitude	W Longitude
1	DIF	Deer Island Flats/3 taken[a]	42º20.4’	70º58.4’	42º20.19’	70º58.55’
1	DIF	Deer Island Flats/12 taken[a]	42º20.4’	70º58.4’	42º20.21’	70º58.34’
4	OS	Outfall Site[b]	42º23.1’	70º49.3’	42º22.14’	70º47.84’
5	ECCB	East Cape Cod Bay[c]	41º58.02’	70º07.26’	41º54.20’	70º07.02’

[a]July 29, 1999
[b]November 12, 1999
[c]September 9, 1999

Table 2-3. Planned and Actual Sampling and Locations for Mussels Surveys.

Station #	Station Abbrev.	Sampling Site	Planned Location		Actual Location	
			N Latitude	W Longitude	N Latitude	W Longitude
1M	DI	Deer Island Light	42º20.4’	70º57.2’	NA[a]	NA[a]
M4	OS	Outfall Site	42º23.1’	70º49.3’	42°22.68’	70°46.98’
6	BIH	Boston Inner Harbor	42º21.5’	71º02.9’	42°21.50’	71°02.90’
7	Glouceste r	Gloucester - Pre-deployment	42º35.0’	70º40.0’	42°40.20’	70°40.20’
8	Sandwich	Sandwich/Cape Cod – Pre-deployment	41º50.0’	70º30.0’	41°45.60’	70°28.50’
9	CCB	Cape Cod Bay	41º55.5’	70º20.0’	41°56.28’	70°19.74

[a]Within the Deer Island effluent plume

Table 2-4. Summary of Mussels Deployment Scheme.

Site	Description/ Location	Water Depth	Cage Height Above Bottom	# Arrays	# Cages/Array	# Mussels/ Cage
DI	Deer Island Light	Various	2m	3	2 Gloucester/ 1 Sandwich	30
BIH	Boston Inner Harbor	8-11m	1.5-4.5m[1]	3	2 Gloucester/ 1 Sandwich	30
OS	42°22.68′ 70°46.98′	33m	15m	4	2 Gloucester/ 1 Sandwich	48 30
CCB	41°56.28′ 70°19.74′	40m	15m	4	2 Gloucester/ 1 Sandwich	48 30

[1] Rise and fall with tide, so that its constant depth below the water surface is 5 meters.

Table 2-5. Summary of Chemical Analyses Performed by Organism.

Sample Type	Number of Samples	Metals (1) (other than Hg and Pb)	Hg	Pb	PCBs	PAHs	Pesticides	Lipids
Flounder Meat	15	NR	*	NR	*	NR	*	*
Flounder Liver	15	*	*	*	*	*	*	*
Lobster Meat	9	NR	*	NR	*	NR	*	*
Lobster Hepatopancreas	9	*	*	*	*	*	*	*
Mussel Tissue								
Gloucester	26	NR	NR	NR	*	*	*	*
Sandwich	26	NR	*	*	NR	NR	NR	NR

*Targeted for Analysis
(1) Additional metals: Ag, Cd, Cr, Cu, Ni, and Zn
NR = Not Required

Table 2-6. Fish and Shellfish Sample Analyses.

Parameter	Unit of Measurement	Method	Reference
Organic Analyses			
Organic Extraction	NA	Tissuemize/Methylene Chloride	Peven and Uhler (1993)
Polycyclic Aromatic Hydrocarbons (PAH)	ng/g dry wt.	GC/MS	Peven and Uhler (1993)
Polychlorinated Biphenyls (PCB)/Pesticides	ng/g dry wt.	GC/ECD	Peven and Uhler (1993)
Metals Analyses			
Trace Metals (Ag, Cd, Cr, Cu, Ni, Pb, Zn, Hg)	µg/g dry wt	Digestion ICP-MS (all metals) GFAA (as required) CVAA-FIAS (Hg)	SOP MSL-I-006-00 and SOP MSL-I-005-01 EPA 1638 (EPA 1996) and EPA 1640 (EPA 1997) EPA 200.9 (EPA 1991b) EPA 245.6 (EPA 1991a)
Ancillary Parameters			
Lipids	% by dry weight	Gravimetric	Peven and Uhler (1993)
Dry Weight	% by dry weight	Gravimetric	Peven and Uhler (1993)

Table 2-7. Specific Chemical Analytes Included in Tissue Chemistry Analyses.

Chemical Analytes	
Trace Metals[a]	**Polynuclear Aromatic Hydrocarbons (PAHs)** (continued)
Ag Silver	C_1-Phenanthrenes/anthracene
Cd Cadmium	C_2-Phenanthrenes/anthracene
Cr Chromium	C_3-Phenanthrenes/anthracene
Cu Copper	C_4-Phenanthrenes/anthracene
Hg Mercury[b,e]	Dibenzothiophene
Ni Nickel	C_1-dibenzothiophenes
Pb Lead[e]	C_2-dibenzothiophenes
Zn Zinc	C_3-dibenzothiophenes
Polychlorinated biphenyls (PCBs)[c,d]	Fluoranthene
2,4'-Cl_2(8)	Pyrene
2,2N,5-Cl_3(18)	C_1-fluoranthenes/pyrene
2,4,4N-Cl_3(28)	C_2-fluoranthenes/pyrene
2,2N,3,5N-Cl_4(44)	C_3-fluoranthenes/pyrene
2,2N,5,5N-Cl_4(52)	Benzo[*a*]anthracene
2,3N,4,4N-Cl_4(66)	Chrysene
3,3N,4,4N-Cl_4(77)	C_1-chrysene
2,2N4,5,5N-Cl_5(101)	C_2-chrysene
2,3,3N,4,4N-Cl_5(105)	C_3-chrysene
2,3N,4,4N5-Cl_5(118)	C_4-chrysene
3,3N,4,4N,5-Cl_5(126)	Benzo[*b*]fluoranthene
2,2N,3,3',4,4N-Cl_6(128)	Benzo[*k*]fluoranthene
2,2N,3,4,4N,5-Cl_6(138)	Benzo[*a*]pyrene
2,2N4,4N,5,5N-Cl_6(153)	Dibenzo[*a*,*h*]anthracene
2,2N3,3',4,4N,5-Cl_7(170)	Benzo[g,h,i]perylene
2,2N,3,4,4N,5,5N-Cl_7(180)	Indeno[1,2,3-*c*,*d*]pyrene
2,2N,3,4',5,5N,6-Cl_7(187)	Perylene
2,2N,3,3N,4,4N,5,6-Cl_8(195)	Biphenyl
2,2N,3,3N4,4N,5,5N,6-Cl_9(206)	Benzo[*e*]pyrene
Decachlorobiphenyl-Cl_{10}(209)	Dibenzofuran
Polynuclear Aromatic Hydrocarbons (PAHs)[a,d]	Benzothiazole
Naphthalene	**Pesticides**[c,d]
C_1-naphthalenes	Hexachlorobenzene
C_2-naphthalenes	Lindane
C_3-naphthalenes	Endrin
C_4-naphthalenes	Aldrin
1-methylnaphthalenes[f]	Dieldrin
2-methylnaphthalenes[f]	Mirex
2,6-methylnaphthalenes[f]	Heptachlor
2,3,5-methylnaphthalenes[f]	Heptachlorepoxide
Acenaphthylene	alpha-chlordane
Acenaphthene	cis-chlordane
Fluorene	trans-Nonachlor
C_1-fluorenes	2,4N-DDD
C_2-fluorenes	4,4N-DDD
C_3-fluorenes	2,4N-DDE
Phenanthrene	4,4N-DDE
1-methylphenanthrene[f]	2,4N-DDT
Anthracene	4,4N-DDT
	DDMU
	Lipids[c,d]

[a] Flounder liver; lobster hepatopancreas
[b] Flounder and lobster edible tissue
[c] Flounder edible tissue and liver; lobster edible tissue and hepatopancreas
[d] Mussel soft tissue (Gloucester)
[e] Mussel soft tissue (Sandwich)

[f] Measured in mussel tissue in 1992–1994 and 1996–1999.

Table 2-8. Statistical Analyses Performed by Tissue Type.

Matrix	Test	Data
Flounder Fillets	ANOVA	Compare 1999 stations for Total PCBs, Pesticides, and mercury.
Flounder Liver	ANOVA	Compare 1999 stations for Total PAHs, Total PCBs, Pesticides, and select metals.
Lobster Meat	ANOVA	Compare 1999 stations for Total PCBs, Pesticides, and mercury.
Lobster Hepatopancreas	ANOVA	Compare 1999 stations for Total PCBs, Total PAHs, Pesticides, and select metals.
Mussels	ANOVA	Compare 1999 40/60 day deployed station data for Total PCBs, Total LMW-PAHs, Total HMW-PAHs, Pesticides, lead, and mercury.
Mussels	t-test	Compare background to 40/60-day data for Total PCBs, Total LMW-PAHs, Total HMW-PAHs, Pesticides, lead, and mercury.

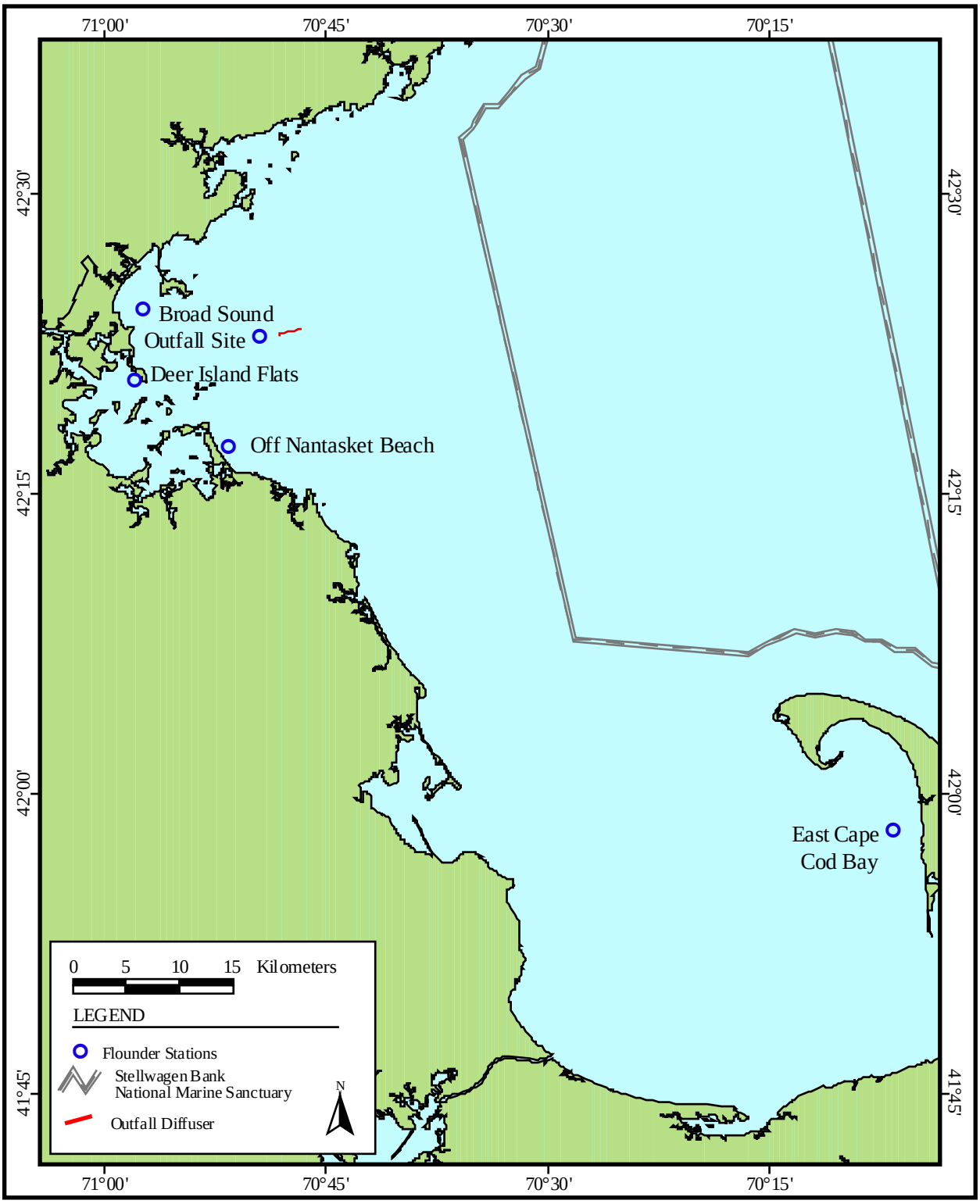


Figure 2-1. Flounder Monitoring Locations.

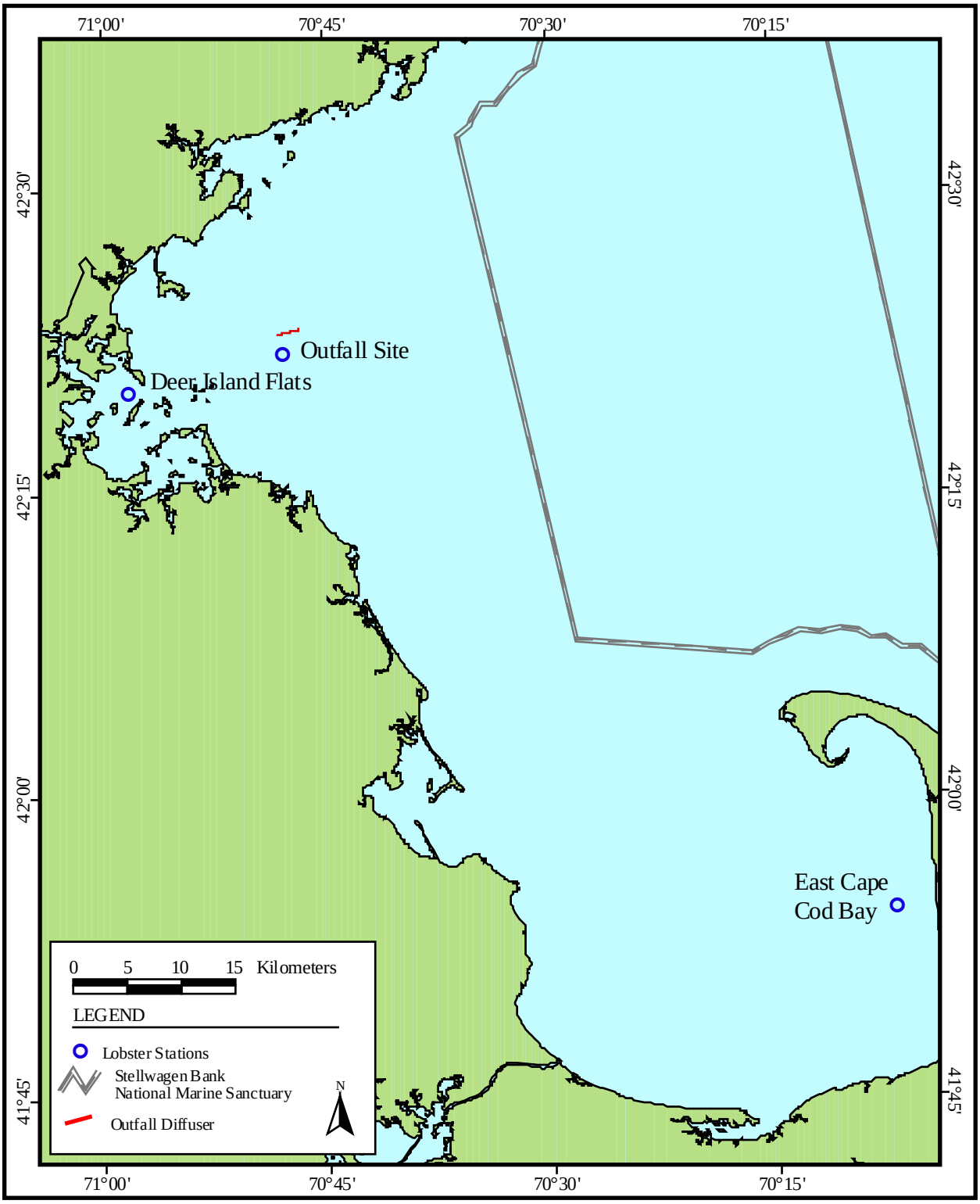


Figure 2-2. Lobster Monitoring Locations.

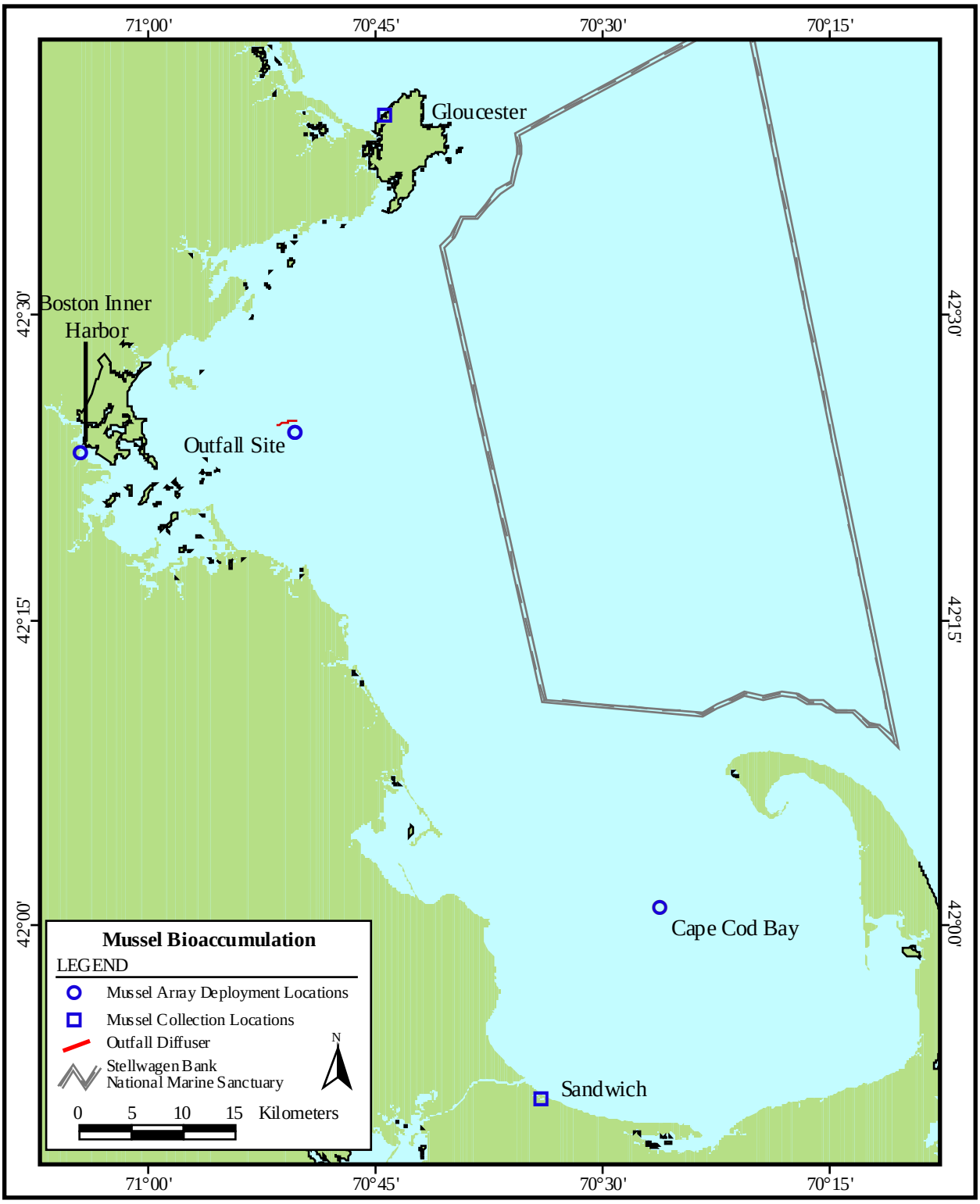


Figure 2-3. Mussel Collection and Deployment Locations.

3.0 RESULTS AND DISCUSSIONS

3.1 Winter Flounder

3.1.1 Fish Collected

Winter flounder, each a minimum 30 cm in length, were collected between April 14 and May 10, 1999 at five stations in the study area (Figure 2-1). Fifty flounder were collected from each station. All fish were sampled for liver histology and age. Fifteen of these fish from each station were sampled for chemical analysis of liver and fillet. The catch per unit effort (CPU), defined as the number of fish obtained per minute of bottom trawling time, is reported per station in Table 3-1. The May catch at Deer Island increases the CPU at that station to the highest level seen in this project. On the other hand, Nantasket Beach CPU has been declining over the past several years to the point that 1999 had the lowest CPU since the program began. CPU for the other sites were within historical ranges.

3.1.2 Age/Length Parameters

The physical characteristics (*i.e*. mean length, weight, age) of the winter flounder collected in 1999 are given in Table 3-2. Mean length at each station ranged from 33 cm at Broad Sound (BS) to 37 cm at DIF. The flounder taken from DIF on May 5th were significantly larger in size than from other sites and from DIF in previous years (Table 3-2). A similar anomalous size grouping was observed in BS in 1991. Mean age ranged from 3.9 years at DIF and BS to 4.4 years at OS.

