1998 Fish and Shellfish Report

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EXECUTIVE SUMMARY

The Massachusetts Water Resources Authority (MWRA) continued to conduct its biomonitoring program for fish and shellfish in 1998. The 1998 activities represent the latest year in a continuing biomonitoring program that supports evaluation of the MWRA effluent in 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 1998 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*). Specimens were collected from established sites in Boston Harbor and the Bays: Deer Island Flats (DIF), adjacent to the Aquarium in Boston Inner Harbor (BIH); the Future Outfall Site (FOS), off Nantasket Beach (NB), Broad Sound (BS) and East Cape Cod Bay (ECCB). The DIF, FOS and ECCB sites are core sites for the monitoring study, while BS and NB are ancillary sites providing information on fish in the general area of the existing Deer Island outfall. Since these last two sites are only sampled bi-annually for chemical analyses, they are not discussed in the 1998 Fish and Shellfish Report in terms of chemical contaminants. Two additional sites were added in 1998 as part of the mussel bioaccumulation study: Quincy Bay, as an indicator of activities at the Nut Island facility and CCB, as an additional outer harbor reference station.

Baseline conditions of the species collected were characterized in terms of biological parameters (length, weight, biological condition); the presence/absence of disease (both internal and external); and concentrations of organic and inorganic compounds in both edible and liver tissue. The monitored parameters were examined for spatial trends between stations in 1998 and interannual 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 limits to evaluate potential risk or trends.

Flounder

Winter flounder were collected at the five established monitoring locations in 1998. The mean age and length of fish collected at DIF were 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 significantly higher than at the other stations, however, current levels are consistent with recent studies and are substantially lower than those observed, but not quantified, prior to 1990 at the Deer Island site.

Flounder liver histology results indicated that the prevalence of tubular and centrotubular hydropic vacuolation was highest at DIF and BS and lowest at ECCB. Interannual comparison showed that lesion prevalence has not changed substantially at any of the stations since 1991. However, lesion prevalence at DIF has shown a statistically significant decrease over the period 1987-1998. Neoplasia was absent from all but one fish collected at BS in 1998. Neoplasm prevalence at DIF has fallen from elevated levels in the 1980's to undetectable levels during the period 1992-1998.

Fifteen winter flounder were collected at each of the three core monitoring locations for chemical analysis of edible and liver tissues. The spatial patterns of tissue contaminant levels in winter flounder were examined. Mean 1998 concentrations of organic compounds in both fillets and liver tissue were generally highest at Deer Island and lowest at ECCB. Mercury was slightly higher at the FOS in both fillet and

liver tissue with lowest concentrations observed in fish from ECCB. 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 1998 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. Chlorinated pesticides show relatively low and stable concentrations (endrin, mirex) or a slight decline (DDTs, dieldrin, chlordane, hexachlorobenzene), since 1992. Mercury concentrations measured in edible tissue and liver were lower than those measured in previous years. Concentrations of other metals were variable over the period from 1992-1998. Spatially, overall levels of most metals appeared to be slightly higher at the FOS, rather than DIF, as observed for organic contaminants.

As in previous years, organic contaminant body burdens appeared to be predictive of liver histopathology. Although 1998 body burdens are on the low end of the contaminant burdens measured since 1992, a 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 and FDA regulatory action limits. The 1998 levels (determined on a wet weight basis), like those detected in previous monitoring years (1992-1997), were well below the federal legal limits.

Lobster

Fifteen lobsters were collected at the three core monitoring stations for the 1998 study (DIF, FOS, 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 all males found at ECCB, equal numbers of males and females at the FOS and mostly females collected at DIF. Little or no deleterious external conditions were noted.

Mean 1998 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 were highest at DIF, while mercury concentrations in the hepatopancreas were highest at the FOS. Comparison of 1998 data with previous years (1992-1997) indicates that most tissue contaminant levels and spatial trends were similar.

Comparison was made between lobster edible tissue contaminant levels, MWRA Caution and Warning limits and FDA regulatory action limits for pesticides, PCBs and mercury. The 1998 levels, like other monitoring years, were well below the federal legal limits and indicate no risk for human consumption. However, concentrations of PCBs in hepatopancreas have slightly exceeded the FDA legal limits in lobsters collected from the Deer Island location since 1996 and concentrations of PCBs at the FOS have come close to 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), the FOS and Cape Cod Bay (CCB), as well as, BIH and Quincy Harbor. 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 Cape Cod and BIH. A partial sixty-day deployed array (one cage of Sandwich mussels) was retrieved from Quincy Harbor. Full arrays were obtained from DI and the FOS at forty days only. Mussel survival within the deployed arrays was high (>95%).

The 1998 data were similar to previous years with the highest body burdens of contaminants observed in mussels deployed in BIH and lowest concentrations found in mussels deployed at the FOS. Contaminant levels overall were among the lowest measured since 1991. The lowest concentrations overall were found in mussels deployed at CCB, a station added in 1998 as an outer harbor reference site. The Quincy Bay site was added in 1998 to assess the transfer of discharge from the Nut Island facility to the Deer Island facility, which occurred from mid-April to July 6, 1998. Although concentrations in mussels deployed in Quincy Bay were elevated relative to the reference mussels, they were similar to concentrations found in a similar study conducted in 1987.

Comparison was made between mussel tissue contaminant levels and MWRA Caution and Warning levels and FDA regulatory limits for mercury and lead. The 1998 levels were well below the federal legal 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 the FOS during the period 1992 through 1998. The significant increase value is the 95th percentile upper confidence limit (based on the “t” distribution) of the arithmetic mean of the baseline period. Warning Levels have been set at 80% of the FDA legal 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 Limits and FDA regulatory limits. Similarly, the monitoring hypothesis regarding future increases of the prevalence of flounder liver centrotubular hydropic vacuolation at the FOS relative to baseline levels measured in outer Boston Harbor also appears to be 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),* blue mussel *(Mytilus edulis*). Measured parameters include length, weight, biological condition, the presence of external or internal disease, and inorganic and/or 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 1998 and a comparison of the 1998 data with data collected from 1992 through 1997. 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 1998 as well as selected data from previous studies, and Section 4 presents the conclusions drawn from the 1998 survey results and historical trends. Finally, recommendations for future sampling and analyses are summarized in Section 5.

There have been a number of changes in fish and shellfish monitoring over the past 6 years of monitoring. The following table summarizes those changes.

Organism	Laboratory		Composites per Station	Organisms per Composite
	Chemistry	Histology/ Mussel Condition[a]		
Flounder				
1992	Battelle	M. Moore	4	1
1993	Battelle	M. Moore	9-10	1
1994	Battelle	M. Moore	3	1
1995	ADL/ENVITEC	M. Moore	3	5
1996	ADL/ENVITEC	M. Moore	3	5
1997	ADL/ENVITEC	M. Moore	3	5
1998	Battelle	M. Moore	3	5
Lobster				
1992	Battelle	Battelle	3	1
1993	Battelle	Battelle	3	1
1994	Battelle	Battelle	3	1
1995	ADL/ENVITEC	ENSR	3	5
1996	ADL/ENVITEC	ENSR	3	5
1997	ADL/ENVITEC	ENSR	3	5
1998	Battelle	Battelle	3	5
Mussel				
1992	Aquatec	Aquatec	5-8	10
1993	Aquatec	Aquatec	3-8	10
1994	Aquatec	Aquatec	3-8	10
1995	ADL/ENVITEC	Aquatec	5	At least 200 g
1996	ADL/ENVITEC	Aquatec	5	At least 200 g
1997	ADL/ENVITEC	Aquatec	5	At least 200 g
1998	Battelle	Battelle	5	5-8

[a]Histology on 50 mussels each site each year.

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

2.0 METHODS

This section provides an overview of the methods and protocols used in the three surveys. 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 and whether contaminant tissue burdens approach human consumption limits

2.1.1 Stations and Sampling

A flounder survey was conducted between April 21, 1998 and April 29, 1998. Five sites were sampled to collect winter flounder for histological and chemical analyses:

- Deer Island Flats (DIF)
- Off Nantasket Beach (NB) (no chemical analyses in 1998)
- Broad Sound (BS) (no chemical analyses in 1998)
- The Future Outfall Site (FOS)
- East Cape Cod Bay (ECCB).

Table 2-1 provides the planned and actual sampling sites and locations for the 1998 flounder sampling. Adjustments in location were made to ensure that flounder 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.

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. Of the 50 flounder collected from each site, 15 were designated for tissue chemical analysis. These fish were maintained alive on-board and transported to Battelle, Duxbury for histological and chemical analysis. At the time these fish were also examined for external condition. 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.

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

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	2	42º20.4'	70º58.4'	42°20.8'	70°58.4'
2	NB	Off Nantasket Beach	2	42º17.6'	70º52.2'	42°17.4'	70°51.8'
3	BS	Broad Sound	2	42º24.4'	70º57.2'	42°24.2'	70°57.5'
4	FOS	Future Outfall Site	4	42º23.1'	70º49.3'	42°23.3'	70°49.6'
5	ECCB	East Cape Cod Bay	2	41º56.2'	70º06.6'	41°57.3'	70°07.5'

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

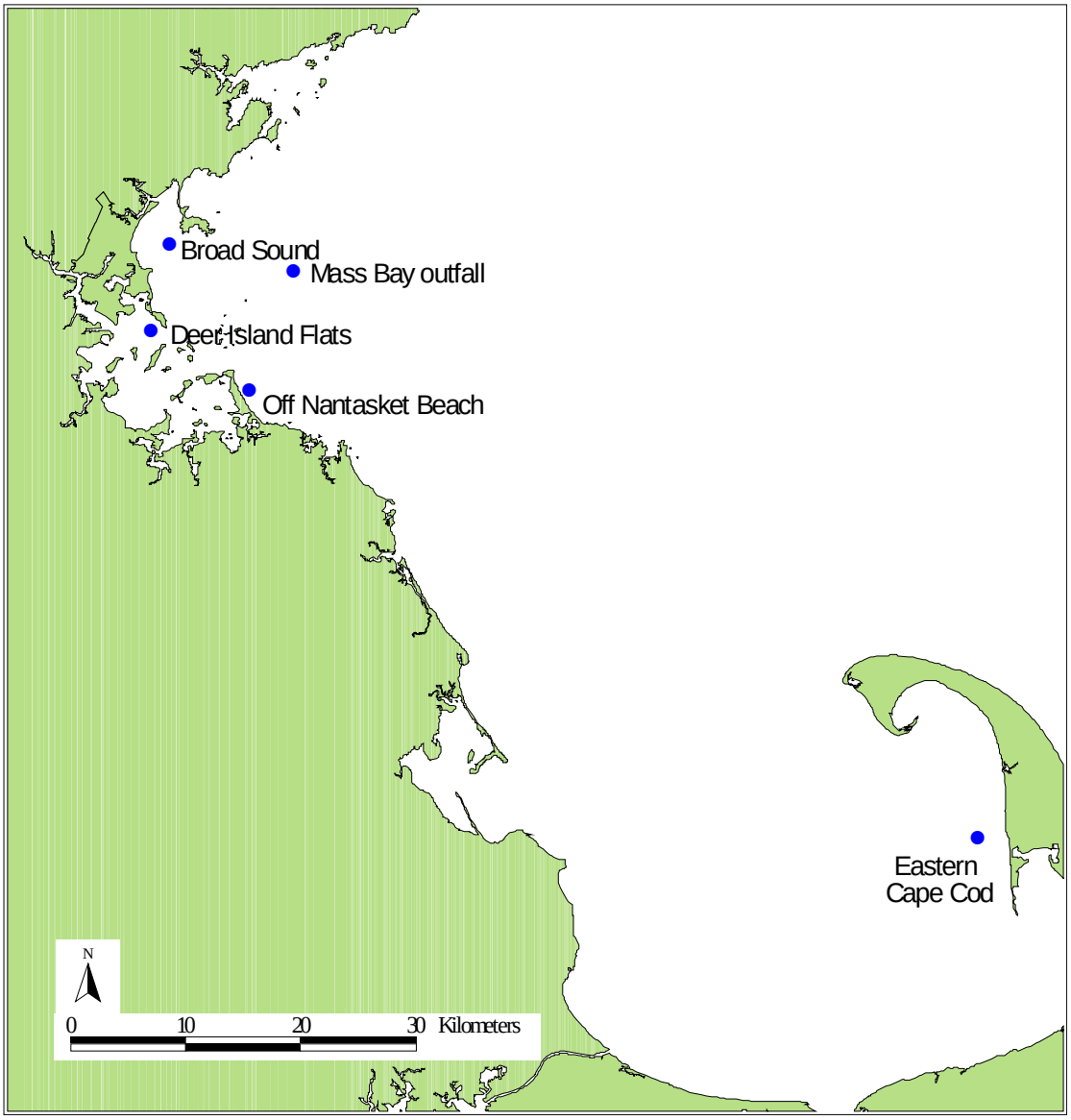


Figure 2-1. Flounder Monitoring Locations.

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. Using a pre-cleaned (i.e., rinsed with 10% HCL, Milli-Q (18 megohm) water, acetone, DCM, and hexane) stainless steel knife, the fillets (muscle) were removed from the flounder and the skin was removed from the fillet.

From each site 3 composites were prepared, each composed of approximately equal masses of top and bottom tissue from 5 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. (Livers from the remaining 35 fish not used for chemical analyses were removed ship-board 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.

The same fish were composited for both liver and fillet chemistry to ensure comparability. This resulted in 18 pooled samples for analysis in 1998 (9 pooled fillets and 9 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/Pestsicides and Hg (fillet measurements only).

2.1.4 Histological Processing

After the fish were completely examined and scales removed, if applicable, 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, the FOS, 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 additional flounder samples collected from NB and BS were frozen and archived. 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). Histopathological indices and prevalence of lesions were compared between classes of fish by differences in station, age, sex and length. Chemical constituents were presented graphically.

Histopathological observations of the livers of the winter flounder from all sites were conducted and, where possible, comparisons of the result 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, 1994).

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 QAPP

Samples were held according to the method described in the CW/QAPP (held in coolers replenished with seawater and aerated) while aboard the ship. However, between the time of receipt at the lab and actual sample processing (up to 12 hours for some samples) water in the coolers was aerated but not replenished. Mortality of the majority of the fish was noticed at the time of processing, possibly due to this method of holding the fish subsequent to laboratory receipt. Based on visual observation of the fish organs, including the liver, no signs of decay were present, and it was determined by MWRA that there would be

no effect on the subsequent histological or chemical evaluations. Subsequent histological analysis confirmed that autolysis had not occurred in these specimens.

2.2 Lobster Monitoring

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

2.2.1 Stations and Sampling

A lobster survey was conducted between September 10, 1998 and September 24, 1998. Lobster surveys originally scheduled to take place in July were postponed to September when lobsters were more abundant in the sampling locations. The three sites sampled to collect lobster for chemical analyses were:

- Deer Island Flats (DIF)
- Future Outfall Site (FOS)
- East Cape Cod Bay (ECCB)

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

Lobsters were purchased from commercial lobsterman. 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.

Table 2-2. 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	42º20.4'	70º58.4'	42º20.2'	70º58.3'
4	FOS	The Future Outfall Site	42º23.1'	70º49.3'	42º21.9'	70º47.3'
5	ECCB	East Cape Cod Bay	42º56.2'	70º06.6'	41º53.6'	70º24.3'

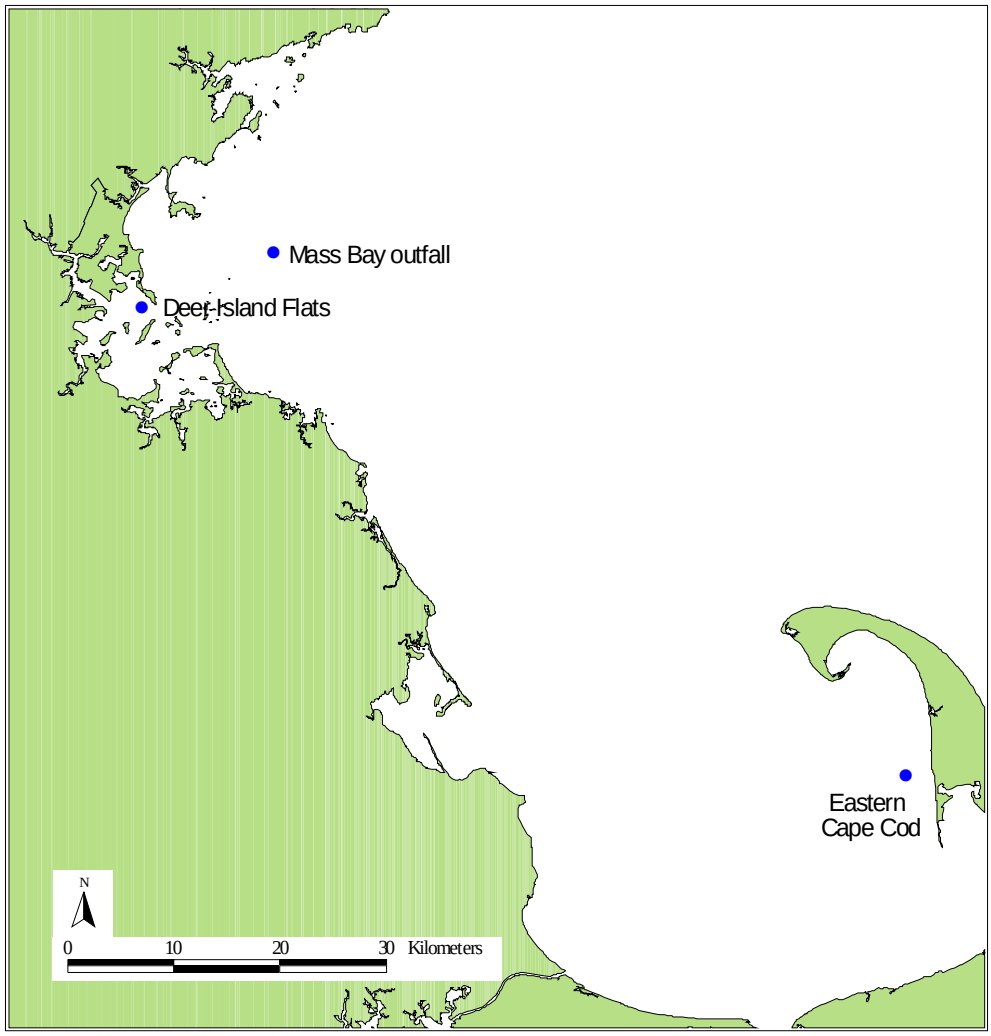


Figure 2-2. Lobster Monitoring Locations.

2.2.2 Size and Sex Determination

Carapace length was determined by measuring the distance from the tip of the rostrum to the posterior edge of the median uropod with calipers. 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 these groups, edible meat (claw and tail) 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 1998.

2.2.4 Tissue Processing and Chemical Analyses

Chemical analyses were performed on composite samples of lobster tissue. Two tissue types (hepatopancreas and edible meat) were analyzed. Edible lobster meat and hepatopancreas were analyzed for PCBs/Pesticides, lipids, and mercury. In addition, lobster hepatopancreas 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). Spatial and temporal trends of contaminants in edible lobster tissue and hepatopancreas tissue were evaluated through available data from 1985 through 1997. Comparisons were made to the FDA Legal Limits and other appropriate levels of regulatory concern.

2.2.6 Deviations from CW/QAPP

There were no deviations from the CW/QAPP.

2.3 Mussel Bioaccumulation Monitoring

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

2.3.1 Stations and Reference Area

During the 1998 surveys, mussels were collected from reference sites in Gloucester and Sandwich and deployed at five sites:

- Off Deer Island Light (DI) (~2 m above bottom)
- In vicinity of the Future Outfall Site (FOS)
- New Quincy Bay Station
- 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.

Table 2-3. Sampling and Locations for Mussel Surveys.

Station #	Sampling Site	Abbrevs.	Planned Location		Actual Location	
			N Latitude	W Longitude	N Latitude	W Longitude
1M	Deer Island Light	DI	42º20.4'	70º57.2'	42°20.4'	70°57.2'
M4	Future Outfall Site	FOS	42º23.1'	70º49.3'	42°23.1'	70°47.9'
6	Boston Inner Harbor	BIH	42º21.5'	71º02.9'	42°21.5'	71°02.9'
7	Gloucester - Predeployment	Gloucester	42º35.0'	70º40.0'	42°40.2'	70°40.2'
8	Sandwich/Cape Cod – Predeployment	Sandwich	41º50.0'	70º30.0'	41°45.6'	70°28.5'
9	Cape Cod Bay	CCB	41º55.5'	70º20.0'	41°54.8'	70°20.1'
M7	Quincy Bay	Quincy	NA	NA	42°17.6'	70°57.4'

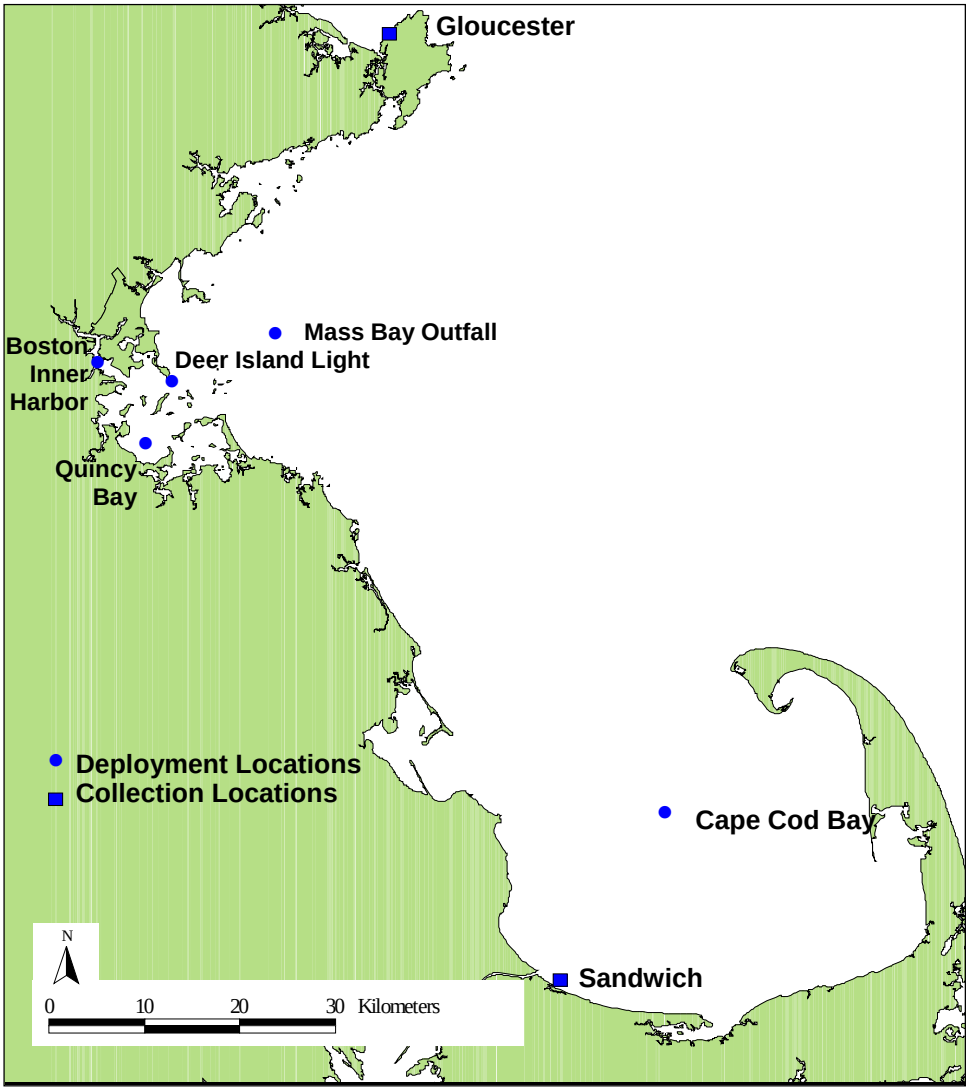


Figure 2-3. Mussel Collection and Deployment Locations.