3.1.3 External Condition

The external conditions (*i.e*. fin erosion, gross abnormalities) of winter flounder collected in 1999 are presented as averages per station in Table 3-2. As described in Section 2.1.5, each of the individual winter flounder collected were assessed for external conditions, and rated on a scale of 0 to 4 (no units), with 0 indicating the absence of the condition and 4 indicating extreme abnormalities (or erosion). As shown in Table 3-2, fin erosion at all stations was at a low level, ranging from 0.1 to 0.3. These levels continue to be extremely low at all stations.

3.1.4 Inter-station Comparison of Liver Lesion Prevalence

Neoplasms and focal hydropic vacuolation in flounder liver were absent from all stations, except for one focal hydropic vacuolation occurrence from DIF (Table 3-3). This sustains the trend of neoplasms being rare to absent since 1992 at Deer Island and Broad Sound (Figure 3-1). They have always been rare or absent at the other three stations.

As found previously in the baseline period, centrotubular hydropic vacuolation (CHV) was the most common form of vacuolation. CHV prevalence at Deer Island (Station 1) was the rarest it has been during the monitoring program (28%). This is the first occasion during the Monitoring Program that Deer Island Flats flounder have shown a lower prevalence of CHV than Nantasket Beach (Figures 3-2 and 3-3). In contrast, in 1999 CHV prevalence rose somewhat at Eastern Cape Cod Bay, Nantasket Beach and Broad Sound relative to 1998 and remained much the same at the Outfall Site. In 1991, when fish were sampled in February, April and May, the CHV prevalences at Deer Island Flats were 50, 72 and 35%, respectively (Moore *et al*., 1992). Because the lowest prevalence of CHV in 1991 at DIF occurred during the May sampling, the low level of vacuolation at DIF in May 1999 should be treated with some caution, given the later sampling date (May 10 as compared to mid-April for the other stations). This could, however, be a real trend showing an ongoing decline of contaminant response at the Deer Island Flats Station.

3.1.5 Relationships Between Age, Length and Lesion Prevalence

There were no obvious relationships between age or length and lesion prevalence, suggesting that lesion prevalence differences observed among stations were not driven by differences in sampling, but by differences in environmental conditions among the stations.

3.1.6 Spatial Comparison of Tissue Contaminant Levels in 1999

The body burdens of contaminants were determined for both edible tissue (fillets) and liver tissue for winter flounder collected in the 1999 survey. All PCB congener 180 data for flounder tissue and liver were considered suspect and not used in the calculation of total PCBs. Since PCB congener 180 tends to contribute five to ten percent of total PCBs, 1999 totals for PCBs are probably low by 5–10 percent. Mean values for selected organic compounds and metals were compared and tested for significance using ANOVA and a two-tailed student t-test assuming equal sampling distribution and variances (Microsoft Excel®) ($p=0.05$). Statistically significant results of the flounder analyses ($p < 0.05$) performed in 1999 are presented in Table 3-4 (for fillets) and Table 3-5 (for livers). A summary of both individual flounder replicate concentrations and mean and standard errors of the replicate analyses for both 1999 fillet and liver tissues are provided in Appendix B and Appendix C, respectively.

3.1.6.1 Edible Tissue

Comparison of the 1999 mean concentrations of organic compounds in fillets across the study area indicates that the concentrations of organic contaminants were numerically similar among all sites except ECCB, where concentrations of all organic contaminants were found to be the lowest (Figures 3-4 and 3-5). The highest concentrations for total DDT and chlordane were found at NB and the highest concentrations for total PCB and dieldrin were found at OS. Mercury, the only metal measured in edible tissue, was highest in fillet samples from OS and lowest at ECCB (Figure 3-6).

Results from the single factor ANOVA evaluating whether contaminants in flounder fillet differ between sampling sites suggest that total PCB, total DDT, total chlordane and mercury concentrations were significantly different between the sampling sites ($p < 0.05$) (Table 3-4). For most of the organic compounds, the concentrations at ECCB were significantly lower than at DIF, NB, and BS. ECCB and OS organic concentrations were not significantly different. For mercury, concentrations at ECCB were significantly lower than at the other four stations.

3.1.6.2 Liver

Comparison of the 1999 mean concentrations of organic compounds in flounder livers across the study area showed a different trend than observed for edible tissue. In general, the highest concentrations of organic contaminants were found in samples from DIF and the lowest at ECCB (Figures 3-7 and 3-8). Metals concentrations in livers, however, were more variable between sites (Figures 3-9 and 3-10). Lead, cadmium, and copper were highest at the OS, similar to the trend observed for organics in fillets. Mercury, silver, and zinc were highest at NB. The highest concentrations of chromium and nickel were found at BS. Unlike the organic compounds, most of the metals were found at their lowest concentrations at DIF. The exceptions were lead and chromium, which were lowest at ECCB.

Of the organic contaminants measured, total PCB, total DDT, total chlordane, and hexachlorobenzene (HCB) were significantly different between DIF and the other sampling sites in 1999 (Table 3-5). Total DDT and total chlordane levels were significantly higher at DIF than at the other four sites. For total PCB, concentrations in 1999 at DIF were significantly higher than those at the other four stations, and concentrations at NB and BS were significantly higher than at ECCB. Of the inorganic contaminants measured, only copper and mercury showed a statistically significant difference in liver contaminant concentrations among any of the five sites tested ($p = 0.035$ and 0.0009, respectively). At DIF, copper

levels were significantly lower than at OS, and mercury levels were significantly lower than at NB, BS, and OS.

3.1.7 Comparison of 1999 Contaminant Levels to Other Baseline Data

Body burdens of selected contaminants have been measured in winter flounder since 1992. This section discusses the temporal trends observed from 1992 through the present. A summary of means and standard errors of the replicate analyses for both 1999 and historical fillet and liver tissues are provided in Appendix C.

3.1.7.1 Edible Tissue

Body burdens of organic compounds monitored in edible tissue in 1999 were consistently similar to or lower than the levels measured in previous years (Figures 3-4 and 3-5). Total PCB and DDT at DIF show an apparent downward trend since 1996. However, dieldrin was slightly higher at all locations compared to previous years. These changes could be due to co-elution encountered during the analysis of PCBs and pesticides in 1999. The concentrations among stations were less variable in 1999 than during previous years.

Mercury was the only metal measured in edible tissue from winter flounder. The 1999 concentrations of mercury at DIF, OS, and ECCB were consistently higher than the concentrations in 1998 (Figure 3-6). Mercury concentrations at all stations have been variable over time, with the lowest concentrations routinely found at ECCB and BS.

Total PCBs and DDTs at NB in 1999 are within the historical range (Figures 3-4 and 3-5). Fillets from fish collected at BS appear to have decreasing levels of PCBs and DDTs since 1992. Mercury concentrations at both NB and BS were within the historical range (Figure 3-6).

3.1.7.2 Liver

Concentrations of organic contaminants (PCBs, chlorinated pesticides, PAHs) in livers from winter flounder in 1999 were generally comparable to or lower than those measured in previous years and very similar to 1998 concentrations. Generally, the highest concentrations in all years were detected in livers from fish collected at DIF and the lowest concentrations were observed at ECCB.

The spatial pattern in metals concentrations, for the most part, did not follow that of organic contaminants (Figures 3-9 and 3-10). Metals concentrations tended to be highest at OS and ECCB throughout the baseline period for the three core sites, rather than at DIF, as observed for organic contaminants. Inorganic contaminants showed no clear trends during the baseline period. 1999 concentrations were generally within the established baseline range at DIF and ECCB. However, in 1999, lead, mercury, cadmium, copper, and silver were at the upper end of the historical range at OS.

1999 total PCB concentrations at NB were within the range of measured values for the baseline period, and BS shows a downward trend in total PCB since 1992 (Figure 3-7). Concentrations of total DDT in 1999 were the lowest measured during the baseline period at NB and similar to the 1996 value at BS (Figure 3-8). Mercury concentrations at NB and BS were within the range of previously measured baseline values. 1999 chromium and silver data for NB suggest possible increasing trends for these metals since 1992 (Figures not given, but data are presented in Appendix C).

3.1.8 Relationship of Contaminant Levels to Histopathology

As previously observed, relationships between contaminant burdens and histopathology varied depending on the compounds and tissue compared. Broadly speaking, the lowest levels of centrotubular hydropic

vacuolation and lowest organic contaminant burden were found at the ECCB, intermediate levels at OS and higher levels at the stations at or around Boston. The relationship for CHV and fillet and liver chlordane is shown as an example in Figures 3-11 and 3-12. For chlordane at DIF, 1999 appears to have been on the low side of what the previous years would have predicted for both chlordane concentrations and CHV prevalence. The relationships between inorganic contaminants and CHV prevalence are, as previously observed, more complex, and show no obvious correlations.

3.1.9 Relationship to Contaminant Levels to FDA Action Limits

The U.S. Food and Drug Administration (FDA) has set action limits for the maximum tissue concentrations of specific contaminants in the edible portions of fish and fishery products. For the MWRA biomonitoring program, Caution Levels are set at 2 times the OS baseline mean (1992-1998). Warning Levels are set at 80% of the FDA Limits (MWRA 1997a – Contingency Plan). Caution and Warning Levels apply to the outfall (OS) only. These two levels provide reference benchmarks for detecting adverse changes (and their potential human health risks) once the new outfall is on line. The means at DIF and ECCB were also compared for information only. The 1999 mean concentrations of target analytes in flounder edible meat, per station, were compared to the FDA's Action Limits and the MWRA caution and warning levels through 1998 for the outfall (Table 3-6). In 1999, the mean value for dieldrin at OS exceeded the MWRA Caution Level. There were no exceedences of the MWRA Warning Levels or the FDA Limits in 1999. No edible winter flounder tissues from previous years exceeded any of the MWRA Warning levels.

3.2 Lobster

3.2.1 Lobster Collection

The 1999 lobster survey was conducted by purchasing lobster from commercial lobstermen (the alternate method presented in the CW/QAPP). Fifteen lobsters were collected from each location. Due to lack of lobsters in the site areas from July until September, samples were not collected at OS until November.

3.2.2 Size, Sex, and External Conditions

The size, sex and external conditions (*i.e*. black gill disease, shell erosion, parasites, external tumors, etc.) were determined for the lobsters collected in the 1999 survey. The mean length and weight of lobsters collected in 1999 are presented in Table 3-7. Little difference in lobster length or weight was observed between the three sampling sites. The ratio of female to male lobster is also presented in Table 3-7. Mostly males were found at DIF and ECCB and mostly females at OS.

Table 3-8 presents the average values for general external observations made for the 15 lobsters collected at each station in the 1999 survey. In general, no deleterious conditions were noted in any of the lobsters collected during the survey.

3.2.3 Spatial Comparison of Tissue Contaminant Levels in 1999

The body burdens of contaminants were determined for both edible tissue (tail and claw meat) and liver tissue (hepatopancreas) for lobster collected in the 1999 survey. Mean values for selected organic compounds and metals were compared and tested for significance using ANOVA and a two-tailed student t-test assuming equal sampling distribution and variances (Microsoft Excel®) ($p=0.05$). Statistically significant results ($p < 0.05$) of the lobster analyses performed in 1999 are presented in Table 3-9 (for meat) and Table 3-10 (for hepatopancreas). All 1999 individual replicate concentrations for each contaminant can be found in Appendix B. Means, standard error, and *n* were determined for all stations and all years, and are presented in Appendix C.

3.2.3.1 Edible Tissue

Comparison of the 1999 mean concentrations of organic compounds in lobster meat across the study area indicate that the highest concentrations were found at DIF and the lowest concentrations were found at ECCB (Figures 3-13 and 3-14). However, for DDT, the lowest concentrations were found at OS. Mercury, the only metal measured in lobster meat, was highest in samples from OS and DIF and lowest at ECCB (Figure 3-15).

Most organic contaminants in lobster edible tissue had statistically significantly result from the ANOVA analysis (Table 3-9). Concentrations at DIF for total PCBs, total DDT, total chlordane and dieldrin were significantly higher than were those at OS and ECCB. Concentrations of all detected organic compounds at DIF were significantly higher than were those at ECCB. OS concentrations were significantly greater than at ECCB, except for Total DDT and mirex. Concentrations of mercury were not significantly different among the three sites.

3.2.3.2 Hepatopancreas

Comparison of the 1999 mean concentrations of organic compounds in lobster hepatopancreas across the study area showed the same spatial pattern as for edible tissue, with the highest concentrations generally found in samples from DIF and the lowest at ECCB (Figures 3-16 through 3-18). This high-to-low pattern is a general one, with HCB and lindane being the exceptions. Metal body burdens were more variable spatially (Figures 3-19 and 3-20). Although there was no clear spatial pattern for the inorganics, a majority of the metals were highest in samples from DIF (Pb, Cu, Zn) or from OS (Hg, Cd, Ag).

Total PCB, total PAH, total DDT, total chlordane and dieldrin levels all had statistically significant differences in contaminant concentrations between two or more of the sampling sites, and all but dieldrin were significantly higher at DIF than at OS and ECCB (Table 3-10). Concentrations of total PCB, total chlordane and dieldrin were significantly lower at ECCB than at DIF and OS. Of the inorganic contaminants, cadmium, copper, lead, mercury and zinc concentrations were found to be significantly different among two or more of the sampling sites. Levels of lead and copper in samples from DIF were significantly higher than in samples from ECCB. Cadmium and mercury concentrations in samples from OS were significantly higher than were those from DIF. Zinc levels at DIF and ECCB were significantly higher than were those at OS.

3.2.4 Comparison of 1999 Tissue Contaminant Levels to Other Baseline Data

Body burdens of selected contaminants have been measured in lobster since 1992. The data for stations DIF, OS, and ECCB are presented below.

3.2.4.1 Edible Tissues

The general spatial pattern observed in 1999 (*i.e.*, DIF having the highest and ECCB the lowest body burdens of organic contaminants) is consistent with the historical spatial patterns (Figure 3-13 and 3-14). Concentrations were within the historical range of values, though 1999 levels were slightly higher than 1998 levels.

The spatial pattern of mercury body burdens observed in 1999 (*i.e.*, OS generally the highest and ECCB the lowest) was consistent with historical trends (Figure 3-15). 1999 mercury concentrations at all three stations tended to be in the middle of the historical range.

3.2.4.2 Hepatopancreas

In general, the spatial pattern of organic contaminants observed in lobster hepatopancreas in 1999 was consistent with historical patterns (*i.e.*, DIF having the highest and ECCB the lowest body burdens of

organic contaminants) (Figures 3-16 through 3-18). 1999 total PCBs and DDTs continued apparent upward trends since 1994 at all three stations but especially at DIF. An upcoming Toxics Review will address this issue. Total PAHs appear to have decreased during the baseline period.

Historically, metal body burdens have been more variable than the organic burdens, with ECCB and OS metals often being as high or higher than those from DIF (Figures 3-19, 3-20, and 3-21). In 1999, tissue concentrations of silver at all three sites and of copper at DIF and OS continued an apparent upward trend and were the highest detected during the program. Lead concentration in DIF lobster hepatopancreas in 1999 were notably higher than any previously observed. Concentrations of lead in CCB lobster hepatopancreas were slightly higher in 1998 and 1999 in relation to concentrations from 1993 to 1997.

3.2.5 Relationship of Contaminant Levels to FDA Action Limits

The U.S. Food and Drug Administration (FDA) has set action limits for the maximum tissue concentrations of specific contaminants in the edible portions of fish and fishery products. For the MWRA biomonitoring program, Caution Levels are set at 2 times the OS baseline mean (1992-1998). Warning Levels are set at 80% of the FDA Limits (MWRA 1997a – Contingency Plan). Caution and Warning Levels apply to the outfall (OS) only. These two levels provide reference benchmarks for detecting adverse changes (and their potential human health risks) once the new outfall is on line. The means at DIF and ECCB were also compared for information only. The 1999 mean concentrations of target analytes in lobster edible meat, per station, were compared to the FDA's Action Limits and the MWRA caution and warning levels through 1998 for the outfall (Table 3-11). No exceedances of the MWRA Caution (1992-1998 baseline) and Warning Levels or the FDA Limits were noted in 1999 for lobster meat. To date, no lobster meat tissues have exceeded any of the FDA Action Limits. However, concentrations of PCBs in hepatopancreas have slightly exceeded the FDA Action Limits at DIF since 1996. Concentrations of PCBs in hepatopancreas tissue in lobsters from the OS have also come close to FDA limits since 1995. This is consistent with the current MA State Advisory regarding consumption of lobster tomalley (*i.e*. hepatopancreas) for lobsters caught in Massachusetts' waters.

3.3 Blue Mussel

3.3.1 Mussels Collected

The 40-day mussel retrieval was performed on August 9 and 10, 1999. Samples were successfully collected at BIH, OS and CCB stations (Table 3-12). No arrays and no samples were recovered at Deer Island. As all four arrays were still present at CCB, only one array containing the short count of Sandwich mussels (13) was recovered for archival.

On August 20, 1999, a supplemental effort was mounted to search for and recover the missing moorings from the Deer Island station. A side scan sonar system was used to search a large area (approximately 1/4 mile by 1/4 mile) at and around the mooring deployment location just south of the old Outfall structure. Hard hat divers were used to search and recover targets identified by the side scan sonar. The moorings were not found.

The 60-day retrieval was performed on August 30 and September 2, 1999. Samples were successfully recovered at BIH, OS and CCB stations (see Table 3-13). Because of the limited number of Sandwich Mussels collected, two of the three mooring arrays collected at CCB contained only 13 mussels each. The third contained the standard 30. With all CCB moorings recovered and very low mortality, there were more than enough samples collected for analysis.

3.3.1.1 Survival

The percent survival observed in the caged mussels was high (*i.e.*, ≥ 86%) for both the 40- and 60-day harvested mussels (Table 3-14). OS showed no mortality in either the 40- or 60-day collections. Survival at CCB was also high (97% and 100%, respectively). The lowest survival rates were observed at BIH for both the 40-day collection (86%) and the 60-day collection (87%).

3.3.2 Spatial Comparison of Tissue Contaminant Levels in 1999

The differences in mussel tissue contaminant levels were examined across the various sampling and deployment locations. Mean values for selected organic compounds and metals were compared among deployment stations and compared to pre-deployment means and tested for significance using a two-tailed student t-test assuming equal sampling distribution and variances (Microsoft Excel®) (p=0.05). Details of the results of the mussel analyses performed in 1999 are presented in Tables 3-15 and 3-16 and discussed below. Summary tables of organic and inorganic contaminant concentrations for individual mussel composites are included in Appendix B. Concentrations of station means, standard errors of the means and *n* values are summarized in Appendix C.

3.3.2.1 Mercury and Lead

Mercury tissue concentrations were highest at BIH (0.099 μg/g) and lowest at CCB (0.053 μg/g) (Figure 3-22). The concentrations of mercury at all three deployment sites were significantly different from one another (Table 3-15). Mercury concentrations at CCB were significantly lower than in the pre-deployed Sandwich mussels (Table 3-16). Mercury levels at BIH were significantly higher than levels in the Sandwich mussels. There was a significant difference between the mercury concentrations in mussels from OS and Sandwich.

Lead concentrations in mussels at BIH were significantly higher than at OS and CCB and were significantly higher than in the pre-deployed Sandwich mussels (Figure 3-23). Mussels at OS had lead concentrations significantly lower than the Sandwich mussels. CCB mussel lead concentrations were not significantly different than the pre-deployed values.

3.3.2.2 Polychlorinated Biphenyls

Mussel tissues were analyzed for 20 polychlorinated biphenyl (PCB) congeners. The total concentrations of these 20 PCBs were significantly higher at BIH (491.8 ng/g) than at the other stations (Figure 3-24). All three stations had concentrations of total PCBs that were significantly different from one another (Table 3-15). Concentrations of total PCBs in BIH deployed mussels were significantly higher than the pre-deployed Gloucester mussels (Table 3-16). Total PCB concentrations in mussels at OS were significantly lower than in the pre-deployed Gloucester mussels. The concentrations found at CCB and Gloucester were not significantly different.

3.3.2.3 Pesticides

Mussel tissues were analyzed for individual chlorinated pesticides. Most pesticides measured were detected in mussels from at least one location. Only aldrin and endrin were not detected in any of the samples. In general, highest pesticide concentrations were found in mussels deployed at BIH (Figure 3-25). Total chlordane, dieldrin and mirex concentrations were significantly higher in mussels deployed at BIH than at OS and CCB (Table 3-15) Total DDT and lindane concentrations were significantly different among all three stations. Concentrations of HCB in OS deployed mussels were significantly lower than concentrations in BIH and CCB deployed mussels.

The concentrations at BIH were significantly higher than in the pre-deployed mussels for total DDT, total chlordane, dieldrin and mirex (Table 3-16). Concentrations of all pesticides were either not significantly

different or were significantly lower at OS and CCB than in the pre-deployment mussels. Concentrations of lindane, however, were significantly higher at OS and CCB than pre-deployment levels.