2.3.2 Mussel Collection

In late June, approximately 2000 mussels were collected from Gloucester MA to be used for organic contaminant analysis and 1000 from Sandwich 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, with only mussels measuring between 55-65 mm to be used for this study. A subsample 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. Mussel deployment occurred from June 30 to July 2 in replicate arrays at the five 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 were deployed except for the offshore locations (FOS 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).

Table 2-4. Summary of Mussels Deployment Scheme.

Site	Description/ Location	Water Depth	Cage Height Above Bottom	# Arrays	# Cages/Array	# Mussels/ Cage
BIH	New England Aquarium	6m	1.5-4.5m[1]	3	2 Gloucester/ 1 Sandwich	45
DI	Deer Island Light	6m	2m, 1m[2]	3	2 Gloucester/ 1 Sandwich	45
Quincy Bay	Aid to Navigation Platform “4P”	10m	2m	3	2 Gloucester/ 1 Sandwich	45
FOS	42°23.15′ 70°47.92′	33m	15m	4	2 Gloucester/ 1 Sandwich	60
CCB	41°54.79′ 70°20.10′	33m	15m	4	2 Gloucester/ 1 Sandwich	60

[1] Rise and fall with tide.
[2] One array shortened to 1m above bottom and deployed in 5m water depth.

2.3.4 Mussel Retrieval

Mussel retrieval was planned for two occasions with collection of up one half of the mussels (one array) at 40-days to provide tissue in the event of failure of the 60-day collection. At DI and the FOS, only 40-day mussels were retrieved, and for Quincy Bay, only Sandwich mussels were retrieved at 60 days. Actual mussel recovery is summarized in Section 2.3.8 and details are discussed in Section 3.3. The amount of biofouling of the arrays was also assessed at 40 days.

2.3.5 Determination of Biological Condition

For biological analyses, a random subsample of 15 (Sandwich) or 30 (Gloucester) mussels were selected from the pre-deployment mussels and from each of the stations' 60-day collection. Mussels for biological analyses were processed to obtain total shell length, total wet weight and reproductive condition.

In the laboratory, each mussel was cleaned of attached material (barnacles, byssal threads, etc.). The total shell length (umbo to distal portion of valve gape) was measured with a Vernier caliper (to the nearest 0.1mm). The total soft tissue, gonadal tissue, and the non-gonadal tissue weights were measured on an electronic balance to the nearest 0.01g wet weight.

Each mussel was opened by slicing the adductor mussels between the valves with a microtome blade. The gill tissue was drawn back to expose the gonad to determine the sex.

Biological condition analyses were only performed on the pre-deployment mussels from both Gloucester and Sandwich and the 60-day mussels collected from BIH.

2.3.6 Tissue Processing and Chemical Analyses

Each individual mussel was cleaned of attached material, all byssal threads removed, and all soft tissue including fluids placed directly into an amber 500-ml I-Chem Certified clean bottle. Mussel composite samples were prepared for chemical analyses by dissection of individual mussels using disposable Teflon-coated stainless steel blades rinsed with methanol and de-ionized water prior to use. Each mussel for a given composite was placed in a sample container clearly identified with a unique sample identifier.

For organic analysis composites groups of 10 mussels were pooled from the 50 Gloucester mussels deployed and collected to create 5 pooled samples per site, except for the FOS and Cape Cod site, where 8 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 5 pooled samples per site, except for the FOS and Cape Cod Bay site, where 8 pooled samples were created from 40 Sandwich mussels. Gloucester and Sandwich pre-exposed mussels were also analyzed for organic and inorganic parameters, respectively. Details of actual mussel retrievals and analytical implications are discussed in Section 3.3.

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 (and organics as discussed below). 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.

2.3.7 Data Reduction and Statistical Analyses

The extent of bioaccumulation of contaminants in blue mussels was evaluated and 1998 results of deployed mussels were compared statistically to initial contaminant levels in the control mussels. Further evaluation focused on spatial and temporal trends in contaminant accumulation.

2.3.8 Deviations from the 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:

- Quincy Bay - Limited retrieval occurred at Quincy Bay, where at 40-days, only 2 Sandwich cages remained; one of which was collected at 40-days and the remaining one collected at 60-days. To obtain organic analyses at the Quincy site, both the pre- and post-deployed

Sandwich mussels were analyzed for organics. To maximize the amount of tissue for organics analyses from the Quincy deployed mussels, a single homogenate was prepared using 15 Sandwich mussels and 5 aliquots were prepared for organic analyses.

- Future Outfall Site - A complete set of mussels was collected at 40-days, however, at 60-days, no arrays were located. All chemical analyses from the FOS were performed on 40-day samples.

- Deer Island - A complete set of mussels was collected at 40-days, however, at 60-days, no arrays were located. All chemical analyses from Deer Island were performed on 40-day samples.

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.

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	9	NR	*	NR	*	NR	*	*
Flounder Liver	9	*	*	*	*	*	*	*
Lobster Meat	9	NR	*	NR	*	NR	*	*
Lobster Hepatopancreas	9	*	*	*	*	*	*	*
Mussel Tissue								
Gloucester	36	NR	NR	NR	*	*	*	*
Sandwich	36	NR	*	*	(2)	(2)	(2)	(2)

*Targeted for Analysis
(1) Additional metals: Ag, Cd, Cu, Ni, Zn
(2) Sandwich pre-deployment mussels were analyzed for organics to compare to Quincy 60-day Sandwich mussels, which were also analyzed for organics due to loss of Gloucester mussels.
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)	ug/g dry wt	Digestion ICP-AES (all metals) GFAA (as required) CVAA-FIAS (Hg)	EPA 3052 (EPA 1996) EPA 2007 (EPA 1991) EPA 200.9 EPA 245.1 (EPA 1991)
Ancillary Parameters			
Lipids	% by dry weight	Gravimetric	Peven and Uhler (1993)
Dry Weight	% by dry weight	Gravimetric	Peven and Uhler (1993)

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 wt.

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.

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

Chemical Analytes

Trace Metals[a]
- Ag Silver
- Cd Cadmium
- Cr Chromium
- Cu Copper
- Hg Mercury[b,e]
- Ni Nickel
- Pb Lead[e]
- Zn Zinc

Polychlorinated biphenyls (PCBs)[c,d]
- 2,4'-Cl_2(8)
- 2,2N,5-Cl_3(18)
- 2,4,4N-Cl_3(28)
- 2,2N,3,5N-Cl_4(44)
- 2,2N,5,5N-Cl_4(52)
- 2,3N,4,4N-Cl_4(66)
- 3,3N,4,4N-Cl_4(77)
- 2,2N4,5,5N-Cl_5(101)
- 2,3,3N,4,4N-Cl_5(105)
- 2,3N,4,4N5-Cl_5(118)
- 3,3N,4,4N,5-Cl_5(126)
- 2,2N,3,3',4,4N-Cl_6(128)
- 2,2N,3,4,4N,5-Cl_6(138)
- 2,2N4,4N,5,5N-Cl_6(153)
- 2,2N3,3',4,4N,5-Cl_7(170)
- 2,2N,3,4,4N,5,5N-Cl_7(180)
- 2,2N,3,4',5,5N,6-Cl_7(187)
- 2,2N,3,3N,4,4N,5,6-Cl_8(195)
- 2,2N,3,3N4,4N,5,5N,6-Cl_9(206)
- Decachlorobiphenyl-Cl_{10}(209)

Polynuclear Aromatic Hydrocarbons (PAHs)[a,d]
- Naphthalene
- C_1-naphthalenes
- C_2-naphthalenes
- C_3-naphthalenes
- C_4-naphthalenes
- 1-methylnaphthalenes[f]
- 2-methylnaphthalenes[f]
- 2,6-methylnaphthalenes[f]
- 2,3,5-methylnaphthalenes[f]
- Acenaphthylene
- Acenaphthene
- Fluorene
- C_1-fluorenes
- C_2-fluorenes
- C_3-fluorenes
- Phenanthrene
- 1-methylphenanthrene[f]
- Anthracene

Polynuclear Aromatic Hydrocarbons (PAHs) (continued)
- C_1-Phenanthrenes/anthracene
- C_2-Phenanthrenes/anthracene
- C_3-Phenanthrenes/anthracene
- C_4-Phenanthrenes/anthracene
- Dibenzothiophene
- C_1-dibenzothiophenes
- C_2-dibenzothiophenes
- C_3-dibenzothiophenes
- Fluoranthene
- Pyrene
- C_1-fluoranthenes/pyrene
- C_2-fluoranthenes/pyrene
- C_3-fluoranthenes/pyrene
- Benzo[*a*]anthracene
- Chrysene
- C_1-chrysene
- C_2-chrysene
- C_3-chrysene
- C_4-chrysene
- Benzo[*b*]fluoranthene
- Benzo[*k*]fluoranthene
- Benzo[*a*]pyrene
- Dibenzo[*a,h*]anthracene
- Benzo[g,h,i]perylene
- Indeno[1,2,3-*c,d*]pyrene
- Perylene
- Biphenyl
- Benzo[*e*]pyrene
- Dibenzofuran
- Benzothiazole

Pesticides[c,d]
- Hexachlorobenzene
- Lindane
- Heptachlor
- Endrin
- Aldrin
- Heptachlorepoxide
- alpha-chlordane
- trans-Nonachlor
- Dieldrin
- Mirex
- 2,4N-DDD
- 4,4N-DDD
- 2,4N-DDE
- 4,4N-DDE
- 2,4N-DDT
- 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] Compounds Monitored in 94-97; will be analyzed in 1998 - 2000, HOM 3.

2.4.2 Metals Tissue Digestion

Tissue samples were digested using an aqua-regia microwave digestion procedure following the modified EPA Method 3052 as described in Battelle SOP 5-059. This digestion method prepares samples for analysis by inductively coupled atomic emission spectrometry (ICP-AES), graphite furnace atomic absorption (GFAA), or cold vapor atomic absorption (CVAA). Samples were homogenized, freeze dried for digestion and sample mass was determined and recorded. Under a fumehood, 2.0 ml of concentrated HNO3 was swirled into the sample until all of the material was wetted. Then 5.0 ml of concentrated HCL was added and swirled until all of the material was suspended. Samples were allowed to stand at least 1 hour, or at most, overnight. Samples were then placed in the microwave carousel and connected to the central vapor collection container. The loaded carousel was placed into the microwave digester and the instrument was set as follows: 15% power for 5 minutes (90 watts), 40% power for 20 minutes (240 watts). Samples were diluted to volume by weight and the density value was recorded and used to determine the final digestate volume.

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

ICP-AES Analysis - An aliquot of the tissue digestate was analyzed for all metals except Hg by ICP-AES following Battelle SOP 5-277 - *Determination Of Elemental Metals By Inductively Coupled Plasma Atomic Emission Spectrometer (ICP/AES)* based on EPA Method 200.7 (EPA 1991). If metals were non-detected by this method further analyses by Graphite Furnace Atomic Absorption (GFAA) were performed. Atomic Emission Spectroscopy (AES) is a spectral technique for the analysis of metals that relies on the desolvation/atomization of an element of interest in a plasma and measurement of the emitted spectra for quantitation. The ICP-AES was calibrated before each set of samples was analyzed. All metals results have been reported in µg/g dry wt.

GFAAS- Operation of the GFAA instrument is detailed in Battelle SOP 3-103 *Operation Of Perkin-Elmer Model 5100 And 5100zl Atomic Absorption Spectrophotometers: Graphite Furnace (GFAAS).* All GFAA results have been reported in µg/g dry wt.

CVAA-FIAS – Hg determinations were made on microwave tissue digestates using cold-vapor atomic absorption with flow injection analysis system (CVAA/FIAS) following Battelle SOP 5-224-01 - *Sample*

Preparation Procedures For The Analysis Of Arsenic, Antimony, Selenium, And Mercury Using FIAS. All Hg results have been reported in μg/g dry wt.

2.5 General Data Treatment and Reduction

This section describes data reduction performed on 1998 Fish and Shellfish data as well as historical data as part of the 1998 MWRA Harbor and Outfall Monitoring Project.

Specifics of data handling are as follows:

- All laboratory duplicates for pre-1998 data were averaged for reporting and calculating. No laboratory duplicate data were entered for 1998 data.

- "s" (suspect) flagged data were not included in any calculations or graphs; "f" (analyte detected below detection limit) flagged data were not included in graphical presentation of results but were included in calculations of thresholds and baseline means.

- 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 used in comparison to MWRA thresholds and FDA action levels were calculated by multiplying the sample percent dry weights by the dry weight concentrations for that sample.

- All 1998 chemical data were generated at Battelle and loaded directly into the database. All pre-1998 data were obtained directly from the MWRA Database with the exception of selected PAH results for 1995 mussels (see Section 3.3.4.4).

- 1993 lobster collection at Deer Island consisted of two animals collected in June and one in August. Results were calculated using the mean of the June event and the August data. However, "n" was still considered to be equal to three for calculation of standard error. Future reports should calculate a single mean for the three individuals.

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 21 and April 29, 1998 at five stations in the study area (Figure 2-1). The catch per unit effort (CPU), defined as the number of fish obtained per minute of bottom trawling time, was highest at FOS (Table 3-1). The lowest CPU of 1998 was observed at ECCB. The individual CPU for 1998 was higher at three of the five stations (DIF, FOS, and BS) than in any other baseline year. The CPU was determined to make a relative comparison of catch efficiency among years.

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

	1991	1992	1993	1994	1995	1996	1997	1998
DIF	0.38	0.23	0.15	0.39	0.10	0.16	0.11	0.69
NB	0.48	1.29	1.52	0.76	0.88	0.77	0.43	0.56
BS	1.26	2.80	0.49	0.42	0.29	0.23	0.59	2.57
FOS	0.13	0.48	0.62	0.24	0.60	0.31	0.81	2.62
ECCB	0.67	0.49	0.77	0.42	0.21	1.38	0.32	0.23

CPU = # fish caught per minute of bottom time

3.1.2 Age/Length Parameters

The physical characteristics (i.e. mean length, weight, age) of the winter flounder collected in 1998 are given in Table 3-2. Mean age and length for fish from DIF were significantly higher than other stations in 1998, although this is unlikely to be biologically significant. In terms of length, weight, and age, the 1998 samples were representative of the previous decade for all stations. The inter-annual trends for mean length and age at the five stations are depicted in plots provided in Appendix C.

3.1.3 External Condition

The external conditions (i.e. fin erosion, gross abnormalities) of winter flounder collected in 1998 are presented as averages per station in Table 3-2. As described in Section 2.2.1, 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, only a few fish at each station exhibited gross physical abnormalities. Fin erosion ranged between 0.04 and 0.56 with fin erosion observed at DIF (0.56) significantly higher than other sites. However, current levels are all substantially lower than those observed, but not quantified, between 1987 and 1990 at the Deer Island site.

In terms of the previous decade, levels are at a plateau at DIF, having been lowest in 1993, at an all time low for NB, falling from an all-time high in 1997 at FOS and persistently low at the ECCB site. Plots of fin erosion scores over time at each station are presented in Appendix C.

Table 3-2. Summary of Physical Characteristics of Winter Flounder Collected in 1998.

Station name		DIF	NB	BS	FOS	ECCB
Station Number		1	2	3	4	5
	N	50	50	50	50	50
Total Length (mm)	Mean	363.0	341.8	336.2	340.0	341.1
	Std. Dev.	38.0	23.1	27.7	36.1	30.1
	ANOVA*	2,3,4,5				
Weight (g)	Mean	556	477	452	515	461
	Std. Dev.	148	103	110	202	125
	ANOVA	2,3,5		4		
Age (yrs)	Mean	4.3	4.1	3.8	3.8	3.5
	Std. Dev.	0.9	.7	.8	.9	.7
	ANOVA	3,4,5	5			
Fin erosion	Mean	0.56	0.04	0.20	0.36	0.06
	Std. Dev.	0.76	0.20	0.50	0.60	0.24
	ANOVA	2,3,4,5	4		5	
Gross score	Mean	0.02	0.02	0.00	0.02	0.00
	Std. Dev.	0.14	0.14	0.00	0.14	0.00
	ANOVA					

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

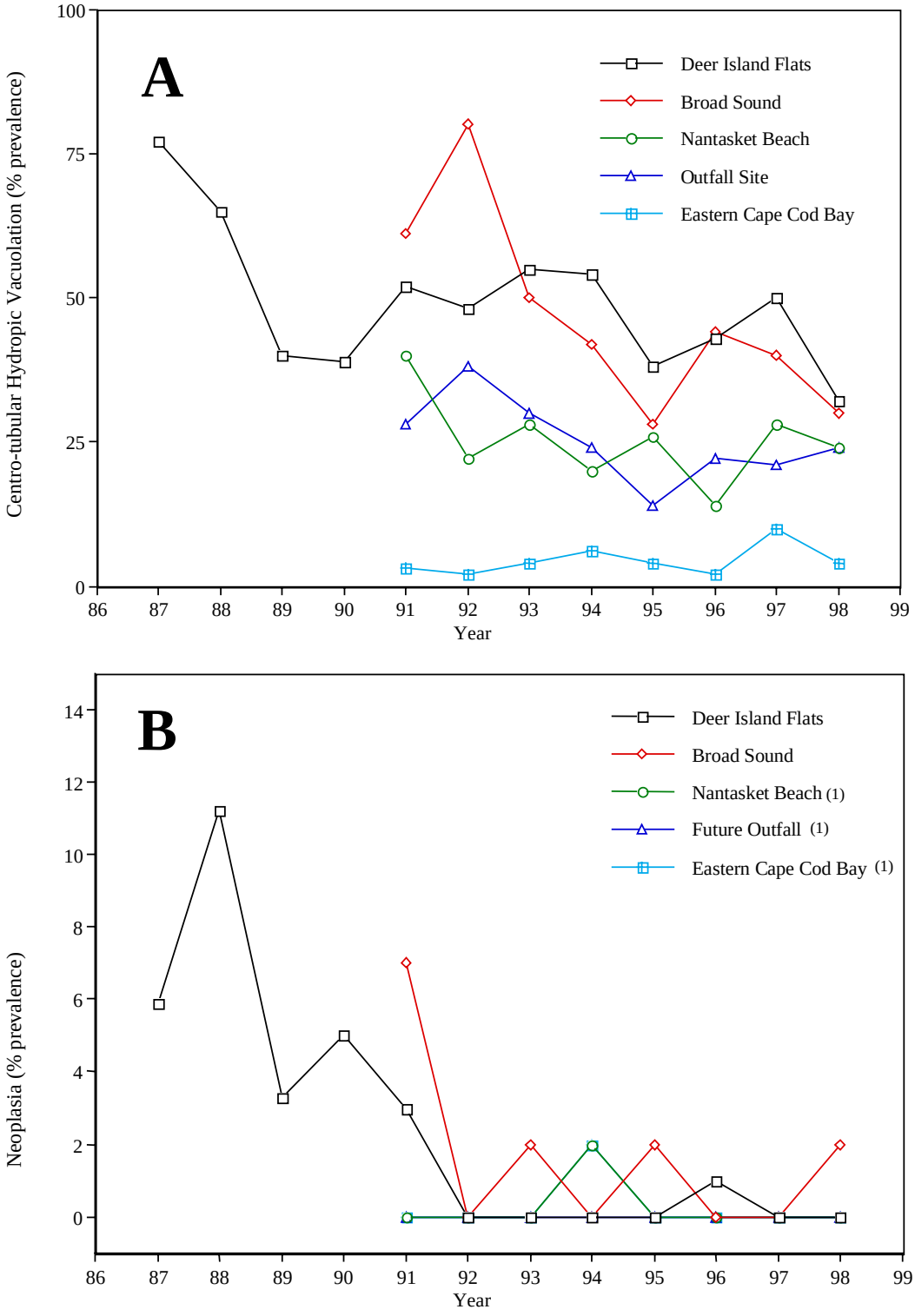
3.1.4 Inter-station Comparison of Liver Lesion Prevalence

Neoplasia and focal hydropic vacuolation in flounder liver were absent from all stations, except for one neoplasm occurrence from BS (Table 3-3). The prevalence of tubular and centrotubular hydropic vacuolation was highest at DIF and BS, intermediate at the FOS and NB and lowest at the ECCB site. Temporal comparison of lesion prevalence shows that the above inter-station pattern for 1998 mirrors what has been seen in previous years (Figures 3-1, 3-2, Appendix C). With the possible exception of BS, levels of tubular and centrotubular vacuolation through 1998 have not changed substantially since 1991 at any station. Levels at DIF between 1991 and 1998 are significantly lower than they were in 1987 and 1988. Data are unavailable from the other sites for those years. Figure 3-1 illustrates these trends for neoplasia and Tubular Hydropic Vacuolation prevalence over time at each station.

Table 3-3. Prevalence (%) of Lesions in Winter Flounder Liver from Five Stations in Massachusetts and Cape Cod Bays – 1998.

	Station Name	DIF	NB	BS	FOS	ECCB
Station Number		**1**	**2**	**3**	**4**	**5**
	N	50	50	50	50	50
Lesion type*	Neoplasm	0	0	2	0	0
	Focal HV	0	0	0	0	0
	Tubular HV	28	12	22	20	0
	Centrotubular HV	32	24	30	24	4
	Macrophage Aggregation	54	54	70	60	40
	Biliary proliferation	42	36	48	38	20

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



(1) Data points overlap in recent years.

Figure 3-1. Temporal Comparison of Lesion Prevalence: a) Prevalence in Flounder Liver of Centro-Tubular Hydropic Vacuolation and b) Neoplasia by Station over Time.

Figure 3-2 compares the severity of centrotubular hydropic vacuolation between years and stations. Core stations rank from the most contaminated to the least as follows: DIF>FOS>ECCB.

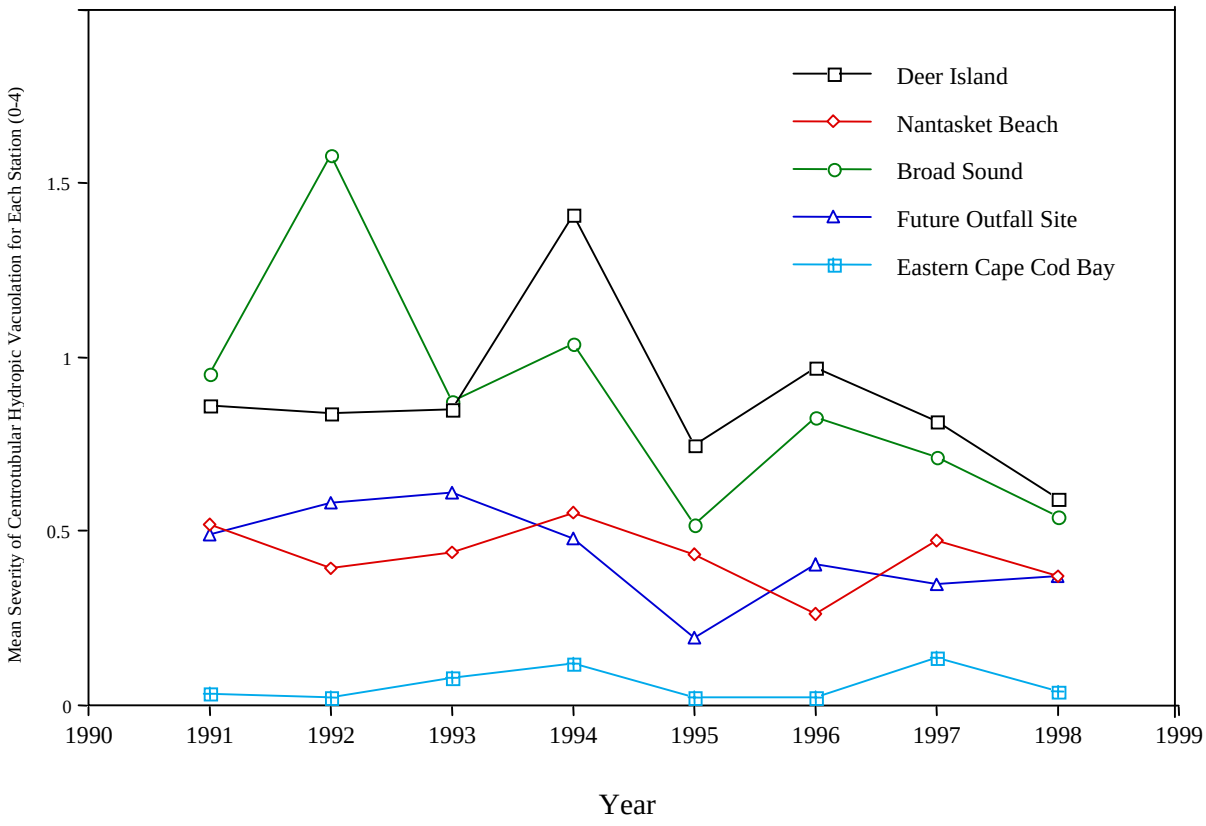


Figure 3-2. Centrotubular Hydropic Vacuolation Severity Compared Among Sites and Years.

3.1.5 Relationships Between Age, Length and Lesion Prevalence

As have been shown previously (Moore 1991, Mitchell et al. 1998), lesion prevalence increases with age at any one station. However, the sampling protocol in place has ensured that over the period of this program the age and length of the fish examined have remained relatively unchanged. Thus, comparisons between stations and years are not significantly biased by differences in age and length.

3.1.6 Spatial Comparison of Tissue Contaminant Levels

The body burdens of contaminants were determined for both edible tissue (fillets) and liver tissue for winter flounder collected in the 1998 survey. A summary of both individual flounder replicate concentrations and mean and standard errors of the replicate analyses for both 1998 fillet and liver tissues, presented as ug/kg dry wt, are provided in Appendix B to this report.

3.1.6.1 Edible Tissue

Comparisons of the 1998 mean concentrations of organic compounds in fillets across the study area indicate that for all compounds, the highest concentrations were found at DIF and the lowest at ECCB (Figures 3-3 and 3-4). Mercury, the only metal measured in edible tissue, was highest in fillet samples from FOS and lowest at ECCB (Figure 3-6).

3.1.6.2 Liver

Comparison of the 1998 mean concentrations of organic compounds in flounder livers across the study area showed the same trend as for edible tissue. The highest concentrations were found in samples from DIF and the lowest at ECCB (Figures 3-3, 3-4 and 3-5). Metals concentrations in livers, however, showed a different pattern (Figures 3-6 and 3-7). Mercury and lead were highest at the FOS, similar to the trend seen in fillets. Cadmium, copper, and zinc concentrations were highest at ECCB. Nickel and silver concentrations were similar at the FOS and ECCB and lowest at DIF. Only chromium was found at the highest concentrations at DIF.

3.1.7 Comparison of 1998 Contaminant Levels to Other Baseline Data

Body burdens of selected contaminants have been measured consistently in winter flounder since 1992. This section discusses the temporal and spatial trends observed from 1992 through the present. Selected data, plotted by contaminant and station (DIF, FOS and ECCB only) for both edible tissue and liver, are presented below.

3.1.7.1 Edible Tissue

Body burdens of organic compounds monitored in edible tissue in 1998 were consistently similar or lower than measured in previous years. Concentrations have historically been highest at DIF and lowest at ECCB for all organic contaminants. Most contaminants for most sites do not appear to show any upward or downward trends. Only the FOS data for DDT (Fig 3-4a) and the DIF data for total chlordanes suggest interesting trends that will need to be followed closely over the next few years.

Mercury was the only metal measured in edible tissue from winter flounder. Mercury concentrations at all stations have been variable over time with the lowest concentrations routinely found at ECCB (Figure 3-6).

3.1.7.2 Liver

Concentrations of organic contaminants (PCBs, chlorinated pesticides, PAHs) in livers from winter flounder mirrored the trends observed in edible tissue during the period 1992 through 1998. Concentrations measured in 1998 were generally lower than measured in previous years. Generally, the highest concentrations in all years were detected in livers from fish collected at DIF and the lowest concentrations were observed at ECCB. Total PCB concentrations appear to be relatively constant over time with the exception of elevated levels reported in 1995 (Figure 3-3). Figure 3-4a shows total DDT concentrations in flounder livers since 1992 and illustrates the overall trend of chlorinated pesticides in livers during this period. PAH concentrations in liver have been similar over time with the exception of 1993 at all locations (Figure 3-5). The elevated total PAH measured in 1993 is due in part to high levels of naphthalenes. This is inconsistent with subsequent measurements and suggests a common source other than environmental exposure.

A number of metals, along with mercury, were measured in flounder livers during the period 1992 through 1998. The trend in metals concentrations, for the most part, did not follow those of organic contaminants. Metals concentrations tended to be highest at the FOS and ECCB, rather than at DIF, as observed for organic contaminants. This appeared to be a consistent trend during the recorded period for

all metals except mercury, where mercury concentrations at DIF in 1992 and 1993 were higher than at the other sites.

At DIF, concentrations of metals measured in 1998 were within the range of recorded values (1992-1997), with no clear upward or downward historical trend observed for any metal (Figures 3-6 and 3-7). Similarly, no clear historical trends were observed at FOS.

For ECCB, cadmium and nickel do appear to be trending up, whereas lead appears to be trending down (Figure 3-7). The values at ECCB will be watched closely over the next several years to ascertain whether the 1998 observations continue.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	SE	N	Mean	SE	N	Mean	SE	N
1992	458.5	168.0	4	220.4	46.3	4	51.1	11.4	4
1993	196.8	30.1	10	211.3	38.9	9	53.9	8.37	10
1994	520.0	35.0	3	249.9	32.5	3	60.2	5.75	3
1995	613.5	176.2	3	236.2	15.1	3	106.0	5.63	3
1996	285.3	30.1	3	193.7	43.1	3	63.8	10.9	3
1997	324.3	37.1	3	206.0	30.9	3	60.3	6.19	3
1998	238.4	17.9	3	105.6	34.7	3	39.4	2.09	3

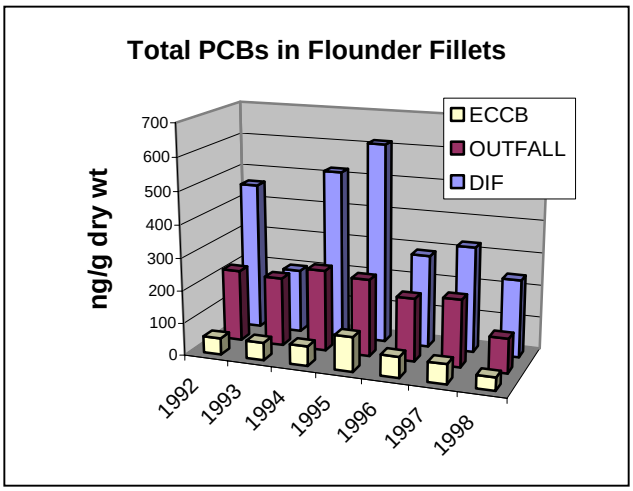


Figure 3-3a. Total PCBs in Flounder Fillet at DIF, Outfall and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	SE	N	Mean	SE	N	Mean	SE	N
1992	2660.1	523.0	4	2414.8	471.7	4	372.7	65.1	4
1993	1797.0	NA	1	1732.91	NA	1	335.1	NA	1
1994	3614.9	596.0	3	2381.5	561.77	3	343.7	52.9	3
1995	9242.1	839.5	3	6090.63	1747.82	3	1249.4	520.6	3
1996	3672.3	687.7	3	2600.57	463.19	3	778.1	33.6	3
1997	4638.0	992.2	3	2629.27	727.44	3	938.4	177.4	3
1998	3059.5	660.2	3	1254	246.52	3	448.1	128.1	3

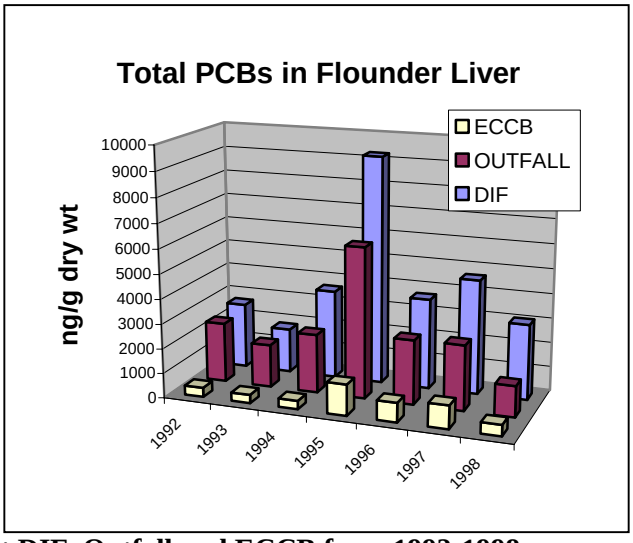


Figure 3-3b. Total PCBs in Flounder Liver Tissue at DIF, Outfall and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
1992	47.31	8.64	4	22.2	3.4	4	10.1	2.2	4
1993	31.33	5.82	10	26.98	4.15	9	11.80	1.66	10
1994	43.83	2.38	3	22.66	1.33	3	13.82	0.88	3
1995	43.23	16.63	3	22.80	2.87	3	27.47	1.88	3
1996	32.07	2.53	3	19.07	4.80	3	9.53	1.73	3
1997	46.27	3.75	3	22.47	4.80	3	13.07	2.09	3
1998	29.87	2.72	3	11.87	4.12	3	5.74	0.39	3

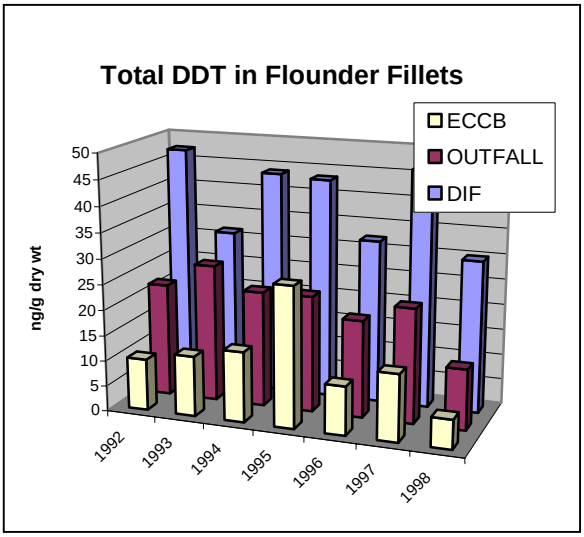


Figure 3-4a. Total DDT in Flounder Fillet at DIF, Outfall and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
1992	214.45	44.37	4	207.07	36.88	4	48.76	5.13	4
1993	257.9	0.0	1	247.3	0.0	1	66.5	0.0	1
1994	407.3	40.8	3	264.1	47.2	3	73.5	9.8	3
1995	866.3	76.8	3	455.2	100.0	3	160.3	17.1	3
1996	420.0	88.5	3	274.3	93.2	3	104.0	11.0	3
1997	635.2	130.2	3	342.4	56.2	3	237.4	84.2	3
1998	381.8	99.2	3	130.81	17.90	3	63.03	22.56	3

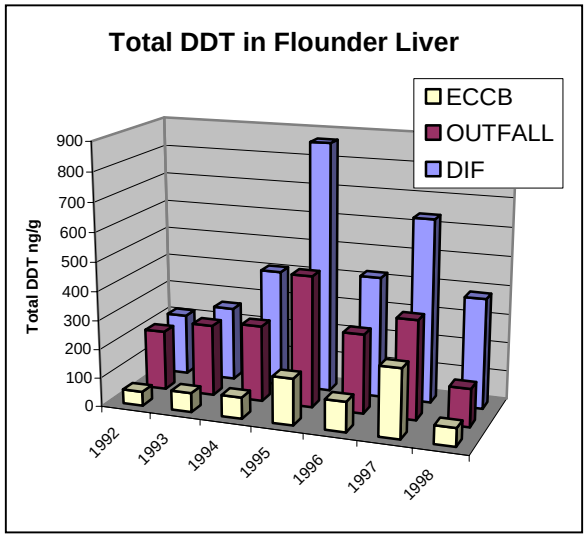


Figure 3-4b. Total DDT in Flounder Liver at DIF, Outfall and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
1993	877.1	0.0	1	427.1	0.0	1	405.6	0.0	1
1994	215.4	27.6	3	239.4	71.2	3	146.3	38.5	3
1995	229.7	40.3	3	54.0	7.00	3	31.0	1.15	3
1996	242.3	31.1	3	304.3	94.7	3	262.0	40.5	3
1997	199.7	20.4	3	105.3	2.73	3	60.7	17.1	3
1998	73.25	13.61	3	44.03	8.84	3	31.15	9.31	3

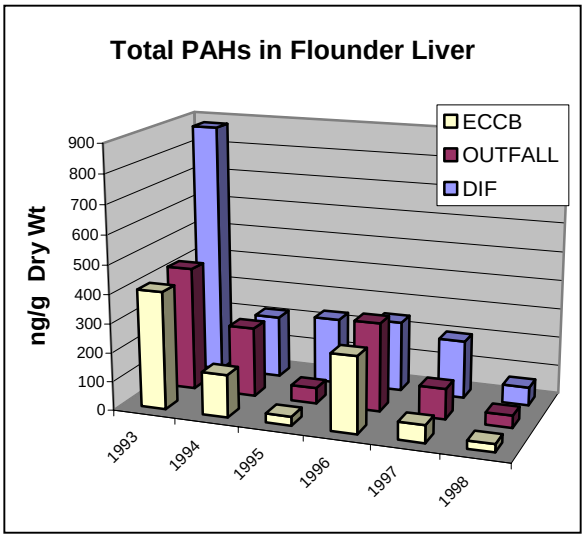


Figure 3-5. Total PAH in Flounder Liver at DIF, Outfall and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
1992	0.44	0.11	4	0.61	0.23	4	0.06	0.02	4
1993	0.46	0.10	10	0.41	0.07	9	0.19	0.03	10
1994	0.28	0.03	3	0.43	0.09	3	0.12	0.01	3
1995	0.40	0.02	3	0.31	0.04	3	0.10	0.01	3
1996	0.46	0.07	3	0.55	0.15	3	0.40	0.03	3
1997	0.51	0.09	3	0.28	0.20	3	0.20	0.02	3
1998	0.23	0.01	3	0.33	0.04	3	0.14	0.02	3

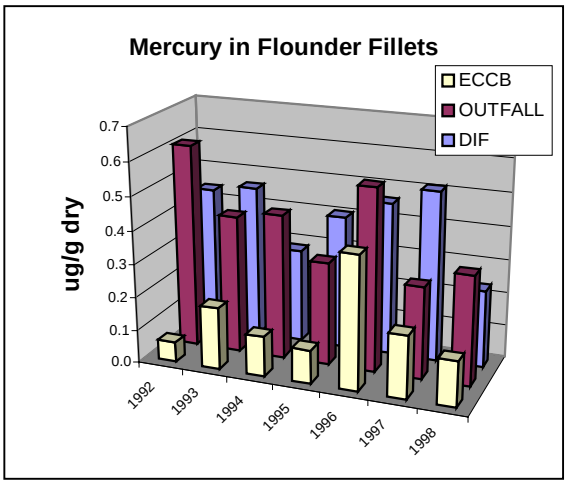


Figure 3-6a. Total Mercury in Flounder Fillets at DIF, Outfall and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Code Bay		
	Mean	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
1992	1.00	0.28	4	0.56	0.11	4	0.28	0.13	4
1993	0.69	0.00	1	0.42	0.00	1	0.23	0.00	1
1994	0.28	0.03	3	0.54	0.16	3	0.23	0.02	3
1995	0.25	0.05	3	0.39	0.02	3	0.30	0.05	3
1996	0.53	0.09	3	0.55	0.03	3	0.44	0.04	3
1997	0.34	0.05	3	0.34	0.07	3	0.21	0.02	3
1998	0.27	0.03	3	0.39	0.03	3	0.27	0.04	3

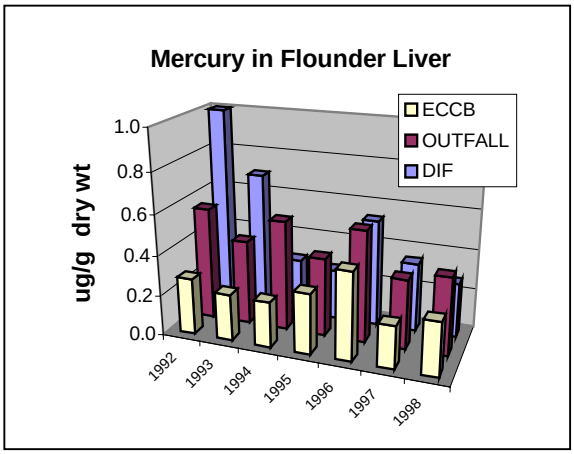


Figure 3-6b. Total Mercury in Flounder Liver at DIF, Outfall and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	SE	N	Mean	SE	N	Mean	SE	N
1992	2.28	0.62	4	1.82	0.58	4	0.51	0.29	4
1993	0.91		1	0.85		1	0.42		1
1994	0.98	0.44	3	2.16	0.89	3	0.97	0.21	3
1995	0.44	0.07	3	1.42	0.09	3	0.66	0.01	3
1996	0.90	0.30	3	3.33	0.79	3	1.09	0.20	3
1997	2.25	1.50	3	1.04	0.10	3	1.83	0.49	3
1998	0.66	0.10	3	1.22	0.29	3	1.65	0.51	3

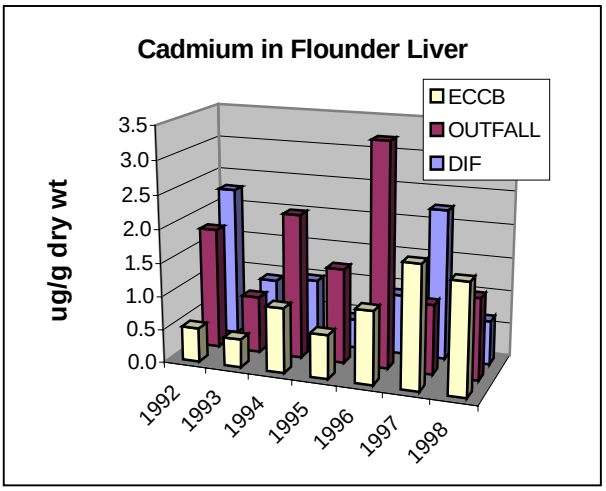


Figure 3-7a. Total Cadmium in Flounder Liver at DIF, Outfall and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	SE	N	Mean	SE	N	Mean	SE	N
1992	0.24	0.09	4	0.055	0.02	4	0.043	0.027	4
1993	0.74	0.000	1	0.917	0.000	1	0.000	0.000	1
1994	0.19	0.046	3	0.142	0.003	3	0.099	0.012	3
1995	0.14	0.011	3	0.089	0.023	3	0.087	0.018	3
1996	0.08	0.004	3	0.116	0.032	3	0.039	0.014	3
1997	0.42	0.225	3	0.304	0.293	3	0.327	0.323	3
1998	0.36	0.136	3	0.186	0.044	3	0.058	0.010	3

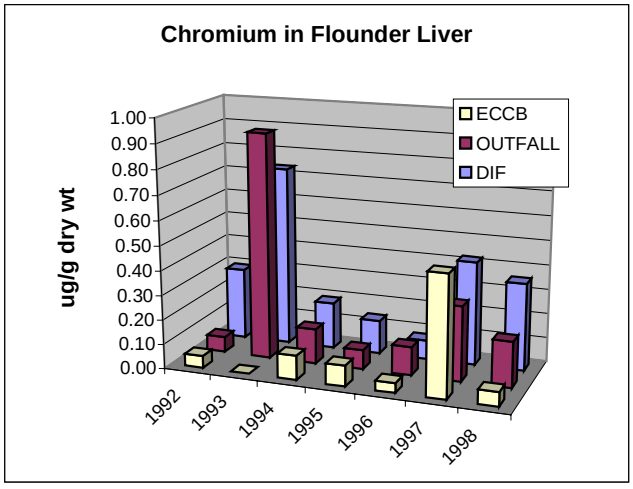


Figure 3-7b. Total Chromium in Flounder Liver at DIF, Outfall and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
1992	66.28	48.30	4	91.73	19.98	4	72.63	26.27	4
1993	82.7	0.0	1	50.6	0.0	1	26.4	0.00	1
1994	51.8	6.84	3	112.2	29.9	3	121.3	5.67	3
1995	55.86	22.31	3	121.4	12.89	3	64.54	4.16	3
1996	42.3	19.6	3	125.5	34.4	3	65.6	7.73	3
1997	54.93	1.71	3	75.07	11.75	3	87.01	17.91	3
1998	42.5	9.30	3	91.6	19.6	3	138.8	29.9	3

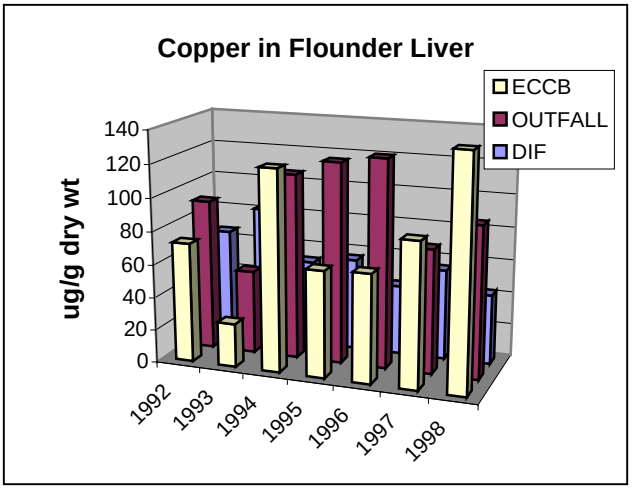


Figure 3-7c. Total Copper in Flounder Liver at DIF, Outfall and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
1992	0.840	0.391	4	0.799	0.293	4	0.362	0.072	4
1993	0.62	0.00	1	0.65	0.00	1	0.40	0.00	1
1994	0.24	0.01	3	0.60	0.04	3	0.37	0.05	3
1995	0.138	0.015	3	0.437	0.113	3	0.461	0.050	3
1996	na	na	0	0.17	0.12	2	na	na	0
1997	0.405	0.120	3	0.384	0.030	3	0.422	0.072	3
1998	0.58	0.29	3	0.64	0.07	3	0.660	0.150	3