3.3.2.4 PAH Compounds

Total PAHs, as well as total low and high molecular weight PAHs, have been calculated by different methodologies during the course of this study. For purposes of comparison across multiple study years, the method common to most years was used for evaluating temporal trends (see section 3.3.3). This method is referred to here as the "Historical NOAA List" (see Table 3-17). This list is much less comprehensive than the current list, referred to as the "Total PAH List"(Table 3-17). The historical NOAA list includes primarily parent PAH compounds and only five individual alkylated naphthalenes. The lack of quantitation of additional alklyated groups (*e.g*. alkyl dibenzothiophenes, phenanthrenes, anthracenes etc.) results in a significantly lower calculated total PAH value. In addition, in 1995, the individual five alkylated "NOAA" PAHs were not measured. Instead, the C1, C2 and C3-napthalene homologue groups were quantified. To make 1995 results more comparable to the NOAA historical list, values for the individual naphthalene compounds were estimated using ratios of the individuals to their respective homologue groups from 1996 and 1997 data sets.

Current data are discussed in terms of the more recent "Total PAH List". Temporal trends, discussed in Section 3.3.3, are presented using the "Historical NOAA List".

The target list of PAH compounds analyzed in 1999 is presented in Table 3-17 and includes all compounds in the "Total PAH List".

Summary tables of total low molecular weight PAHs (LMW-PAH) (defined as those target 2 and 3 ringed compounds) and total high molecular weight PAHs (HMW-PAH) (defined 4, 5 and 6 ringed compounds) for individual mussel composites are included in Appendix B. Mean concentrations of total LMW-PAH and total HMW-PAH are presented in Appendix C, as are the standard errors and *n* values associated with these means for each station. The concentrations of LMW and HMW-PAHs at all locations are shown in Figure 3-26.

The 1999 average body burdens of Total LMW and HMW PAH were highest in mussels deployed at BIH, and the concentrations of PAH were significantly different among the three stations (Table 3-15). Concentrations at BIH were significantly higher than the pre-deployed concentrations observed at Gloucester (Table 3-16). LMW and HMW PAH concentrations in mussels deployed at OS and CCB were significantly lower than pre-deployment levels.

3.3.2.5 Lipid Results

Lipid concentrations were measured in all mussel composites (Appendix B). Values in 1999 were very similar for BIH (6.13 ±0.2% dry), and Gloucester (6.59 ± 0.5% dry) and slightly higher for OS (8.15 ± 0.2% dry) and CCB (11.9 ± 0.5% dry). Based on the findings of Mitchell *et al.* (1998), it does not appear that normalization for lipid content elucidates any trends in chemical concentrations. No lipid normalization of mussel data was performed.

3.3.3 Comparison of 1999 Contaminants Levels to Other Baseline Data

Mussel tissue burdens were also compared across the various study years. In the past, when an analyte was reported as not detected, the detection limit value was used in calculations. For consistency with other fish and shellfish data and to avoid the problems introduced by the use of varying magnitudes of reporting/detection limits used over the years, all non-detects were equated with "zero" in this report. The

following section provides a discussion of trends observed for the analytes measured. Selected figures are presented to illustrate these trends.

3.3.3.1 Mercury and Lead

Mercury concentrations measured in mussels in 1999 at all sites were similar to the concentrations and to the spatial pattern in 1998, though measured concentrations were slightly lower in 1999 (Figure 3-27). In fact, the levels at all four stations were among the lowest measured values for mercury since 1993.

Lead concentrations measured in 1999 at Sandwich (1.56 μg/g) and OS (1.09 μg/g) were among the lowest measured since the beginning of the program (Figure 3-28). Lead concentrations measured at BIH in 1999 were similar to 1998 levels and more than 2 times lower than 1997 levels.

3.3.3.2 Polychlorinated Biphenyls

Data for 1999 PCBs at most stations were in the low end of the historical range. The spatial pattern observed in 1999 was similar to the pattern observed in previous years, with BIH having the highest concentrations and OS the lowest concentrations. Figure 3-29 shows the distribution of total PCBs since 1991 at Gloucester, BIH, DI, OS and CCB.

3.3.3.3 Pesticides

1999 concentrations of total DDTs, chlordanes, and dieldrin were similar to or lower than concentrations observed in previous years (Figure 3-30 and Appendix C). Spatial patterns have remained constant over time, with concentrations in BIH mussels higher than at other stations.

3.3.3.4 PAHs

Pre-deployment total PAHs in mussels collected in 1999 were the highest measured since 1991 (Figure 3-31). This was mainly due to the HMW PAHs. At the other stations, PAHs were within the historical range.

3.3.4 Relationship of Contaminants to FDA Action Limits

The U.S. Food and Drug Administration (FDA) has set action limits for the maximum tissue concentrations of specific contaminants in the edible portions of fish and fishery products. For the MWRA biomonitoring program, Caution Levels are set at 2 times the OS baseline mean (1992-1998). Warning Levels are set at 80% of the FDA Limits (MWRA 1997a – Contingency Plan). Caution and Warning Levels apply to the outfall (OS) only. These two levels provide reference benchmarks for detecting adverse changes (and their potential human health risks) once the new outfall is on line. The 1999 mean concentrations of target analytes in mussel tissue, per station, were compared to the FDA's Action Limits and the MWRA caution and warning levels through 1990 for the outfall (Table 3-18). In 1999, there were no exceedences of the MWRA Caution and Warning Levels or for the federal limits.

Table 3-1. Catch per Unit Effort (CPU) for Winter Flounder Trawled in April/May.

Location	1991	1992	1993	1994	1995	1996	1997	1998	1999
Deer Island	0.38	0.23	0.15	0.16	0.10	0.16	0.16	0.56	1.09
Nantasket Beach	0.48	1.29	1.52	0.88	0.88	0.77	0.43	0.41	0.21
Broad Sound	1.26	2.80	0.49	0.46	0.29	0.23	0.59	0.69	0.38
Outfall Site	0.10	0.48	0.62	0.25	0.60	0.31	0.81	0.42	0.31
East Cape Cod Bay	0.67	0.49	0.77	0.45	0.50	1.38	0.32	0.50	0.92

CPU = # fish caught per minute of bottom time
The same vessel and net were used at all times

Table 3-2. Summary of Physical Characteristics of Winter Flounder Collected in 1999.

Station Name		DIF	NB	BS	OS	ECCB
Station Number		**1**	**2**	**3**	**4**	**5**
N		50	50	50	50	50
Total Length (mm)	Mean	372.3	336.2	327.6	347.4	342.7
	Std. Dev.	35.6	32.8	26.7	36.5	28.4
	AVOVA*	2,3,4,5	1,4,5	1,4,5	1,2,3,5	1,2,3,4
Weight (g)**	Mean	728.5	493.9	502.7	555.9	513.7
	Std. Dev.	163.8	182.1	231.1	243.1	158.2
	ANOVA	2,3,4,5	1	1	1	1
Age (years)	Mean	3.9 ***	4.1	3.9	4.4	4.1
	Std. Dev.	0.8	0.8	0.7	0.8	0.7
	ANOVA	4	4		1,2,5	4
Fin erosion (0-4)	Mean	0.3	0.3	0.1	0.2	0.1
	Std. Dev.	0.5	0.6	0.4	0.5	0.4
	ANOVA					
Gross liver score (0-4)	Mean	0.0	0.0	0.1	0.0	0.0
	Std. Dev.	0.1	0.1	0.3	0.0	0.1
	ANOVA					

* Differences by ANOVA given as the station(s) that differed significantly from the station in that column
** Sample size = 15 (first 15 fish collected at each station)
*** Sample size = 48

Table 3-3. Prevalence (%) of Lesions in Winter Flounder Liver from Five Stations in Massachusetts and Cape Cod Bays – 1999.

Station Name		DIF	NB	BS	OS	ECCB
Station Number		**1**	**2**	**3**	**4**	**5**
N		50	50	50	50	50
Lesion type*	Neoplasm	0	0	0	0	0
	Focal HV	2	0	0	0	0
	Tubular HV	14	14	32	6	2
	Centrotubular HV	28	36	44	22	14
	Macrophage Aggregation	42	68	86	66	54
	Biliary Proliferation	4	20	28	12	12

*Prevalence calculated as the percentage of fish from each station showing each lesion type
HV – Hydropic Vacuolation

Table 3-4. ANOVA Results Comparing Contaminant Concentrations in Flounder Fillets in 1999.

Station Name		DIF	NB	BS	OS	ECCB
Station Number		**1**	**2**	**3**	**4**	**5**
N		3	3	3	3	3
Mercury (p=0.0006)	Mean	0.35	0.53	0.42	0.54	0.22
	Std. Dev.	0.02	0.12	0.02	0.08	0.02
	ANOVA*	3, 4, 5	5	1,5	1,5	1,2,3,4
Total PCB (p=0.019)	Mean	141.5	133.3	111.4	166.2	51.70
	Std. Dev.	7.67	19.36	13.39	71.26	10.04
	ANOVA	3, 5	5	1,5		1,2,3
Total DDT (p=0.046)	Mean	21.40	23.29	17.07	22.31	11.74
	Std. Dev.	2.30	2.80	4.31	7.71	2.07
	ANOVA	5	5			1,2
Total Chlordane (p=0.019)	Mean	9.73	10.10	8.84	7.12	2.34
	Std. Dev.	0.59	2.00	1.55	4.83	0.85
	ANOVA	5	5	5		1,2,3

*Differences by ANOVA given as the station(s) that differed significantly from the station in that column

Table 3-5. ANOVA Results Comparing Contaminant Concentrations in Flounder Livers in 1999.

Station Name		DIF	NB	BS	OS	ECCB
Station Number		**1**	**2**	**3**	**4**	**5**
N		3	3	3	3	3
Copper (p=0.035)	Mean	33.51	90.58	67.98	129.94	70.89
	Std. Dev.	4.79	48.60	22.16	32.08	28.16
	ANOVA*	4			1	
Mercury (p=0.0009)	Mean	0.22	0.74	0.49	0.65	0.31
	Std. Dev.	0.006	0.12	0.03	0.21	0.07
	ANOVA	2,3,4	1,3,5	1,2,5	1	2,3
Total PCB (p=0.00001)	Mean	2761.07	825.35	1213.75	1270.92	360.31
	Std. Dev.	56.09	170.34	178.78	565.57	192.83
	ANOVA	2,3,4,5	1,5	1,5	1	1,2,3
Total DDT (p=0.00002)	Mean	484.47	116.34	187.00	181.02	80.56
	Std. Dev.	42.64	27.01	55.79	77.57	46.05
	ANOVA	2,3,4,5	1	1	1	1
Total Chlordane (p=0.0001)	Mean	225.85	41.68	68.38	47.80	15.42
	Std. Dev.	18.22	18.81	63.29	26.48	10.65
	ANOVA	2, 3, 4, 5	1	1	1	1
HCB (p=0.018)	Mean	6.53	2.97	4.43	3.84	3.49
	Std. Dev.	0.44	0.42	0.95	0.46	2.07
	ANOVA	2, 3, 4	1	1	1	

*Differences by ANOVA given as the station(s) that differed significantly from the station in that column

Table 3-6. Comparison of FDA and MWRA Thresholds to Mean 1999 Flounder Fillet Concentrations for Selected Parameters.

Station	Total PCB (ng/g wet wt.)			Total DDT (ng/g wet wt.)			Total Chlordane (ng/g wet wt.)			Dieldrin (ng/g wet wt.)			Mercury (μg/g wet wt.)		
	mean	**se**	**n**	**mean**	**se**	**n**	**mean**	**se**	**n**	**mean**	**se**	**n**	**mean**	**se**	**n**
Deer Island Flats	24.87	0.60	3	3.76	0.20	3	1.71	0.06	3	0.65	0.19	3	0.06	0.00	3
Nantasket Beach	23.19	1.55	3	4.05	0.13	3	1.76	0.18	3	0.52	0.04	3	0.09	0.01	3
Broad Sound	20.43	2.16	3	3.14	0.53	3	1.60	0.13	3	0.49	0.08	3	0.08	0.00	3
Outfall Site	26.63	7.52	3	3.57	0.84	3	1.15	0.49	3	0.77	0.29	3	0.09	0.01	3
ECCB	8.62	0.89	3	1.96	0.18	3	0.39	0.08	3	0.12	0.03	3	0.04	0.00	3
FDA Limit	2000			5000			300			300			1		
MWRA Caution Level (2x baseline, 1992-1998)	76.22			7.99			2.88			0.55			0.17		
MWRA Warning Level (80% FDA)	1600			4000			240			240			0.8		

Table 3-7. Mean Length, Weight, and Sex Ratio of Lobsters Collected in 1999.

Parameter	N	DIF		OS		ECCB	
		Station Mean	S.E.	Station Mean	S.E.	Station Mean	S.E.
Carapace Length (mm)	15	112.9	10.8	117.9	3.2	115.2	7.5
Weight (g)	15	521.5	159.2	535.0	40.0	555.8	72.2
RATIO Male/Female*	15	12/3	NA	1/14	NA	13/2	NA

S.E. = Standard Error

Table 3-8. Mean Score – 1999 Lobster External Condition.

Parameter	N	DIF		OS		ECCB	
		Station Mean	S.E.	Station Mean	S.E.	Station Mean	S.E.
Black Gill	15	0	0	0	0	0	0
External Tumors	15	0	0	0	0	0	0
Parasites	15	0	0	0	0	0	0
Shell Erosion	15	0	0	0	0	0	0

Note: Values range from 0 (absent) to 4 (extreme).
S.E. = Standard Error

Table 3-9. ANOVA Results Comparing Contaminant Concentrations in Lobster Meat in 1999.

Station Name		DIF	OS	ECCB
Station Number		**1**	**4**	**5**
N		3	3	3
Total PCB (p=0.0003)	Mean	154.22	73.73	52.91
	Std. Dev.	22.47	5.51	7.80
	ANOVA*	4, 5	1,5	1,4
Total DDT (p=0.0006)	Mean	15.98	7.36	9.32
	Std. Dev.	1.84	0.17	1.44
	ANOVA	4, 5	1	1
Total Chlordane (p=0.000003)	Mean	5.47	2.30	1.49
	Std. Dev.	0.16	0.40	0.07
	ANOVA	4, 5	1,5	1,4
Dieldrin (p=0.00003)	Mean	6.79	5.15	4.26
	Std. Dev.	0.10	0.26	0.29
	ANOVA	4, 5	1,5	1,4
HCB (p=0.005)	Mean	0.47	0.46	0.33
	Std. Dev.	0.03	0.01	0.05
	ANOVA	5	5	1,4
Mirex (p=0.027)	Mean	0.56	0.31	0.23
	Std. Dev.	0.18	0.07	0.04
	ANOVA	5		1

* Differences by ANOVA given as the station(s) that differed significantly from the station in that column

Table 3-10. ANOVA Results Comparing Contaminant Concentrations in Lobster Hepatopancreas in 1999.

Station Name		DIF	OS	ECCB
Station Number		**1**	**4**	**5**
N		3	3	3
Cadmium (p=0.04)	Mean	4.58	15.53	12.42
	Std. Dev.	0.60	6.67	2.62
	ANOVA*	4, 5	1	1
Copper (p=0.01)	Mean	895.2	830.47	477.97
	Std. Dev.	29.29	178.69	123.50
	ANOVA	5	5	1,4
Lead (p=0.03)	Mean	0.52	0.42	0.25
	Std. Dev.	0.05	0.14	0.05
	ANOVA	5		1
Mercury (p=0.03)	Mean	0.31	0.53	0.32
	Std. Dev.	0.03	0.14	0.03
	ANOVA	4	1	
Zinc (p=0.005)	Mean	88.07	47.37	75.73
	Std. Dev.	12.83	9.33	5.29
	ANOVA	4	1,5	4
Total PCB (p=0.00001)	Mean	10255	6353	3132
	Std. Dev.	217.8	783.0	417.9
	ANOVA	4, 5	1,5	1,4
Total PAH (p=0.0001)	Mean	7597	1563	1310
	Std. Dev.	1403	285.9	135.3
	ANOVA	4, 5	1	1
Total DDT (p=0.00007)	Mean	1297	745.9	559.1
	Std. Dev.	50.00	115.48	57.95
	ANOVA	4, 5	1	1
Total Chlordane (p=0.0005)	Mean	138.0	57.94	31.85
	Std. Dev.	25.11	11.69	5.58
	ANOVA	4, 5	1,5	1,4
Dieldrin (p=0.005)	Mean	59.63	51.66	28.13
	Std. Dev.	6.40	10.94	3.36
	ANOVA	5	5	1,4

* Differences by ANOVA given as the station(s) that differed significantly from the station in that column.

Table 3-11. Comparison of FDA and MWRA Thresholds to Mean 1999 Lobster Concentrations for Selected Parameters.

Station	Total PCB (ng/g wet wt.)			Total DDT (ng/g wet wt.)			Total Chlordane (ng/g wet wt.)			Dieldrin (ng/g wet wt.)			Mercury (µg/g wet wt.)		
	mean	se	n	mean	se	n	mean	se	n	mean	se	n	mean	se	n
Deer Island Flats	23.82	2.42	3	2.46	0.17	3	0.85	0.09	3	1.05	0.09	3	0.16	0.04	3
Outfall Site	10.03	0.68	3	1.00	0.04	3	0.31	0.03	3	0.70	0.02	3	0.14	0.03	3
ECCB	6.87	0.59	3	1.21	0.10	3	0.19	0.01	3	0.55	0.02	3	0.09	0.01	3
FDA Limit	2000			5000			300			300			1		
MWRA Caution Level (2x baseline, 1992-1998)	37.28			4.56			0.78			1.80			0.30		
MWRA Warning Level (80% FDA)	1600			4000			240			240			0.8		

Table 3-12. Samples Collected During 40-day Retrieval.

Site	# Cages	Approximate # Mussels/ Cage	Approximate Total # Mussels
BIH	2 Gloucester 1 Sandwich	30	90 (60 Gloucester, 30 Sandwich)
DI	0 Gloucester 0 Sandwich	30	0 (0 Gloucester, 0 Sandwich)
OS	2 Gloucester 1 Sandwich	48 30	126 (96 Gloucester, 30 Sandwich)
CCB	2 Gloucester 1 Sandwich	48 13	109 (96 Gloucester, 13 Sandwich)

Table 3-13. Samples Collected During 60-day Retrieval.

Site	# Cages	Approximate # Mussels/ Cage	Approximate Total # Mussels
BIH	4 Gloucester 2 Sandwich	30	180 (120 Gloucester, 60 Sandwich)
DI	0 Gloucester 0 Sandwich	30	0 (0 Gloucester, 0 Sandwich)
OS	6 Gloucester 3 Sandwich	48 30	378 (288 Gloucester, 90 Sandwich)
CCB	6 Gloucester 3 Sandwich	48 30,13,13	344 (288 Gloucester, 56 Sandwich)

Table 3-14. 1999 Caged Mussels Survival Data.

Collection	Site	Total Mussels	Dead Mussels	Survival Rate
40-day	BIH	90	13	86%
	OS	90	0	100%
	CCB	74	2	97%
60-day	BIH	180	24	87%
	OS	271	1	100%
	CCB	239	0	100%

Table 3-15. ANOVA Results Comparing Contaminant Concentrations in Deployed Mussels in 1999.

Station Name		OS	BIH	CCB
Station Number		**4**	**6**	**9**
N		8	5	8
Lead (p=<0.001)	Mean	1.09	4.69	1.26
	Std. Dev.	0.23	0.80	0.25
	ANOVA*	6	4,9	6
Mercury (p=<0.001)	Mean	0.063	0.099	0.053
	Std. Dev.	0.008	0.009	0.005
	ANOVA	6, 9	4,9	4,6
Total PCB (p=<0.001)	Mean	36.87	491.80	47.66
	Std. Dev.	3.04	46.83	5.47
	ANOVA	6, 9	4,9	4,6
Total HMW PAHs (p=<0.001)	Mean	29.88	3679.7	17.85
	Std. Dev.	2.70	324.58	2.86
	ANOVA	6, 9	4,9	4,6
Total LMW PAHs (p=<0.001)	Mean	36.44	2372.7	45.73
	Std. Dev.	6.14	306.54	6.88
	ANOVA	6, 9	4,9	4,6
Total DDT (p=<0.001)	Mean	12.19	85.90	17.72
	Std. Dev.	1.32	7.03	1.95
	ANOVA	6, 9	4,9	4,6
Total Chlordane (p=<0.001)	Mean	7.72	22.50	7.52
	Std. Dev.	0.71	2.3	0.67
	ANOVA	6	4,9	6
Dieldrin (p=<0.001)	Mean	1.47	9.06	1.57
	Std. Dev.	0.10	1.14	0.22
	ANOVA	6	4,9	6
HCB (p=<0.001)	Mean	0.22	0.45	0.36
	Std. Dev.	0.09	0.07	0.07
	ANOVA	6, 9	4	4
Lindane (p=<0.001)	Mean	0.36	0.28	0.65
	Std. Dev.	0.03	0.05	0.10
	ANOVA	6, 9	4,9	4,6
Mirex (p=<0.001)	Mean	0.05	0.41	0.05
	Std. Dev.	0.02	0.03	0.01
	ANOVA	6	4,9	6

* Differences by ANOVA given as the station(s) that differed significantly from the station in that column.