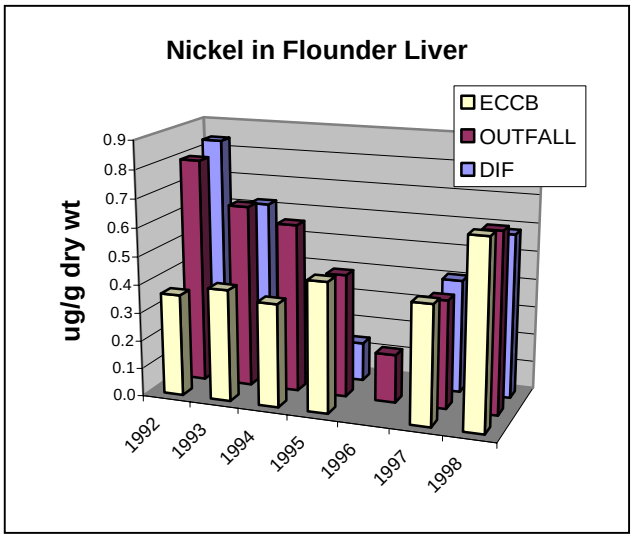


Figure 3-7d. Total Nickel in Flounder Liver at DIF, Outfall and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
1992	2.753	1.46	4	3.287	0.871	4	6.254	2.528	4
1993	2.02	0.00	1	2.32	0.00	1	1.14	0.00	1
1994	1.417	0.257	3	6.22	1.04	3	4.15	0.870	3
1995	0.840	0.160	3	5.938	1.687	3	5.219	1.172	3
1996	2.12	0.19	3	4.24	0.87	3	2.58	1.57	3
1997	3.059	0.643	3	4.386	0.643	3	1.071	0.309	3
1998	2.47	0.20	3	3.82	0.37	3	2.28	0.50	3

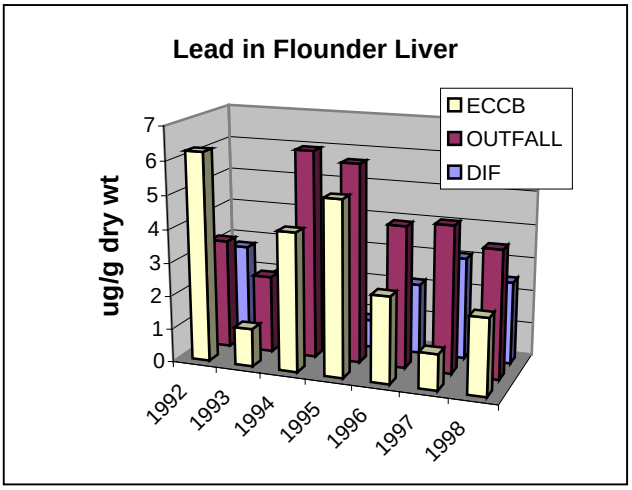


Figure 3-7e. Total Lead in Flounder Liver at DIF, Outfall and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
1992	2.656	1.745	4	4.768	1.065	4	4.465	1.073	4
1993	5.46	0.00	1	4.78	0.00	1	1.41	0.00	1
1994	3.76	0.32	3	10.11	4.11	3	6.11	0.81	3
1995	3.417	1.879	3	9.891	2.599	3	4.549	0.395	3
1996	4.472	1.529	3	22.404	6.415	3	4.160	0.219	3
1997	5.471	0.096	3	9.170	1.362	3	8.015	1.220	3
1998	2.55	0.78	3	7.02	1.33	3	6.90	1.93	3

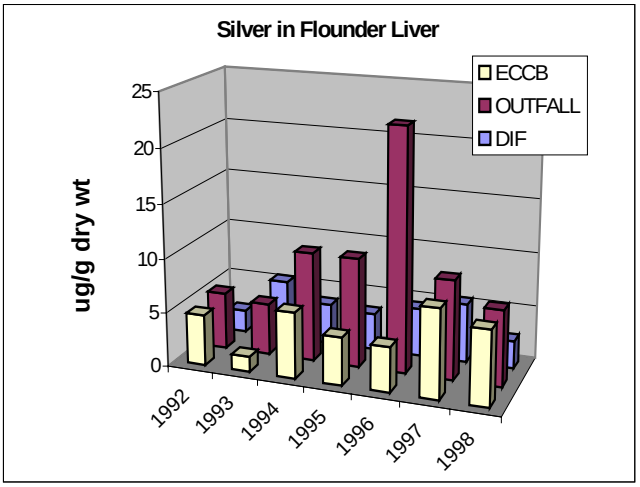


Figure 3-7f. Total Silver in Flounder Liver at DIF, Outfall and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
1992	117.75	4.516	4	163.25	4.442	4	158.25	6.09	4
1993	86.70	0.00	1	85.30	0.00	1	82.30	0.00	1
1994	112.27	0.37	3	154.00	9.02	3	176.67	15.59	3
1995	105.68	1.384	3	151.65	6.487	3	138.12	11.654	3
1996	87.07	24.87	3	120.99	5.77	3	126.28	2.45	3
1997	127.46	2.546	3	141.24	6.67	3	137.22	7.102	3
1998	106.26	1.59	3	113.63	10.19	3	147.75	6.29	3

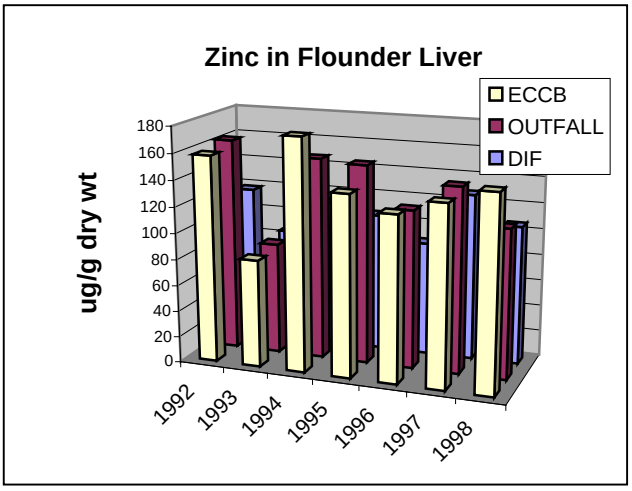


Figure 3-7g. Total Zinc in Flounder Liver at DIF, Outfall and ECCB from 1992-1998.

3.1.8 Relationship of Contaminant Levels to Histopathology

As in previous years, the liver and skeletal organic contaminant burdens are highly predictive of centrotubular hydropic vacuoloation (Moore et al. 1996, Mitchell et al. 1998). When examining the relationship between prevalence and contaminant burden, in general, the 1998 contaminant burdens are on the low end of the scatter of values for the period 1992 to 1998. Of the organic contaminants, many of which track well with the hydropic vacuolation, chlordane burdens track the disorder most closely, as shown in Figure 3-8, and are used here as an example. It should be pointed out, however, that this

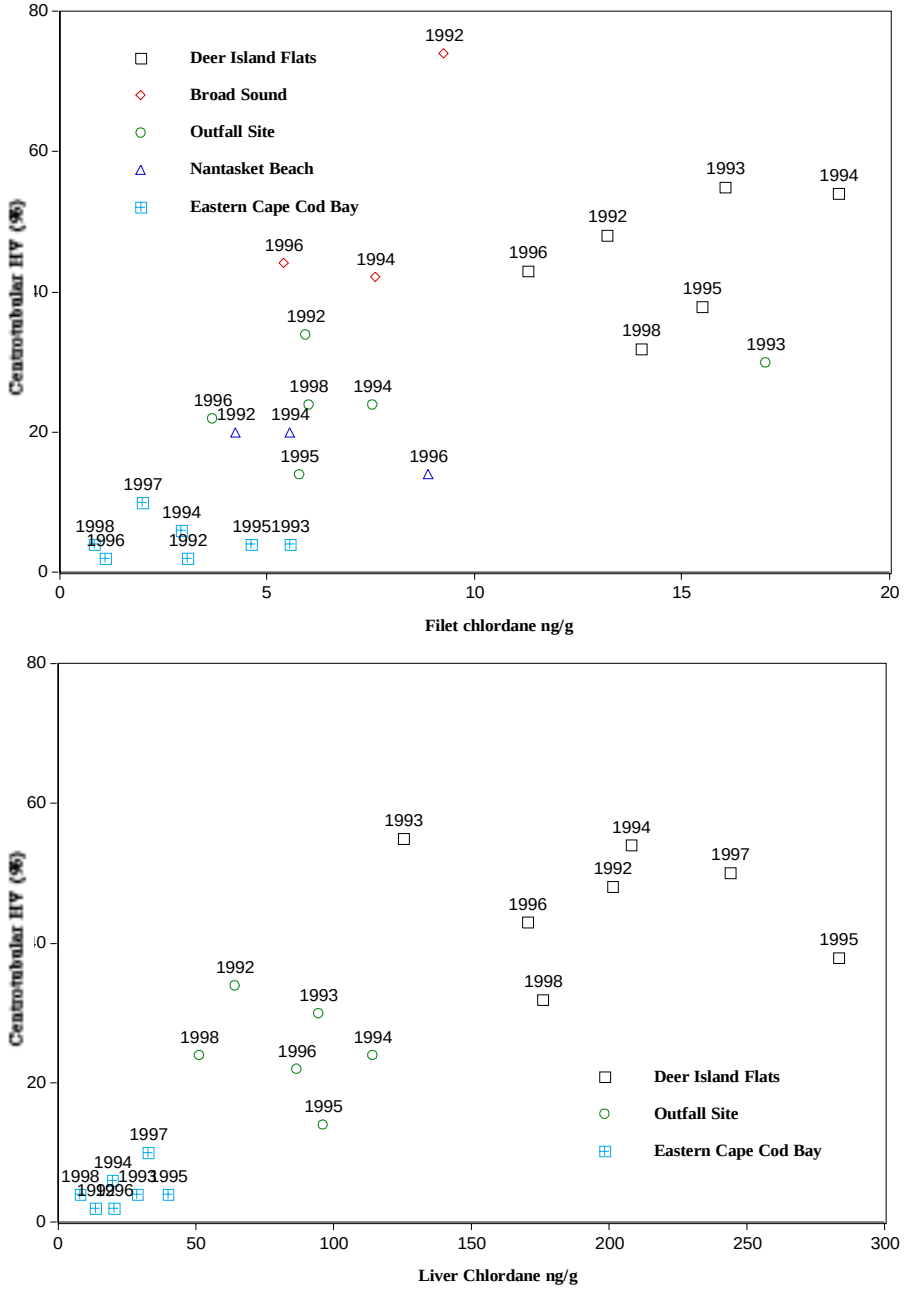


Figure 3-8. Scatter Plot Comparing Centrotubular Hydrovacuolation Prevalence with Chlordane Fillet and Liver Concentration in Winter Flounder from DIF, FOS and ECCB.

relationship does not necessarily imply a cause and effect. It should also be pointed out that the relationship is driven by having low, mid, and high contaminant sites, and that within a given site, the relationship does not always hold true.

3.1.9 Relationship to Contaminant Levels to FDA Legal Limits

The U.S. Food and Drug Administration (FDA) has set legal 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 FOS baseline mean. Warning Levels are set at 80% of the FDA Limits (MWRA 1998 – Contingency Plan). Caution and Warning Levels apply to the outfall (FOS) only. These three levels provide reference benchmarks for detecting adverse changes (and their potential human health risks) once the new outfall is on line. The 1998 mean concentrations of target analytes per station were compared to the FDA's Legal Limits and the MWRA caution and warning levels through 1997 for the outfall and DIF and ECCB samples and are presented in Table 3-4. No exceedances of any of the three benchmarks were noted in 1998. In previous years, the Caution Level was set at 50% of the FDA Limits. No edible winter flounder tissues from previous years exceeded any of the FDA legal limits.

Table 3-4. Comparison of FDA and MWRA Limits to Mean 1998 Flounder Fillet Concentrations for Selected Parameters.

STATION	Total PCB (ng/g wet wt)		Total DDTs (ng/g wet wt)		Total Chlordanes (ng/g wet wt)		Dieldrin (ng/g wet wt)		Mercury (Hg) (ug/g wet wt)	
	Mean	*s.d.*	Mean	*s.d.*	Mean	*s.d.*	Mean	*s.d.*	Mean	*s.d.*
DIF (1998)	52.4	*8.0*	6.5	*0.8*	3.0	*0.4*	0.55	*0.05*	0.05	*0.01*
FOS (1998)	19.7	*11.0*	2.2	*1.3*	1.0	*0.6*	0.22	*0.11*	0.06	*0.02*
ECCB (1998)	8.10	*0.6*	1.2	*0.1*	0.3	*0.0*	0.14	*0.01*	0.03	*0.01*
FDA Limit	2000		5000		300		300		1.0	
MWRA Caution Level (2 x FOS Baseline; 1992-1997)	79.5		8.51		3.0		0.57		0.16	
MWRA Warning Level (80% FDA)	1600		4000		240		240		0.8	

3.2 Lobster

3.2.1 Lobster Collection

The 1998 lobster survey was conducted according to the alternate method presented in the CW/QAPP by purchasing lobster from commercial lobsterman. Fifteen lobsters were collected from each location. Due to inclement weather conditions and lack of lobster in the site areas from July until September, surveys were not completed until late September.

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 1998 survey. The mean length and weight of lobsters collected in 1998 are presented in Table 3-5. 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 3-5. Similar numbers of females and males were found at DIF; twice the number of males compared to females were found at FOS and all males were found at ECCB.

Table 3-5. Mean Length, Weight and Sex Ratio of Lobsters Collected in 1998.

		DIF		FOS		ECCB	
Parameter	**N**	**Station Mean**	**S.E.**	**Station Mean**	**S.E.**	**Station Mean**	**S.E.**
Carapace Length (mm)	15	113.0	3.6	114.6	2.7	116.3	1.6
Weight (g)	15	458.5	19.5	518.7	14.8	497.1	20.8
RATIO Female/Male	15	7/8	--	5/10	--	0/15	--

Table 3-6 presents the average values for general external observations made for the 15 lobsters collected at each station in the 1998 survey. In general, no deleterious conditions were noted, although minimal shell erosion was observed for one lobster from FOS and two lobsters from ECCB, and external tumors were observed for one lobster from ECCB where the rim of the carapace appeared to be ciliated.

Table 3-6. Mean Score - 1998 Lobster External Condition.

		DIF		FOS		ECCB	
Parameter	**N**	**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	0.07	0.07
Parasites	15	0	0	0	0	0	0
Shell Erosion	15	0	0	0.07	0.07	0.13	0.09

Note: Values range from 0 (absent) to 4 (extreme).

3.2.3 Spatial Comparison of Tissue Contaminant Levels

The body burdens of contaminants were determined for both edible tissue (meat) and liver tissue (hepatopancreas) for lobster collected in the 1998 survey. All 1998 individual replicate concentrations for each contaminant can be found in Appendix B. Means and standard errors are calculated from the three replicates at each site.

3.2.3.1 Edible Tissue

Comparisons of the 1998 mean concentrations of organic compounds in lobster meat across the study area indicate that for most compounds, the highest concentrations were found at DIF and the lowest concentrations were found at ECCB (Figures 3-9 through 3-12). However, for DDT, the lowest

concentrations were found at FOS, while that site had the highest concentrations of Dieldrin, HCB, and Mirex. Mercury, the only metal measured in lobster meat, was highest in samples from FOS and lowest at ECCB (Figure 3-14a). This was similar to the trend observed in flounder

3.2.3.2 Hepatopancreas

Comparison of the 1998 mean concentrations of organic compounds in lobster hepatopancreas across the study area showed the same trend as for edible tissue, with the highest concentrations generally found in samples from DIF and the lowest at ECCB (Figures 3-9 through 3-13). This high-to-low pattern is a general one. Metal body burdens were more variable (Figures 3-14b, 15 a-d). The most common pattern was FOS the numerically highest and Deer Island the lowest (Cr, Ni, Cd, Pb, and Zn).

3.2.4 Comparison of 1998 Tissue Contaminant Levels to Other Baseline Data

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

3.2.4.1 Edible Tissues

The general pattern observed in 1998 (i.e., DIF having the highest and ECCB the lowest body burdens of organic contaminants) is consistent with the historical data set. The only point of interest is that the 1998 organic concentrations at all three stations tended to be among the lowest recorded during the monitoring period.

As for organics, the spatial pattern of mercury body burdens observed in 1998 (i.e., FOS generally the highest and ECCB the lowest) was consistent with historical trends. 1998 mercury concentrations at all three stations tended to be in the middle of the historical range

3.2.4.2 Hepatopancreas

The spatial pattern of organic contaminants observed in lobster edible tissue in 1998 was consistent with historical patterns. 1998 total DDT and PCB data continued an apparent upward trend in body burden concentrations at all three stations. On the other hand, total PAHs appear to have decreased at DIF.

Historically metal body burdens have been more variable than the organic data with ECCB and FOS metals often being as high or higher than those from DIF. In 1998 tissue concentrations of silver at all three sites continued an apparent upward trend. Silver and lead concentrations in ECCB lobster tissues were significantly higher than any previously observed.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
1992	99.61	8.72	3	60.60	11.86	3	87.27	32.84	3
1993	178.9	2.73	3	61.6	4.00	2	61.4	15.6	10
1994	137.2	13.4	3	177.9	66.6	2	66.8	15.8	3
1995	121.6	22.12	3	117.3	8.82	3	75.1	12.49	3
1996	218.4	27.43	3	147.3	1.97	3	67.0	6.08	3
1997	309.6	141.95	3	157.2	21.91	3	75.8	1.52	3
1998	112.8	11.0	3	71.4	11.4	3	53.7	5.33	3

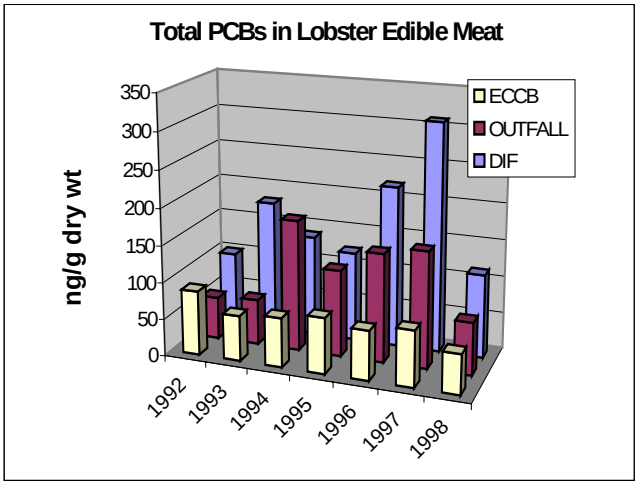


Figure 3-9a. Total PCBs in Lobster Meat at DIF, FOS and ECCB from 1992-1998.

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	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
1992	3254	510	3	2046	357	3	1206	394	3
1993	2966	255	3	2253	726	2	2140	684	10
1994	2482	319	3	2452	1527	2	657	60.8	3
1995	4525	1354	3	5234	342	3	2779	305	3
1996	7225	677	3	5583	580	3	2465	299	3
1997	7076	2620	3	4931	288	3	2476	225	3
1998	7723	179	3	6004	241	3	3410	155	3

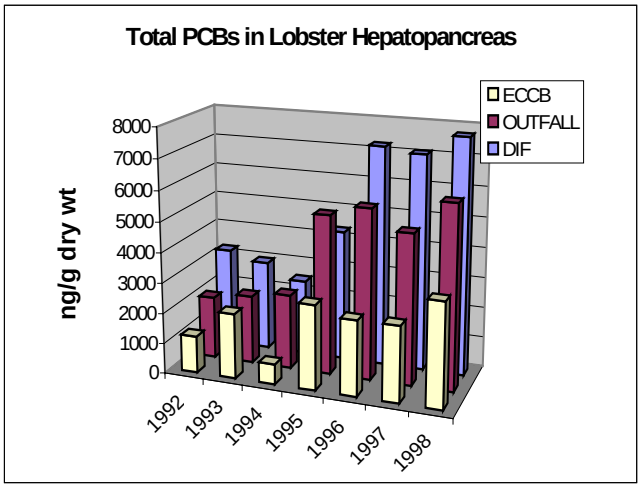


Figure 3-9b. Total PCBs in Lobster Hepatopancreas at DIF, FOS and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	SE	N	Mean	SE	N	Mean	SE	N
1992	14.0	1.26	3	8.98	1.17	3	17.8	6.73	3
1993	32.1	1.95	3	7.89	2.31	2	9.05	1.28	10
1994	23.8	1.80	3	21.9	4.36	2	10.3	1.38	3
1995	13.1	2.15	3	13.9	0.98	3	12.9	2.70	3
1996	25.6	4.10	3	18.5	2.81	3	12.4	1.22	3
1997	46.2	23.1	3	20.2	6.62	3	12.7	0.89	3
1998	11.26	0.61	3	8.46	1.48	3	9.46	1.28	3

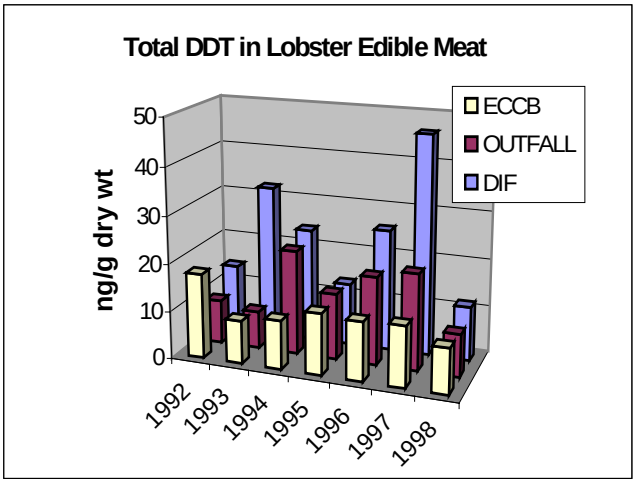


Figure 3-10a. Total DDT in Lobster Meat at DIF, FOS and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	SE	N	Mean	SE	N	Mean	SE	N
1992	577	246	3	475	165	3	208	48.1	3
1993	642	38.2	3	288	70.5	2	285	33.2	10
1994	405	49.2	3	309	119	2	166	12.8	3
1995	671	155	3	930	29.6	3	745.9	92.1	3
1996	1251	68.6	3	1026	30.5	3	702	117	3
1997	1079	650	3	1089	360	3	789	142	3
1998	1106	26.2	3	1034	74.8	3	761	23.4	3

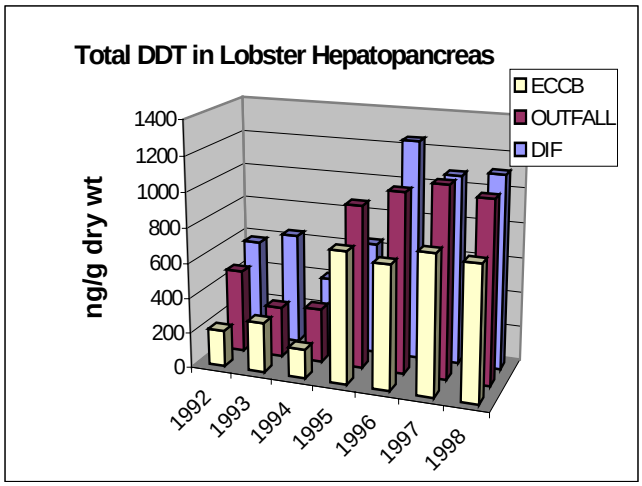


Figure 3-10b. Total DDT in Lobster Hepatopancreas at DIF, FOS and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	SE	N	Mean	SE	N	Mean	SE	N
1992	3.73	0.40	3	1.49	0.16	3	1.57	0.05	3
1993	6.39	0.46	3	0.77	0.09	2	1.14	0.66	10
1994	5.19	0.67	3	5.13	1.55	2	1.36	0.19	3
1995	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
1996	5.47	0.73	3	3.80	0.32	3	0.80	0.42	3
1997	6.20	1.29	3	2.93	1.62	3	0.80	0.40	3
1998	4.1	0.44	3	2.89	0.708	3	1.68	0.04	3

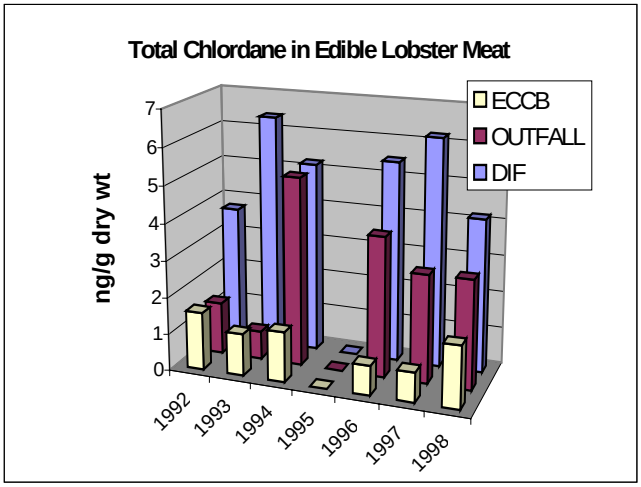


Figure 3-11a. Total Chlordane in Lobster Meat at DIF, FOS and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	SE	N	Mean	SE	N	Mean	SE	N
1992	197	106.7	3	50.7	22.6	3	18.6	8.93	3
1993	193	6.62	3	46.5	4.62	2	73.7	25.6	10
1994	116	19.7	3	21.4	6.91	2	13.2	2.08	3
1995	38.67	13.57	3	73.7	37.0	3	65.0	22.7	3
1996	199	16.3	3	157	22.9	3	81.2	19.0	3
1997	127	26.3	3	57.4	11.6	3	41.5	6.93	3
1998	234	4.66	3	93.9	6.03	3	42.0	2.84	3

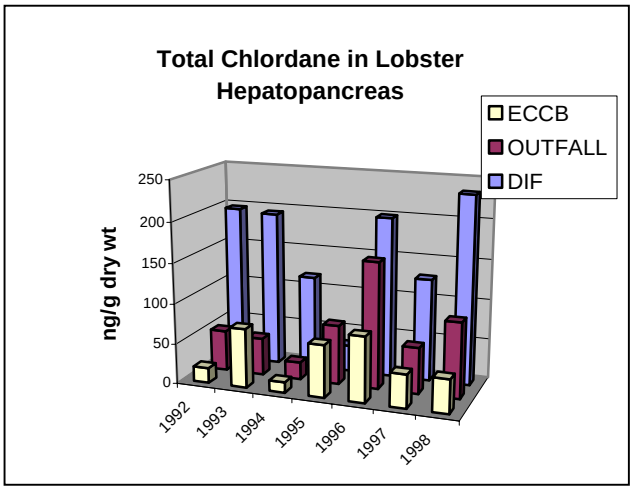


Figure 3-11b. Total Chlordane in Lobster Hepatopancreas at DIF, FOS and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	SE	N	Mean	SE	N	Mean	SE	N
1992	5.51	0.33	3	3.95	0.21	3	3.52	0.45	3
1993	9.54	0.39	3	4.66	0.44	2	3.52	0.21	10
1994	11.5	4.07	3	6.43	1.40	2	3.73	0.32	3
1995	6.50	0.15	3	5.77	0.23	3	3.93	0.33	3
1996	8.53	0.74	3	9.50	1.83	3	3.77	0.32	3
1997	6.80	0.76	3	6.27	1.07	3	4.23	0.34	3
1998	3.75	0.25	3	3.81	0.06	3	2.38	0.09	3

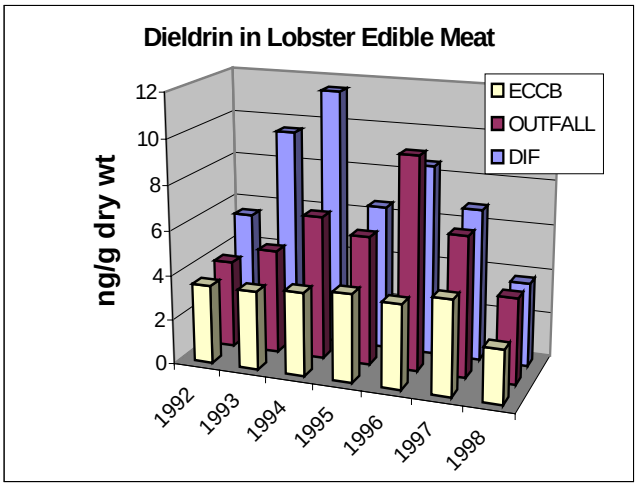


Figure 3-12a. Total Dieldrin in Lobster Meat at DIF, FOS and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	SE	N	Mean	SE	N	Mean	SE	N
1992	65.7	23.6	3	27.0	9.97	3	13.4	4.75	3
1993	115	24.5	3	56.6	10.6	2	39.8	5.41	10
1994	40.7	13.7	3	17.1	7.3	2	9.41	2.83	3
1995	52.67	26.84	3	107	11.8	3	30.0	15.0	3
1996	127	14.5	3	143	43.3	3	50.3	6.01	3
1997	46.0	4.2	3	50.7	12.1	3	32.7	2.19	3
1998	44.6	3.9	3	45.1	3.7	3	25.9	0.83	3

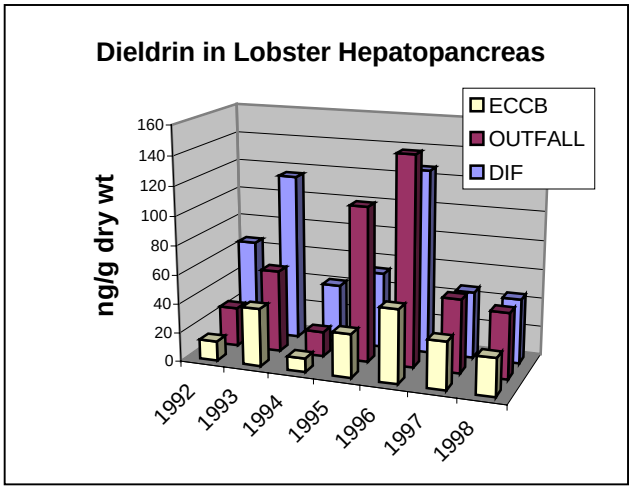


Figure 3-12b. Total Dieldrin in Lobster Hepatopancreas at DIF, FOS and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
1992	29708	4886	3	4060	273	3	4055	731	3
1993	13693	5292	3	5765	2206	2	2524	896	12
1994	16572	2919	3	4595	280	2	764	76.2	3
1995	5363	718	3	6564	676	3	4302	832	3
1996	12809	2479	3	6230	1643	3	2347	711	3
1997	8404	5180	3	3018	1158	3	167766 *	11612	3
1998	7413	501	3	2429	250	3	1478	84.9	3

* Note: The 1997 concentration of PAH at East Cape Cod Bay was extremely elevated and the value has been removed from the plot. Please refer to the report for further explanation.

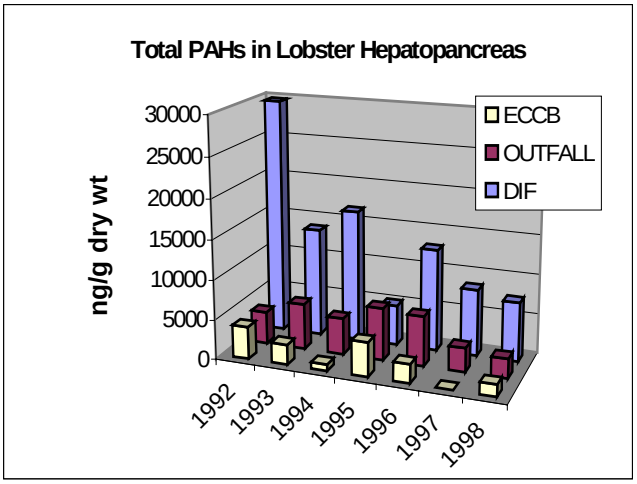


Figure 3-13. Total PAH in Lobster Hepatopancreas at DIF, FOS and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	SE	N	Mean	SE	N	Mean	SE	N
1992	1.228	0.304	3	0.854	0.163	3	0.921	0.274	3
1993	0.844	0.015	3	1.013	0.308	2	0.659	0.057	10
1994	0.827	0.067	3	1.043	0.313	2	0.498	0.055	3
1995	0.610	0.297	3	1.089	0.260	3	0.535	0.055	3
1996	0.858	0.071	3	1.067	0.216	3	0.939	0.102	3
1997	1.467	0.111	3	1.120	0.083	3	0.983	0.072	3
1998	0.767	0.029	3	0.990	0.064	3	0.598	0.047	3

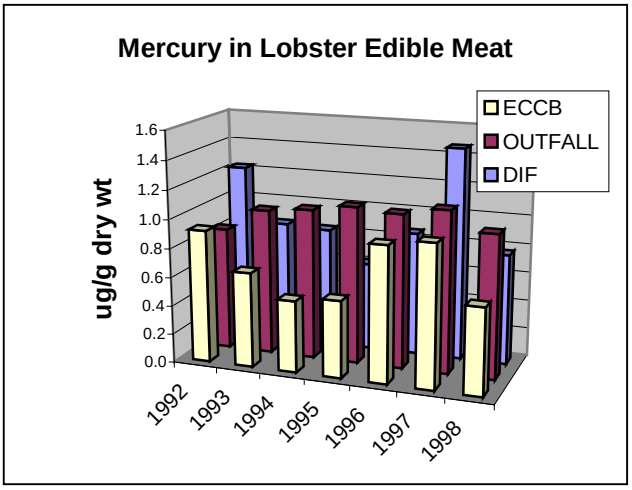


Figure 3-14a. Total Mercury in Lobster Meat at DIF, FOS and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	SE	N	Mean	SE	N	Mean	SE	N
1992	0.240	0.031	3	0.537	0.273	3	0.423	0.146	3
1993	0.322	0.028	3	0.236	0.044	2	0.192	0.039	10
1994	0.269	0.010	3	0.399	0.059	2	0.236	0.019	3
1995	0.350	0.032	3	0.335	0.050	3	0.271	0.068	3
1996	0.202	0.033	3	0.260	0.033	3	0.243	0.023	3
1997	0.432	0.082	3	0.437	0.045	3	0.400	0.013	3
1998	0.262	0.010	3	0.365	0.013	3	0.243	0.017	3

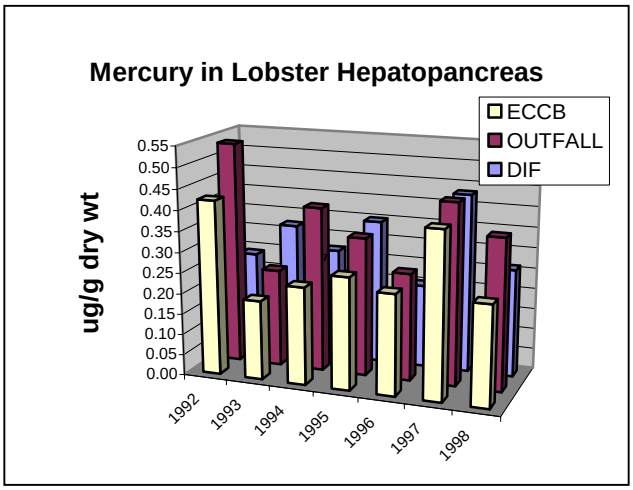


Figure 3-14b. Total Mercury in Lobster Hepatopancreas at DIF, FOS and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	SE	N	Mean	SE	N	Mean	SE	N
1992	2.91	0.38	3	3.358	1.059	3	2.09	0.27	3
1993	1.43	0.01	3	1.27	0.06	2	1.09	0.11	10
1994	0.25	0.03	3	0.49	0.29	2	0.19	0.04	3
1995	0.24	0.04	3	0.18	0.03	3	0.10	0.03	3
1996	0.15	0.03	3	0.12	0.01	3	0.08	0.01	3
1997	0.26	0.02	3	0.30	0.07	3	0.10	0.02	3
1998	0.09	0.02	3	0.23	0.02	3	0.15	0.03	3

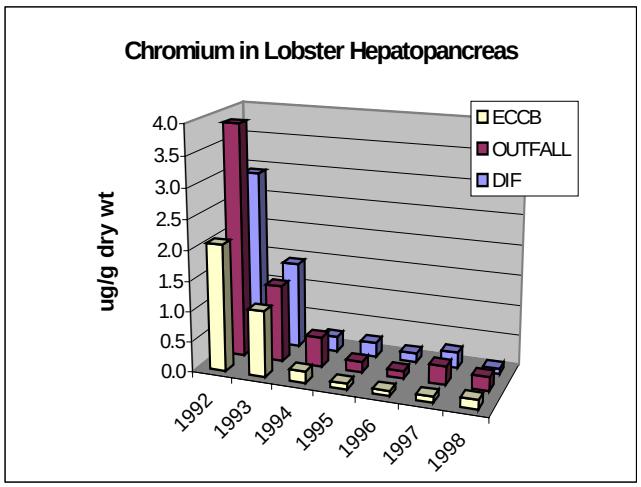


Figure 3-15a. Total Chromium in Lobster Hepatopancreas at DIF, FOS and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	SE	N	Mean	SE	N	Mean	SE	N
1992	261	193	3	440.77	372.7	3	1014	496	3
1993	641	229	3	309	178	2	464	127	10
1994	537	93.8	3	558	63.5	2	284	89.0	3
1995	325	60.2	3	314	35.1	3	125.24	33.84	3
1996	485	98.9	3	371.03	70.86	3	167	43.4	3
1997	641.20	106.74	3	513	203	3	294	40.6	3
1998	612	42.1	3	611	89.8	3	573	53.7	3

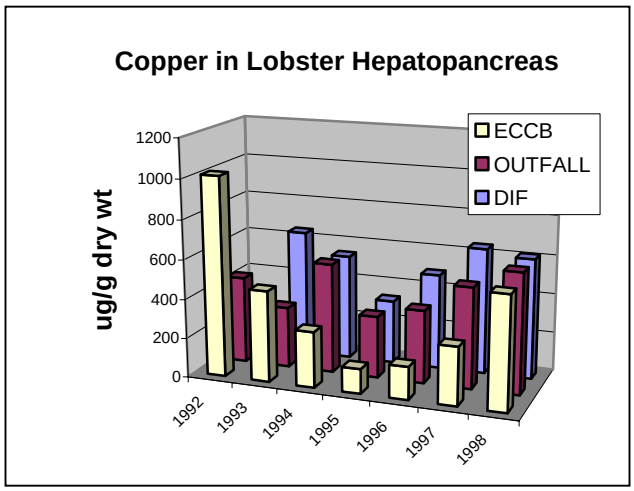


Figure 3-15b. Total Copper in Lobster Hepatopancreas at DIF, FOS and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	SE	N	Mean	SE	N	Mean	SE	N
1992	0.80	0.42	3	1.601	0.986	3	0.95	0.33	3
1993	0.75	0.01	3	0.47	0.03	2	1.31	0.21	10
1994	0.44	0.05	3	0.97	0.20	2	1.19	0.07	3
1995	0.42	0.09	3	0.43	0.04	3	0.45	0.04	3
1996	0.13	0.02	3	0.40	0.02	3	0.68	0.04	3
1997	0.570	0.069	3	1.26	0.23	3	0.89	0.24	3
1998	0.36	0.02	3	1.21	0.03	3	0.73	0.11	3

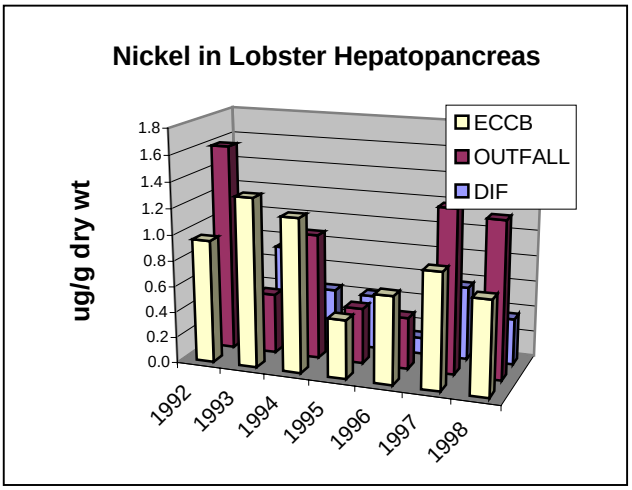


Figure 3-15c. Total Nickel in Lobster Hepatopancreas at DIF, FOS and ECCB from 1992-1998.

	Deer Island			Outfall Site			East Cape Cod Bay		
	Mean	SE	N	Mean	SE	N	Mean	SE	N
1992	5.07	2.44	3	3.517	0.201	3	3.53	1.08	3
1993	6.75	0.22	3	2.43	0.75	2	6.35	2.01	10
1994	10.7	3.11	3	7.47	2.21	2	14.6	3.00	3
1995	27.6	1.95	3	22.0	3.37	3	8.099	2.352	3
1996	32.9	9.31	3	21.284	3.632	3	15.3	4.06	3
1997	6.522	0.580	3	13.2	2.41	3	9.42	2.33	3
1998	30.4	2.10	3	29.9	4.66	3	29.7	4.28	3

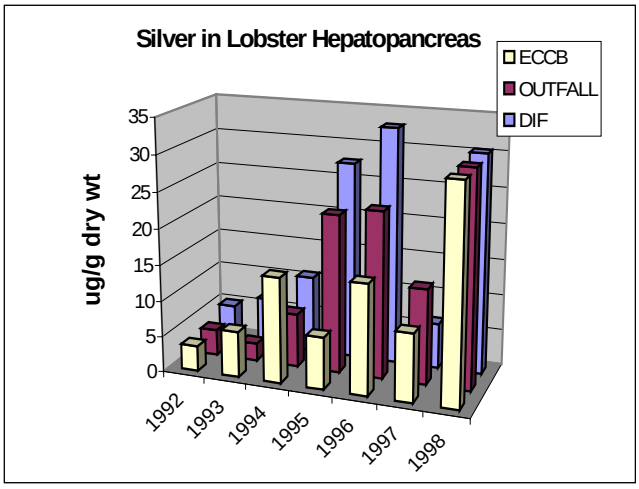


Figure 3-15d. Total Silver in Lobster Hepatopancreas at DIF, FOS and ECCB from 1992-1998.

3.2.5 Relationship of Contaminant Levels to FDA Legal Limits

The U.S. Food and Drug Administration (FDA) has set legal 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 FOS baseline mean. Warning Levels are set at 80% of the FDA Limits as stated in the MWRA Contingency Plan (MWRA 1997a). Caution and Warning Levels apply to the outfall (FOS) only. These three levels provide reference benchmarks for detecting adverse changes (and their potential human health risks) once the new outfall is on line. The 1998 mean concentrations of target analytes in lobster meat, per station, were compared to the FDA's Legal Limits and the MWRA caution and warning levels (through 1997) for the outfall and DIF and ECCB samples and are presented in Table 3-7. No exceedances of any of the three benchmarks were noted in 1998 for lobster meat. To date, no lobster meat tissues have exceeded any of the FDA legal limits. However, concentrations of PCBs in hepatopancreas have slightly exceededed the FDA legal limits at DIF since 1996. Concentrations of PCBs in hepatopancreas tissue in lobsters from the FOS 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.

Table 3-7. Comparison of FDA and MWRA Limits to Mean 1998 Lobster Concentrations for Selected Parameters.

STATION	Total PCB (ng/g wet wt)		Total DDTs (ng/g wet wt)		Total Chlordanes (ng/g wet wt)		Dieldrin (ng/g wet wt)		Mercury (Hg) (ug/g wet wt)	
	Mean	***s.d.***	**Mean**	***s.d.***	Mean	***s.d.***	**Mean**	***s.d.***	**Mean**	***s.d.***
DIF (1998)	16.73	3.42	1.67	0.21	0.60	0.09	0.56	0.09	0.11	0.01
FOS (1998)	9.69	2.63	1.15	0.34	0.39	0.16	0.52	0.02	0.13	0.02
ECCB (1998)	7.79	1.76	1.38	0.39	0.24	0.02	0.34	0.01	0.09	0.01
FDA Limit	2000		5000		300		300		1.0	
MWRA Caution Level (2 x Baseline; 1992-1997)	36.1		4.71		0.84		1.9		0.32	
MWRA Warning Level (80% FDA)	1600		4000		240		240		0.8	

3.3 Blue Mussel

3.3.1 Mussels Collected

In 1998, we experienced numerous problems with lost arrays and cages. During the 40-day retrieval arrays were successfully collected from all sites except Quincy Bay where only Sandwich mussels could be recovered (see Table 3-8).

Table 3-8. Samples Collected during 40-day Retrieval.

Site	# Cages	Approximate # Mussels/Cage	Approximate Total # Mussels
Boston Inner Harbor	2 Gloucester 1 Sandwich	45	135 (90 Gloucester, 45 Sandwich)
Deer Island	2 Gloucester 1 Sandwich	45	135 (90 Gloucester, 45 Sandwich)
Quincy Bay	0 Gloucester 1 Sandwich	45	45 (0 Gloucester, 45 Sandwich)
Future Outfall Site	2 Gloucester 1 Sandwich	60	180 (120 Gloucester, 60 Sandwich)
Cape Cod Bay	2 Gloucester 1 Sandwich	60	180 (120 Gloucester, 60 Sandwich)

During the 60-day collection full arrays were successfully collected from the BIH and CCB sites. All cages at DIF and FOS were lost. At Quincy Bay only Sandwich mussels were recovered due to loss of remaining cages from the array (see Table 3-9).

Table 3-9. Samples Collected during 60-day Retrieval.