Table 3-16. T-test Results Comparing Contaminant Levels in Deployed Mussels with Pre-deployed Mussels in 1999.

Station Name		OS	BIH	CCB	Pre-deployed*
Station Number		**4**	**6**	**9**	**7/8**
N		8	5	8	5
Total PCB	Mean	36.87	491.80	47.66	53.73
	Std. Dev.	3.04	46.83	5.47	10.32
	Prob.	0.001	< 0.001	0.19	NA
Total HMW PAHs	Mean	29.88	3679.7	17.85	610.85
	Std. Dev.	2.70	324.58	2.86	304.29
	Prob.	< 0.001	< 0.001	< 0.001	NA
Total LMW PAHs	Mean	36.44	2372.7	45.73	348.06
	Std. Dev.	6.14	306.54	6.88	94.27
	Prob.	< 0.001	< 0.001	< 0.001	NA
Total DDT	Mean	12.19	85.90	17.72	34.34
	Std. Dev.	1.32	7.03	1.95	8.17
	Prob.	< 0.001	< 0.001	< 0.001	NA
Total Chlordane	Mean	7.72	22.50	7.52	7.63
	Std. Dev.	0.71	2.3	0.67	2.18
	Prob.	0.91	< 0.001	0.90	NA
Dieldrin	Mean	1.47	9.06	1.57	1.44
	Std. Dev.	0.10	1.14	0.22	0.26
	Prob.	0.72	< 0.001	0.32	NA
HCB	Mean	0.22	0.45	0.36	0.38
	Std. Dev.	0.09	0.07	0.07	0.17
	Prob.	0.04	0.44	0.80	NA
Lindane	Mean	0.36	0.28	0.65	0.30
	Std. Dev.	0.03	0.05	0.10	0.05
	Prob.	0.01	0.69	< 0.001	NA
Mirex	Mean	0.05	0.41	0.05	0.15
	Std. Dev.	0.02	0.03	0.01	0.04
	Prob.	< 0.001	< 0.001	< 0.001	NA
Lead	Mean	1.09	4.69	1.26	1.56
	Std. Dev.	0.23	0.80	0.25	0.34
	Prob.	0.01	< 0.001	0.10	NA
Mercury	Mean	0.063	0.099	0.053	0.08
	Std. Dev.	0.008	0.009	0.005	0.005
	Prob.	0.01	< 0.001	< 0.001	NA

* Pre-deployed mussels for organic analysis were from Gloucester. Pre-deployed mussels for inorganic analysis were from Sandwich.

Table 3-17. Summary of PAH Lists of Analytes Used for Biaccumulation Study 1992-1999.

Total PAH List	"Historical" NOAA PAH List
Low Molecular Weight PAHs	**Low Molecular Weight PAHs**
1-METHYLNAPHTHALENE	1-METHYLNAPHTHALENE
1-METHYLPHENANTHRENE	1-METHYLPHENANTHRENE
2,3,5-TRIMETHYLNAPHTHALENE	2,3,5-TRIMETHYLNAPHTHALENE
2,6-DIMETHYLNAPHTHALENE	2,6-DIMETHYLNAPHTHALENE
2-METHYLNAPHTHALENE	2-METHYLNAPHTHALENE
ACENAPHTHENE	ACENAPHTHENE
ACENAPHTHYLENE	ACENAPHTHYLENE
ANTHRACENE	ANTHRACENE
BENZOTHIAZOLE *	
BIPHENYL	BIPHENYL
C1-DIBENZOTHIOPHENES	
C1-FLUORENES	
C1-NAPHTHALENES	
C1-PHENANTHRENES/ANTHRACENES	
C2-DIBENZOTHIOPHENES	
C2-FLUORENES	
C2-NAPHTHALENES	
C2-PHENANTHRENES/ANTHRACENES	
C3-DIBENZOTHIOPHENES	
C3-FLUORENES	
C3-NAPHTHALENES	
C3-PHENANTHRENES/ANTHRACENES	
C4-NAPHTHALENES	
C4-PHENANTHRENES/ANTHRACENES	
DIBENZOFURAN	
DIBENZOTHIOPHENE	
FLUORENE	FLUORENE
NAPHTHALENE	NAPHTHALENE
PHENANTHRENE	PHENANTHRENE
High Molecular Weight PAHs	**High Molecular Weight PAHs**
BENZ(A)ANTHRACENE	BENZ(A)ANTHRACENE
BENZO(A)PYRENE	BENZO(A)PYRENE
BENZO(B)FLUORANTHENE	BENZO(B)FLUORANTHENE
BENZO(E)PYRENE	BENZO(E)PYRENE
BENZO(G,H,I)PERYLENE	BENZO(G,H,I)PERYLENE
BENZO(K)FLUORANTHENE	BENZO(K)FLUORANTHENE
C1-CHRYSENES	
C1-FLUORANTHRENES/PYRENES	
C2-CHRYSENES	
C2-FLUORANTHENES/PYRENES	
C3-CHRYSENES	
C3-FLUORANTHENES/PYRENES	
C4-CHRYSENES	
CHRYSENE	CHRYSENE
DIBENZO(A,H)ANTHRACENE	DIBENZO(A,H)ANTHRACENE
FLUORANTHENE	FLUORANTHENE
INDENO(1,2,3-C,D)PYRENE	INDENO(1,2,3-C,D)PYRENE
PERYLENE	PERYLENE
PYRENE	PYRENE

*** Not Included in Total PAH**

Table 3-18. Comparison of FDA and MWRA Thresholds to Mean 1999 Mussel Concentrations for Selected Parameters.

Station	Total PCB (ng/g wet wt.)			Total DDT (ng/g wet wt.)			Total Chlordane (ng/g wet wt.)			Dieldrin (ng/g wet wt.)			Total PAH[1] (ng/g wet wt.)			Mercury (µg/g wet wt.)			Lead (µg/g wet wt.)		
	mean	se	n	mean	se	n	mean	se	n	mean	se	n	mean	se	n	mean	se	n	mean	se	n
Outfall Site	6.85	0.27	8	2.27	0.11	8	1.43	0.06	8	0.27	0.01	8	8.65	0.23	8	0.013	0.001	8	0.22	0.02	8
BIH	57.76	4.92	5	10.10	0.87	5	2.65	0.25	5	1.07	0.12	5	317.15	33.08	5	0.019	0.001	5	0.90	0.07	5
CCB	9.52	0.24	8	3.55	0.11	8	1.51	0.05	8	0.32	0.02	8	10.33	0.51	8	0.012	0.000	8	0.29	0.02	8
FDA Limit	2000			5000			300			300			NA			1.000			3.75		
MWRA Caution Level (2x baseline, 1992-1998)	25.73			6.80			2.47			0.61			31.01			0.041			1.02		
MWRA Warning Level[2] (80% FDA)	1600			4000			240			240			NA			0.800			3		

[1]Based on NOAA PAHs only

[2]Massachusetts Water Resources Authority (MWRA) 1997a. Contingency Plan

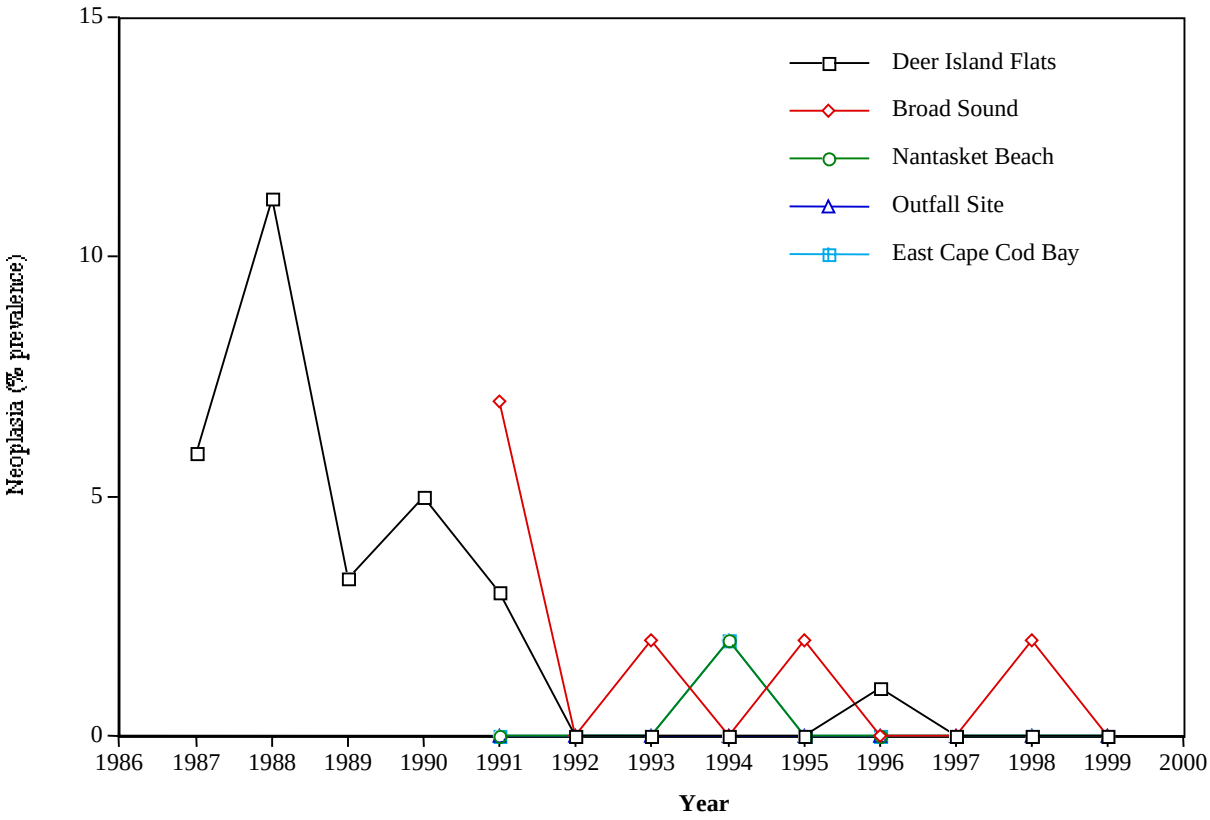


Figure 3-1. Temporal Comparison of Neoplasia Prevalence by Station Over Time.

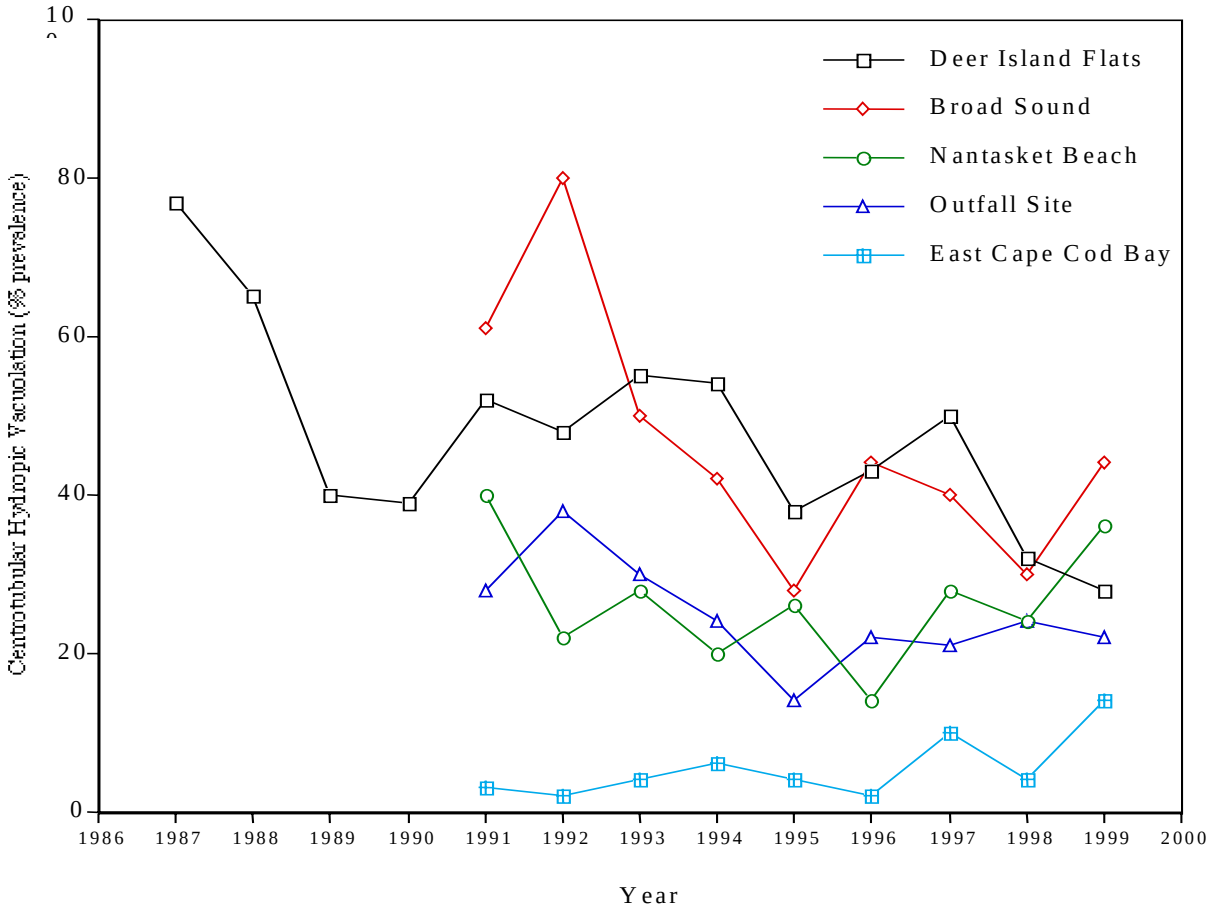


Figure 3-2. Temporal Comparison of Prevalence of Centrotubular Hydropic Vacuolation by Station Over Time.

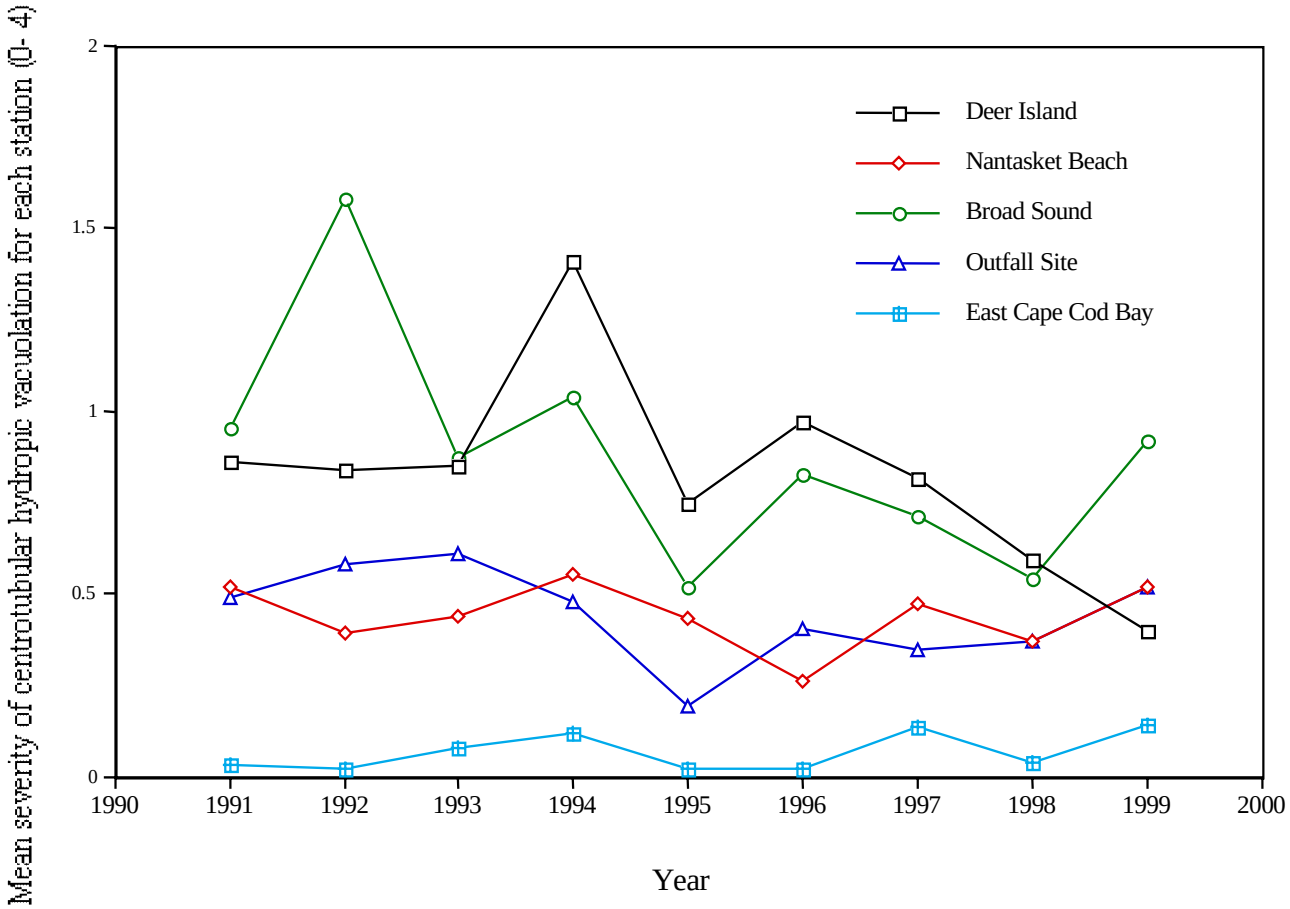


Figure 3-3. Centrotubular Hydropic Vacuolation Severity Compared Between Sites and Years.

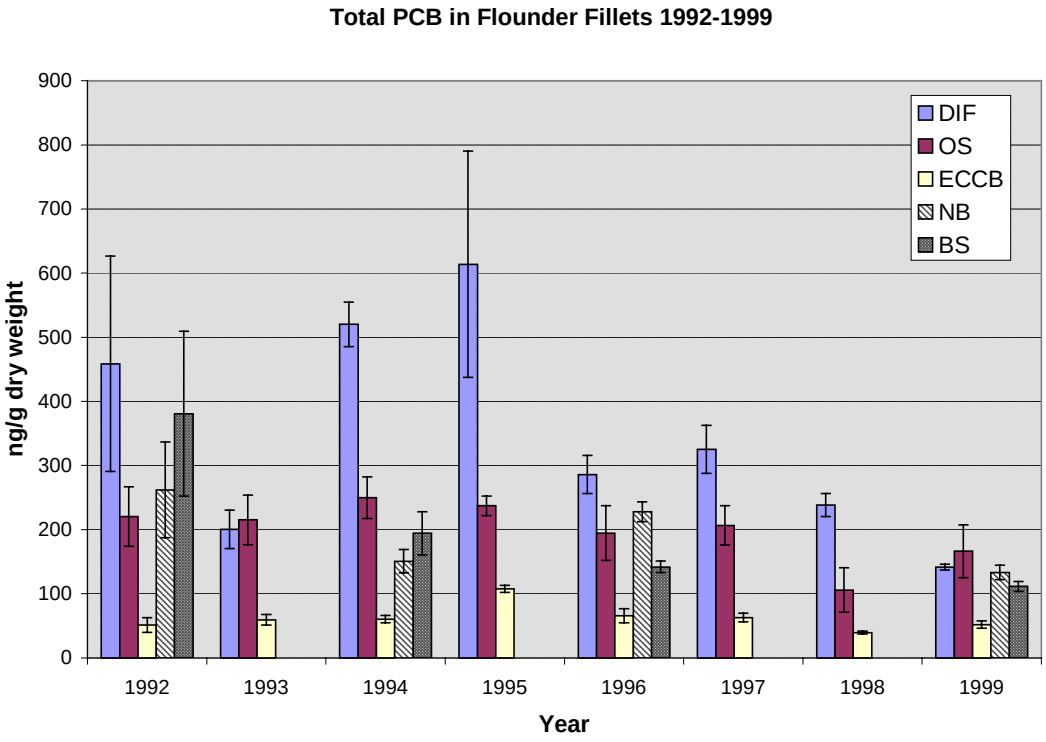


Figure 3-4. Total PCB in Flounder Fillets at the Five Collection Sites from 1992-1999.