Site	# Cages	Approximate # Mussels/Cage	Approximate Total # Mussels
Boston Inner Harbor	2 Gloucester 1 Sandwich	45	135 (90 Gloucester, 45 Sandwich)
Deer Island	0 Gloucester 0 Sandwich	45	0 (0 Gloucester, 0 Sandwich)
Quincy Bay	0 Gloucester 1 Sandwich	45	45 (0 Gloucester, 45 Sandwich)
Future Outfall Site	0 Gloucester 0 Sandwich	60	0 (0 Gloucester, 0 Sandwich)
Cape Cod	2 Gloucester 1 Sandwich	60	180 (120 Gloucester, 60 Sandwich)

3.3.2 Analytical Implications of Reduced Mussel Recovery

40-day mussels were used for chemical analyses at DI and the FOS due to the loss of the 60-day deployments at these locations. Due to the lack of retrieval of the Gloucester mussels from the Quincy Bay Arrays, the Sandwich mussels were used for organic analyses at this site. This required organic

analysis of the pre-exposed Sandwich mussels for reference. Table 3-10 summarizes the numbers of analytical composites that were submitted for chemical analyses as a result of the retrieval success for 1998. This resulted in 36 pooled samples (5 pools of pre-exposed mussels + 5 pools x 3 sites+8 pools x 2 sites) for both organic and inorganic analyses plus an additional 5 pools of pre-exposed Sandwich mussels for organic analyses.

Table 3-10. Number of Mussel Composites Submitted for Chemical Analyses from 1998 Collection/Deployment.

Location	Deployment	Gloucester Mussels (organics)	Sandwich Mussels (metals)	Sandwich Mussels (organics)
Pre-exposed	NA	5	5	5 (1)
BIH	60-day	5	5	
Quincy	60-day	0	5	5
DI	40-day	5	5	
FOS	40-day	8	8	
CCB	60-day	8	8	

(1)5 replicates of a single composite of 15 pre-exposed mussels.

3.3.3 Biological Condition Indices

Mussels were deployed for retrieval after 40 days and 60 days. Experience has shown that retrieval of each set of exposures at each site is not always possible because of occasional tray loss at one or more of the sites. This does not constitute a major problem, however, because little difference between the results of a 40-day and 60-day exposure at a given site can be expected (Peven et al. 1996). Thus, results of a 40-day exposure at one site may be compared validly to results of a 60-day exposure at another site.

3.3.3.1 Survival

Survival was observed upon retrieval of the mussels both at 40- and 60-day collections. Overall, survival at each site was greater than 95%.

3.3.3.2 Growth and Condition

Due to difficulties in retrieving 60-day and Quincy mussels, biological condition was only assessed on pre-deployment mussels and the 60-day collection from the BIH. Overall, no acute mortality was observed during deployments and biomass increases indicated the overall health of the organisms and is consistent with observations made in previous years.

3.3.4 Spatial Comparison of Tissue Contaminant Levels in 1998

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 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 1998 are discussed below.

3.3.4.1 Mercury and Lead

Results of the t-test analysis comparing mercury and lead concentrations to pre-deployed mussels are summarized in Table 3-11. Concentrations of individual mussel composites as well as station means and standard errors of the means are summarized in Appendix B.

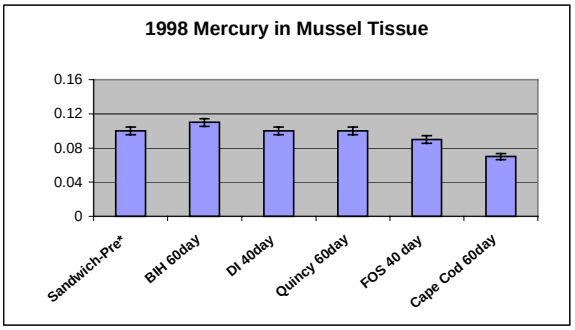
Mercury tissue concentrations were similar at all locations. Only CCB mussel mercury concentrations were significantly lower than the Sandwich pre-deployment values (P<0.05) (Figure 3-16a).

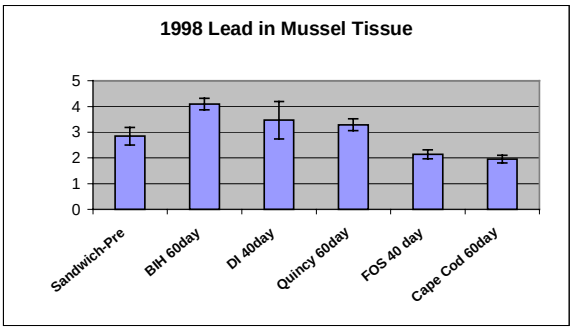
Lead concentrations in mussels were highest at BIH (Figure 3-16b). These were the only mussels with lead concentrations significantly higher than pre-deployed Sandwich mussels (P<0.05). DI and FOS mussel lead concentrations were similar to pre-deployed values and CCB mussel lead concentrations were significantly lower than pre-deployed levels (P<0.05).

Table 3-11. Results of Student t-Test (p=0.05); Comparisons of Lead and Mercury in Deployed Mussels to Pre-Deployment Mussels.

Comparisons of Deployed Mussels to Pre-deployment Mussels - Student T Test Results					
Means Significantly Different From Sandwich - Pre-deployment (P<0.05) (1)					
Parameter	**BIH**	**DI**	**FOS**	**CCB**	**Quincy**
Mercury	No	No	No	Yes	No
Lead	Yes	No	No	Yes	No

Notes:
(1) Using Student T test; assume random sampling, normal distribution and equal variances
Shading indicates that means were significantly lower than pre-deployment mussels.





* Indicates predeployment Station

Figure 3-16a. Mercury in 1998 Mussel Tissue in µg/g dry wt.

Figure 3-16b. Lead in 1998 Mussel Tissue in µg/g dry wt.

3.3.4.2 Polychlorinated Biphenyls

Mussel tissues were analyzed for 20 polychlorinated biphenyl (PCB) congeners. Results of the statistical t-Test analysis comparing total PCBs to pre-deployed mussels is summarized in Table 3-12. Individual congener and Total PCB concentrations for individual mussel composites, as well as, means and standard errors for each station, are provided in Appendix B.

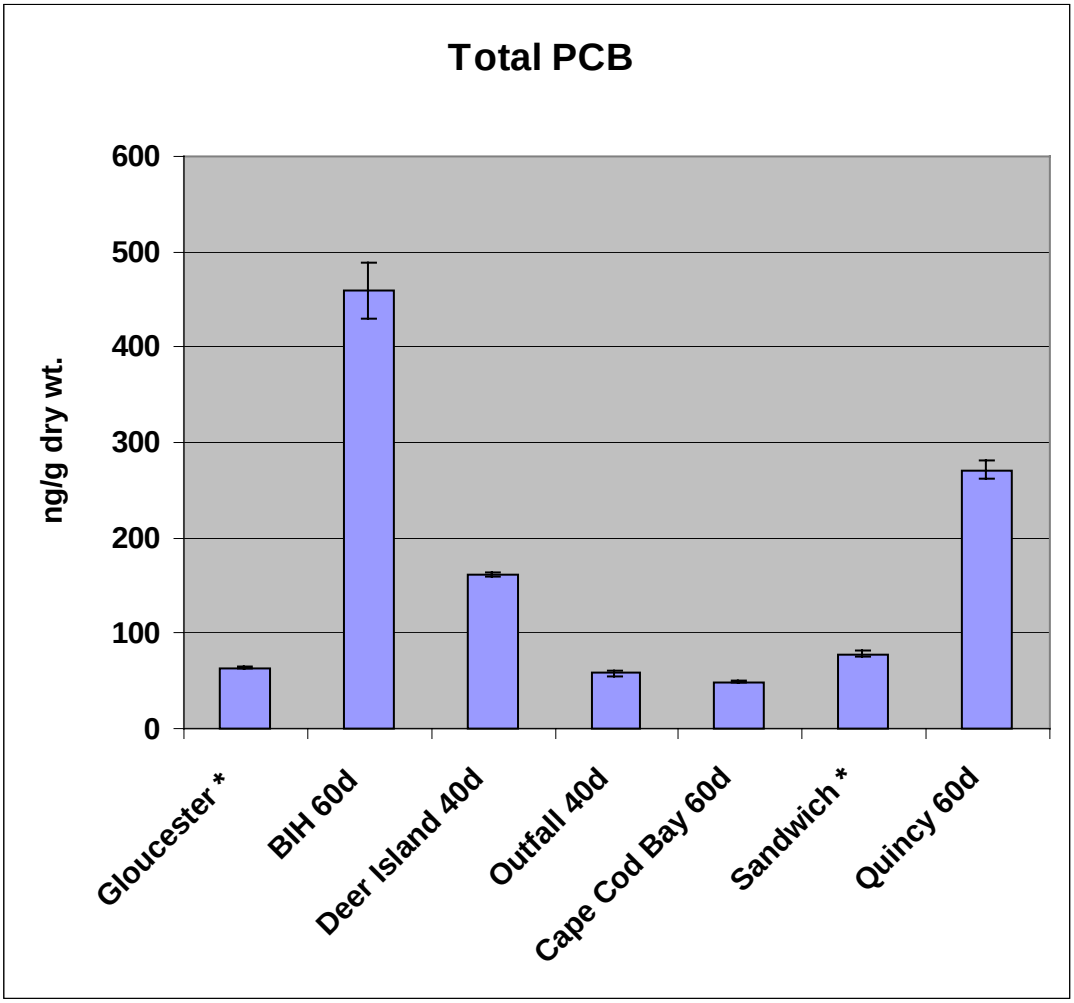
Highest concentrations of total PCBs were found at BIH (Figure 3-17). The next highest concentrations were found at Quincy and DIF. Concentrations of Total PCBs at these locations were significantly higher than the pre-deployment mussels (P<0.05). Total PCBs at the FOS were not significantly different than

pre-deployment values (P> 0.05). Total PCBs at CCB were significantly lower than pre-deployment values (P<0.05). In general, the pattern of PCB congeners detected at the various locations was similar. Three congeners (PCB77, PCB128, PCB209) were detected at low levels (below the MDL) in mussels from FOS that were not detected in mussels from any of the other locations.

Table 3-12. Results of Student t-Test (p=0.05); Comparisons of PCBs in Deployed Mussels to Pre-Deployment Mussels.

Means Significantly Different From -Pre-deployment (P<0.05) (1)					
Parameter	**BIH**	**DI**	**FOS**	**CCB**	**Quincy (2)**
Total PCBs	Yes	Yes	No	Yes	Yes

Notes:
(1) Assume random sampling, normal distribution and equal variances
(2) Compared to Sandwich Pre-Deployment Mussels
Shading indicates that means were significantly lower than pre-deployment mussels.



* Indicates pre-deployment mussels.

Figure 3-17. Total PCBs (ng/g dry wt) in 1998 Pre-Deployed Mussels and Five Deployment Locations.

3.3.4.3 Pesticides

Mussel tissues were analyzed for individual chlorinated pesticides. Results of the t-Test analysis comparing selected pesticide concentrations to pre-deployed mussels is summarized in Table 3-13. Concentrations of individual mussel composites for pesticides as well as means and standard errors for each site are summarized in Appendix B.

Most pesticides measured were detected in mussels from at least one location. Only aldrin, endrin, hexachlorobenzene and 2,4-DDE were not detected in any samples. Highest pesticide concentrations were found in mussels at BIH. Concentrations of total DDTs, total Chlordanes, dieldrin and lindane (G-BHC) were significantly higher than the pre-deployment Gloucester mussels at both BIH and DIF.

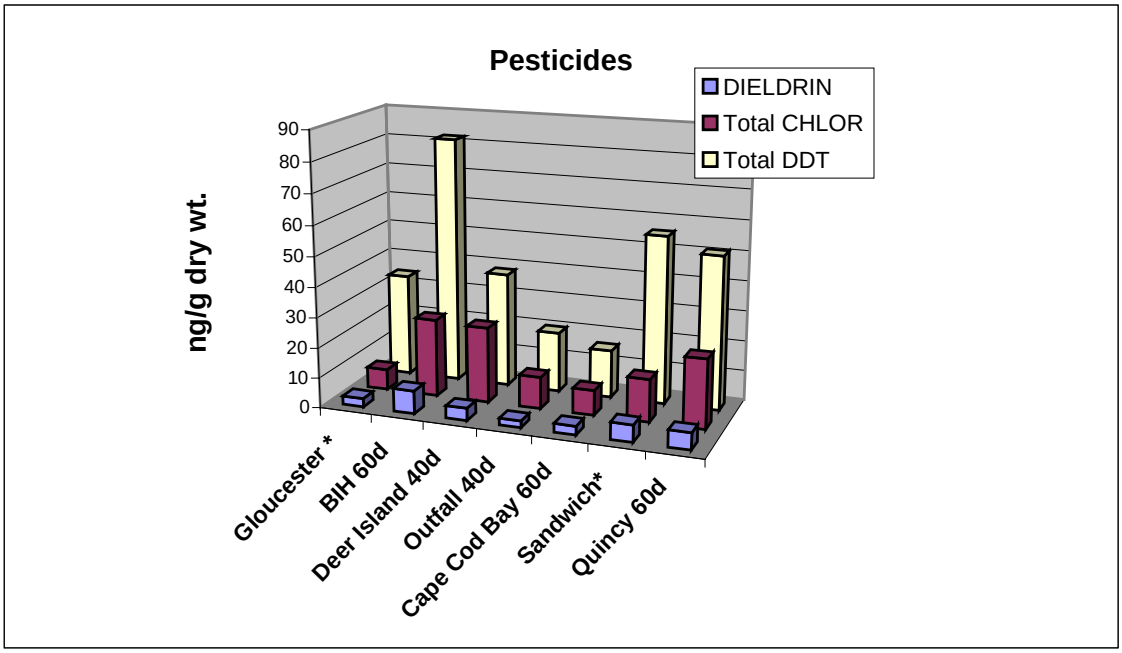
Concentrations of all pesticide were either not significantly different or were significantly lower than the pre-deployment mussels at CCB. This was also true at FOS for total DDTs, Dieldrin and lindane. Concentrations of total chlordanes at FOS, however, were significantly higher than pre-deployment levels, primarily due to the presence of elevated levels of cis-chlordane. Figure 3-18 shows DDT, chlordane and dieldrin concentrations at both pre-deployment and deployed locations.

Pesticide concentrations in Sandwich mussels were relatively high — significantly higher than the Gloucester pre-deployment mussels. Only chlordanes were significantly higher in the deployed Quincy samples compared to the pre-deployed Sandwich mussels.

Table 3-13. Results of Student t-Test (p=0.05); Comparisons of Pesticides in Deployed Mussels to Pre-Deployment Mussels.

Means Significantly Different From Pre-deployment (P<0.05) (1)					
Parameter	**BIH**	**DI**	**FOS**	**CCB**	**Quincy (2)**
Total DDTs	Yes	Yes	Yes	Yes	No
Total Chlordanes	Yes	Yes	Yes	No	Yes
Dieldrin	Yes	Yes	Yes	No	No
Lindane	Yes	Yes	No	No	No

Notes:
(1) Assume random sampling, normal distribution and equal variances
(2) Quincy results compared to Sandwich Pre-Deployment Mussel Results
Shading indicates that means were significantly lower than pre-deployment mussels.



	Gloucester n=5		BIH n=5		DI n=5		FOS n=8		CCB n=8		Sandwich n=5		Quincy n=5	
Parameter	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
DIELDRIN	2.83	0.13	7.61	0.40	4.10	0.08	2.25	0.09	2.82	0.13	5.67	0.20	5.57	0.22
Total CHLOR	6.79	0.21	25.8	1.77	25.0	0.56	10.5	0.74	8.30	0.54	14.2	0.62	22.9	0.94
Total DDT	26.7**	6.76	82.0	5.12	38.0	0.63	19.8	1.07	15.8	0.85	55.8	2.55	50.8	2.24

* indicates pre-deployment mussels

** n=4 due to one suspect values in one replicate

Figure 3-18. Pesticides Concentrations in Pre-Deployed and Deployed Mussels – 1998.

3.3.4.4 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 3.3.5). This method is referred to here as the "Historical NOAA List" (see Table 3-14). This list is much less comprehensive than the current list, referred to as the 97/98' List and shown in Table 3-14. The NOAA historical 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 both the "Historical NOAA List" and the more recent 97/98' list. Temporal trends, discussed in Section 3.3.5, are presented using the "NOAA Historical List" exclusively.

3.3.4.5 PAH Compounds – 97/98 List

The target list of PAH compounds analyzed in 1998 is presented in Table 3-14 and includes all compounds in the 97/98 list.

Results of the t-Test analysis comparing total PAHs to pre-deployed mussels is summarized in Table 3-15. Mean concentrations of the individual PAHs, as well as, total low molecular weight PAH (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) are presented in Appendix B as are the means and standard errors associated with these means for each station. The concentrations of LMW and HMW-PAHs at all locations are shown in Figure 3-19.

The 1998 average body burdens of Total LMW and HMW PAH were highest in mussels deployed at BIH. Concentrations at BIH were 5 to 10 times higher than observed at any other stations. The next highest concentrations were found in mussels from Deer Island. It should be noted, however, that the DI mussels were only exposed for 40-days versus 60 days at BIH. The ratio of LMW to HMW PAHs was lower at BIH versus DI, possibly indicating different sources (Figures 3-19 and 3-20).

Comparison of concentrations in deployed mussels versus pre-deployed concentrations indicated that total PAHs were significantly higher in mussels deployed at BIH and DIF ($P<0.05$)(Table 3-15). Concentrations of mussels deployed at FOS and CCB were actually significantly lower than the pre-deployed concentrations.

Due to the inability to retrieve deployed Gloucester mussels at Quincy, deployed Sandwich mussels were used for organic analyses at this site. Comparison of pre-deployed PAH concentrations in mussels collected at Sandwich with mussels collected at Quincy indicated that overall, total PAHs were significantly higher in deployed Quincy mussels (Table 3-15). Further investigation revealed that this was due to significantly higher levels of the HMW-PAHs in Quincy mussels. LMW-PAHs were not significantly different between pre-deployed and deployed mussels ($P>0.05$).

3.3.4.6 PAH Compounds – "NOAA Historical List"

Total PAHs for 1998 samples, quantified using the NOAA Historic List (see Table 3-14) were also plotted at both the pre-deployment and deployment locations. Figure 3-20 shows the relative concentrations of the low and high molecular weight PAHs summed using this list. Both LMW and HMW PAH concentrations were lower than those measured using the 97/98' list.

The "NOAA List" HMW PAHs in the mussels from the BIH deployment are elevated relative to the LMW PAHs. This relative pattern was not nearly as evident when evaluating the 97/98' list of PAHs (Figure 3-19), primarily because the predominant alkylated PAHs present at the BIH site are the LMW alkylated PAHs. The majority of these compounds are not quantified in the "NOAA" list, therefore, the LMW PAHs are underestimated.

This underestimate of LMW PAHs is also reflected when assessing whether deployed PAH concentrations are significantly elevated above the pre-deployed values. In recent years, DI PAHs have not been found to be significantly elevated above pre-deployed values (Mitchell 1998). These results were corroborated with 1998 "NOAA List" PAH data as shown in Table 3-16. However, as discussed previously, when assessing PAH contamination using the 97/98' PAH list, LMW, HMW and total PAHs were all found to be significantly elevated above pre-deployed levels (Table 3-15).

Table 3-14. Summary of PAH Lists of Analytes Used for Bioaccumulation Study 1992-1998.

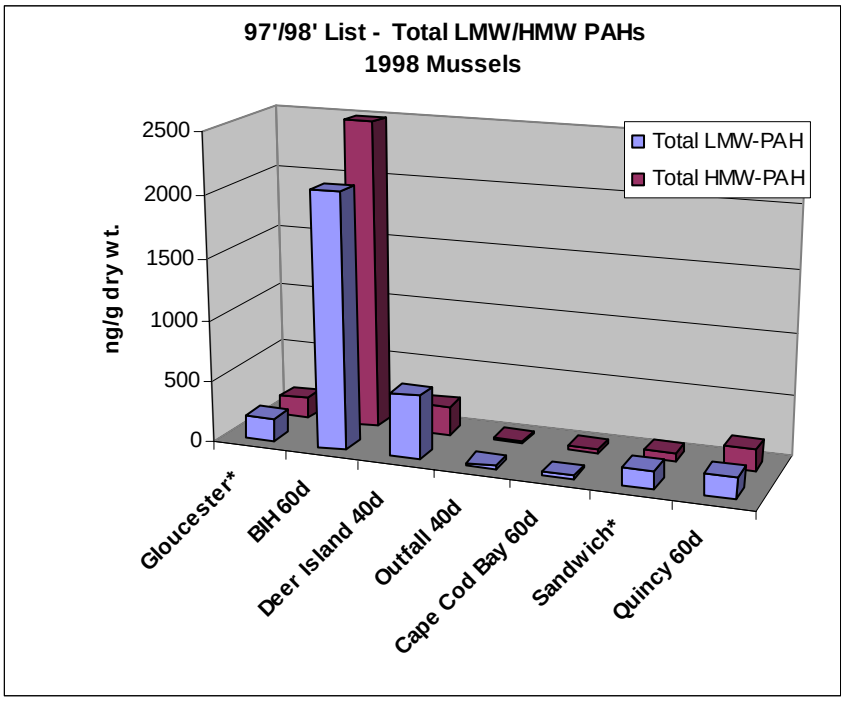
1997/1998 Complete PAH List	NOAA "Historical" PAH List
Low Molecular Weight PAHs	**Low Molecular Weight PAHs**
1-METHYLNAPHTHALENE	1-METHYLNAPHTHALENE
1-METHYLPHENANTHRENE	1-METHYLPHENANTHRENE
2,3,5-TRIMETHYLNAPHTHALENE	2,3,5-TRIMETHYLNAPHTHALENE
2,6-DIMETHYLNAPHTHALENE	2,6-DIMETHYLNAPHTHALENE
2-METHYLNAPHTHALENE	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 3-15. Results of t-Test (P=0.05); Comparisons of PAHs (97/98'List) in Deployed Mussels to Pre-Deployment Mussels.

Means Significantly Different From Gloucester -Pre-deployment (P<0.05) (1)					
Parameter	**BIH**	**DI**	**FOS**	**Cape Cod Bay**	**Quincy (2)**
Total LMWPAH	**Yes**	**Yes**	**Yes**	**Yes**	**No**
Total HMWPAH	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Total PAH	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Notes:
(1) Assume random sampling, normal distribution and equal variances
(2) Quincy results compared to Sandwich Pre-Deployment Mussel Results
Shading indicates that means were significantly lower than pre-deployment mussels.



*** indicates predeployment stations**

Figure 3-19. Total Low and High Molecular Weight PAHs (ng/g dry units) in 1998 Mussels Using the 97'/98' PAHs.

Table 3-16. Results of Student t-Test (p=0.05); Comparison of 1998 PAHs ("NOAA Historic List") in Deployed Mussels to Pre-Deployment Mussels.

Means Significantly Different From Pre-deployment (P<0.05) (1)					
Parameter	**BIH**	**DI**	**FOS**	**Cape Cod Bay**	**Quincy (2)**
Total LMWPAH	Yes	Yes	Yes	Yes	No
Total HMWPAH	Yes	No	Yes	Yes	Yes
Total PAH	Yes	No	Yes	Yes	Yes

Notes:
(1) Assume random sampling, normal distribution and equal variances
(2) Comparison to Sandwich Pre-deployment Mussels
Shading indicates that means were significantly lower than pre-deployment mussels.