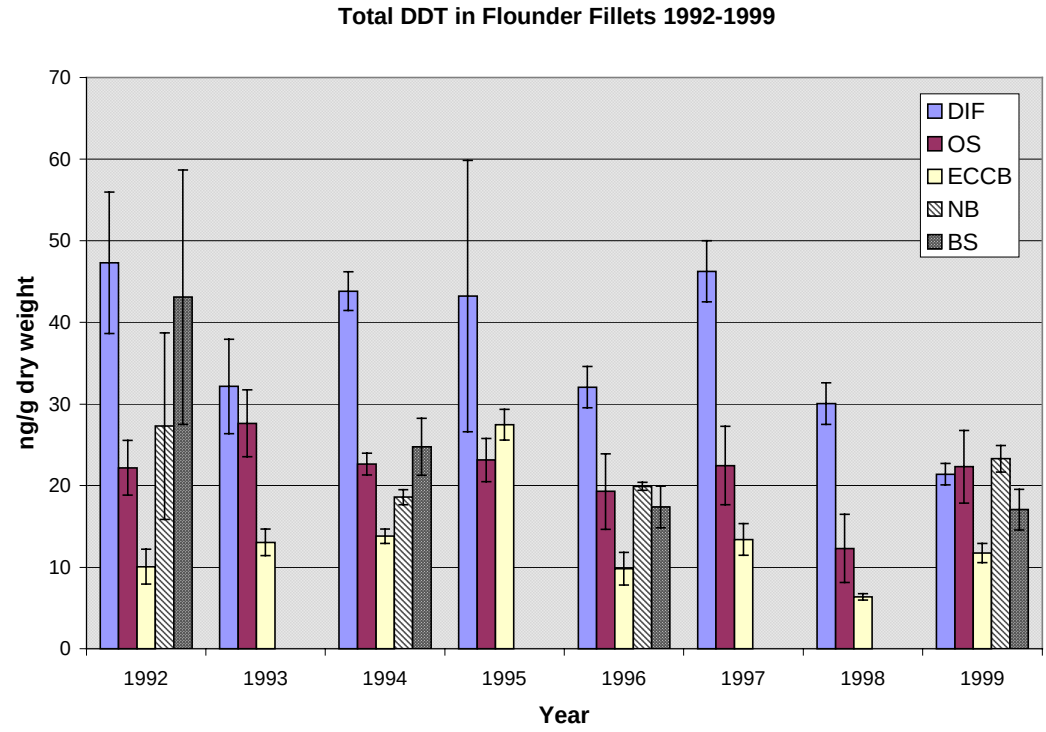


Figure 3-5. Total DDT in Flounder Fillets at the Five Collection Sites from 1992-1999.

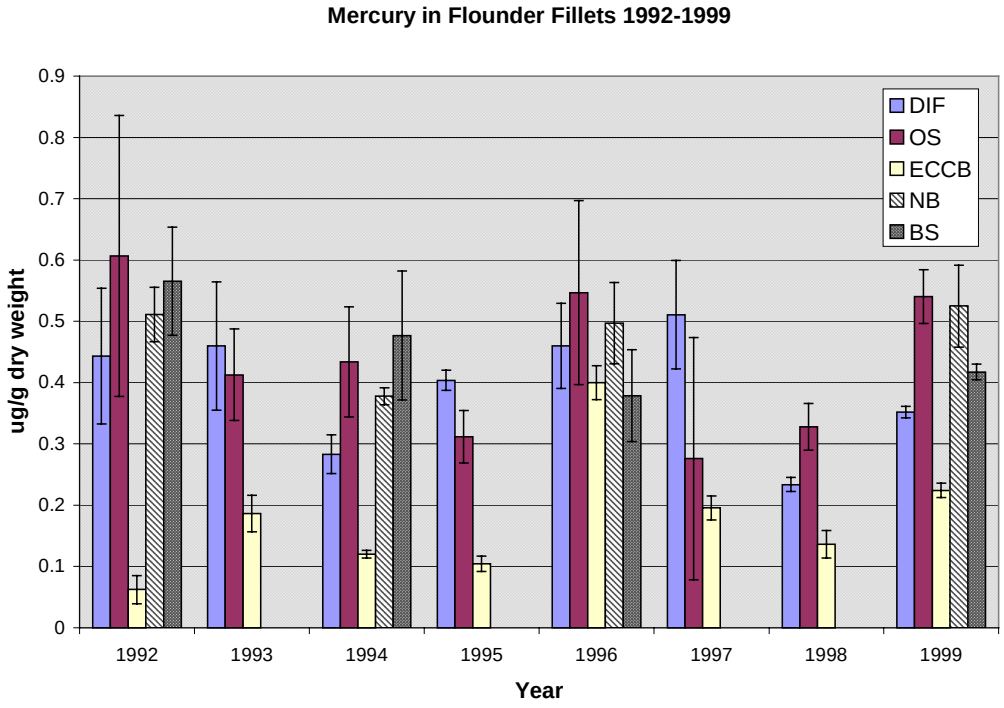


Figure 3-6. Mercury in Flounder Fillets at the Five Collection Sites from 1992-1999.

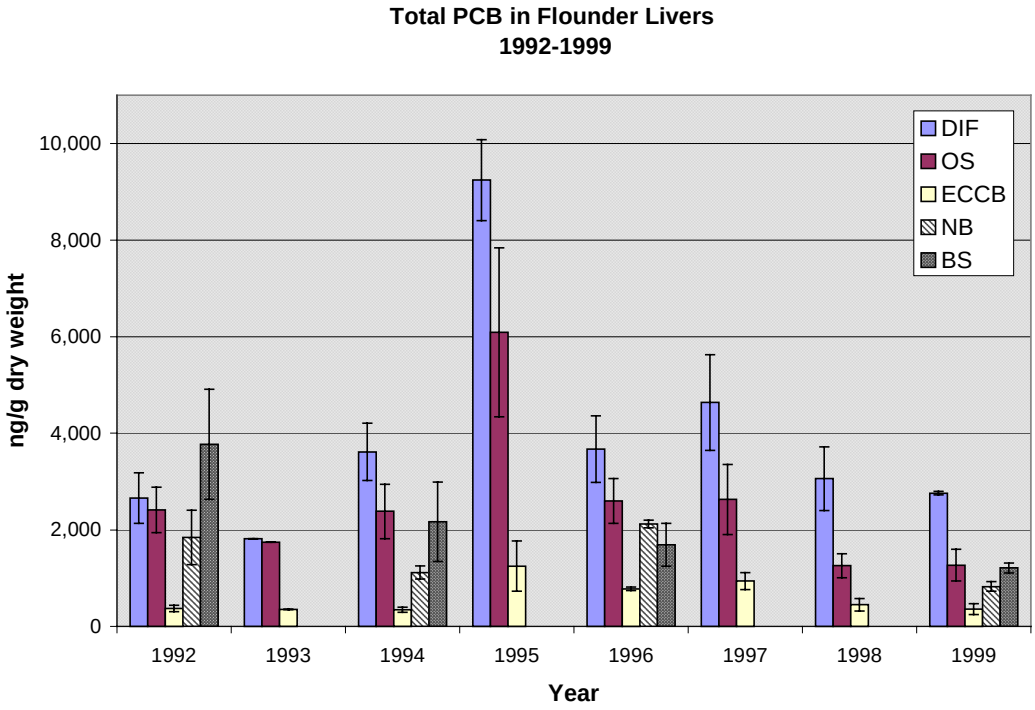


Figure 3-7. Total PCB in Flounder Livers at the Five Collection Sites from 1992-1999.

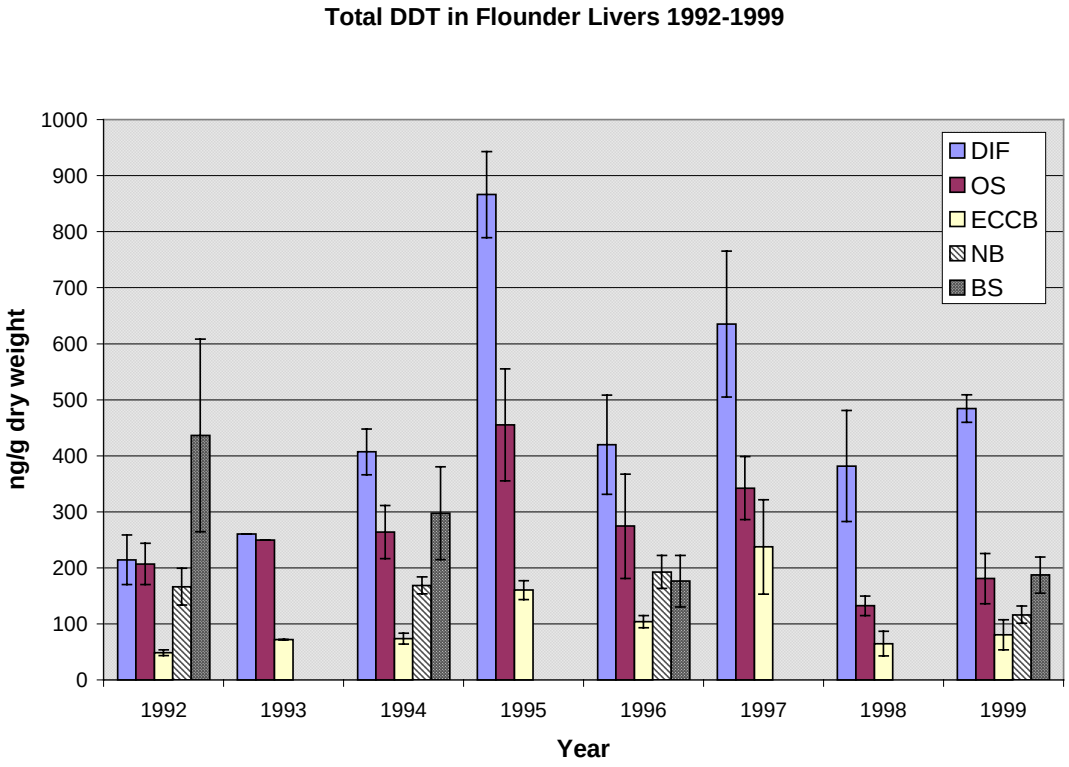


Figure 3-8. Total DDT in Flounder Livers at the Five Collection Sites from 1992-1999.

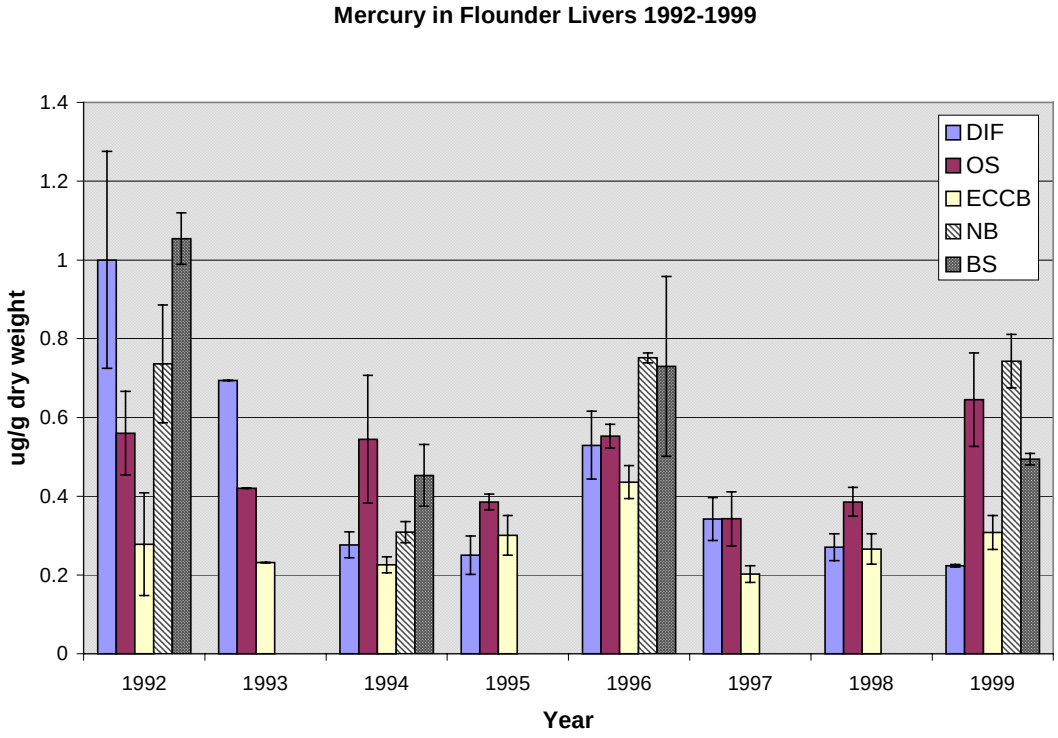


Figure 3-9. Mercury in Flounder Livers at the Five Collection Sites from 1992-1999.

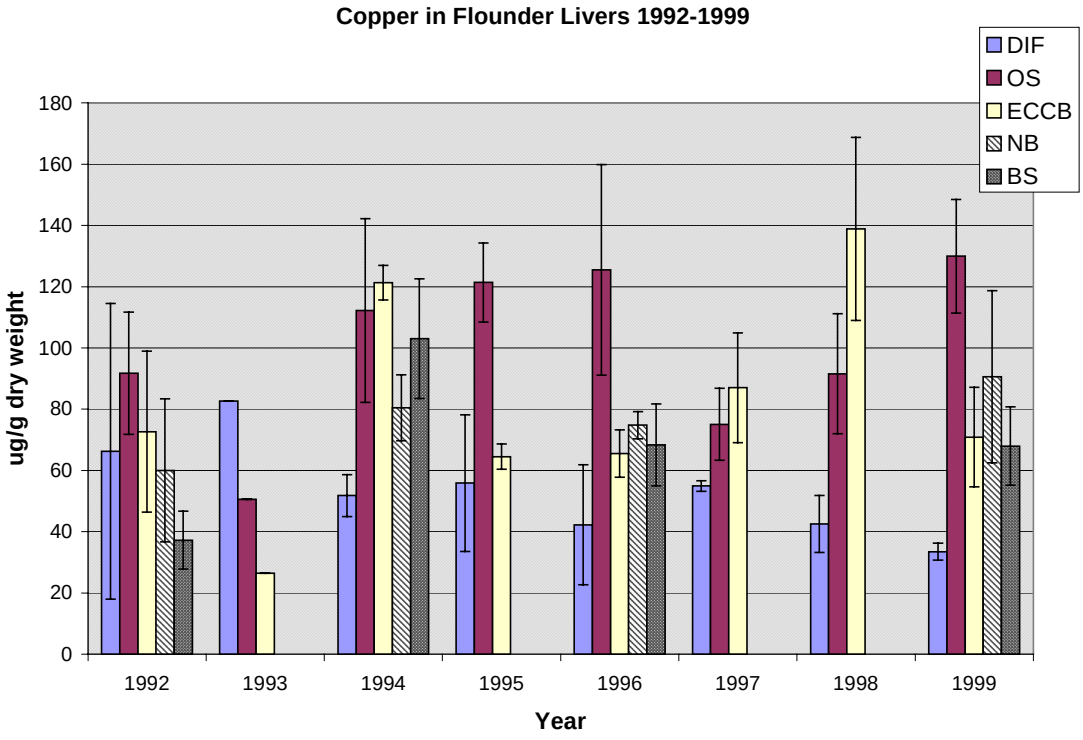


Figure 3-10. Copper in Flounder Livers at the Five Collection Sites from 1992-1999.

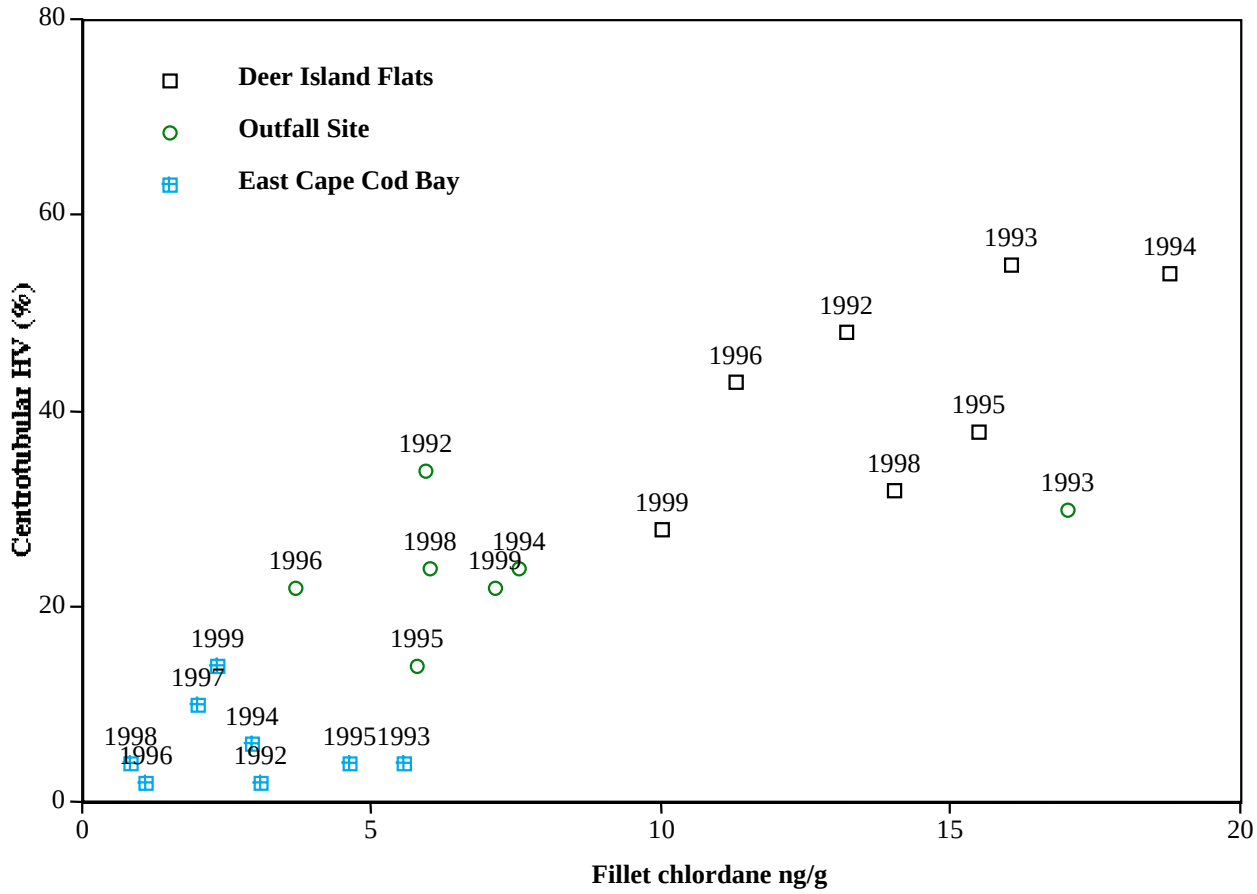


Figure 3-11. Scatter Plot Comparing Centrotubular Hydropic Vacuolation Prevalence with Chlordane Fillet Concentration in Winter Flounder from DIF, OS, and ECCB.

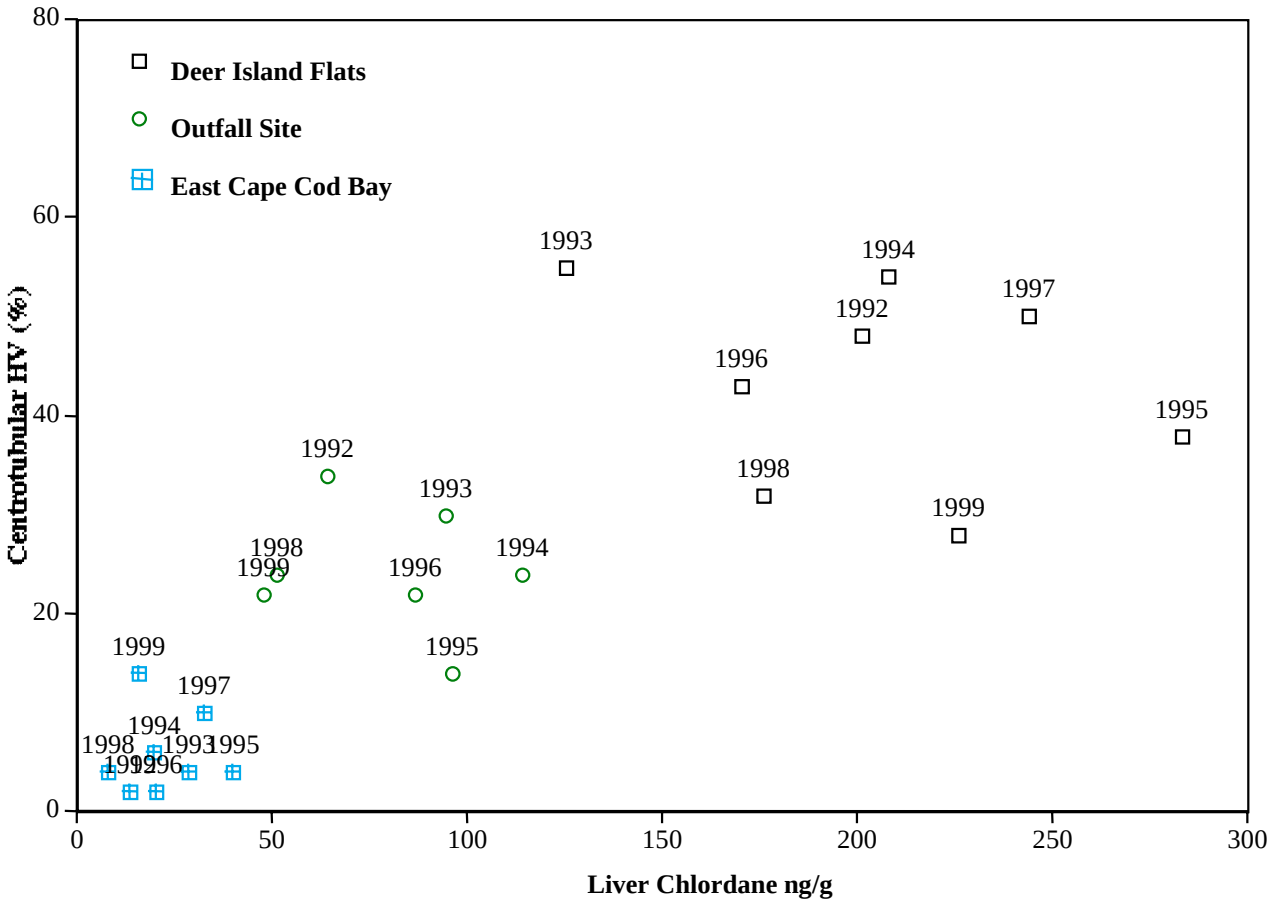


Figure 3-12. Scatter Plot Comparing Centrotubular Hydropic Vacuolation Prevalence with Chlordane Liver Concentration in Winter Flounder from DIF, OS, and ECCB.

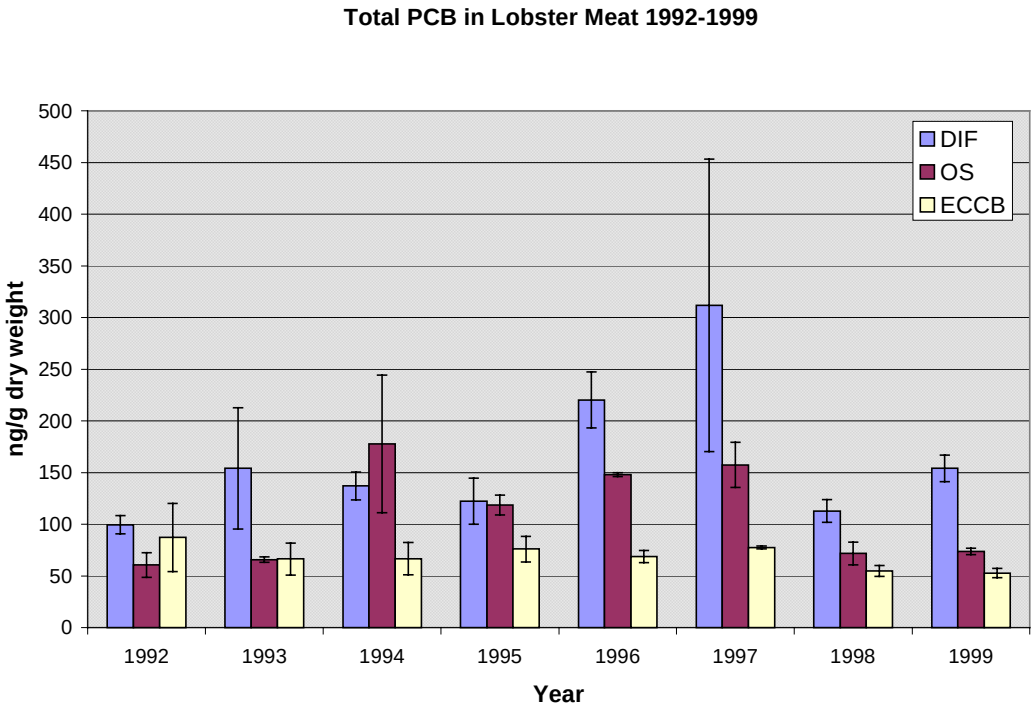


Figure 3-13. Total PCB in Lobster Meat at DIF, OS and ECCB from 1992-1999.

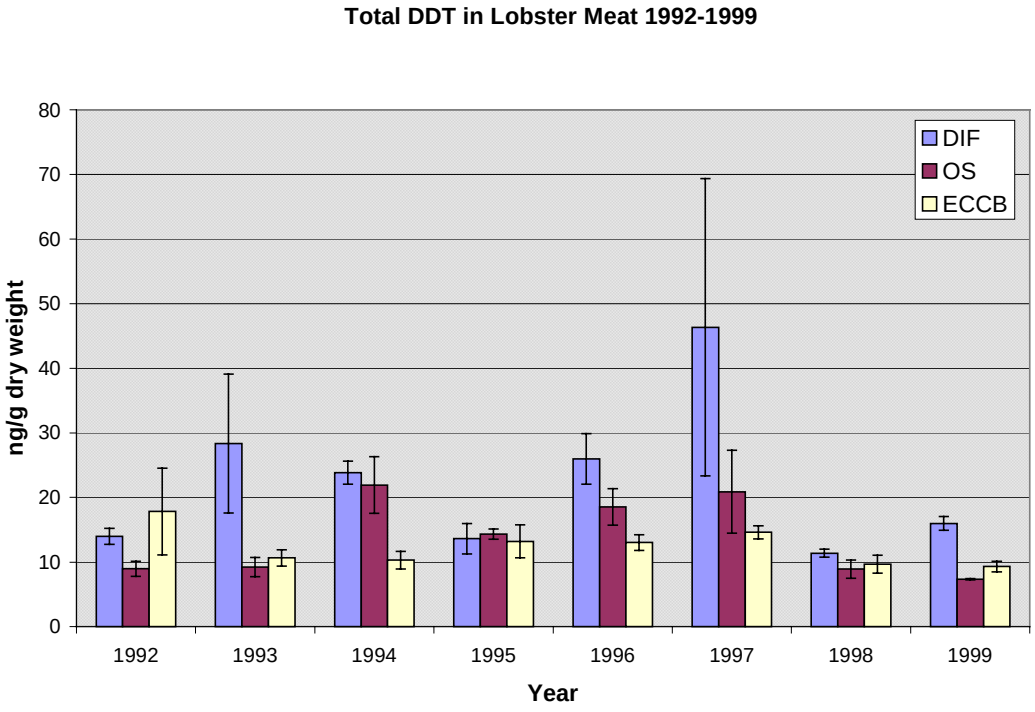


Figure 3-14. Total DDT in Lobster Meat at DIF, OS and ECCB from 1992-1999.

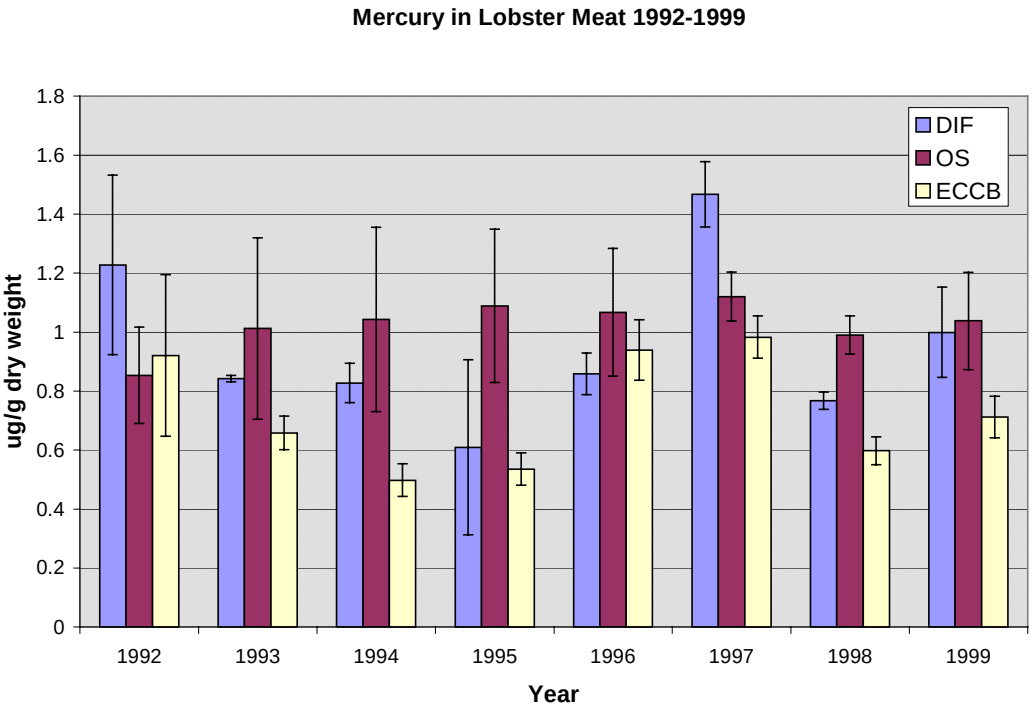


Figure 3-15. Mercury in Lobster Meat at DIF, OS and ECCB from 1992-1999.

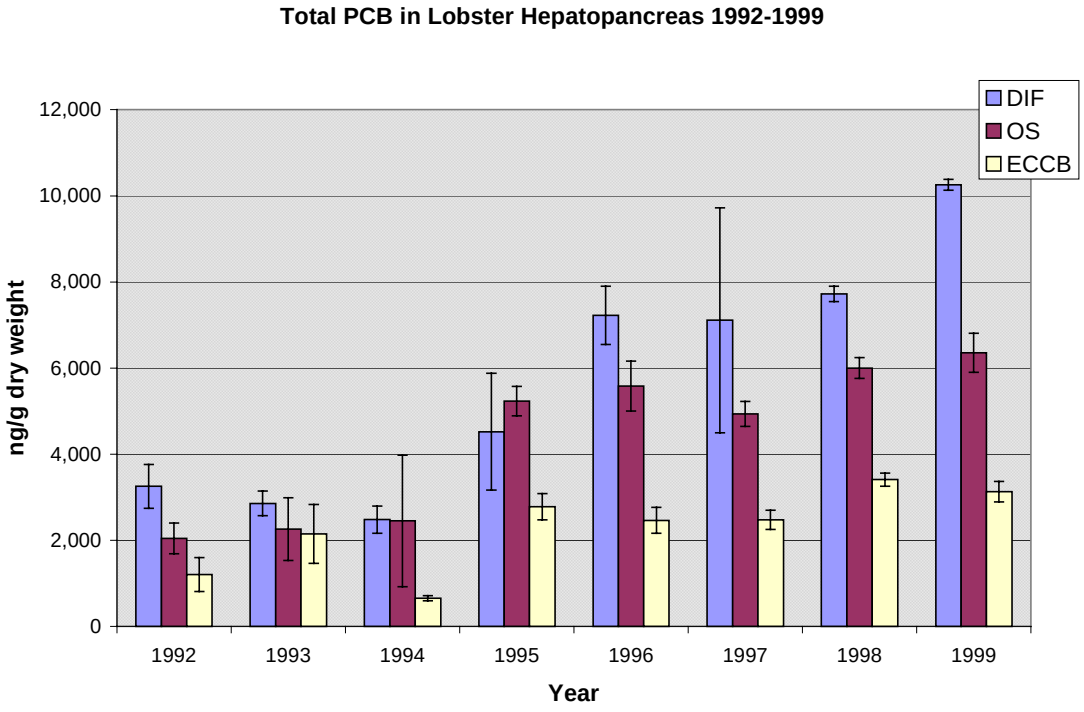


Figure 3-16. Total PCB in Lobster Hepatopancreas at DIF, OS and ECCB from 1992-1999.

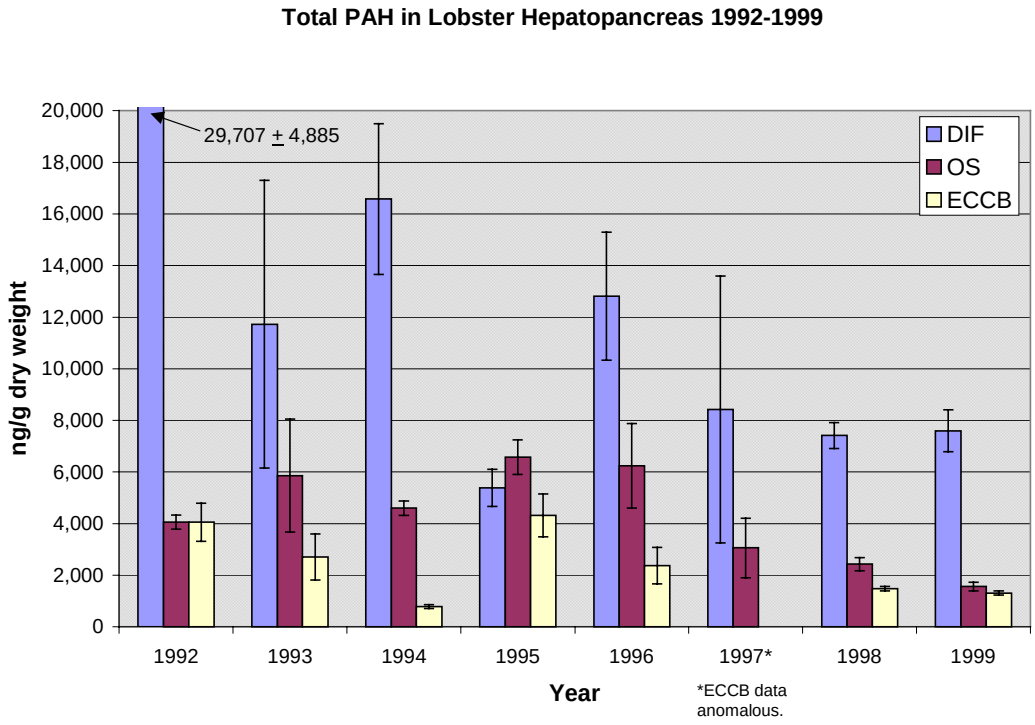


Figure 3-17. Total PAH in Lobster Hepatopancreas at DIF, OS and ECCB from 1992-1999.

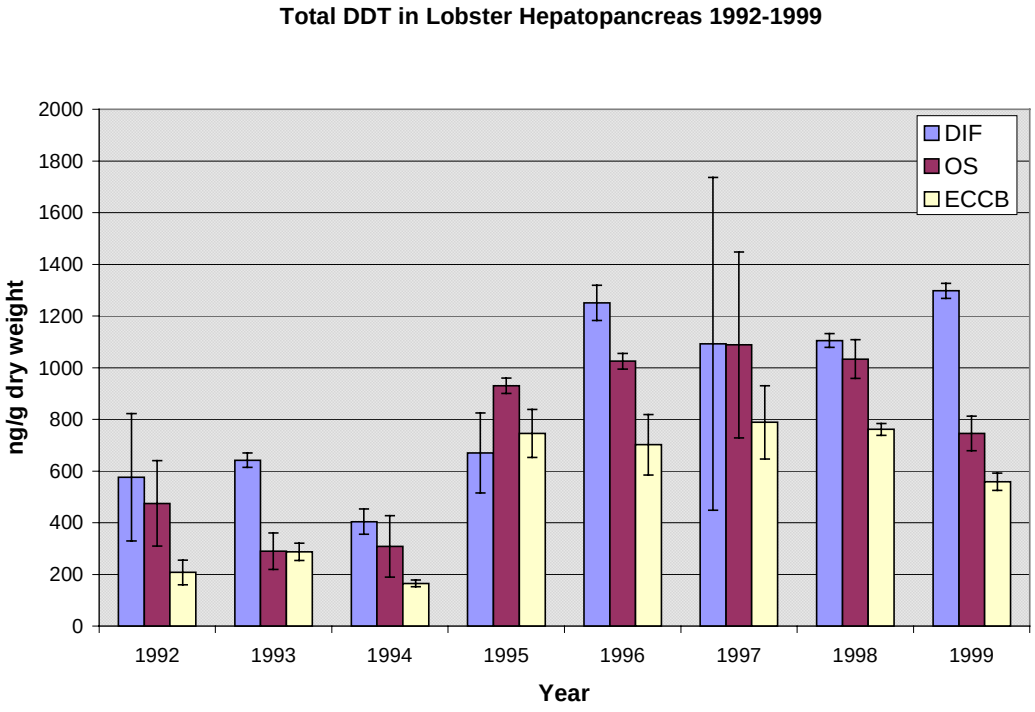


Figure 3-18. Total DDT in Lobster Hepatopancreas at DIF, OS and ECCB from 1992-1999.

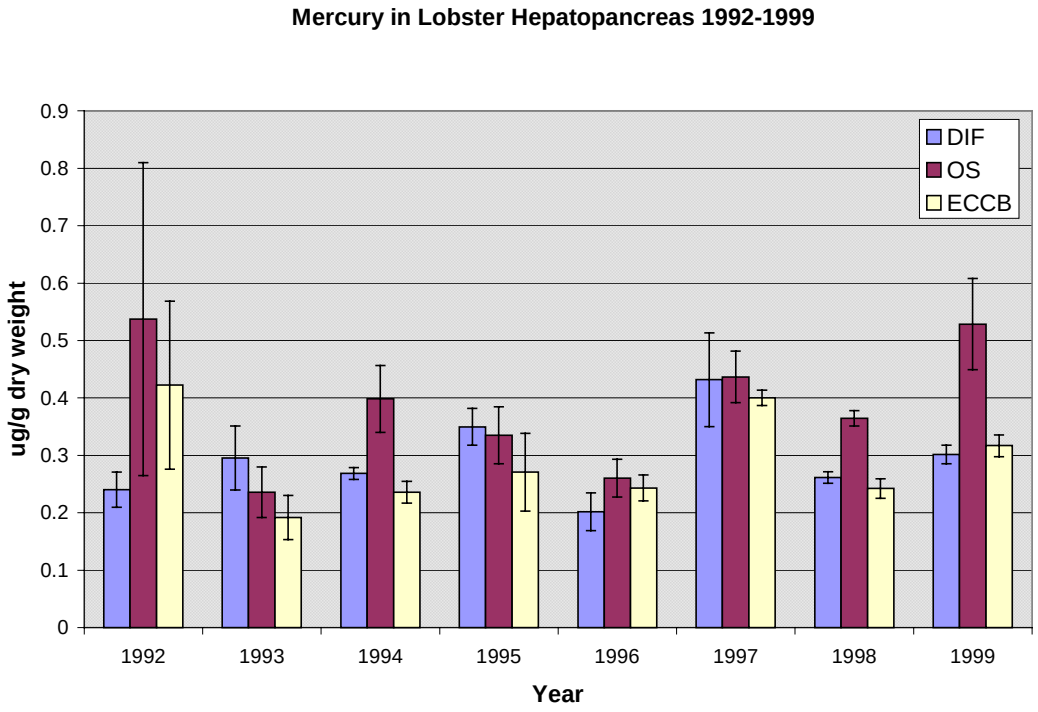


Figure 3-19. Mercury in Lobster Hepatopancreas at DIF, OS and ECCB from 1992-1999.

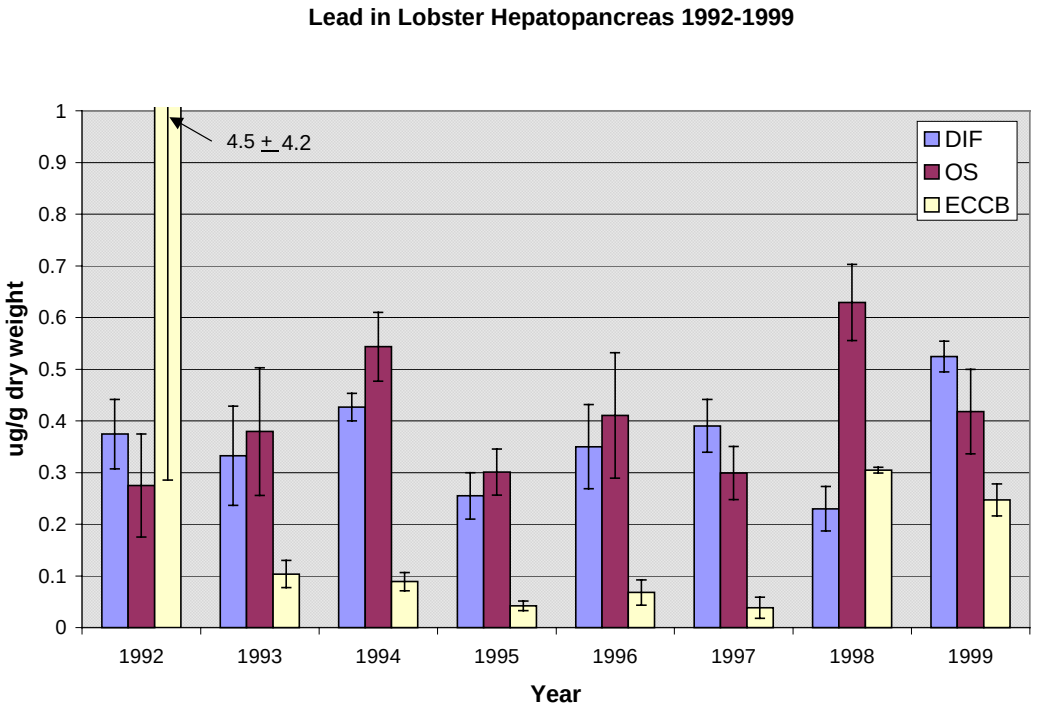


Figure 3-20. Lead in Lobster Hepatopancreas at DIF, OS and ECCB from 1992-1999.