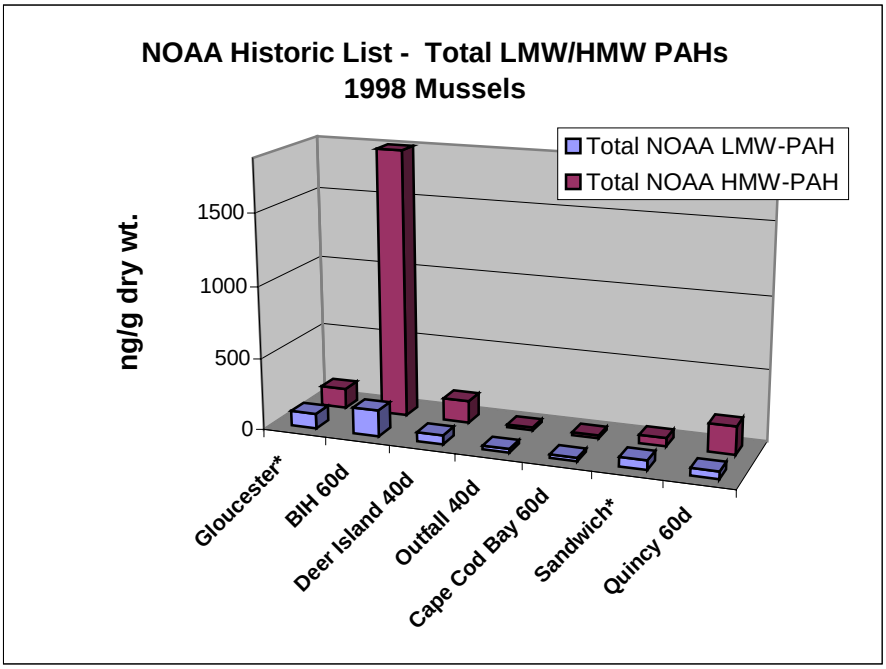


Figure 3-20. Total Low and High Molecular Weight PAHs (ng/g dry units) in 1998 Mussels Using the NOAA Historical PAH List.

3.3.4.7 Lipid Results

Lipid concentrations were measured in all mussel composites (Appendix B). Values were very similar for all samples at all locations (7.3 ± 1.2 % dry). Based on these results and 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.

3.3.5 Comparison of 1998 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.

3.3.5.1 Mercury and Lead

Lead concentrations measured in 1998 were similar to past concentrations measured for Sandwich pre-deployment mussels (Figure 3-21). Lead concentrations measured at BIH and DI in 1998 were more than 2 times lower than measured in 1997. The level at DI was almost two times lower than that measured at BIH, a further indication of sources of lead to the BIH in addition to the DIF POTW effluent discharge as suggested by Mitchell et al. (1998). Lead concentrations at these sites in 1998 were also below the NOAA "high" lead concentration of 4.3 mg/kg reported by O'Connor (1992) as part of NOAA's Mussel Watch Program, unlike lead concentrations measured prior to 1998. Lead concentrations measured at FOS in 1998 were similar to concentrations measured in 1996 and 1997 indicating little change in lead availability at this site.

Mercury concentrations measured in mussels in 1998 at all sites were numerically similar to those of the Sandwich predeployment mussels (0.1 mg/kg dry). At BIH, however, they were considerably lower than those measured at that site in 1997, when they were the highest of any site since 1994. Mercury concentrations dropped slightly at the Outfall site from 1997 levels, but rose slightly at Deer Island. Mercury concentrations at each site in 1998 were still lower than in 1994 and 1996 levels, though all were higher than the 1995 levels. Data from the 1998 Sandwich mussels were comparable to those data from 1995 through 1997.

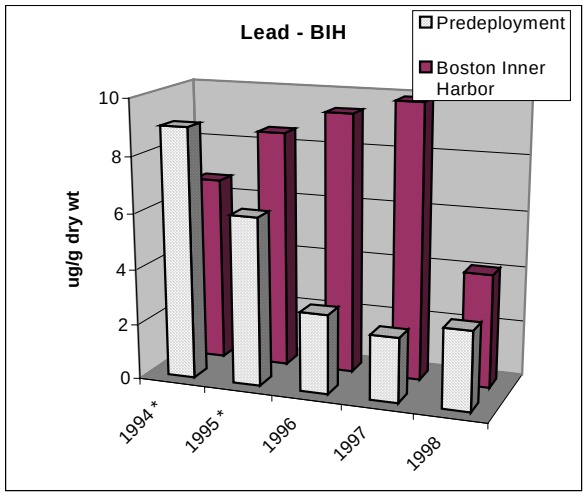
3.3.5.2 Polychlorinated Biphenyls

Data for 1998 PCBs at all stations were in the low end of the historical range. The spatial pattern observed in 1998 was similar to the pattern observed in previous years. Figure 3-23 shows the distribution of total PCBs since 1992 at Gloucester, BIH, DI and FOS.

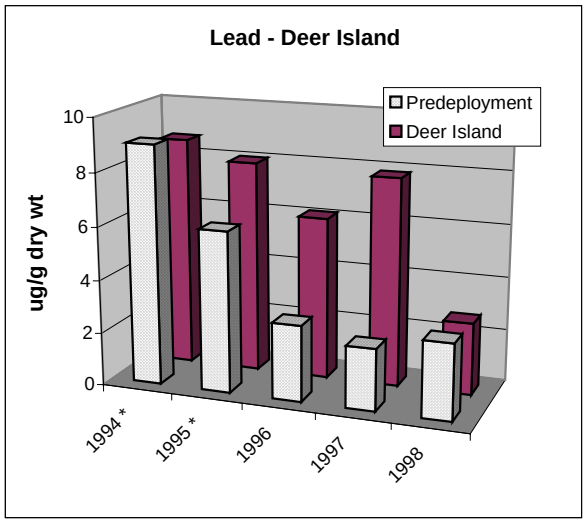
3.3.5.3 Pesticides

Total DDTs in mussels measured in 1998 were lower at all sites compared to 1997 concentrations (Figure 3-24), and were generally in the lower half of the range of concentrations at all sites. DDT levels continue to remain higher at BIH than at the other sites. Total DDT concentrations in mussels deployed at both DI and FOS appear to be numerically similar to levels found in pre-deployed Gloucester mussels.

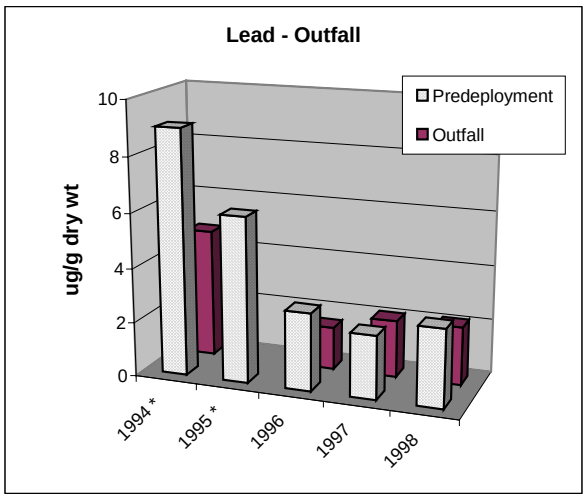
Total chlordane concentrations measured in 1998 are generally similar or lower to concentrations measured in the past for Gloucester pre-deployed mussels and mussels deployed at BIH and DI. Concentrations at FOS were the highest measured during the study.



	BIH			Predeployment		
	Mean	**S.E.**	**N**	**Mean**	**S.E.**	**N**
1994*	6.67	1.29	3	9.00	1.89	4
1995*	8.53	0.51	5	6.05	0.36	5
1996	9.36	0.98	3	2.86	0.73	5
1997	9.89	1.61	5	2.44	0.34	5
1998	4.09	0.22	5	2.85	0.35	5



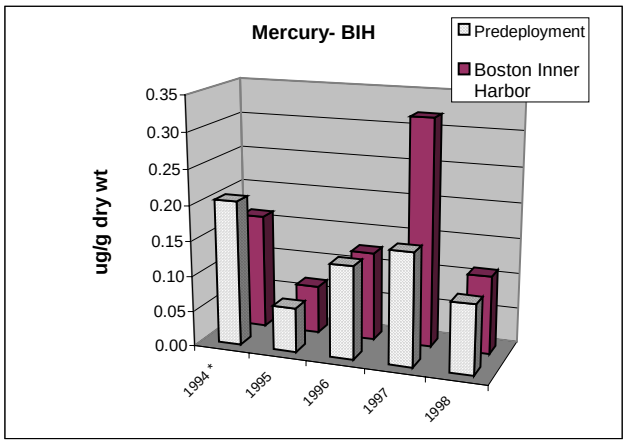
	Deer Island			Predeployment		
	Mean	**S.E.**	**N**	**Mean**	**S.E.**	**N**
1994*	8.68	0.99	5	9.00	1.89	4
1995*	8.40	0.76	5	6.05	0.36	5
1996	6.27	0.58	5	2.86	0.73	5
1997	7.83	0.49	5	2.44	0.34	5
1998	3.47	0.24	5	2.85	0.35	5



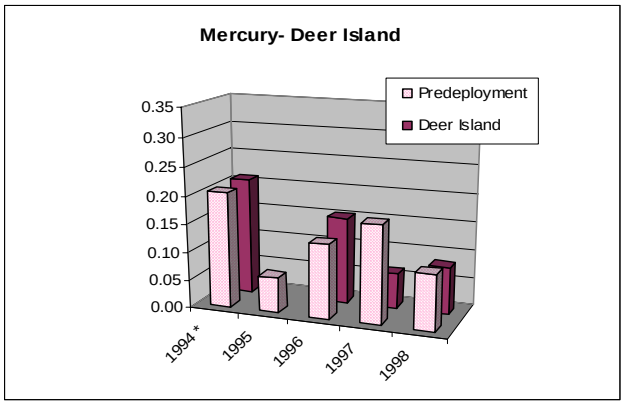
	Outfall			Predeployment		
	Mean	**S.E.**	**N**	**Mean**	**S.E.**	**N**
1994*	4.73	0.20	9	9.00	1.89	4
1995*	NA	NA	0	6.05	0.36	5
1996	1.57	0.14	5	2.86	0.73	5
1997	2.09	0.09	5	2.44	0.34	5
1998	2.14	0.17	8	2.85	0.35	5

*Pre-Deployment Mussels from Gloucester

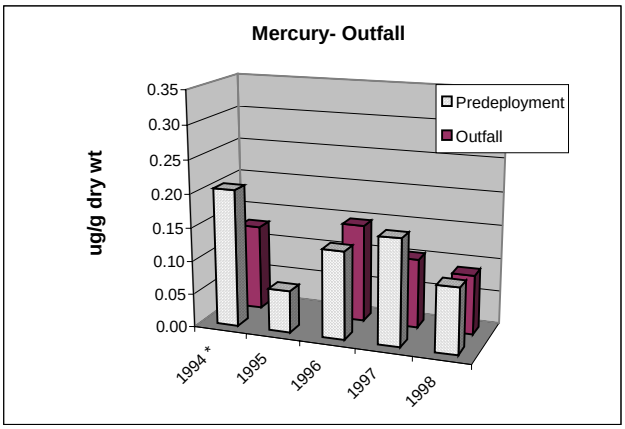
Figure 3-21. Lead Concentrations in Mussels from 1994-1998



	BIH			Predeployment		
	Mean	**S.E.**	**N**	**Mean**	**S.E.**	**N**
1994 *	0.163	0.004	3	0.205	0.071	4
1995	0.080	0.039	5	0.063	0.011	5
1996	0.126	0.014	3	0.131	0.056	5
1997	0.320	0.039	5	0.173	0.025	5
1998	0.110	0.003	5	0.098	0.006	5



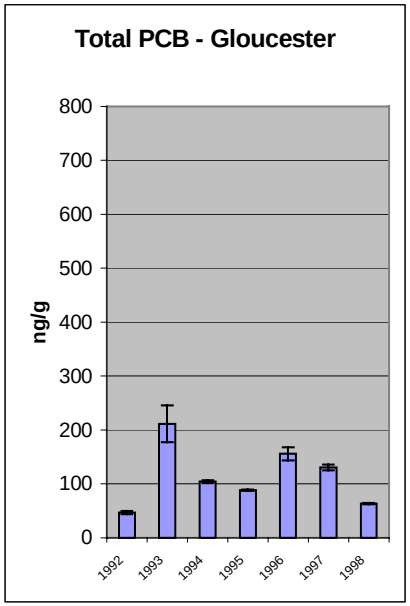
	Deer Island			Predeployment		
	Mean	**S.E.**	**N**	**Mean**	**S.E.**	**N**
1994 *	0.208	0.037	4	0.205	0.071	4
1995	NA	NA	0	0.063	0.011	5
1996	0.154	0.02	5	0.131	0.056	5
1997	0.063	0.0167	5	0.173	0.025	5
1998	0.084	0.0089	5	0.098	0.006	5



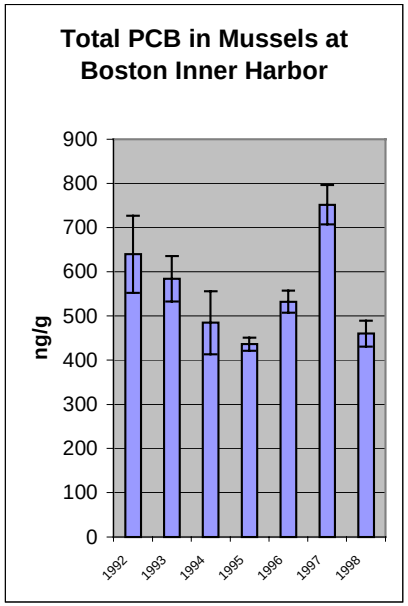
	Outfall			Predeployment		
	Mean	**S.E.**	**N**	**Mean**	**S.E.**	**N**
1994 *	0.128	0.012	9	0.205	0.071	4
1995	NA	NA	0	0.063	0.011	5
1996	0.146	0.041	5	0.131	0.056	5
1997	0.104	0.043	5	0.173	0.025	5
1998	0.089	0.003	8	0.098	0.006	5

*Pre-deployment Mussels from Gloucester

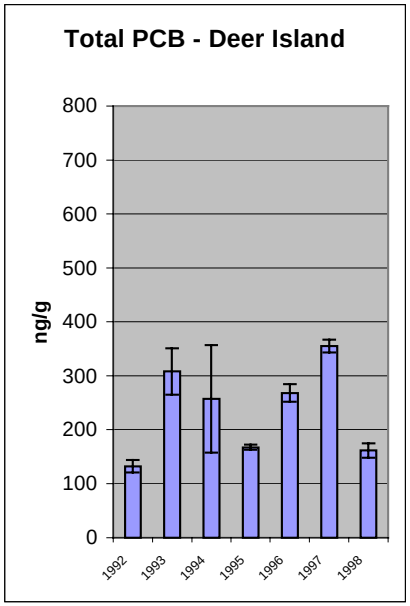
Figure 3-22. Mercury Concentrations in Mussels from 1994- 1998



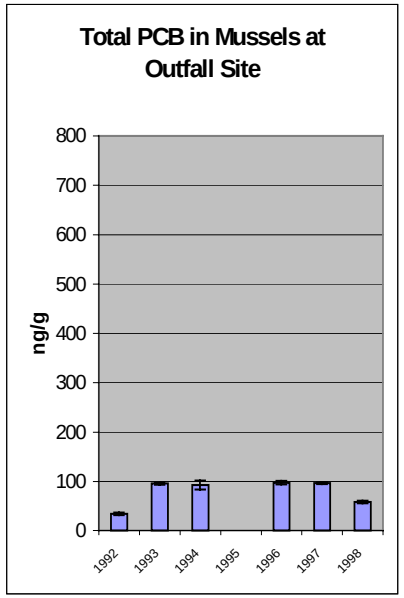
	Gloucester		
	Mean	SE	N
1992	46.7	3.22	5
1993	211	34.2	5
1994	104	2.73	3
1995	88.3	1.04	5
1996	156	12.2	3
1997	130	5.18	5
1998	63.2	1.15	5



	BIH		
	Mean	SE	N
1992	639	87.0	5
1993	584	51.2	4
1994	484	71.3	3
1995	436	14.5	5
1996	532	25.2	5
1997	752	44.6	5
1998	460	29.2	5



	Deer Island		
	Mean	SE	N
1992	120	8.6	8
1993	307	42.5	5
1994	257	99.6	4
1995	165	4.40	5
1996	268	16.0	5
1997	355	11.7	5
1998	149	2.24	5



	Outfall		
	Mean	SE	N
1992	34.3	2.72	8
1993	95.6	2.29	8
1994	92.4	9.03	8
1995	NA	NA	0
1996	97.5	3.60	5
1997	96.2	2.20	5
1998	58.3	2.73	8

Figure 3-23. Total PCBs in Mussels from 1992-1998

Dieldrin concentrations were generally similar to concentrations measured in 1997. Concentrations in Gloucester mussels were slightly higher in 1998 compared to 1997 and, overall, concentrations of dieldrin appear numerically to be relatively similar at all locations since the early 90's.

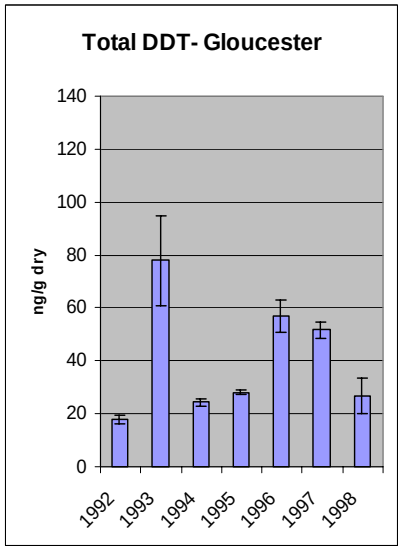
3.3.5.4 PAHs

PAHs compared from 1991 through 1998 were evaluated using the "Historic NOAA List" as discussed in Section 3.3.4.6 (Figure 3-25). Pre-deployment total PAHs in mussels collected in 1998 were slightly elevated compared to 1997 but were within the range measured in previous years. Total PAHs in deployed mussels were within the concentration range found in previous years. Concentrations of total PAHs measured in 1998 were the lowest measured during the study at DI and FOS.

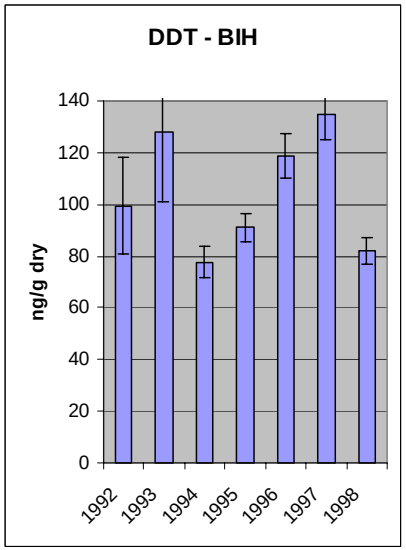
1998 data support the trend of decreasing PAH body burdens in mussels deployed at Deer Island. This trend has been mainly driven by reductions in LMW-PAHs. Effluent characterization studies (Hunt et al 1995; Butler et al 1997; and Sung and Higgins 1998) have shown that LMW-PAH concentrations make up most of the total-PAH concentrations in Deer Island effluent. From the data presented in Fig3-25 it is evident that, historically, mussels deployed at Deer Island had higher concentrations that at BIH (the opposite is true for almost all other contaminants studied). On the basis of these data it is assumed that Deer Island has been a major source of LMW-PAH to the harbor. As a result of the cessation of sludge discharge in 1991, the upgraded primary treatment plant in 1995, the secondary treatment facility coming on line in 1997, limits on industrial discharges of petroleum products into the MWRA system, and an educational campaign to encourage the public to dispose petroleum products in a safe manner, reductions in mussel body burdens at Deer Island would be expected. Long-term data sets for Deer Island mussels seem to support this hypothesis.

3.3.5.5 Evaluation of Quincy Bay Deployment

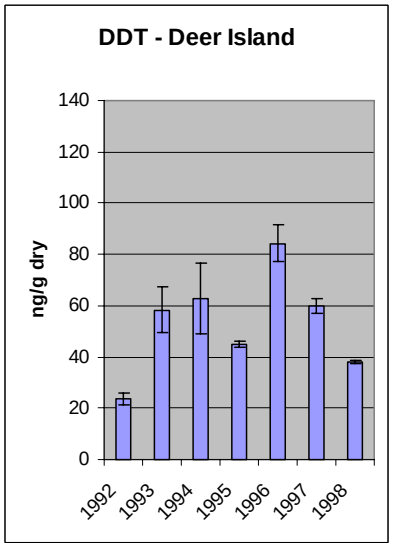
Prior to deployment, mussels were collected from Sandwich in 1987 and 1998. In 1998 Quincy Mussels were deployed for 60 days, while in 1987 they were deployed for 30 days. This location was not part of the original Harbor and Outfall Monitoring program but was added in 1998 to evaluate changes in operations at the Nut Island facility. Diversion of discharge from Nut Island to Deer Island began in April of 1998. Discharge was completely diverted by July 6, 1998. Previous deployments in this area were performed in 1987 (MWRA 1988). Comparison of selected parameters suggests that while predeployment concentrations may not have changed, deployed mussel concentrations at the Nut Island site have (Figures 3-26a ,b, and c). PAH concentrations have decreased by about one third since 1987. PCB and pesticide concentrations have not decreased substantially, though numerically, concentrations measured in 1998 are lower for total DDTs, total chlordane and dieldrin. Pre-deployment mussels for both deployments originated from Sandwich, MA, and concentrations in pre-deployment mussels are very similar from both studies.



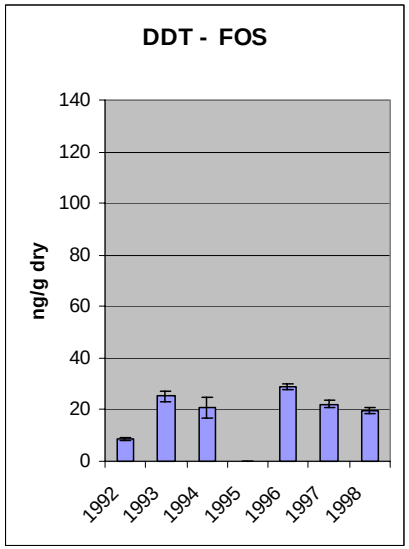
	Mean	SE	N
1992	17.63	1.63	5
1993	77.82	17.16	5
1994	24.31	1.49	3
1995	28.11	0.66	5
1996	56.77	6.20	3
1997	51.76	3.05	5
1998	34.08	1.45	4*



	Mean	SE	N
1992	99.48	18.82	5
1993	127.98	26.87	4
1994	77.72	5.83	3
1995	91.12	5.47	5
1996	118.50	8.60	5
1997	134.86	9.61	5
1998	81.95	5.12	5



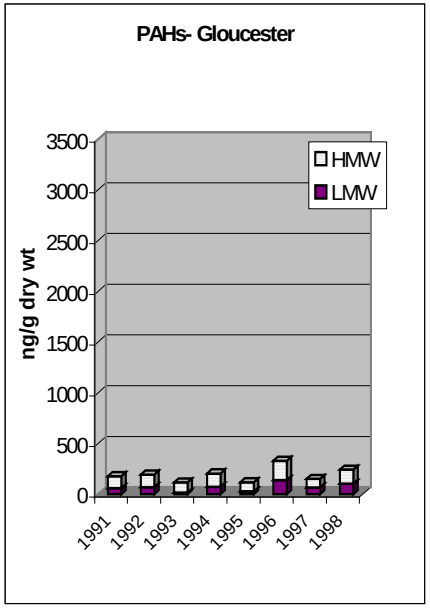
	Mean	SE	N
1992	23.44	2.30	8
1993	58.42	9.09	5
1994	62.88	13.81	4
1995	44.80	1.03	5
1996	84.40	7.37	5
1997	60.04	3.04	5
1998	38.04	0.63	5

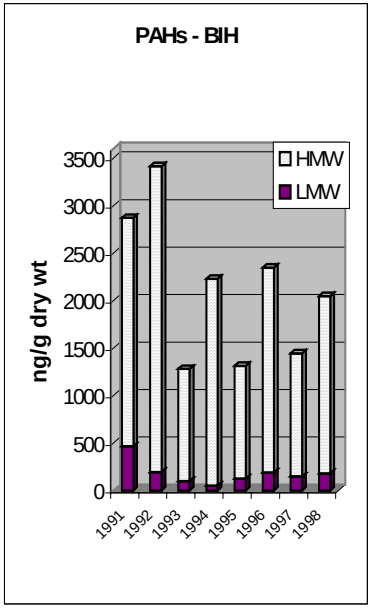


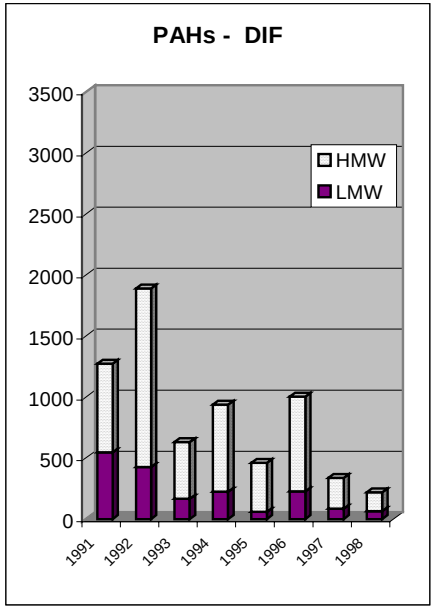
	Mean	SE	N
1992	8.91	0.54	8
1993	25.19	2.19	8
1994	20.71	4.02	8
1995	NA	NA	0
1996	29.02	1.16	5
1997	22.24	1.33	5
1998	19.82	1.07	8

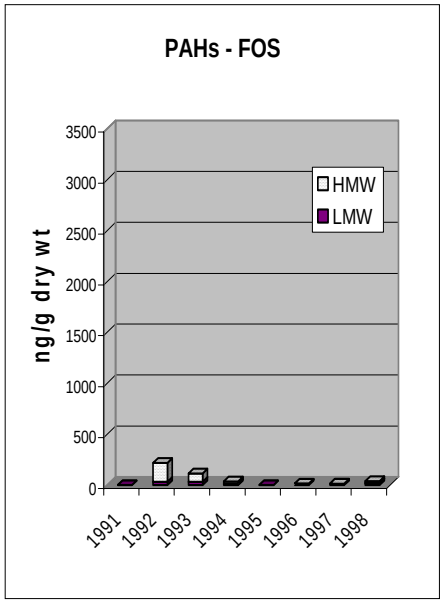
*One sample replicate was suspect; data not used.

Figure 3-24. Total DDTs in Mussels from 1992-1998









	LMW			HMW		
	Mean	SE	N	Mean	SE	N
1991	61.64	14.94	11	115.2	19.69	11
1992	70.14	6.43	5	132	21	5
1993	16.17	6.50	6	105	26	6
1994	71.67	3.18	3	132.3	59.88	3
1995	5.00	5.00	5	55.60	6.00	5
1996	107.0	21.00	3	167.0	21.00	3
1997	36.00	11.00	5	51.40	5.00	5
1998	104.3	12.40	5	138.6	6.45	5

	LMW			HMW		
	Mean	SE	N	Mean	SE	N
1991	466	258	5	2,404	179	5
1992	195	44.1	5	3343	405	5
1993	92.0	15.1	6	1,210	73.1	6
1994	53.3	4.37	3	2,176	231	3
1995	116	1.16	5	1,231	28.4	5
1996	158	7.22	5	2,232	127	5
1997	107	12.5	5	1,339	97.4	5
1998	182	21.6	5	1,865	107	5

	LMW			HMW		
	Mean	SE	N	Mean	SE	N
1991	545	78.4	10	728	66.1	10
1992	426	48.4	8	1504	127	8
1993	164	22.4	6	495	54.3	6
1994	224	21.2	4	713	93.9	4
1995	45.0	4.66	5	405	20.2	5
1996	208	46.6	5	790	131	5
1997	37.0	4.53	5	234	13.3	5
1998	63.4	4.77	5	154	2.7	5

	LMW			HMW		
	Mean	SE	N	Mean	SE	N
1991	NA	NA	0	NA	NA	0
1992	31.8	4.67	8	190	145	8
1993	33.3	4.37	8	83.6	12.5	8
1994	14.5	1.64	8	19.4	5.21	8
1995	NA	NA	0	NA	NA	0
1996	11.0	6.98	5	4.6	2.86	5
1997	15.0	12.60	5	0.0	0.00	5
1998	18	1.16	8	19.75	0.66	8

Figure 3-25. Total NOAA PAHs in Mussels from 1991-1998

3.3.5.6 Comparison of Predeployed Mussels from Gloucester and Sandwich for Organic Contaminants

Sandwich mussels were analyzed for the suite of organic contaminants so that the Quincy deployed mussels could be evaluated against pre-deployed values (see section 3.3.2 for discussion). The following is a comparison of pre-deployment concentrations of selected parameters between the two sites and is summarized in Table 3-17.

Overall, PAHs were significantly higher ($p<0.05$) in the Gloucester mussels, primarily attributed to the presence of the HMW-PAHs. LMW-PAHs, based on the sum of the 97/98 list of PAHs, were not significantly different between pre-deployed Sandwich and Gloucester mussels.

PCB concentrations in Gloucester mussels were significantly lower ($p<0.05$) than Sandwich mussels however, Gloucester pre-deployment mussels were slightly enriched in the lower chlorinated congeners relative to the Sandwich pre-deployment mussels.

Pesticides were also significantly lower in Gloucester mussels ($p<0.05$) compared to Sandwich mussels. For most parameters, the Gloucester mussel pesticide concentrations were generally 2-fold lower.

Table 3-17. Comparison of Sandwich and Gloucester Pre-deployment Organic Concentrations for Significant Differences Using a Student t Test (p< 0.05).

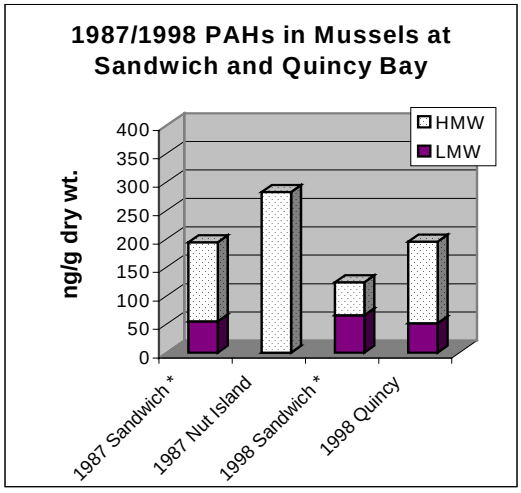
Parameter	SANDWICH		GLOUCESTER		Means significantly different?
	mean	s.e.	mean	s.e.	
Total PCB	79.1	3.5	63.2	1.2	YES
Total Chlordane	14.2	0.6	6.8	0.2	YES
Total DDT	55.8	2.6	34.1	1.5	YES
DIELDRIN	5.7	0.2	2.8	0.1	YES
Total LMW PAH	146.0	16.2	189.2	12.3	NO
Total HMW PAH	65.1	4.1	166.3	7.8	YES
Total PAH	199.2	12.6	355.5	17.3	YES
Total NOAA LMW PAH	65.8	7.7	104.3	12.4	YES
Total NOAA HMW PAH	58.1	4.1	138.6	6.4	YES
TOTAL NOAA PAH	120.23	7.1	242.8	14.9	YES

Notes:

(1) Assume random sampling, normal distribution and equal variances

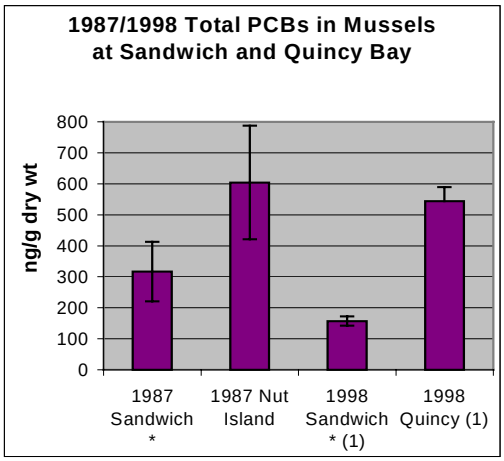
(2) Comparison to Sandwich Pre-deployment Mussels

Shading indicates that Gloucester pre-deployment means were significantly lower than Sandwich pre-deployment mussels.



	LMW			HMW		
	Mean	**SE**	**N**	**Mean**	**SE**	**N**
1987 Sandwich *	55.3	30.4	**3**	139.3	4.34	**3**
1987 Nut Island	0.0	0.0	**3**	282.7	4.34	**3**
1998- Sandwich *	65.8	7.7	5	58.1	4.14	5
1998- Quincy	47.6	3.2	5	143.8	6.56	5

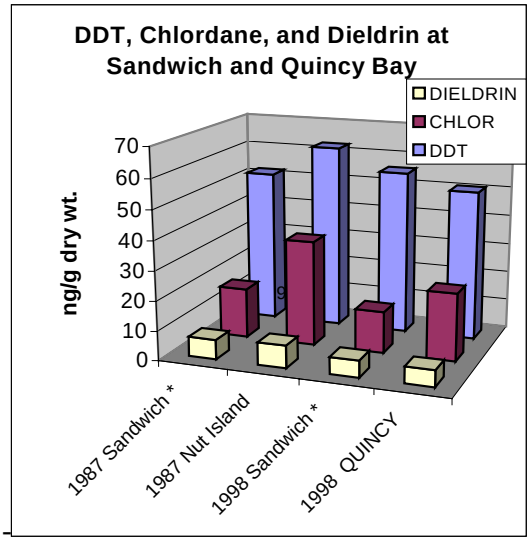
Figure 3-26a. 1987/1998 PAHs in Mussels at Sandwich and Quincy Bay



	TOTAL PCBs		
	MEAN	**S.E.**	**N**
1987 Sandwich *	317	55.4	3
1987 Nut Island	605	106	3
1998 Sandwich * (1)	158	7.0	5
1998 Quincy (1)	544	20.8	5

(1) Note that total 1998 PCBs were estimated as 2X the sum of 20 PCB congeners.

Figure 3-26b. 1987/1998 Total PCBs in Mussels at Sandwich and Quincy Bay



	DDT			CHLOR			DIELDRIN		
	Mean	**S.E.**	**N**	**Mean**	**S.E.**	**N**	**Mean**	**S.E.**	**N**
1987 Sandwich *	52.0	7.36	3	16.9	2.64	3	6.6	0.90	3
1987 Nut Island	62.637	19.47	**3**	35.5	6.16	**3**	7.6	2.82	**3**
1998- Sandwich *	55.81	2.55	5	14.15	0.62	5	5.67	0.20	5
1998- Quincy	50.81	2.24	5	22.88	0.94	5	5.57	0.22	5

* Pre-Deployment Mussel Concentrations

Figure 3-26c. DDT, Chlordane, and Dieldrin at Sandwich and Quincy Bay

3.3.6 Relationship of Contaminants to FDA Legal Limits

The U.S. Food and Drug Administration (FDA) has set legal 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 FOS baseline mean. Warning Levels are set at 80% of the FDA Limits (MWRA 1998 – Contingency Plan). Caution and Warning Levels apply to the outfall (FOS) only. These three levels provide reference benchmarks for detecting adverse changes (and their potential human health risks) once the new outfall is on line. The 1998 mean concentrations of target analytes in mussel tissue, per station, were compared to the FDA's Legal Limits and the MWRA caution and warning levels (based on data collected through 1997) for the outfall, as well as, DIF and ECCB samples, and are presented in Table 3-18.

Table 3-18. Comparison to FDA and MWRA Limits to Mean 1998 Mussel Concentrations for Selected Paramters.

STATION	N	% Dry Wt.	Total PCB (ng/gwet wt.)		Total DDTs (ng/g wetwt.)		Total Chlordanes (ng/g wet wt.)		Dieldrin (ng/g wet wt.)		Total PAH (ng/g wet wt.)		Mercury (Hg) (ug/g wet wt.)		Lead (Pb) (ug/g wet wt.)	
		Mean	Mean	*s.e.*	Mean	*s.e.*	Mean	*s.e.*	Mean	*s.e.*	Mean	*s.e.*	Mean	*s.e.*	Mean	*s.e.*
Deer Island(1)	**5**	14.75	23.7	*1.7*	5.6	*0.2*	3.7	*0.14*	0.60	*0.02*	110.1	2.4	0.016	*0.001*	0.57	*0.13*
Inner Harbor(6)	**5**	11.92	55.6	*6.9*	9.9	*1.2*	3.1	*0.40*	0.92	*0.10*	556.9	66.5	0.016	*0.001*	0.58	*0.04*
Cape Cod Bay(9)	**8**	18.32	8.9	*0.4*	2.9	*0.2*	1.5	*0.12*	0.52	*0.03*	8.3	0.5	0.014	*0.001*	0.40	*0.03*
Outfall(4)	**8**	15.77	9.2	*0.4*	3.1	*0.1*	1.6	*0.09*	0.35	*0.01*	7.4	0.3	0.015	*0.001*	0.36	*0.03*
Quincy(M7)	**5**	15.35	41.7	*1.5*	7.8	*0.3*	3.5	*0.12*	0.85	*0.03*	55.5	1.4	0.016	*0.001*	0.52	*0.03*
FDA Limit			2000		5000		300		300		NA		1.000		NA	
MWRA Caution Level (2 x Baseline 1992-1997)					7						38		0.044		1.1	
MWRA Warning Level (80% FDA)			1600		4000		240		240		NA		0.800		NA	

4.0 CONCLUSIONS

The 1998 Fish and Shellfish Monitoring program was completed successfully 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 and current results continue to support improved conditions since the beginning of the program in 1992. Conclusions for the various animals from the surveys are given below.

4.1 Winter Flounder

The 1998 Flounder Survey provided samples from three locations (DIF, FOS 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. There appeared to be a continued relationship between centrotublular hydropic vacuolation and tissue contaminant levels for selected analytes. A continuing decrease in the frequency and severity of neoplasms in flounder livers was also evident. The levels of most tissue contaminant concentrations were comparable to 1997 results. 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 Caution and Warning limits, thus indicating no risk for human consumption.

4.2 Lobster

The 1998 Lobster Survey collected specimens from three sampling locations by direct shipboard collection from commercial lobstermen. The levels of tissue contaminants were similar to those 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. Lobster edible tissue contaminant concentrations were below the FDA legal limits and the caution and warning limits set by MWRA, thus indicating no risk for human consumption.

4.3 Blue Mussel

The 1998 Mussel Bioaccumulation study involved deployment of caged mussels at two offshore locations (FOS and CCB) and three near-shore locations (BIH, DI, and Quincy Bay). Two of the locations, ECCB and Quincy, were added in 1998. Contaminant levels measured in 1998 were among the lowest observed since 1991, especially at DI and the FOS. Among the stations previously studied, concentrations were routinely highest at BIH and lowest at the FOS organics. Lead and mercury concentrations were more variable.

PAH concentrations in 1998 were evaluated using two different lists of PAH compounds. Pre-1995 studies only evaluated PAH trends based on a shortened list of compounds specified by NOAA's Status and Trends program. This list only includes a limited number of alkylated PAHs and underestimates the total PAH body burden. While 1998 data supports the overall conclusion that PAH concentrations in mussels at all locations have decreased numerically since the late 80's, actual body burdens, may have been underestimated in previous years. This was especially evident when comparing the low-molecular weight PAH fraction in DI mussels, where previous studies have indicated a substantial LMW-PAH reductions at DI relative to the high molecular weight PAHs. This change was attributed to change in the exposure patterns of mussels at DI. However, when using the extended PAH list to evaluate PAH body burden, the ratio of LMW to HMA PAHs shows a much smaller reduction in the relative levels of LMW

PAHs. Future interpretation of PAH body burdens and trends should continue to include the extended list of PAHs to better evaluate PAH exposure.

4.4 Evaluation of 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 the FOS during the period 1992 through 1998 (with the exceptions noted in the table). The significant increase value is the 95th percentile upper confidence limit (based on the "t" distribution) of the mean of the annual means. Warning Levels have been set at 80% of the FDA legal limit.

Current tissue concentrations are generally an order of magnitude or more below Warning Limits and FDA regulatory limits (Table 4-1). Moreover, the caution levels are set above or just above (in several cases) values that can be detected. Similarly, the monitoring hypothesis regarding future increases of the prevalence of flounder liver CHV at FOS 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. Based on 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 Thresholds at the Future Outfall Site.

Parameter	Baseline Mean[1]	Baseline Standard Deviation	Baseline Standard Error of the Means	N	Significant Increase[2]	Caution Level[3]	Warning Level[4]
Mercury (ppm wet)							
Flounder	0.085	0.014	0.005	7	0.111	0.169	0.8
Lobster	0.154	0.014	0.005	7	0.181	0.308	
Mussels	0.022	0.005	0.003	4	0.033	0.043	
Lead (ppm wet)							
Mussels	0.43	0.24	0.12	4	0.947	0.87	---
PCBs (ppb wet)							
Flounder	38.11	8.42	3.18	7	54.055	76.22	1600
Lobster	17.07	6.84	2.58	7	30.026	34.14	
Mussels	13.457	4.86	1.99	6	22.907	26.91	
PAH[5] (ppb wet)							
Mussels	17.30	10.68	4.36	6	38.059	34.59	
Chlordane (ppm wet)							240
Flounder	1.44	0.828	0.313	7	3.011	2.88	
Lobster	0.42	0.210	0.079	7	0.817	0.84	
Mussels	1.30	0.385	0.157	6	2.050	2.60	
Dieldrin (ppm wet)							240
Flounder	0.28	0.130	0.049	7	0.522	0.55	
Lobster	0.88	0.288	0.109	7	1.422	1.75	
Mussels	0.30	0.089	0.036	6	0.475	0.60	
DDT (ppb wet)							4000
Flounder	3.99	0.845	0.32	7	5.594	7.99	
Lobster	2.19	0.788	0.30	7	3.687	4.39	
Mussels	3.55	1.23	0.50	6	5.949	7.11	

Notes:

[1] Mean Concentration of Annual Means, 1992-1998 (Flounder and Lobster). Mean concentration, 1992-1994, 1996-1998 (Mussels; no 1992 metals data, 1993 metals data suspect,1995 array was lost).

[2] Level at which change from the mean is considered significant from baseline mean at 5% level (I.e., 95th percent UCL based on "t" distribution. [mean+t(0.1,n)*s.e.]

[3] Based on "appreciable change from baseline"; see text for discussion. [2 x baseline mean]

[4] Massachusettes Water Resources Authority (MWRA) 1997. Contigency Plan. Warning Level is 80% of the FDA Legal Limit.

[5] Representing NOAA PAHs only.

5.0 RECOMMENDATIONS

An evaluation of the 1998 Fish and Shellfish tasks indicates that the program is achieving its monitoring goals. However, refinements to the program may be warranted. Based on the 1998 results, several recommendations for future effort are suggested:

- Collection of Flounder at DIF should be postponed until late in April or early in May to maximize collection of sufficient numbers of organisms;
- Lobster collection should be coordinated with commercial lobsterman both temporally and spatially to maximize collection efficiency;
- Continuation of the use of mussels collected from the Sandwich reference site to evaluate the bioaccumulation of mercury and lead;
- Continue to evaluate results against Caution Levels defined as two times the baseline means as a more sensitive means of detecting change in tissue concentrations;
- Express all Caution and Warning levels on a Wet weight basis to be consistent with FDA and other Federal regulatory limits.

6.0 REFERENCES

Downey PC. 1994. Bioaccumulation of Selected Organic Compounds and Metals in Mussels Deployed Near DIF Discharge and in Massachusetts Bay, 1993. MWRA Environmental Quality Department Technical Report Series No. 94-8. Boston: Massachusetts Water Resources Authority.

EPA (United States Environmental Protection Agency). 1991. *Methods for the Determination of Metals in Environmental Samples.* EPA-600/4-91-010. Environmental Services Division, Monitoring Management Branch.

Hillman RE, Peven CS. 1995. 1994 Annual Fish And Shellfish Report. MWRA Environmental Quality Department Technical Report Services No. 95-5. Boston: Massachusetts Water Resources Authority.

Mitchell DF, Butler E, McGrath D. 1995. Combined work/quality assurance plan for fish and shellfish monitoring: 1995-1997. MWRA Environmental Quality Technical Report Series No. MS-39. Boston: Massachusetts Water Resources Authority. 71 pp.

Mitchel DF, Sullivan K, Moore M, Downey P. 1998. 1997 Annual Fish and Shellfish Report. MWRA Environmental Quality Technical Report Series 98-12. Boston: Massachusetts Water Resources Authority.

Moore MJ, Shea D, Hillman RE, Stegeman JJ. 1996. Trends in hepatic tumours and hydropic vacuolation, fin erosion, organic chemicals and stable isotope ratios in winter flounder from Massachusetts, USA. Marine Pollution Bulletin, Vol 32, No. 6. Great Britain. 12 pp.

MWRA. 1988. Secondary Treatment Facilities Plan, Volume V, Appendix X. March 31, 1988.

MWRA. 1991. Massachusetts Water Resources Authority effluent outfall monitoring plan. Phase I: baseline studies. MWRA Environmental Quality Department, November 1991. Boston: Massachusetts Water Resources Authority. 95 pp.

MWRA 1997a. Contingency plan. Boston: Massachusetts Water Resources Authority. 40 pp.

MWRA. 1997b. Massachusetts Water Resources Authority effluent outfall monitoring plan: Phase II post-discharge monitoring. MWRA Environmental Quality Department Miscellaneous Report No. ms-44 Boston: Massachusetts Water Resources Authority. 61 pp.

O'Connor TP, Beliaeff B. 1995. Recent Trends in Coastal Environmental Quality: Results from the Mussel Water Project 1986 to 1993. NOAA Office of Ocean Resources, Conservation and Assessment. Coastal Monitoring and Bioeffects Assessment Division Rockville, MD.

Peven CS, Uhler AD. 1993. Analytical procedures to quantify organic contaminants. In Sampling and Analytical Methods of the National Status and Trends Program National Benthic Surveillance and Mussel Watch Project. Volume IV. NOAA Technical Memorandum NOS ORCA 71. National Oceanic and Atmospheric Administration, Silver Spring, MD.

See Appendix A - Summary of Measurement Program from 1991-1998

See Appendix B - Summary Tables of Lipids (% dry wt), PCB, Pest, PAH and Metals for Individual Composites of Flounder, Lobster and Mussels

See Appendix C - Flounder Histology Time Plots

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