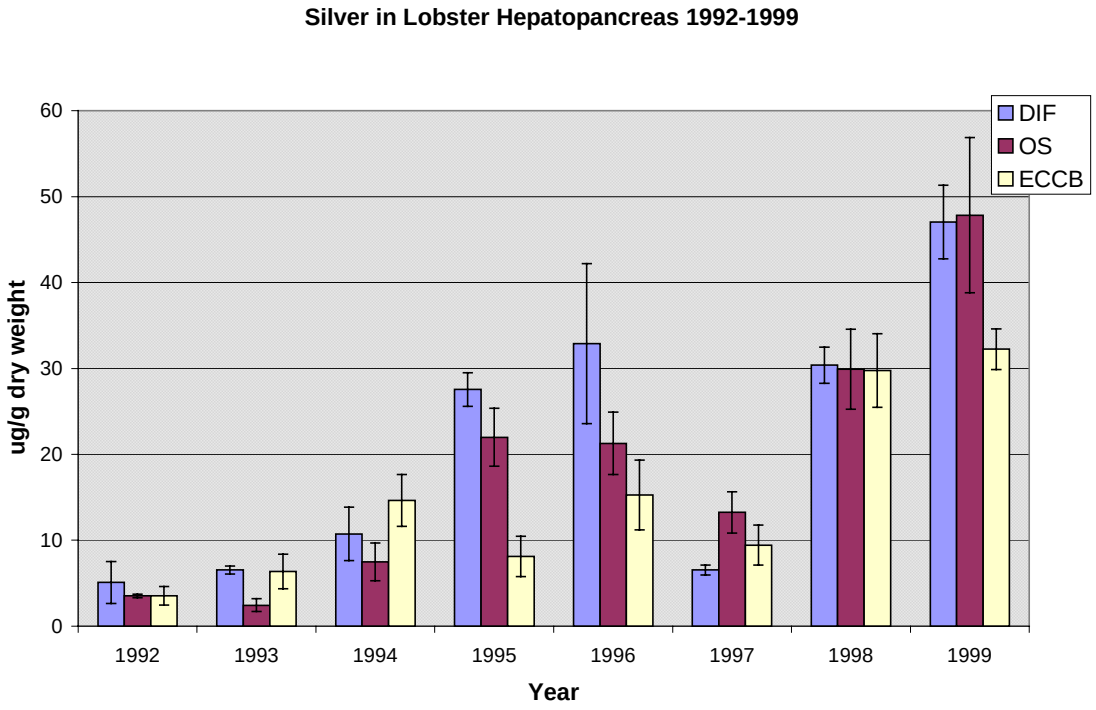


Figure 3-21. Silver in Lobster Hepatopancreas at DIF, OS and ECCB from 1992-1999.

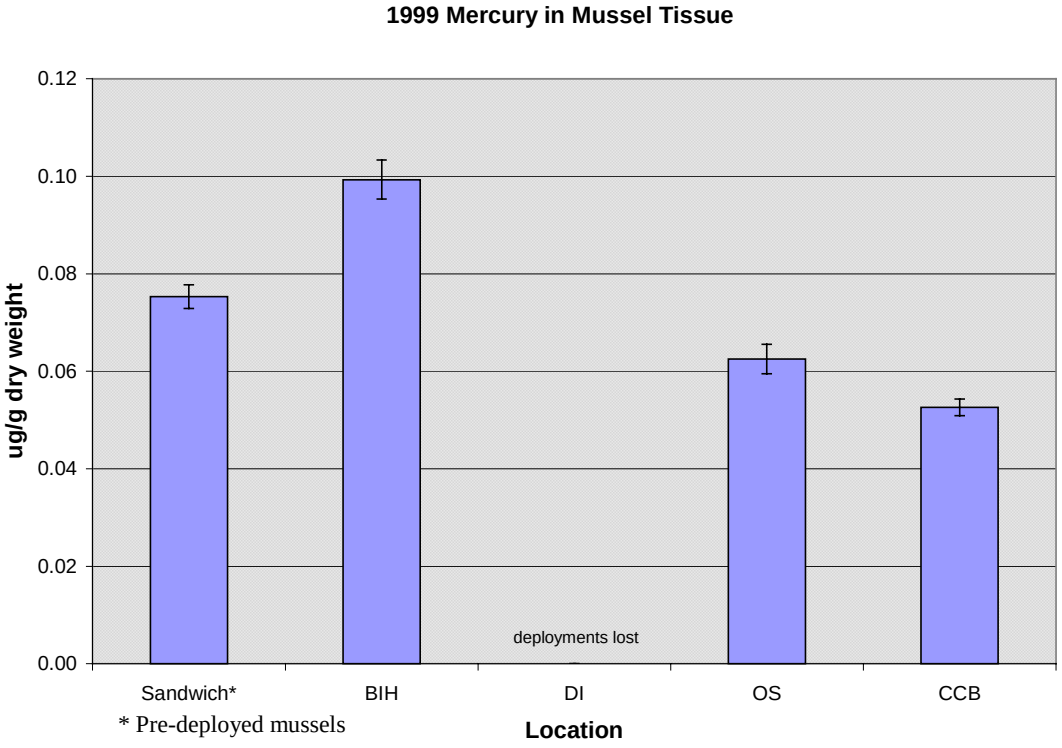
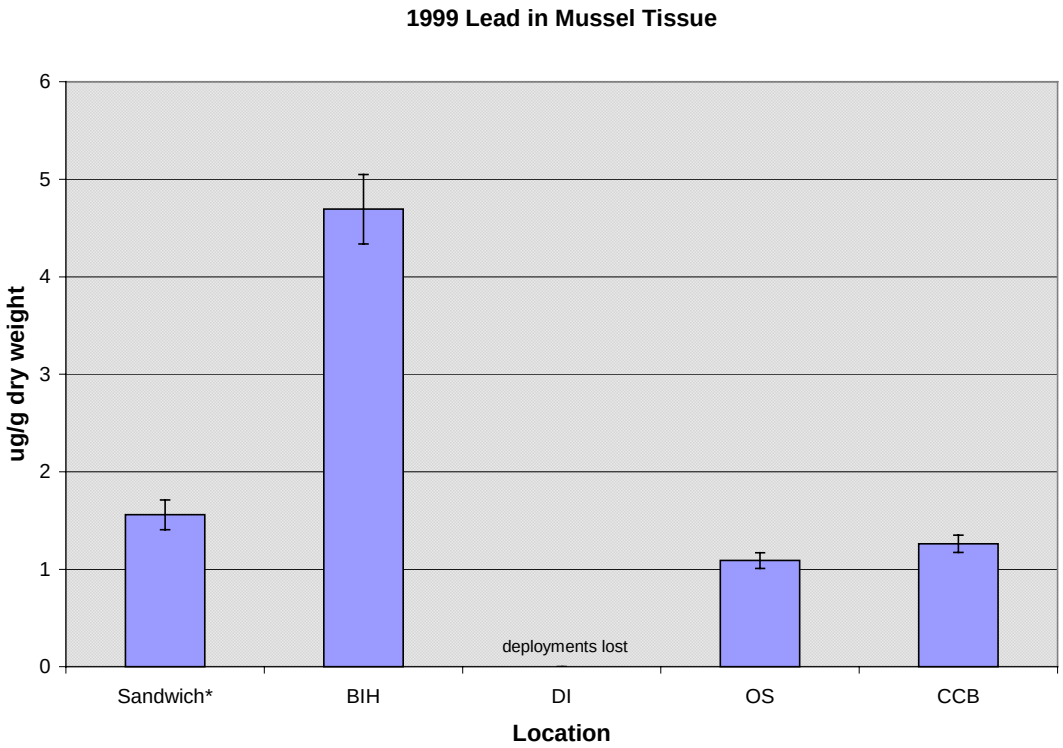
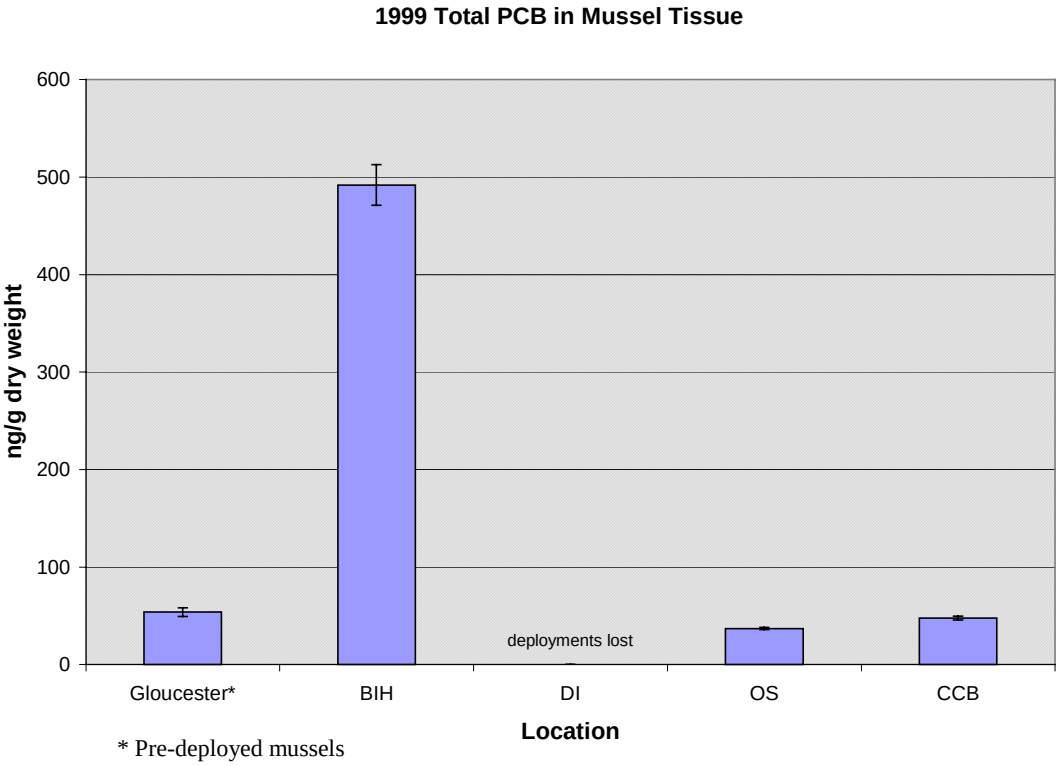


Figure 3-22. Mercury in 1999 Pre-deployed Mussels and Four Deployment Locations.



* Pre-deployed mussels

Figure 3-23. Lead in 1999 Pre-deployed Mussels and Four Deployment Locations.



* Pre-deployed mussels

Figure 3-24. Total PCB in 1999 Pre-deployed Mussels and Four Deployment Locations.

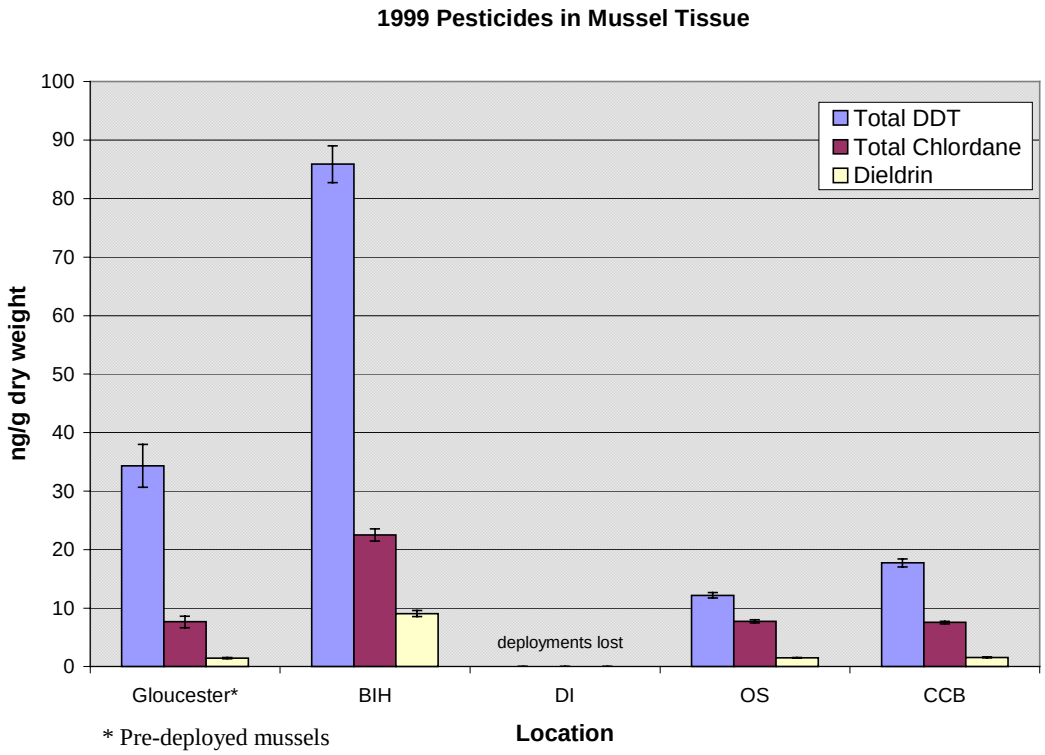


Figure 3-25. Pesticides in 1999 Pre-deployed Mussels and Four Deployment Locations.

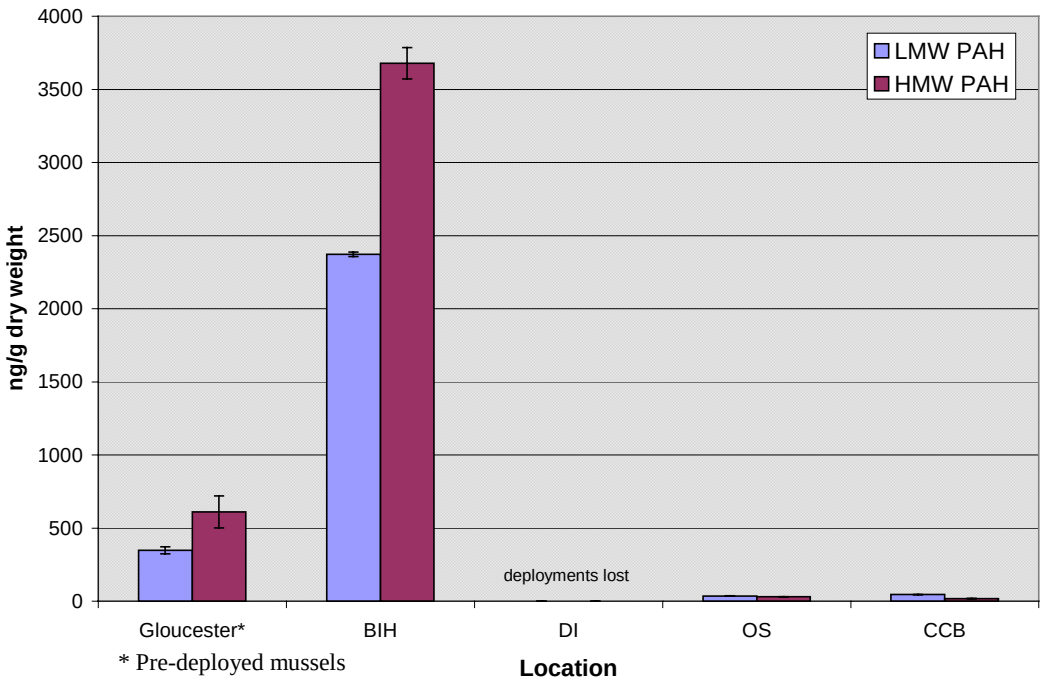
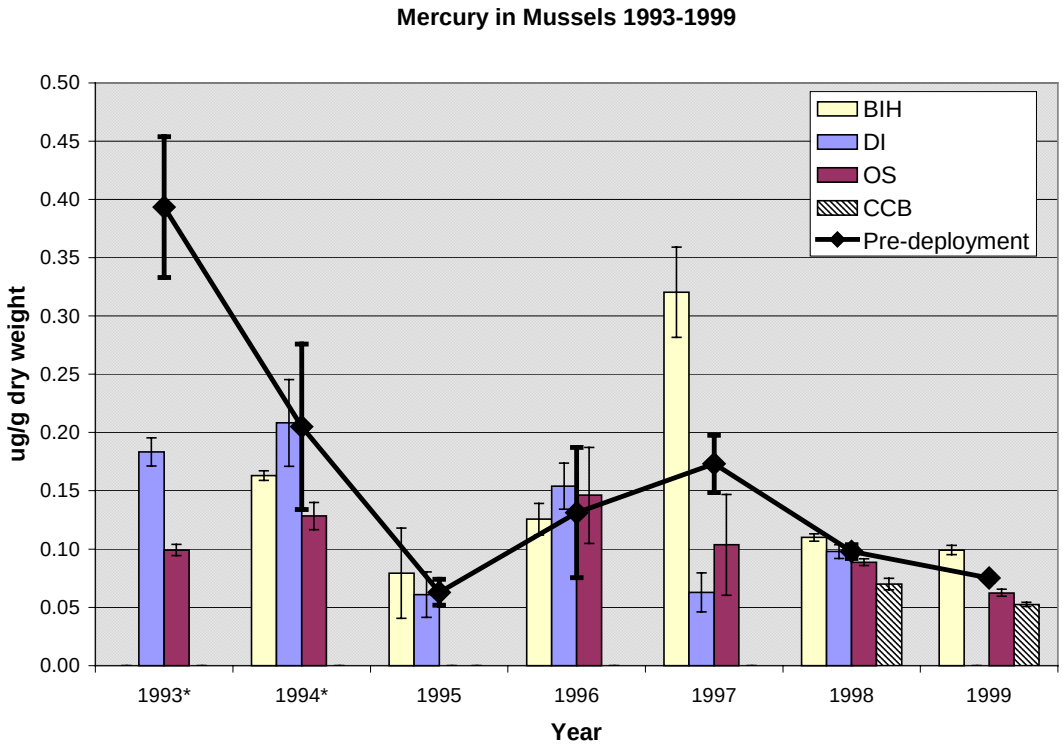
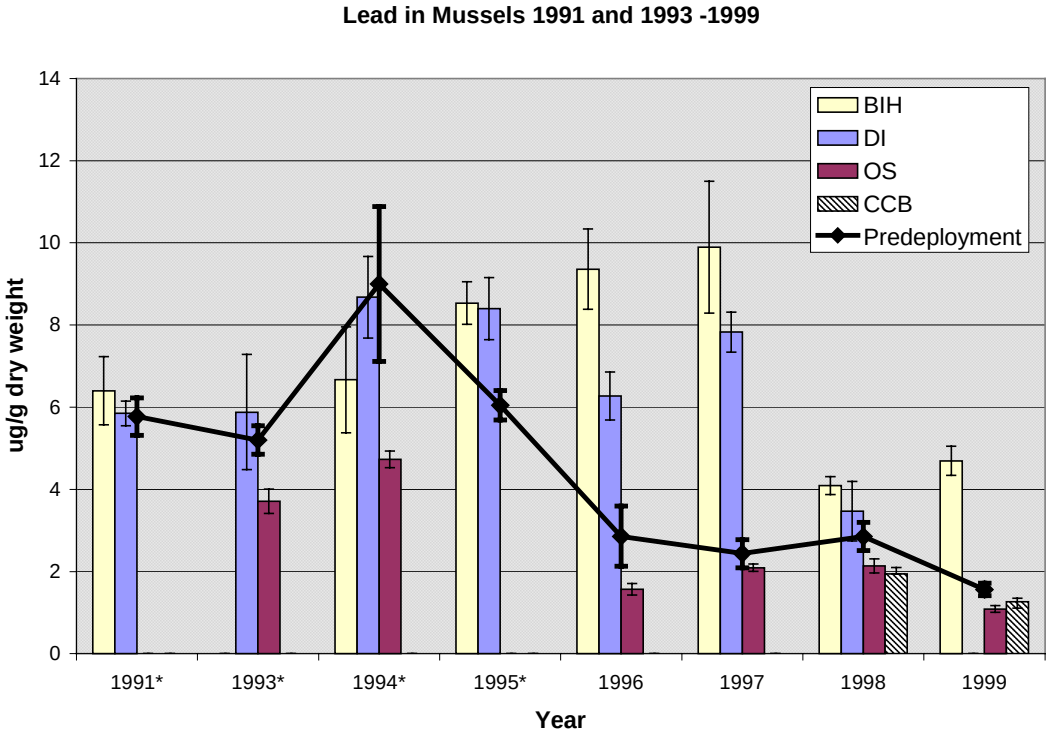


Figure 3-26. Total Low and High Molecular Weight PAHs in 1999 Pre-deployed Mussels and Four Deployment Locations Using the Total PAH List.



* Pre-deployed mussels from Gloucester, rather than from Sandwich, were analyzed in 1993 and 1994.

Figure 3-27. Mercury in Pre-deployed and Deployed Mussels from 1993-1999.



* Pre-deployed mussels from Gloucester, rather than from Sandwich, were analyzed 1991-1995.

Figure 3-28. Lead in Pre-deployed and Deployed Mussels from 1991 and 1993-1999.

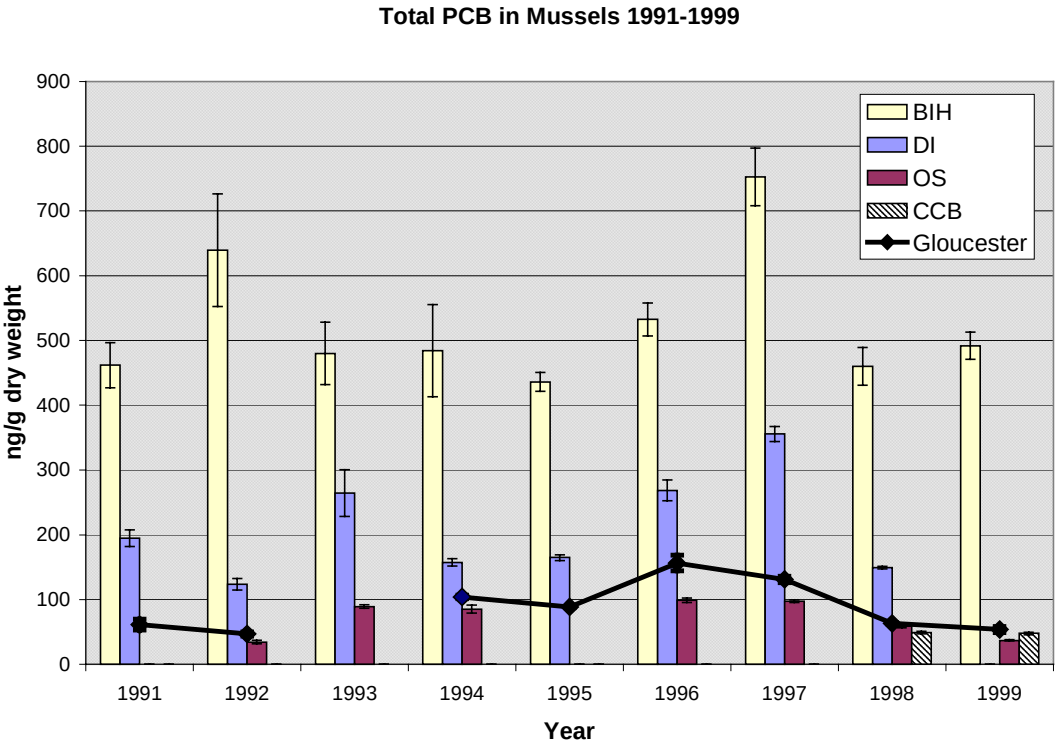


Figure 3-29. Total PCB in Pre-deployed and Deployed Mussels from 1991-1999.

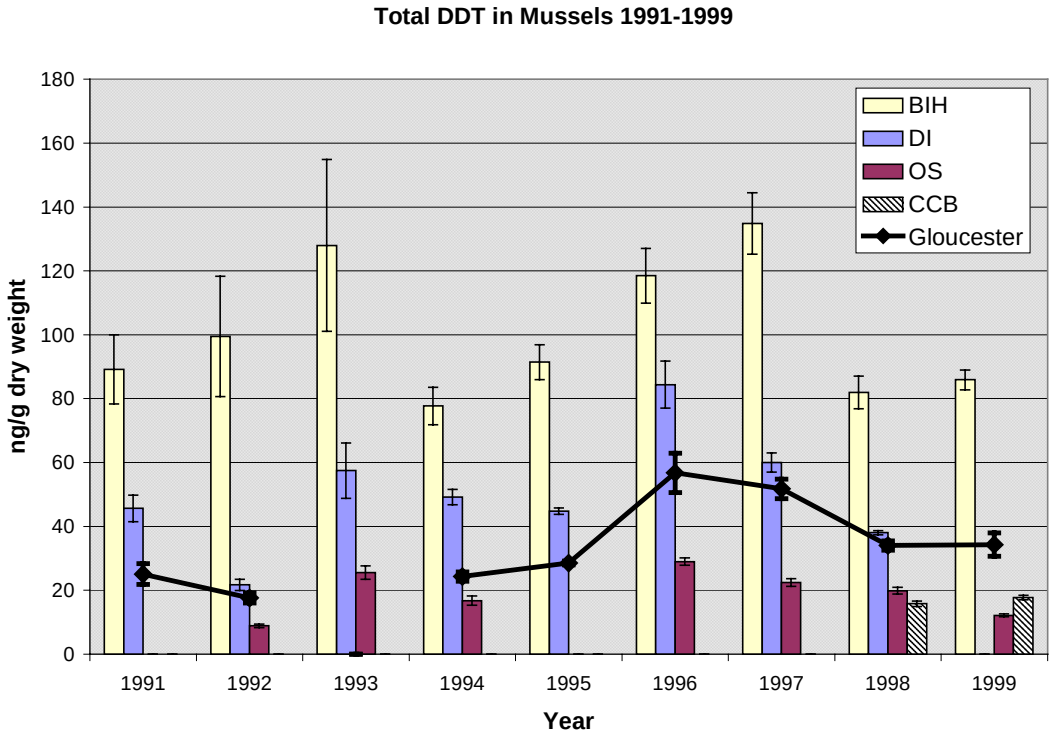
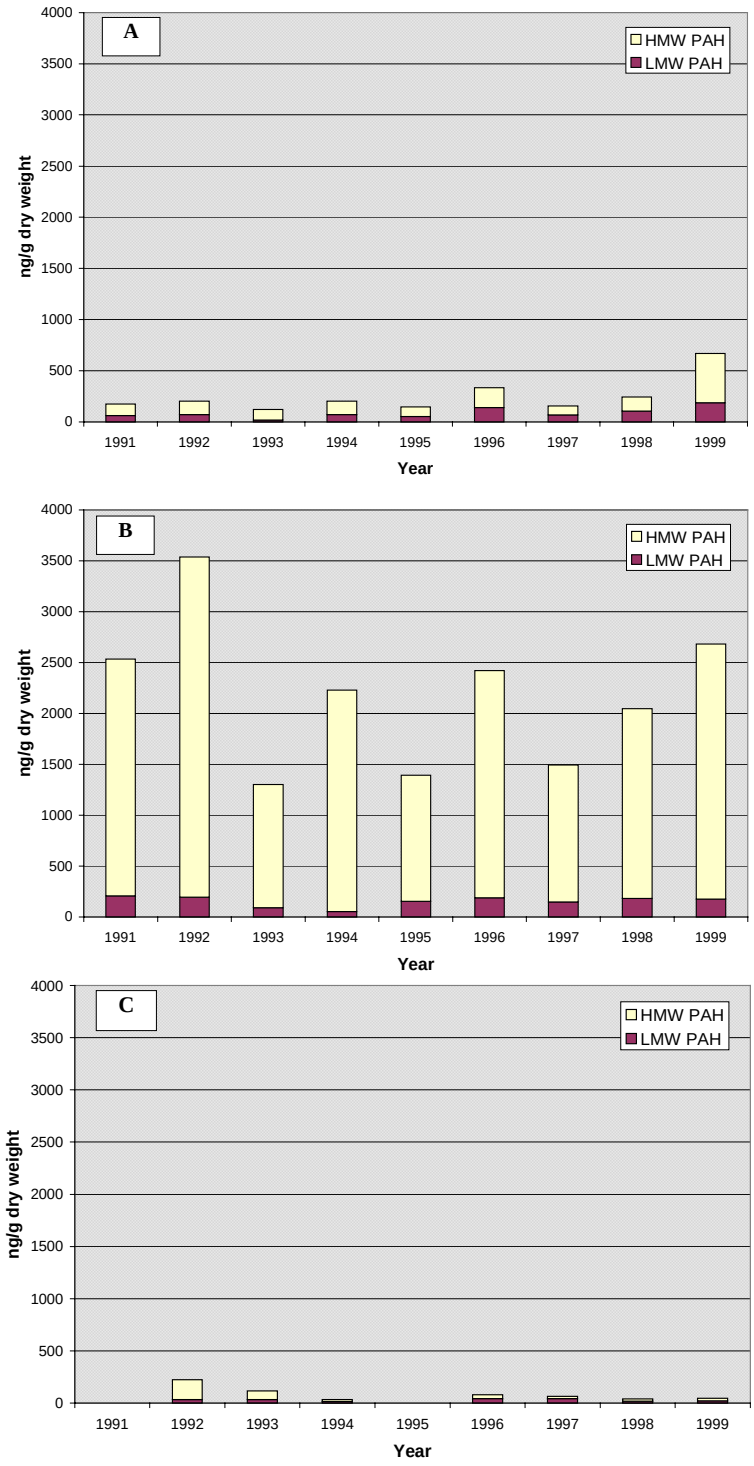


Figure 3-30. Total DDT in Pre-deployed and Deployed Mussels from 1991-1999.



A = Gloucester (Pre-deployment), B = BIH (Deployed), C = OS (Deployed)

Figure 3-31. Total PAHs (Using the "Historical NOAA List") in Pre-deployed and Deployed Mussels from 1991-1999.

4.0 CONCLUSIONS

The 1999 Fish and Shellfish Monitoring Program was completed successfully, except for the DI mussel recovery, and generated data consistent with past years. Results provided in this report further document pre-effluent baseline conditions. Biological conditions in all organisms are stable or improving since the beginning of the program in 1992. There are some apparent upward trends in contaminant concentrations since 1996, especially in the lobster hepatopancreas. Conclusions for the various animals from the surveys are given below.

4.1 Winter Flounder

The 1999 Flounder Survey provided samples from three locations (DIF, OS and ECCB) and was conducted in a manner consistent with previous surveys. Catch per unit effort at DIF was the highest of any year since the project began in 1991. Flounder continue to be in reasonable health from all stations. There is none of the high neoplasm prevalence characteristic of fish from Deer Island Flats in the mid- to late-1980s. The differences between stations continue to be discernible and relatively stable, but at a more subtle level than observed early in the baseline period. East Cape Cod Bay continues to be a useful reference site, although the increasing prevalence of centrotubular hydropic vacuolation bears scrutiny over the next few years.

The levels of most tissue contaminant concentrations were similar to or lower than those measured in previous years. Highest concentrations are routinely found at DIF and the lowest concentrations are found in ECCB. All fillet chemical concentrations were below both FDA and MWRA Warning limits. Dieldrin was slightly above the MWRA Caution Level in edible tissue from OS. This increase in dieldrin could be due to co-elution encountered during the analysis of PCBs and pesticides in 1999 and may not reflect a real trend in dieldrin concentrations.

Concentrations of contaminants in flounder fillet and liver from NB and BS were similar to or lower than those measured in previous years. There were slight downward trends in fillet and liver total PCB body burdens at BS since 1992.

4.2 Lobster

The 1999 Lobster Survey collected specimens from three sampling locations by direct shipboard collection from commercial lobstermen. The spatial pattern of tissue contaminants was similar to that measured in past years, with the highest concentrations generally found at DIF and the lowest at ECCB reference location. This gradient in lobster tissue concentrations between sampling locations supports the premise that legal-sized lobsters exhibit sufficient fidelity to an area to allow establishment of a predictable trend in tissue body burdens due to relative contaminant exposure. Concentrations of total PCB in lobster hepatopancreas continued to show an upward trend in 1999 at OS and DIF. This trend may be real or it may be an analytical artifact caused by the co-elution of PCB congeners and pesticides, observed in 1999. Silver, copper and lead were notably higher in lobster hepatopancreas than previously observed during the baseline period. Lobster edible tissue contaminant concentrations were below the FDA Action Limits and the Caution and Warning Levels set by MWRA.

4.3 Blue Mussel

The 1999 Mussel Bioaccumulation study involved deployment of caged mussels at two offshore locations (OS and CCB) and two near-shore locations (BIH and DI). One of these locations, ECCB, was added in 1998. Contaminant levels measured in 1998 were among the lowest observed since 1991, especially at OS. Among the stations previously studied, concentrations were routinely highest at BIH and lowest at

OS for organics. Lead and mercury concentrations were more variable. All mussel chemical concentrations were below both FDA and MWRA Caution and Warning limits.

4.4 Recalculation of the Baseline Threshold Incorporating 1999 Data and Evaluation of the Monitoring Threshold

A major component of the MWRA fish and shellfish monitoring program is evaluating whether consumption of fish and shellfish in and around the outfall could pose a threat to human health. MWRA has set Caution and Warning Levels to ensure the protection of human health. Caution Levels are set at two times the baseline arithmetic averages of annual means (of composite samples) for organisms collected or deployed at OS during the period 1992 through 1999 (the actual baseline years used for each animal type are footnoted in Table 4-1). To establish when significant increases above the baseline would be detected, a statistical value has been established. The significant increase value is set as the 95th percentile upper confidence limit (based on the "t" distribution) of the mean of the annual means. An example of a "t" distribution of the cumulative frequency has been created for mercury in flounder fillets and is presented in Figure 4-1. Warning Levels have been set at 80% of the FDA Action Limit.

Current tissue concentrations are generally an order of magnitude or more below Warning Levels and FDA Action Limits (Table 4-1). Moreover, the caution levels are greater than values that are detected (two times the OS baseline mean); thus changes in levels can be detected before thresholds are exceeded. Similarly, the monitoring hypothesis regarding future increases of the prevalence of flounder liver CHV at OS relative to baseline levels measured in outer Boston Harbor also appears to be sufficiently sensitive to detect trends based on current data.

In the past, lipid normalized organic contaminant values have been used to define monitoring thresholds. Recent evaluations of lipid normalized data (Mitchell 1998) concluded that no appreciable reduction in variability was evident when comparing temporal trends on a lipid normalized basis relative to data expressed on a dry weight basis. Lipid concentrations will continue to be monitored but threshold testing will be based on wet-weight concentrations only.

Table 4-1. Comparison of Baseline Mean Concentrations, Significantly Increased Levels and Recalculated Threshold (Incorporating 1999 Data) at the Outfall Site.

Parameter	Baseline Mean[1]	Baseline Standard Error	N	Significant Increase[2]	Caution Level[3]	Warning Level[4]
Mercury (ppm wet)						
Flounder	0.078	0.008	8	0.093	0.157	0.8
Lobster	0.151	0.004	8	0.159	0.301	0.8
Mussels	0.019	0.002	6	0.024	0.039	0.8
Lead (ppm wet)						
Mussels	0.46	0.09	6	0.65	0.92	3
PCBs (ppb wet)						
Flounder	35.99	2.66	8	41.04	71.99	1600
Lobster	17.57	3.83	8	24.82	35.13	1600
Mussels	12.00	1.95	7	16.21	24.00	1600
PAH[5] (ppb wet)						
Mussels	14.53	4.02	7	22.23	28.76	----
Chlordane (ppm wet)						
Flounder	1.39	0.26	8	1.88	2.78	240
Lobster	0.38	0.06	8	0.49	0.76	240
Mussels	1.27	0.13	7	1.55	2.54	240
Dieldrin (ppm wet)						
Flounder	0.34	0.07	8	0.47	0.67	240
Lobster	0.87	0.11	8	1.09	1.75	240
Mussels	0.30	0.03	7	0.35	0.60	240
DDT (ppb wet)						
Flounder	3.86	0.22	8	4.28	7.72	4000
Lobster	2.12	0.40	8	2.88	4.24	4000
Mussels	3.24	0.46	7	4.23	6.48	4000
CHV Prevalence						
Flounder	23.25	0.02	9	23.28	> harbor prevalence (1991-1999)	----

[1] Mean Concentration of Annual Means, 1992-1999 (Flounder and Lobster). Mean Concentration 1992-1994, 1996-1999 (Mussels; no 1992 metals data, 1993 metals data suspect, 1995 array was lost).

[2] The significant increase is the concentration at which an increase from the baseline mean is considered statistically significant at the 0.05 level (i.e., 95th percent UCL = mean + $t_{0.1, n-1}$ * S.E.).

[3] Based on "appreciable change from baseline"; see text for discussion. (2 x OS baseline mean from 1992-1999).

[4] Massachusetts Water Resources Authority (MWRA) 1997a. Contingency Plan. Warning Level is 80% of the FDA Level.

[5] Representing NOAA PAHs only.

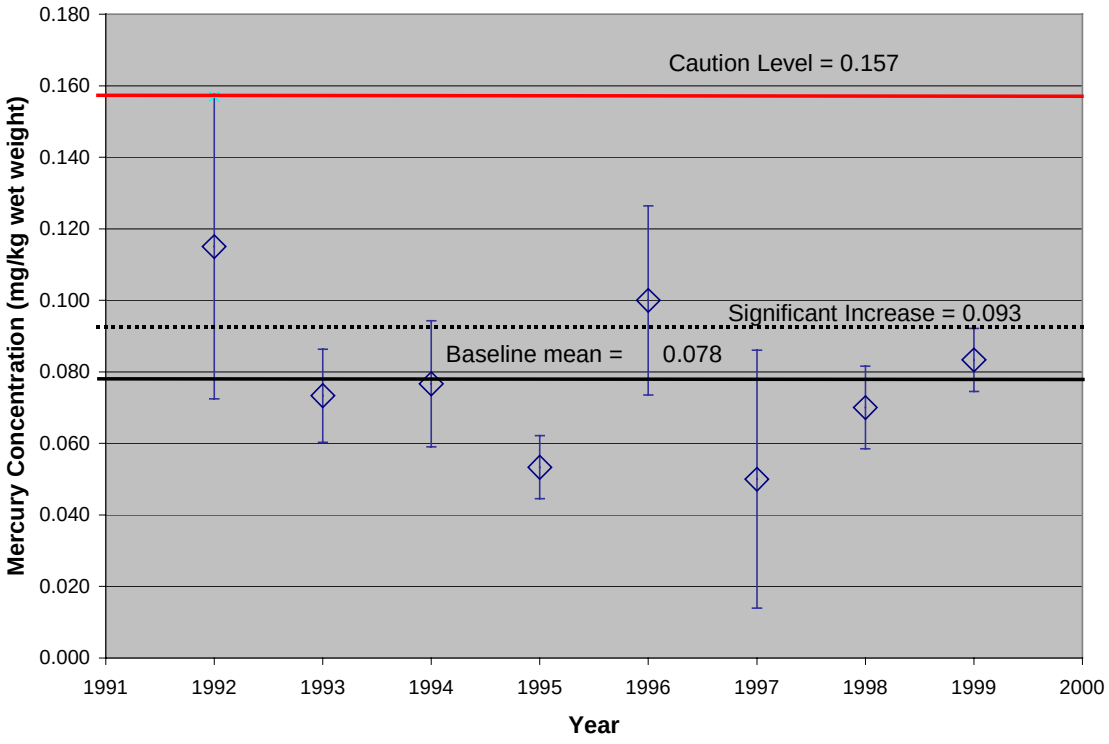


Figure 4-1. Baseline mean (lower solid line), yearly means with standard error (bars), significant increase (dashed line), and caution level (upper solid line), for mercury concentration in flounder fillet.

5.0 RECOMMENDATIONS

An evaluation of the 1999 Fish and Shellfish tasks indicates that the program is achieving its monitoring goals. However, refinements to the program may be warranted. Based on the 1999 results, several recommendations for future effort are suggested:

- As recommended in the 1998 Fish and Shellfish Annual Report, flounder collection at DIF was conducted in early May, after an initial visit in April showed that fish were essentially absent from the area. The catch per unit effort at DIF for 1999 was the highest since the Monitoring Program began in 1991. Collection of flounder at all stations should be conducted in April. Where fish are not available in April, a second collection should be attempted in May;

- Lobster collection should be coordinated with commercial lobstermen both temporally and spatially to maximize collection efficiency. Attempts to collect lobsters in a relatively shorter time period must continue;

- Once the diffuser at the Outfall Site is on line, temporal baseline trends should be evaluated statistically, including all baseline years within the Monitoring Program;

- Due to the apparent upward trend of contaminants (especially total PCB) in lobster hepatopancreas samples from DIF, analytical methods should be examined and temporal and spatial trends analyzed to answer the following questions:

    1. Is the apparent trend of contaminant concentrations in lobster hepatopancreas from Boston Harbor and the Outfall Site “real”?
    2. Are there analytical artifacts associated with quantification of PCBs and chlorinated pesticides that affect observed trends in hepatopancreas concentrations and data interpretation in general?

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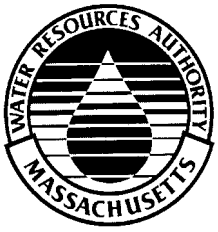
APPENDICES



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